Modelling Human Performance in Maritime Interdiction Operations

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ABSTRACT

Maritime Interdiction (MI) operations are an increasing important element of the littoral environment. This is demonstrated by the International anti-piracy operations around the Horn of Africa and the establishment of the NATO Maritime Interdiction Operational Training Centre (Crete, Greece). The type of MI operation described is the insertion of a ship boarding team, via high speed craft, from where the team are required to board the ship using a 'caving' ladder. Once aboard, the team undertakes a high-tempo offensive operation where accurate target recognition and prosecution is essential for operational success. The maritime environment is arguably one of the harshest work environment in which humans must contend. In addition to either extremes of temperature, the repeated shock and vibration exposure of the high speed craft has been shown to result in high levels of post-transit fatigue which potentially reduces operational effectiveness during subsequent operational phases. On reaching the target ship, the climb up and onto the deck using a free-swinging ladder, whilst potentially carrying in excess of 50kg of equipment, is a physically arduous task particularly in poor environmental conditions. When the boarding team is on deck, the on-target phase of the operation can begin. This is a high-tempo task, made more difficult by the requirement for protective clothing and equipment, and carrying the heavy operational equipment load. This requires high levels of fitness and the ability to make accurate target identification decisions, and subsequently accurate shooting performance, whilst working at increased physical work-rates. To model the human performance aspects of the MI operation the factors influencing the insertion and on-target phases need to be quantified, initially via formal Task Analysis, so as to assess the potential degradation to performance and operational effectiveness. The ability to model these inter-related human, environment and equipment factors provides the ability to develop effective solutions to reduce performance degradation and enhance operational effectiveness. This paper describes an example MI operation, the development of a methodology to assess performance degradation via an operationally specific test battery, the qualification of high speed craft motion and shock mitigation, the results of assessing post-transit fatigue and issues of objectively assessing target prosecution. It is proposed that continued development of the MI human performance model will help enhance operational effectiveness by providing a greater understanding of how the environmental stressors, engineering systems interact with human operators to influence performance. An integrated approach, based on a formal TA, will enhance MI operational effectiveness and readiness for both NATO and its Partners.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **OCT 2010**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Modelling Human Performance in Maritime Interdiction Operations**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **STResearch Ltd Chichester UK**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

See also ADA564696. Human Modelling for Military Application (Applications militaires de la modelisation humaine). RTO-MP-HFM-202

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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**20**	

1.0 INTRODUCTION

Maritime Interdiction (MI) operations are an increasingly important element of the littoral environment, the control of Economic Exclusion Zones and the Global War on Terror. This, for example, is demonstrated by the International anti-piracy operations around the Horn of Africa and the establishment of the NATO Maritime Interdiction Operational Training Centre (NMIOTC) based in Crete, Greece [1]. A common description of MI Operations is Visit, Board, Search, and Seizure (VBSS). For this paper, VBSS provides an appropriate description of a generic MI operation involving the insertion of a ship boarding team, utilising High Speed Craft (HSC), from where the team is required to board the ship using a flexible wire (caving type) ladder. Once aboard, the team undertakes a high-tempo offensive operation where accurate target recognition and prosecution are essential for operational success.

The maritime environment is arguably one of the harshest work environment in which humans contend. In addition to hot, temperate or cold temperatures, the Repeated Shock (RS) and Whole Body Vibration (WBV) exposure of a HSC insertion transit has the potential to induce high levels of post-transit fatigue and injury.

Operational analysis [2] demonstrates two single-points-of-failure that increases the risk of mission failure of the MI operation as described in this paper. These are:

- The HSC coxswain during the insertion phase
- The ladder climb/transfer onto the target vessel

A graphical representation of these risks is shown below in Figure 1. It can be seen that the *Risk to the Mission* is high prior to the *Transfer*; this is where the actions of the coxswain during the approach to the target are critical to mission success. Similarly, the *Risk to the Mission* and *Risk to the Force* are greatest from just prior to the beginning of the *Transfer* through to its completion; this is where the actions of the coxswain during the *Transfer*, and the ability of the boarding team to successfully execute the transfer are critical to mission success.

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Figure 1: A Graphical Interpretation of the *Risk to Mission Success* and the *Risk to the Force* During the Time-Line of a Generic Maritime Interdiction Operation.

