HABITABILITY IN SHIPS
OVERVIEW AND A LOOK AT SOME TRENDS

BY

R.S. BRIDGER, PHD, F.ERG.S
(Institute of Naval Medicine, Gosport)

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Introduction

A habitat is defined as the normal environment of an animal or plant. A habitable environment is one that is capable of being lived in. A habitable warship is therefore a warship with the capability to support the life of its crew. Unlike most work environments, it has to support both working life and life outside of work, principally rest and recreation.

Warship habitability has been the subject of research efforts both at the INM and at DERA. ANDREW and RICH define habitability[1] as follows:

> 'Habitability consists of those environmental and organizational factors to be found aboard a warship which contribute to the quality of life of its personnel in order to maintain their mental and physical well-being at a level sufficient to allow them to achieve sustained effectiveness in the performance of their tasks, both operational and non-operational and to support optimum personnel retention.'

STUSTER (1990) provides an operational definition of habitability:

> 'The features of a designed environment that either enhance or impair human adjustment, performance and productivity.'

At this level, there is nothing elusive about the concept. It is a straightforward matter to define habitability requirements for the support of human life (food, air composition and temperature etc.) However, as soon as an attempt is made to define habitability in operational terms — *habitability for a purpose* — problems arise. We are no longer dealing with minimum standards for life support but with choosing design features which will optimize organizational effectiveness.

Habitability variables and habitability indices

STUSTER identified the following as key habitability variables:

- Sleep
- Clothing
- Exercise
- Medical support
- Personal hygiene
- Food preparation
- Group interaction
- Habitat aesthetics
- Outside communication
- Recreational opportunities
- Privacy and personal space

- Waste disposal and management
- Onboard training and task preparation.

ANDREW and RICH developed a list of the dimensions of habitability and a habitability database consisting of over 980 records relevant to habitability in warships. They also found over 150 indices of different aspects of habitability and discussed the possibility of developing a unified, generic habitability index for warships. There are many problems in developing a general habitability index. For example, although environmental standards exist (e.g. for illuminance levels, air temperature and humidity, noise etc.) it is not clear how the variables interact to determine a habitability level for a given purpose. There is no theoretical or mathematical procedure for the a-priori calculation of a habitability index from component measures. Essentially, the habitability of a warship will depend on how these standards are put together in a final design — a problem for the architects. To complicate matters even further, some aspects of habitability are likely to be context-dependent — for example the concentration of nauseogenic compounds in the air will be more critical in rough seas or at the start of a voyage than at other times.

What do people want?

EDGAR and STRONG[2] identified future habitability features in rank order of perceived importance (Table 1).

TABLE 1. — *Future habitability features in order of importance*

Rank Order	Future Habitability Feature
1	All personnel accommodated in single cabins
2	A separate bunk for everyone
3	A dedicated fitness area
4	Mess areas separate from sleeping areas
5	No smoking throughout the ship or submarine
6	If permitted, separate areas for smoking
7	Access to showers and heads from within sleeping areas
8	Private rest spaces separate from public mess space
9	Facilities/allowances to customize personal space
10	Single Heads to give mixed crews flexibility
11	Integrated galley, serving, dining areas
12	Space for personal computers
13	Facilities to prepare own food/snacks
14	Food facilities for different needs
15	Access to snacks at all times
16	Space for recreational/computer games
17	Self-service meals for all personnel
18	Carpeted sleeping areas
19	Single compartment 'public' Heads to provide flexibility for mixed crews

Practically all of the above are 'high-level' features which are concerned with issues such as:

- Privacy
- Personal space

- The removal of constraints (particularly constraints on the use of leisure time, recreation and 'territory').

There is little mention of features such as temperature and humidity, ship motion and air quality, which is perhaps an indication that these are already at or above the minimum acceptance level. There is a sense in which crew appear to accept the demands placed upon them when *working* on-board ship but are less tolerant of constraints at other times.

Why habitability?

The purpose of making ships more habitable is to make them more effective. In almost any organization, effectiveness depends on:

- Satisfaction and commitment amongst members
- Communication and co-ordination within and between groups
- Optimum work performance
- A mutually supportive relationship with the external (organizational and social) environment — including the environment outside work.

