International Hydrographic Review, Monaco, LXI (1), January 1984

A METHODOLOGICAL APPROACH TO NAUTICAL CHART DESIGN

by Roland PERROTTE(*)

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ABSTRACT

The need for improved nautical chart design has recently been identified. Cumulative addition of various data and the resulting visual clutter are examples of actual problems calling for studies in this field. As has been demonstrated in studies of aeronautical charting, effective communication of navigational information can be achieved through the choice of appropriate graphic solutions. Research on effective graphic encoding should permit optimization of information transfer from the cartographer to the navigator and other users. Cartographic communication theory can provide an organized framework to initiate studies on improved chart encoding.

In the past, cartographers' personal impressions and experience have led the way in nautical chart design. Such indirect research methods were lacking in objectivity. Better ways must now be sought and an approach relying on objective chart evaluation should lead the way. Thus, practical measurement of the reliability of proposed chart designs must be achieved through systematic testing with subjects. The normal chart use conditions are then investigated and simulated to measure the perceptual reactions of the users on specific problems needing investigation.

Adoption of an adequate methodology — hence, following closely the successive steps of scientific experimentation — can also bring the marine cartographer to the realm of scientific research.

(*) Head, Cartographic Research Unit, Canadian Hydrographic Office (Atlantic Region), Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2, Canada.

INTRODUCTION

For decades the Canadian Hydrographic Service has been progressively improving the graphic quality of charts. The product that is now available is the result of very careful workmanship. Successive improvements have been made over the years up until the adoption of the "New Chart" standards, and the calibre of the draughtsmanship and printing of our charts makes us one of the world's leading producers. At the same time, more recent research on the use of computer-assisted cartography is progressing well. The performance of the system in use at the moment has gradually been improved upon, and with the developments anticipated in the medium term a certain optimism for the future is well justified.

It must, however, be mentioned that studies on the effectiveness of the nautical chart as an instrument of communication are somewhat rare. Canada does not lag behind other countries in this — as it seems to be generally the case, worldwide. Except for a thesis on the point depiction of depths on charts (STANLEY, 1973), it was not until 1982 that a preliminary study was made on the effectiveness of the nautical chart (CASTNER and McGRATH, 1982). The Canadian Hydrographic Service's centenary is an occasion that prompts us to pause for reflection upon our cartographic achievements in the past and to look ahead to the future. The very usefulness of research into nautical chart evaluation should motivate us to include it in the list of activities to be promoted in the coming years.

THE NAUTICAL CHART — AN INSTRUMENT FOR CONVEYING INFORMATION

The research-minded cartographer is always looking for ways to help him understand how the chart-user uses the information on his charts. The ultimate aim is obviously to improve upon the chart's effectiveness, and the communication theory seems to provide an appropriate framework within which we should work to achieve this goal.

The function of the nautical chart is to provide the navigator with the necessary information to navigate from one point to another in complete safety. The effective communication of this information will determine the degree of success of this activity. The interest currently aroused by studies on cartographic communication is constantly increasing. The diagram for the communication of information, first developed by SHANNON and WEAVER, has since inspired numerous attempts to create a cartographic model (SHANNON and WEAVER, 1949). The version we give in figure 1 includes the main characteristics of the models we have analysed.

The starting point of the diagram is an exact position in the real world : a portion of sea in a coastal area would constitute a suitable example. The information to be communicated is recorded, then conveyed to the navigator by means of the nautical chart. The operations of encoding and decoding the

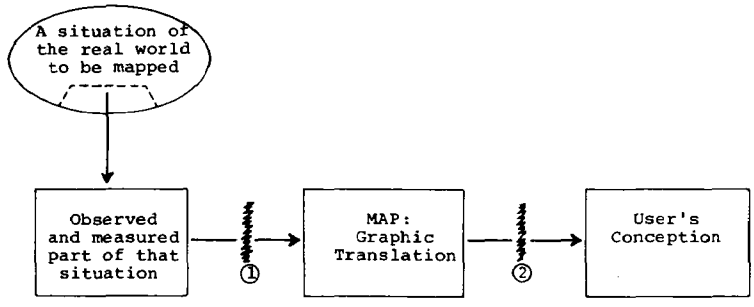

FIG. 1. — A general model of cartographic communication.

information act as filters, resulting in a reduction or even a loss of data as we move towards the right of the model. We must therefore minimize this loss by developing coding methods appropriate for the type of chart under consideration.