This paper describes a generic MI Operation, its Phases, including those of high risk highlighted in Figure 1, and Factors limiting the human operators' performance within the Phases. From these Phases and Factors, a model is constructed to allow the interactions to be observed, how mitigation solutions may be applied along with their potential influence on the model and subsequent operational performance. The paper does not explicitly detail a MI Operation, but provides a framework model from which performance enhancements may be developed.

2.0 PHASES OF A GENERIC MARITIME INTERDICTION OPERATION

To facilitate a greater understanding of the human related factors limiting MI performance the operation is deconstructed into quantifiable factors. The following schematic representation (Figure 2), and descriptions of a generic MI operation, were developed to model the relevant human performance factors and their interaction.

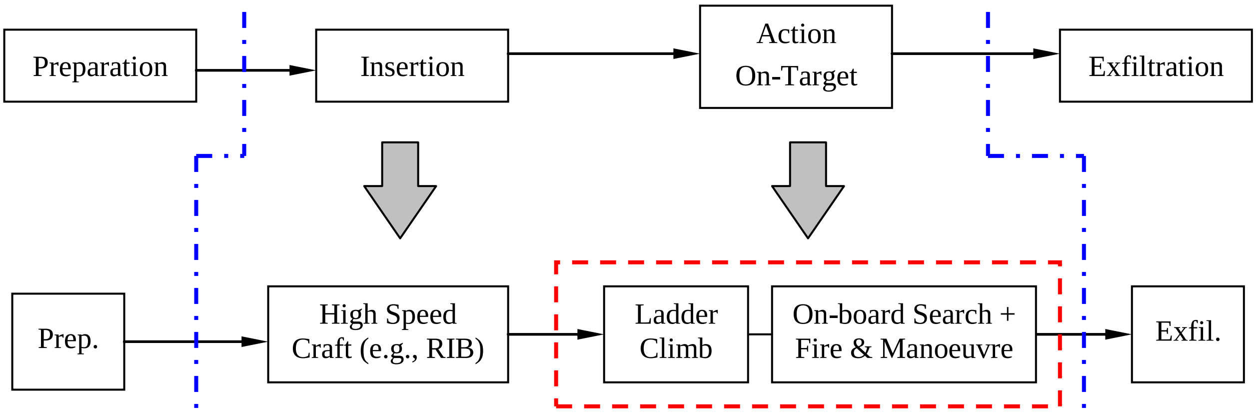

Figure 2: Schematic Representation of a generic Maritime Interdiction Operation.

2.1 Preparation Phase

2.1.1 Planning, Rehearsal & the Move to the Area of Operation

2.1.1.1 Planning & Rehearsal

The MI team, including the boarding and Command & Control (C2) elements, will have completed a through planning activity for a range of different MI scenarios, including wherever possible the use of intelligence specific to the target vessel. From these, the team will have undertaken training and rehearsals to maximise operational effectiveness.

2.1.1.2 Move to the Area of Operation (AOO) / Drop-Off-Point

The move to the start line can be short or long; and can include road, water and air moves. For example, the HSC may be deployed directly from a larger maritime platform operating in the area, whereas a longer deployment could include a road move to an air-head, where the MI team may be flown to the general area of operation. From this Drop-Off-Point the HSC may subsequently need to transit a significant distance to the target vessel, potentially requiring refuelling.

2.1.2 Physiological Factors

2.1.2.1 Nutrition & Hydration

In high-tempo operations where MI teams have to remain on-call, it can be difficult to plan and ensure that the team maintain the appropriate energy and hydration levels. For energy replenishment during the operations insertion and on-target phases there must be the appropriate facilitation for eating and drinking prior to the initiation of the insertion

2.1.2.1 Sleep

Sleep deprivation is a commonly recognised factor influencing military operations. Where MI teams are kept on-call, rather than acting as part of larger planned operations, it can be typical for operations to start at times when the teams have been awake for significant periods of time undertaking normal duties. If an MI operation is initiated when the team has already been awake for 18 hours it is likely that the team members will have been awake for over 24 hours when the boarding phase is initiated. Sleep deprivation has been shown to degrade cognitive function [3, 4], e.g., attention, etc. Pharmacological interventions can assist in the maintenance of cognitive function, e.g., caffeine, but ultimately efficient organisation is required to plan the appropriate work-rest schedules for MI team members.