Optimum habitability, as yet undefined, will not guarantee any of the above but it can prevent dissatisfaction with conditions on board ship, fatigue and unnecessary stress. Satisfaction with the environment is a component of job satisfaction and optimum work performance, if it is to be sustained for long periods, depends on the restorative power of sleep and the opportunity to engage in a variety of recreational activities outside of work.

A new generation of warships: automation and information technology

Some extracts from the Future Surface Combatant Human Factors Integration Policy Paper are of interest:

> 'There is no doubt that there will be an increasing requirement to recruit individuals with information technology skills........rather than rely on training to instil this knowledge.'
>
> 'A future combat system is likely to have a lesser number of more highly/ multi-skilled individuals with deeper systems knowledge of a range of computer systems... this will have an impact on management skills.......as there will be fewer junior individuals to manage.'
>
> 'All accommodation.....should be designed irrespective of the gender that will ultimately use it (*to allow flexibility*). What this means in reality is cabin accommodation with associated heads and showers.'

A recurring theme throughout the policy document is the way in which 'technology push' will impact on habitability and the need to make the right decisions early on. The requirements for successful human factors integration of advanced technologies and the need to compete on the job market to attract recruits with information technology skills will force the pace of change. We are concerned with defining habitability for a changing workforce and a different type of ship.

People size and the secular trend

People have been getting larger for the last 150 years in the UK and elsewhere. Initially, the increases were due to improved living conditions accompanied by heterosis with resulting 'hybrid vigour' as large numbers of people moved from rural areas to work in the rapidly industrializing cities. BOLDSEN[3] demonstrated that 45% of the increase in male stature in Denmark over the last 140 years was due to the former (i.e. 'outbreeding') and 55% due to the latter. The increase has been sustained by:

- Improvements in year-round diet with the adoption of refrigeration and refrigerated transportation by the food industry
- Immunization against debilitating childhood diseases
- The development of effective antibiotics and the supplementation of food, particularly of dairy products with vitamin D to prevent rickets in childhood.

It would seem reasonable to argue that the factors underpinning the trend would, by now, have played themselves out in the UK, since the population is well nourished and unlikely to be inbred. However, recent data[4] suggests that the 10mm/decade increase in stature is continuing, possibly due to non-linear and intergenerational effects which can be expected to continue. Undoubtedly, there will be implications for the overall design of warships (for example, deck heights, headroom etc.) as well as personal protective equipment, workspaces and bunks.

Air quality

Air quality in the workplace has received much attention over the last 15 years with sensationalistic news reports about the 'sick building syndrome' — mucosal irritation and other symptoms associated with working in sealed environments. The problem is only partly due to air quality. Where it occurs in workspaces it is usually associated with poor ventilation (which is easily checked by monitoring carbon dioxide concentration and air flow) and with offgassing of volatile agents from new equipment, furnishings, fuel and even cleaning materials. Other non-atmospheric risk factors are low lighting levels and working with Visual Display Units.

ZHU[5] has suggested an alternative description, namely, 'Modern Indoor Worker Syndrome' because the problem is experienced by people and not by hardware. Smokers, already desensitised to air quality, are less likely to complain. Psychosocial factors and low status are associated with the complaint and women appear to be more sensitive to poor air quality than men. KILDESO et al.[6] have developed a surveillance tool for monitoring human response to indoor air (Table 2).

TABLE 2. — Visual Analogue Scale for 'Sick Building Syndrome' Surveillance

How do you feel right now?

Too cold	____________	Too hot
Too humid	____________	Too dry
Draught	____________	Too little ventilation
Bad air	____________	Good air quality
Too dark	____________	Too light
Too quiet	____________	Too much noise
Nose blocked	____________	Clear nose
Dry nose	____________	Runny nose
Dry throat	____________	Normal throat
Dry mouth	____________	Normal mouth
Dry lips	____________	Normal lips
Dry skin	____________	Normal skin
Brittle hair	____________	Normal hair
Brittle nails	____________	Normal nails
Dry eyes	____________	Eyes not dry
Itching eyes	____________	Normal eyes
Eyes ache	____________	Eyes do not ache