No single graphic symbol exists that would visually translate a characteristic or given variable on the chart. Consequently, the author often hesitates between different solutions. One way out would be to carefully measure the respective efficiency of each design under consideration, which would be a better way of proceeding than basing a decision on the personal choice of the author.

The cartographic communication model (fig. 1) helps us to understand the mechanism of conveying information by means of charts. It also provides a suitable epistemological approach to research on the effectiveness of the nautical chart. The concerns that have been raised over the last decade underline the need for us to adopt more methodical research strategies in the design of charts. And so it is relevant here to analyse the types of research currently used in cartography.

TYPOLOGY OF RESEARCH USED IN CARTOGRAPHIC DESIGN

The cartographer may use various approaches in his cartographic research work. Robinson's classification (1977) is based upon two broad categories. The indirect approach is very subjective whereas the direct approach indicates, in most cases, that more care has been taken to use objective information rather than information based on the cartographer's own tastes and arbitrary choices.

The indirect approach

The main characteristic of the indirect approach is the complete lack of interaction with the chart-users, as no one checks whether the end-product is effective. The "*empirical concept*" is the development of graphic solutions based on the cartographer's personal opinions, experience and theoretical knowledge, and he cannot prove that the choice made is the right one. This procedure, sometimes known as "trial and error method" has been the general practice of the Canadian Hydrographic Service up until now. It is also by far the most common method and the least objective one to be used in cartographic design.

Sometimes new ideas come from "*adapting discoveries made in other fields*". Results of experiments or the principles that have been elaborated in other fields are used in chart design. But since this research has not been carried out in a cartographic context, it is often dangerous to go as far as using the conclusions in the creation of the chart. A chart is a complex picture and the user's concerns are often quite different from those which prevail in related fields (colorimetry, psychology, etc.). Chart designers do not seem to have drawn much from this area. Potentially useful, this procedure would be a sounder proposition if efforts were made to reproduce the experiment in a cartographic context, using a more direct approach.

The direct approach

Research made using the direct approach is based upon consultations with the end-users with a view to justifying the choice made in cartographic depiction. This method is already more objective than the indirect method explained above, and the "*inventory of users' reactions*" analyses the customers' opinions on a product. This type of research, tending to be more concerned with the categories of information on the chart rather than with the symbolization, is often biased by established conventions and the user's own ideas. This sort of study has been carried out in the past by the Canadian Hydrographic Service (SMITH, 1976). This constitutes the first step towards wanting to consult the end-user, but does not measure the real effectiveness of the chart. It is, however, a praiseworthy effort as the conclusions are no longer based on the ideas of the cartographer alone, but we must go one step further towards objectivity by eliminating the simple voting procedure.

The following three types of research fulfil this objective. They are based on the performance of users in simulated use of the chart. This is the most objective way of examining the level of cartographic communication, and future nautical chart evaluations should take inspiration from this. "Psychophysical research", "cognitive research" and "reading-orientated research" are not yet very common in governmental cartographic offices.

"*Reading-orientated research*" looks at the way a user visually approaches the information on the chart. The problem is to find out in what way and how efficiently the navigator uses the chart. How does the user read the chart ? How

successfully does he accomplish this ? The time needed to carry out these visual operations and the accuracy with which the information is extracted provides the answer to this last question. "*Psychophysical research*" looks at the "stimuli-reaction" relationship. What reaction is produced by a given cartographic symbol ? Finally, "*cognitive research*" should be included in ROBINSON's classification. Going beyond the first stage of reading and visual perception, this type of research tries to explain how the user acquires, stores, memorizes, organizes and uses the raw data taken from the graphic elements on the chart. The cognitive mechanisms thus go much further than the simple sensorial input examined in psychophysical research, and include reflection, as well as the elaboration of mental images or space distribution. Study of these mechanisms can help towards a better understanding and easier conception of the chart.

The cartographer-hydrographer should from now on exploit the potential of the direct approach and, above all, the last three areas of research explained above. The nautical chart could certainly benefit from a research programme based on the above three areas. Such research would not only be based on an objective consultation with the navigators, but would also fit in a methodological framework far more scientific than any cartographic design work previously done by national hydrographic services.