2.2 Insertion Phase

2.2.1 High Speed Craft

2.2.1.1 Repeated Shock & Whole Body Vibration Exposure

Repeated shock & WBV exposure from HSC transits has been shown to result in fatigue [5, 6] and an enhanced risk of musculoskeletal injury [7, 8], whilst the use of shock mitigation solutions (e.g., suspension seating) may maintain performance post-transit [9, 10] and thus support operational effectiveness. Figure 3 provides an example of the effectiveness that shock mitigation can provide for maintaining performance post-transit.

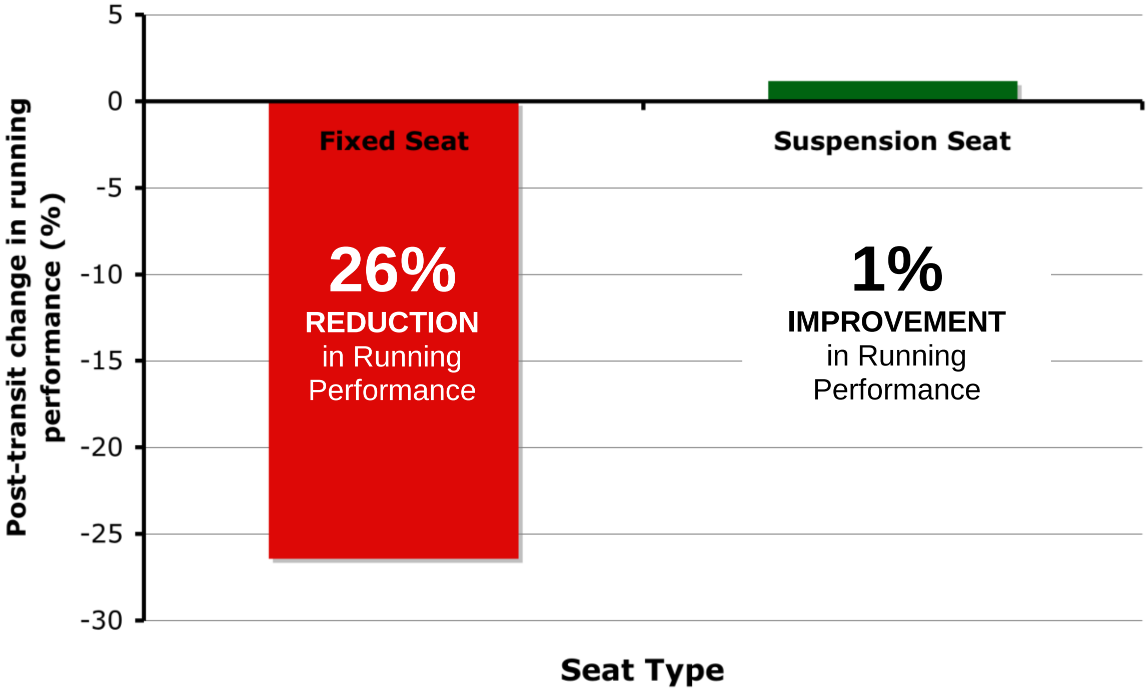

Figure 3: Differences in Post-Transit Performance (Fatigue) Following a 3-Hour Voyage (~Sea State 2) in 8.5m RIBs for Occupants using Fixed and Suspension Jockey-Style Seats.

2.2.1.2 The Coxswains Role

The HSC coxswain is an essential component in the MI operation, having the same level of importance as the pilot for helicopter operations. They have to control the HSC in poor sea conditions, which may appear to be a relatively passive task, but heart rate data [11] supports the anecdotal evidence that the coxswain's work rate is greater than the passengers, which is supported by them wearing less clothing layers than the passengers.

The control of the HSC is achieved via steering, throttle and trim control [12], with effective throttle control being essential for reducing RS & WBV exposure, and ensuring the safety of the craft, embarked crew and passengers. Although this may appear to be a relatively passive 'driving' task, evidence suggests that the Coxswains role is high workload [13] and requires a high level of training [14].

