Behaviour Patterns in Crossing Situations

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ABSTRACT: The January 2009 issue of the Journal of Navigation included a paper (John Wilde Crosbie 2009) entitled, "Revisiting the lessons of the early steering and sailing rules for an e-navigation age." Following a description of the development of the COLREGS from the early 19th century, he concluded that the current steering and sailing rules should be replaced by a single rule more suited to modern conditions. This might take the form of rule stating that a vessel taking action to avoid collision should not pass ahead of the other vessel.

Such a rule would require a radical change in the philosophy of collision avoidance at sea, and evidence is required that it would be both effective and acceptable by mariners. Radar simulator experiments, conducted by the author some years ago, in another context, suggest that this might be the case. An analysis of the experimental results and some conclusions are reported in this paper. The author believes that further trials, specifically designed to test the Crosbie proposals, would be desirable.

1 INTRODUCTION

A recent paper (John Wilde Crosbie, 2009) contained an examination of the development of the COLREGS from the early 19th century to the present day. This led to him to conclude that the current form of the COLREGS is over-complicated and unsuited to present day conditions. Also that they should be replaced by a much simpler convention based on proposals by Commander, later Vice-Admiral, P.H. Colomb of the UK Royal Navy in the late 1800s (Colomb, 1866, 1885). This is referred to in the following sections as the Colomb/Crosbie proposal, and some of its implications are considered in this paper.

A general rule to implement the Colomb/Crosbie proposals might state that a vessel taking action to avoid collision should not pass ahead of the other vessel. Either vessel in an encounter would be permitted to take appropriate action.

In a case where a vessel sees another crossing from her own starboard bow, an alteration of course to starboard to pass under the stern of the approach-

ing ship would be appropriate action and similar to the usual action taken under the current rules. In the case of a ship which sees another crossing from her port bow, an alteration of course to port would be appropriate action under the Colomb/Crosbie convention but this would be quite different to the requirement to maintain course and speed under the current rules.

Clearly, there is a possibility in either of the above situations that, if each ship attempts to pass astern of the other, their actions might cancel and there would be a renewed risk of collision. However, for reasons which he explains in his paper, John Wilde Crosbie (JWC) believes that such conflicting actions would be rare and, if they should occur, they could easily be resolved.

JWC bases his conclusions on an analysis of COLREG developments and the views of commentators, particularly in the UK during the 19th century, when the COLREGS first became properly formalised. He provides no experimental evidence to support his arguments, but the present author is reminded of the results of some radar simulator trials he

conducted some thirty years ago. These results have never been published but, since they shed light on the possible acceptability of JWC's conclusions, they are reported in the following sections of this paper.

2 EXPERIMENTAL DESIGN

In this section, two radar simulator experiments are described. In the first, each subject was presented with a situation in which a "target vessel" was approaching from the port bow of the subject's "own ship" (see fig. 1). The target vessel's course was at right angles to the own ship's course. The own ship's full speed was 15 knots, but it was initially set at half speed of 10 knots. Collision would occur after 33 minutes if the subject took no action.
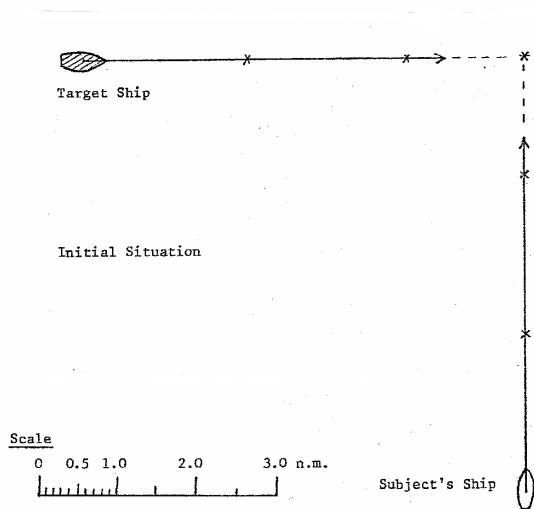