Irritated eyes	______________________	Eyes normal
Severe headache	______________________	No headache
Pressure in head	______________________	Clear head
Dizzy	______________________	Not dizzy
Feeling bad	______________________	Feeling good
Tired exhausted	______________________	Feeling good
Hard to concentrate	______________________	Easy to concentrate
Depressed	______________________	In a good mood

Privacy and personal space

Personal space can be defined as the area immediately around the body, which is regarded as the individual's exclusive preserve. It is linked to territorial behaviour. Invasion of personal space is regarded as stressful. The size of the personal space volume depends on many factors, including cultural factors and the particular context (for example, it is smaller when the individual is in a crowd at a football match than in a sparsely populated library).

Invasion of personal space is stressful in psychological and physiological terms. The nature of stress in future warships is likely to change with the reduction in crew numbers and the increasing levels of automation. Problems and opportunities for stress management at sea will emerge and habitability may need to be more clearly linked to stress management than to basic hygiene factors.

Habitability and the quality of sleep

Sleep quality is very important. Many factors can degrade the quality of sleep and thus reduce its power to restore mental and physical vitality. Disruptions to the normal sleep/wakefulness cycle may be caused by the design of watch systems. Humans can adapt to new routines of sleep and wakefulness and both the speed and completeness of adaptation is enhanced if all environmental cues ('zeitgebers') match the new pattern and if patterns are as stable as possible. This has clear habitability implications. As far as possible, social and workrooms should be well lit, even at night, and sleeping quarters very dark during the day. In principle, except during war, adaptation should be easier to meet on a ship than in land-based occupations because of better control over the internal environment and the relative isolation of the crew from external social cues. Poor segregation of day and night shift workers is problematic for this reason.

Seasickness and ship motion

Ship motion is of fundamental importance to habitability, firstly because it can cause seasickness and secondly because it can cause fatigue and degrade human performance. Research on ship motion is underway at several centres including the INM and DERA[7].

For optimum conditions and the avoidance of sea-sickness:

- Locate critical stations near ship's centre of rotation
- Minimize head movements
- Align operators with the principal axes of the ship's hull
- Avoid combining provocative sources
- Provide an external visual frame of reference
- For postural stability, position feet perpendicular to the axis of rotation

Relationship between technology, architecture and habitability

Technological innovations can have surprisingly little impact on work organization and design for very long periods after they become commercially viable (Sundstrom, 1986). Alternatively, there is often a close relationship between technology and the constraints it imposes and the work environment. Early factories used water as a source of power and were therefore built next to rivers. The absence of a cheap means of artificial lighting resulted in the construction of long, thin buildings, perpendicular to a river with windows on both sides. Shafts from water wheels ran the length of the building. Electrical and steam power removed these constraints and resulted in the factories we are familiar with today. Early offices were modelled on the houses and drawing rooms of the well to do. Electric light bulbs were invented in the 1880's but were not widely used in offices until the 1930's. The invention of air conditioning made it possible to design offices with deep interior spaces — only then did electric lighting become a necessity (useful daylight from windows penetrates no more than a few metres into a building).

The introduction of computers in office work led, initially, to an improvement in the indoor environment (to provide a stable environment for the new machines) and then to a new generation of energy efficient buildings capable of handling the thermal load of both the occupants and the electronics and cathode ray tubes. There are many arguments for the improvement of working conditions in technology-intensive businesses to:

- Motivate staff
- Foster good employer-employee relations
- Minimize ill-health
- Retain people with important skills.

Lavish spending on new buildings, furniture etc. is usually cost-justified using total life-cycle costings. For example, over the 40 year lifespan of an electronic office building, the single biggest cost is occupants' salaries (over 90% of the total expenditure). Erecting and furnishing the building is around 3%, maintenance 2% and the remainder running costs. The values for RN ships are probably different, with salary and associated costs a smaller percentage of the total, but essentially the same arguments can apply (with the rider that, following on from Disraeli, there are Alies, damn lies, statistics and ... Costs").

Conclusions

Habitability is for a purpose — to provide a living and working environment for those on board. In the future, those on board will be fewer in number, probably taller, with information technology skills doing jobs involving information processing. Deciding on the appropriate level of habitability to maximise cost — effectiveness will be a key issue.

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