2.2.1.3 Ergonomics & Posture

Effective MI operations require that the boarding team reach the target vessel in an optimum condition with minimal fatigue. It has been shown that shock mitigation systems have the ability to reduce the magnitude of fatigue induced by the HSC's RS and WBV. Human factors and ergonomics guidance for the design of HSC has been produced [15,16] to support the maintenance of operational effectiveness and readiness. Typically HSC often have poor ergonomics which results in the boarding team experiencing cramped conditions, compromised blood flow and the inability to effectively maintain postural stability [17].

2.2.1.4 Cold Exposure

Exposure to the cold has the potential to degrade on-target performance. Myers, et al. [18] demonstrated that a three-hour exposure to a cold environment on an open RIB resulted in a large post-transit degradation in physical performance of approximately 40%. In the same way, cold and wind-chill exposure reduced climbing performance on a free-swinging caving ladder [19].

A number of solutions to reducing cold exposure are available; these include both HSC design features (e.g., cabin or wind deflection) and Personal Protective Equipment (PPE)(clothing using passive insulation and /or active heating).

On-target high-tempo operations generate heat and therefore clothing needs to reflect the thermoregulatory demands. Currently operators often under-dress for the transit to ensure on-target performance – but this potentially compromises the crucial ladder climb onto the target vessel, and the initial stages of the on-target phase whilst the individuals warm up.

2.2.1.4 Heat Exposure

Heat exposure is a well-recognised problem from military operational experiences in Iraq and Afghanistan; in the same way heat exposure has the potential to degrade on-target MI performance. There is little direct evidence of on-water effects, but it is known that dehydration of as little as 2% body mass leads to deficits in both physical and cognitive performance [20, 21], with reductions in endurance capacity of over 40% being reported [22]. It is known that heat storage and the subsequent difficulties with thermoregulation within the body leads to degraded performance, these will be expatiated in the marine environment where relative humidity is high and PPE with restricted vapour permeability is worn. The requirement for MI operators to wear PPE and operational equipment adds to their insulative and load carriage burden and increases the risk of degrading the individual's performance potential.

Whilst operating in areas of high levels of sun exposure, it is recognised that HSC should be designed to provide the occupants with shade. The use of cooling systems may be employed on HSC, these may be passive (e.g., the use of evaporation) or active systems (e.g., cabin air conditioning and body-worn cooling vests) which have been utilised in vehicles in Iraq and Afghanistan. Such cooling technologies must be able to cope with the HSC environment, particularly the exposure to RS and WBV.

2.2.2 Alternative Insertion Modes

Depending on the location of the MI teams assets and target platform, and the tactical nature of the situation, the insertion options include air and sub-surface modes of transport. These modes have their own limiting factors but are outside of the scope of this paper. However is should be remembered that good planning and procedures can reduce the distance required to reach the target vessel – e.g., making the best use of the prevailing weather conditions.

2.3 Accessing the Target Vessel

This may be considered the most important evolution of the operation and is a single point-of-failure. Therefore resources should be allocated to this phase to reduce the risk of operational failure.

2.3.1 Holding Station on the Target Vessel by the HSC – The Coxswains Role

The position held against the target vessel is a compromise between the wave pattern along the length of the vessel and the potential access points, lower level access being preferred to reduce the climbing height.

The maintenance of the position is a combination of the HSC coxswains skill with steering and throttle control. The coxswain is required to accurately control the following positions:

- Longitudinal position for the access location of the target vessel.

- Distance from vessel – this is important for not getting stuck on the target vessel and to be able to rapidly move away from the vessel if required

For HSC to be an effective part of the MI operation the appropriate Command & Control (C2) is required. This C2 has a number of aspects; communication with the operational command structure, communication for the operation of the HSC, and communication between the HSC crew and the boarding team. A model of HSC C2 (HSC3) has been developed [23] that supports MI operations but specific operational procedures are required to achieve an effective boarding. The communication requirement between HSC crew and boarding team includes:

- Coxswain maintaining the required position alongside the target vessel
- Ideally a 2nd coxswain/crew member managing the climbing operation with the leader of the boarding team.

Following the boarding, the HSC often maintains a support role, requiring continual communication with the operational command centre.