ADOPTION OF A METHODOLOGICAL APPROACH AND PROPOSAL FOR THE PROCESSING OF RESEARCH ON NAUTICAL CHART DESIGN

Examining charts using the three methods that interest us may lead to a proper evaluation of the effectiveness of the graphic solutions considered. Once the research hypothesis has been established, the cartographer recreates experimentally certain conditions of the chart. He collects data on the performance and perception of the sample candidates that he uses for the circumstance. The statistics collected in the cartographic communication study are analysed descriptively, graphically or mathematically, and in the last case statistical methods enable us to check if the results of the experiment are significant. In other words, is it possible to make general conclusions from this one experiment with an acceptable scientific safety margin ?

This series of operations very closely follows the steps of a scientific procedure. Such a methodological approach reinforces the value of the conclusions and recommendations that will result from the research. We can, from now on, leave the tentative research studies to one side. A sound methodological approach always saves time and ensures that the running of a research project is structured in a logical way.

This approach has often been used in thematic cartography, and more recently, it has been used in aeronautical charting with interesting results (HOPKIN and TAYLOR, 1979). The aeronautical chart and the nautical chart, both used for navigation, have points in common. It is time we took advantage of scientific methods and used these to set up research which is suitable for marine cartography.

The following process seems to include all the points we have covered so far :

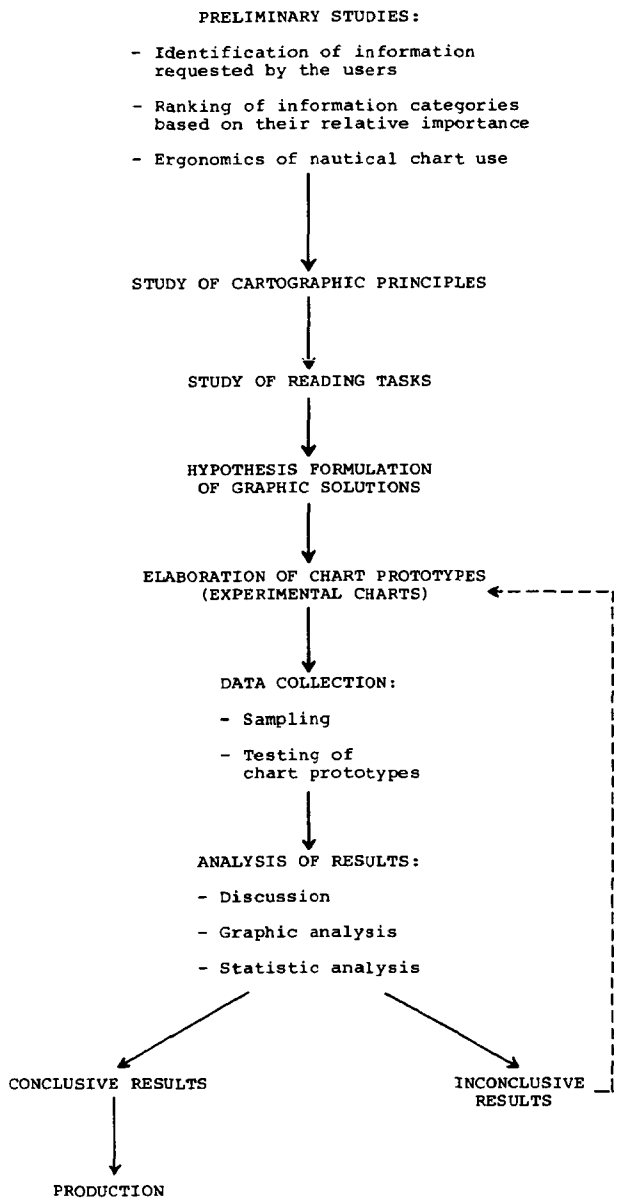

FIG. 2. — A proposed strategy for research on the graphic design of nautical charts.

A PRACTICAL EXAMPLE OF CARTOGRAPHIC RESEARCH : DEPICTION OF SEABED

What do we know of the effectiveness of modern charts ? Can we be sure that in general their design and the conventional symbols used are adequate ? It is evident that Loran-C charts are very cluttered and finding a solution to this difficult problem is of particular interest. The same goes for many other aspects of the nautical chart. KERR and ANDERSON (1982) have suggested that the existing presentation is an amalgam of what cartographers believe to be the best points from charts from various countries. No form of cartographic evaluation can, however, back up these choices. Chart designers have probably not fully exploited the potential of cartographic discoveries and principles, and future efforts ought to be encouraged in this direction. The directives given by the International Hydrographic Organization on symbol standardization have repercussions on charts from many countries. This Organization should consider objectively the recommendations which will be submitted in the future by research cartographers.