Figure 1. Experiment 1 Port bow approach

The second experiment presented each subject with a similar situation except that the target ship was approaching from the own ship's starboard bow (see fig. 2).
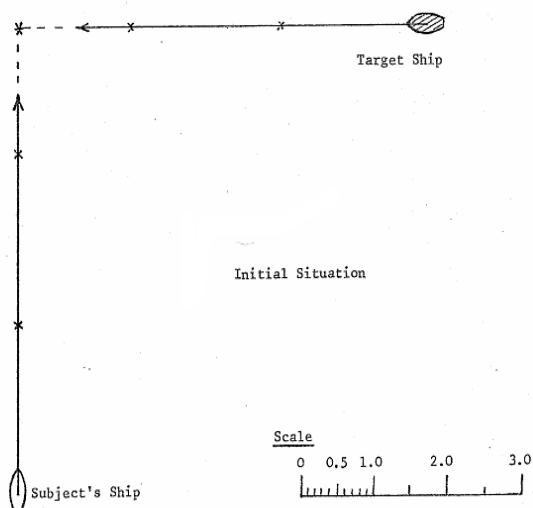

Figure 2. Exp. 2 Starboard bow approach

In both cases, the collision avoidance action taken by the subjects could be allocated to one of three categories: Alteration of course to starboard, alteration of course to port, or change of speed only. These categories are abbreviated to "Stbd", "Port" and "Speed" respectively in the tables of section 3.

Most of the subjects were mariners with at least six years of watchkeeping experience. There was also a smaller "control group" of naïve subjects with no seagoing experience and no knowledge of the COLREGS. Separate analyses were conducted for the two experiments and for each of the experienced and naïve groups of subjects. That is, four analyses in all.

In every case, a χ^2 test was used to find whether there was evidence that subjects had significant preferences amongst the three categories of action defined above. The null hypothesis was an equal probability that the subjects would choose any of the three categories of action. The alternative hypothesis was that this would not be the case. A 0.05 level of significance was considered sufficient to reject the null hypothesis. The results are summarised in section 3, below.

3 ANALYSES

3.1 *Port bow approach, naïve subjects*

Of the 15 naïve subjects who were presented with the port bow situation, the numbers observed to take each of the three categories of action appear in the first row of table 1.

Table 1

	Stbd.	Port.	Speed	Total
Observed (O)	2	10	3	15
Expected (E)	5	5	5	15
$(O - E)^2$	9	25	4	38

$$\chi^2 = (O\text{-}E)^2/E = 38/5 = 7.6$$

This is greater than χ^2 (2, 0.05) = 5.99. We therefore reject the null hypothesis and conclude there is significant evidence that the subjects prefer some manoeuvres rather than others. In this case, they clearly prefer alterations of course to port rather than alterations of course to starboard, and this provides some justification for describing an alteration of course to port as a "natural" manoeuvre in the given situation.

3.2 *Starboard bow approach, naïve subjects*

Of the 14 naïve subjects who were presented with the starboard bow situation, the numbers observed to take each of the three categories of action appear in the first row of table 2.

Table 2

	Stbd.	Port.	Speed	Total
Observed (O)	9	0	5	14
Expected (E)	4.7	4.7	4.7	14
$(O-E)^2$	18.5	22.1	0.1	40.7

$\chi^2 = (O-E)^2/E = 40.7/4.7 = 8.7.$

This is greater than χ^2 (2, 0.05) = 5.99. We therefore reject the null hypothesis and conclude that there is significant evidence that the subjects prefer some manoeuvres rather than others. In this case, alterations of course to starboard are preferred to alterations of course to port. As before, this provides some justification for describing alterations of course to starboard as "natural" manoeuvres in the given situation.

3.3 Port bow approach, experienced subjects

Of the 23 experienced subjects who were presented with the port-bow situation, the numbers observed to take each of the three categories of action appear in the first row of table 3.

Table 3

	Stbd.	Port.	Speed	Total
Observed (O)	8	9	6	23
Expected (E)	7.7	7.7	7.7	23
$(O-E)^2$	0.1	1.7	2.9	4.7

$\chi^2 = (O-E)^2/E = 4.7/7.7 = 0.61$

This is less than χ^2 (2, 0.05) = 5.99. We therefore accept the null hypothesis and conclude that experienced subjects do not have a preference among the three categories of action. In particular, there is no evidence to suggest that they prefer alterations of course to starboard rather than alterations of course to port in the given situation.

3.4 Starboard bow approach, experienced subjects

Of the 24 experienced subjects who were presented with the starboard bow situation, the numbers observed to take each of the three categories of action appear in the first row of table 4.