2.3.2 Boarding Equipment

Placing the ladder, poles, etc., often known as 'hooking-on', is a highly skilled task that must be practiced and perfected. A range of equipment is required by teams for the types of vessels they are likely to encounter. The boarding ladders used are of two designs:

- Fixed: limited height but dimensions and rigidity provide for good biomechanics
- Flexible: light weight and easy roll-up storage, but the flexibility and dimensions of the ladder result in control issues and an increase in the difficulty of climbing.

2.3.3 Human Factors

There are a number of human factors issues that influence the individual’s climbing performance. A number of these are highlighted and briefly described below with graphical examples of day-light ladder climbing training shown in Figure 4:

- Gravity/weight: The individual must use muscular effort to lift themselves and their equipment onto the target ship. It should be remembered that in addition to the weight of the individuals clothing and equipment ensemble it is likely that these will become wet (spray and precipitation) during the transit thereby further increasing the load.
- Mobility: Restrictions (e.g., range of motion) to the individual’s mobility due to clothing and equipment (both PPE and operational) reduces performance.
- Dexterity: Similar to mobility, the individual’s dexterity is reduced by the need to use protective gloves and boots.
- Visibility: MI operations may be planned to occur during the hours of darkness, or in conditions of restricted visibility. This has the potential to degrade performance in the ladder climb and during the on-target phase.
- Ladder climbing technique and skill:
  - Foot and hand placement during caving ladder climbing is crucial. Options include the use of the front and back of the ladder. Currently there is no definitive technique that is universally recognised.
  - Centre of Gravity (CoG): Much of the operational equipment is worn on the sides and rear of the body. This moves the CoG away from the ladder, resulting in the ladder swinging away

from the climber. The equipment can't be worn on the front of the individual as it will restrict mobility and move the body away from the ladder.

- Strength/muscular endurance: There is a recognition amongst the climbing community that the individual must to use leg strength and not arm strength – as the arms are weaker and will tire relatively quickly compared to the legs. However, the arms and legs may be fatigued from the HSC insertion phase where muscular work will be required to absorb the RS exposure, and maintain postural stability.

Figure 4 - *Left*: Example of ladder climbing training without MI PPE and operational equipment;
Figure 4 - *Right*: NMIOTC MIO Boarding Team training (Course 3000 - Practical Training).

2.3.4 The Risk of Falling

There are multiple factors that increase the risk of falling from the ladder. In addition to potentially compromising the mission, the individuals are at risk of potentially fatal injuries. This issue contributes to making the climbing task a single point of mission failure. The following issues are highlighted:

- Stepping onto the ladder
  - This is not a trivial task, stepping from a moving boat to the free-swinging ladder when the HSC is being repeatedly hit by waves is a high-risk activity.
  - If the boat is vertically stationary relative to the vessel, then the step is relatively straightforward. If the boat is moving vertically with the wave swell, it is essential that the individual steps onto the ladder at the highest point – otherwise they risk being hit by their boat from below as it is lifted by the next wave.
  - The coxswain should be able to manoeuvre the boat a small distance away from the vessel (e.g., 1m) once the climber has stepped onto the ladder. When they have initiated the climb the boat can be manoeuvred back in to deliver the next climber. This task requires a very skilled coxswain to successfully achieve this in rough sea conditions with restricted visibility.

- On a long climb and with a heavy operational load the climber may become fatigued and need to rest, the ability to 'clip-on' using a karabiner type system is sometimes used. It should be recognised that this will slow the overall transfer evolution of getting the boarding team onto the target vessel and thus increases the risk of mission failure.

2.4 Action on Target Phase

Once onboard the target vessel the team will execute its Standard Operational Procedures (SOPs) for the action on target. Such procedures are covered in the training provided by NMIOTC. This paper does not address the SOPs, but rather highlights the human related factors that can limit performance and operational effectiveness. Note that the insertion craft may be required to follow the target vessel during this phase, thus extending the boat crews' environmental exposure, to support the on-target operation and assist in the exfiltration if required.