Considerable efforts are needed to arrive at good chart design, and, in order to simplify the task, the researcher must study the chart components separately, or broken down into small groups. Yet each study must be done in the overall context of the chart by inserting the symbols under consideration on the whole chart picture. The following lines show how we could possibly examine one particular aspect of the chart in accordance with the method explained above.

Several methods can be used to depict the sea bottom graphically, among which are : point soundings, isobaths, shading, hypsometrical tints and the Tanaka method which is a combination of isoline and shading. To determine which of these methods is the most useful in navigation, we must make a comparative evaluation. In order to determine which of the five listed methods best suits the nautical chart, the researcher can make certain tests on the five versions. Specific questions can be put to individuals and the speed and accuracy of the replies can be recorded. Obviously, the questions must be closely related to the visual tasks and activities normally associated with the use of a chart.

Does the navigator try to visualize the morphology of the sea bottom or, rather, does he try to determine the relative or absolute depths ? The work done by PHILLIPS *et al.* (1975) shows that the effectiveness of the depiction methods suitable for depicting undersea features varies with the objectives of the navigator. The results that they obtained suggest hypsometric tints are better suited to giving an overall view of the land shapes. This method gives poor results in depiction of specific heights, and numerical representation is then more suitable. These remarks not only show how such experiments can be carried out in a chart context, they also show how relevant the studies on chart utilization are. By carefully identifying the apparent tasks involved in chart-use, a choice of depiction method can be made. Therefore, CASTNER and McGRATH have rightly suggested further continuation of their work on the obvious uses of the chart and the manner in which a nautical chart is read.

The research carried out by PHILLIPS *et al.* is inspiring since their discoveries have provided numerous indications as to our perception of land features.

However, other types of research are necessary, given the special features of a nautical chart. The same kind of research could indicate whether our conception of the nautical chart is adequate or not. The current version of the Canadian chart combines three different depiction methods : soundings, isobaths and hypsometric tints. The reality is often more complex than a separate evaluation of each of these methods, and the obvious interaction of these symbols must be taken into account in experimental research. This would seem to confirm the need to test various combinations of symbols so as to determine the best. Research carried out by PHILLIPS *et al.* has shown that the nautical chart's multiple functions (diversity of users) imply a need to use, simultaneously, more than one type of symbol to depict the ocean bottom features.

The new format of the Canadian chart has now been in use for some years. The "New Chart" brought about changes as regards depiction of the sea bottom. The density of soundings decreased whereas the number of isobaths increased. The originators of this change have not really checked whether the innovation was "for better or for worse". Research work, if carried out in the methodological way, as we have discussed, would enable future changes in symbolization to be more adequately justified.

CONCLUSION

The example of sea-bed depiction is only one of the many aspects of the nautical chart which would benefit from research on chart design. We could include the choice of figurative symbols, the size of point symbols, the disposition of lettering, the depiction of the Loran-C grid in relation to the apparent clutter of the chart, etc. The quality of the final product can gain considerably in effectiveness. Now we must establish a research programme based on certain priorities, and, in this way, the overall structure of depiction must be examined first, before the point symbols, the frequency of use of which varies from one sheet to another.

The nautical chart is the end result of hydrographic surveying operations. It is also the instrument that enables us to convey to the user most of the information he needs for navigation. Considering the financial resources and efforts put into hydrographic surveys and chart production each year, research on the effectiveness of the chart seems pertinent. The chart is the only communication link between the cartographer, who compiles the initial data, and the user. It is our duty to develop the best possible version of this strategic link, and it would be a shame to continue to produce a product whose effectiveness we know little about.

Cartographic research certainly has limits, but we must use the best part of any discoveries that may come from it. The form of presentation of governmental chart series rarely changes; this inertia is sometimes referred to in academic circles. It is true that chart standards affecting an extensive series of charts cannot be modified from one day to the next without causing problems and extra expenditure. However, possible improvements cannot be put off indefinitely. The Canadian Hydrographic Service has already shown its flexibility in this area by creating the "New Chart". It does, therefore, seem possible to follow up any discoveries that may result in the near future from a well-structured research program.

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