Table 4

	Stbd.	Port.	Speed	Total
Observed (O)	23	0	1	24
Expected (E)	8	8	8	24
$(O-E)^2$	225	64	49	338

$\chi^2 = (O-E)^2/E = 338/8 = 42.2$

This is greater than χ^2 (2, 0.05) = 5.99. We therefore reject the null hypothesis and conclude that there is significant evidence to suggest that the expe-

rienced subjects have a preference among the three categories of action in this type of encounter. It is clearly a strong preference for alterations of course to starboard.

4 INITIAL RESULTS

4.1 "Natural" manoeuvres

In sections 3.1 and 3.2, naïve subjects, with no knowledge of the COLREGS, altered course to port for a threat on their port bow and altered course to starboard for a threat from the starboard bow. These are consistent responses, since one situation is the mirror image of the other. Also, since it was taken by the majority of naïve subjects, we may consider these to be "natural" actions rather than responses to a set of rules.

4.2 COLREGS comparison, port bow threat.

In the case of a vessel approaching from a subject's starboard bow, the natural action is in accordance with the COLREGS. In the case of a vessel approaching from a subject's port bow, the natural action is entirely different to that prescribed by the COLREGS. Rule 17, somewhat illogically, requires the subject's vessel, (i) to keep her course and speed and (ii) if she does take action, not to alter course to port. Rule 19, which applies in restricted visibility, states that an alteration of course to port should be avoided for an approaching vessel forward of the beam.

Experienced subjects, faced with a threat from the port bow, were equally divided between alterations of course to starboard (in accordance with the COLREGS) and alterations of course to port (in accordance with natural action and with the Colomb/Crosbie convention).

4.3 COLREGS Comparison, starboard bow

Moving on to the results for the situation where the target vessel is approaching from a subject's starboard bow, we find that both naïve and experienced subjects take similar action. That is, alterations of course to starboard.

In this situation, an alteration of course to starboard was the natural action of the naïve subjects and it is also permitted under rule 15 of the COLREGS and under rule 19 when, in restricted visibility, the approaching vessel is detected by radar. With no conflicting considerations involved, all the experienced subjects (except one who decreased speed) altered course to starboard. In doing so, they complied with both the COLREGS and the Colomb/Crosbie recommendations.

5 THE EFFECT OF EXPERIENCE

5.1 *Conflict with the COLREGS*

The experiments described in section 3 above were not, originally, designed to test the Colomb/Crosbie proposals. However, as discussed in section 4, they shed some light on how readily those proposals might be accepted by mariners. The results show that a considerable proportion of experienced mariners appear willing to take action as implied by the Colomb/Crosbie convention, even in cases where such action is clearly opposed to action prescribed by the COLREGS. Clearly, this proportion could be expected to increase if the present COLREGS were repealed.

5.2 *Rapid versus slow disengagement*

In many collision encounters, the navigator has a choice between an action which resolves the situation quickly but which initially involves a more rapid approach to the other vessel, and an action which gives a more prolonged disengagement and which initially decreases the rate of approach to the other vessel.

In the case of a threat from the starboard bow (as in fig. 2) a manoeuvre for rapid disengagement corresponds with both the COLREGS and "natural" action, - that is an alteration of course to starboard. As the results reported in section 3.4 show, practically all experienced mariners take this action.

In the case of a threat from the port bow (as in fig. 1) a manoeuvre to achieve rapid disengagement, - that is an alteration of course to port, is contrary to the COLREGS. As the results reported in section 3.3 show, experienced mariners are equally divided as to which way they alter course.

5.3 *Rational for a hypothesis*

In the port bow case of fig. 1, one choice is of a safe but time consuming action of an alteration of course to starboard or a reduction of speed. The other choice is an apparently riskier, but more efficient, alteration of course to port or an increase in speed. About half of the experienced subjects took the latter choice although it was clearly not sanctioned by the COLREGS so it is of interest to speculate as to why this should be the case. The tendency of many experienced subjects to take risky action may be explained in terms of behaviour theory as developed by B F Skinner (Skinner, 1953). This suggests that an alteration of course to port, although contrary to the COLREGS, leads to a rapid disengagement and relief from anxiety so it is reinforced on every occasion that it is successful. An alteration of course to starboard may break the initial collision situation but

it leads to a prolongation of the encounter and therefore a continued period of anxiety until disengagement is finally achieved and the own ship can resume its original course. If this suggestion is correct, then alterations of course to port for a threat on the port bow should be more common amongst the more experienced mariners. This was taken as a working hypothesis for a supplementary analysis.