2.4.1 Search – Fire & Manoeuvre

2.4.1.1 Physical Description; e.g., Repeated Sprint Activity

In order to understand human performance during the on-target phase an objective assessment of it is required. It is recognised that military operations are generally stochastic in nature, but similar to sporting events, there are generalisations that can be made. For example, the operators will spend certain amounts of time undertaking the following activities: stand/kneeling, walking, jogging, and sprinting. Using Notational Analysis techniques (similar to those regularly used for analysis of team games e.g., soccer, football, rugby) a typical example of the exercise intensities, and their distribution during the on-target phase, can be used to develop objective test methodologies for developing and assessing performance enhancement strategies. Therefore the following factors, which are recognised as being important for successful on-target tasks, may be examined:

- Load carriage: It is recognised that in contemporary dismounted military operations the loads that the individuals have to carry compromises their performance, and therefore efforts are being made to reduce the load burden on the Warfighter. From load carriage modelling it has been shown that even when stationary for every 1kg of load, an increase in energy expenditure occurs by 60 $W.m^{-2}$ [24]. Increasing load is of specific relevance to ship operations due to the environment where the individuals are required to repeatedly climb and descend flights of stairs/ladders to access different areas of the ship.
- Exercise intensity: In addition to load being directly related to exercise intensity, the speed – or operational tempo – with which operational effectiveness is achieved is important. The higher tempo/exercise intensity leads to a greater the risk of fatigue, energy depletion and dehydration. The existence of a fatigue threshold has been described [25], along with the limitations it brings to enforcement operations and the requirement for near-term solutions. Solutions for reducing/coping with elevated exercise intensities are required for all phases of the operation.
- Mobility: The need to wear PPE and carry operational equipment reduces operator mobility. The mass of the clothing and equipment can routinely be in excess of 30kg and this reduces the individual's mobility and agility. In addition to the mass, the size and location of the equipment can affect mobility by restricting limb range of motion. Load carriage systems should be designed to minimise its impact on mobility.
- Clothing PPE: The clothing worn during an MI operation serves a number of required functions. In addition to these requirements the design has the potential to result in 'side-effects' that may compromise performance:
    - Thermal management: The high-tempo operation on the target vessel means that the individuals generate metabolic heat that they need to dissipate. However, the requirement for

clothing to cope with CBRN and fire exposure means it is often insulative and increases the individuals thermal load. Because the individual will dress for the on-target phase they are often left with inadequate thermal insulation for the insertion phase where the environment exposes them to heat loss and the subsequent loss of performance.

  - Permeability: The need to protect the individuals from the risk of cold-water immersion during the insertion phase means that their clothing will have restricted water vapour permeability, restricting heat loss via evaporation and leading to moisture build-up.
  - Restricted weapon aiming: The dimensions/bulk of the clothing and equipment (e.g., life jacket) can restrict the ability to effectively control and aim the weapons utilised.
- Respiratory PPE: Respirators are commonly used in MI operations (e.g., full CBRN equipment would be used on high level targets with WMD/Dirty Bomb intelligence) and therefore their characteristics must be recognised and accounted for:
  - Work of Breathing: Respirators will increase the individuals' work of breathing which increases their exercise intensity and risk of fatigue [26]. Respirators are designed with features to reduce work of breathing, but this will still inhibit performance and effectiveness.
  - Field of View: Poorly designed respirators limit an individual’s field-of-view, in particular peripherally, and therefore may reduce their Situation Awareness (SA). Without good SA the risk of errors increases.
  - Restricted weapon aiming: The dimensions/bulk of the respirator can restrict the individual's ability to position the eye appropriately to effectively aim the weapons deployed.
- Noise: It is a recognised that during fire and manoeuvre operations the resultant high noise levels will reduce the effectiveness of communication between the team members. Therefore communication systems are needed to overcome this problem.
- Cognitive ability: Increases in exercise intensity can affect cognitive performance; this can be via the concept of cognitive tunnelling where the number of pieces of information that can be attended to is reduced. For this reason SOPs are designed to enhance operational effectiveness and cope with cognitive tunnelling as all the MI team will know what is happening and their required actions/reactions will have been rehearsed to ensure the SOPs are followed.

2.4.1.2 Teamwork

The success of MI operations is dependant on effective teamwork. This requires an undertaking to understand how the following factors interact to facilitate an effective operational outcome:

- Individuals must understand and carry out their role within the operational framework
- SOPs must be understood and executed at both the individual and team level.
- Communication is essential for effective teamwork, and methods of operation are required to cope with failures in communications systems.