6 A SUPPLEMENTARY ANALYSIS

6.1 *Purpose*

This analysis was conducted to test the above hypothesis by investigating a possible relationship between the actions taken by mariners and their respective lengths of experience. For this purpose, their actions were divided into two groups according to whether they were in conformity with the restricted visibility COLREGS (rule following) or in conflict with the COLREGS (rule averse).

Table 5. Experience v. Manoeuvre Class

	Experience Years & months	Manoeuvre class
1	6–6	R
2	6–9	R
3	7–6	R
4	9–1	R
5	9–5	R
6	9–6	A
7	9–9	R
8	10–9	R
9	11–4	A
10	11–8	R
11	12–3	A
12	12–4	A
13	12–8	R
14	13–0	A
15	14–1	A
16	14–7	A
17	14–8	A
18	18–3	A
19	18–6	R
20	19–0	R
21	26–5	A
22	28–2	A
23	29-0	A

In the port bow approach, this corresponded to a choice between a safe manoeuvre that would prolong the encounter (alteration of course to starboard or reduce speed) and a riskier manoeuvre that would resolve the encounter quickly (alteration of course to port or an increase in speed). In table 5, the type of manoeuvre chosen is tabulated against the length of experience of 23 subjects. A Rule–following alteration of course to starboard or reduction of speed is coded as "R". A rule-Averse alteration of course to port or increase in speed is coded as "A".

6.2 *Analysis*

To analyse table 5, we note that, because of wastage amongst younger mariners, experience amongst a random group is likely to be highly skewed rather than normally distributed. Also the effect of experience on a mariner's behaviour is unlikely to be linear so that means and standard deviations, calculated arithmetically, may not be reliable statistics in the context of this analysis.

Of the available non-parametric methods of analysis, the Mann-Whitney U test seems appropriate because the test depends upon ranking but not on an interval scale and it does not assume a particular distribution

From table 5, we note that 11 subjects took actions of class "A" and 12 subjects took actions of class "B". The value of the Mann-Whitney U statistic is calculated as 26. This is less than 28, the value for a one tailed test at a 1% level of significance. We therefore reject the null hypothesis and accept the alternative hypothesis that, as experience increases, mariners are more likely to choose actions that resolve an encounter quickly. Typically, they are more ready to alter course to port for a threat from the port bow.

7 DISCUSSION

A full investigation of the Crosbie/Colomb proposal would require consideration of many factors. This paper simply describes two radar simulator experiments which suggest that an investigation is worth while.

In the case of a threat approaching from a broad angle on the starboard bow (fig. 2) an alteration of course to starboard was the favoured manoeuvre for both experienced and naïve subjects. This was compatible with both the Colomb/Crosbie proposal and the current COLREGS in both clear weather and restricted visibility

In the case of a threat approaching from a broad angle on the port bow (fig. 1) naïve subjects favoured an alteration of course to port. Experienced subjects were equally divided amongst an alteration of course to port, an alteration of course to starboard and an alteration of speed. This might be thought a surprising result in that one would expect experienced mariners to all comply with rule 19 or rule 17 of the COLREGS and avoid an alteration of course to port. This result gives some support to the Colomb/Crosbie proposal, which would allow such an action.

It is also of interest that, in the same situation, a manoeuvre, such as an alteration of course to port, which leads to a rapid disengagement becomes more acceptable as a mariner's experience increases.

Returning to the above observation that some experienced mariners chose to disregard Rule 17 or 19 we should not, perhaps, be too surprised since a number of commentators have, over the years, noted that mariners take a relaxed attitude to following the COLREGS. For example, Syms (2003) analysed the results of a Nautical Institute survey into mariners' interpretations of Rule 19 in a hypothetical collision situation and concluded that, *Fewer than a quarter picked the correct action for both vessels to alter course to starboard*. And, Salinas (2006) found that, in relation to Rule 19d, *….. it has been clearly proved there exists complete disagreement between what the COLREGS state and what seafarers really do*.

8 CONCLUSIONS

At this stage, it should be made clear that the author is not taking a position for or against the Colomb/Crosbie proposal. He is simply presenting some evidence that suggests that an action taken in accordance with that proposal would be acceptable to mariners in two particular situations.

The author does recommend that the Colomb/Crosbie proposal is worth further investigation and that further tests, using a simulator with a daylight display, should be conducted with the specific purpose of investigating the Colomb/Crosbie proposal.

The author also notes that adoption of the Colomb/Crosbie proposal would create such radical changes in the Rules for Avoiding Collisions at Sea that it might be impossible ever to achieve international agreement. That might be shame.

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