2.4.1.3 Target Prosecution

There are two aspects to successful target prosecution that relate to human performance; firstly target recognition, and subsequently shooting accuracy.

- Target recognition: For MI operations effective target recognition, and the subsequent decision-making (following the operational Rules of Engagement), is imperative where there are both opposing forces and civilians embarked on the vessel. Recent research [27] is now providing some insight into how cognitive processes influence target recognition; this includes short-term memory capacity.

- Shooting accuracy: Although important, this aspect is arguably less so than target recognition. Whilst individuals may be capable of accurate shooting on a quiet range, it is their ability to shoot accurately/effectively whilst under pressure, and fatigued, that must be practiced and perfected.

2.5 Exfiltration Phase

This phase is not covered within the scope of this paper, but is generally considered to be a lower intensity activity. It should be noted that the duration of this Phase could be as long as Insertion Phase if conducted in poor weather conditions due to rotary air asset’s reduced flying capability in these conditions.

3.0 RELATED ISSUES

Following the description of the MI operational phases and the factors relating to human performance there are a number of related issues, not covered in Section 2, that support effective operational outcomes.

3.1 Specificity of Training

3.1.1 Enhancing Performance

3.1.1.1 Physical Fitness

Within the human performance domain it is recognised that there are two types of fitness; general and specific. For example both runners and swimmers have good levels of general fitness, but these levels of general fitness do not make the runner a good swimmer and *visa versa*, due to the concept of training specificity. Therefore, the MI personnel require both high levels of general and specific fitness.

The development of specific fitness programmes for MI operations requires a thorough understanding of the physical tasks being undertaken and how both strength and endurance interact with motor skills and technique development for the equipment deployed.

3.1.1.2 Operational Task Skills

It can be difficult to obtain the platform assets required for realistic operational training, e.g., ships and high-speed ferries. Thus training provided by organisations such as the NMIOTC support this requirement for teams with limited access to such assets.

The potential exists for using simulators to support specific elements of MI training, although the validity and effectiveness of the training requires examination before significant investments are made in expensive equipment and infrastructure. Simulation can range from relatively simple mock-ups (e.g., target vessel infrastructure made of plywood), to sophisticated computer-based distributed networks simulating the interaction between the MI Operations C2 assets.

3.1.2 Reducing Injury Risk

3.1.2.1 Injury Proofing

As MI training needs to be realistic the likelihood of individuals sustaining minor injuries (e.g., contusions, strains, sprains etc.) is high but probably unavoidable. However, the risk of sustaining more serious injuries during training should be minimized through good planning and risk assessment procedures.

It is recognised that individuals that are more physically fit are generally more resilient to injury, but it should be noted that general fitness might not be related to a reduced risk of injury. In the sporting environment, elite endurance athletes wouldn't cope well with playing high intensity sports such as rugby, America football and Australian Rules football as they would suffer high levels of pain and soreness from the repeated tackles, bumps and scrapes. Coping with the physical stresses of these games requires specific training, and provides a good analogy for coping with military operations and training.

In the MI environment it has been observed that boarding teams with higher levels of general fitness than highly experienced HSC coxswains suffered much greater muscle soreness following transits.

Specific examples of the demands on MI personnel include:

- HSC Coxswain
  - Insertion/On-Target/Exfiltration phases – coping with Repeated Shock (RS), (eccentric muscle contractions), and maintaining postural stability (isometric muscle contractions).
- Boarding Team
  - Insertion – coping with RS (eccentric muscle contractions), and maintaining postural stability (isometric muscle contractions).
  - Fire & Manoeuvre – coping with multiple levels of multi-directional agility type tasks (e.g., sprinting, jumping, landing with weight, falling and impacts with vessel structures).
  - Exfiltration by rotary wing platform or HSC.

4.0 HUMAN PERFORMANCE MODELLING

Using the model graphically described in Figure 2, what is the performance degradation for each of the phases by the factors than potentially limit performance? Is it possible to quantify the 100% performance for each phase of the operation if undertaken separately? What happens when the phases are put together how does degraded performance in one phase influence performance during subsequent phases? By understanding the factors that limit performance and the magnitude of their effects, potential solutions can be identified and the cost/benefits of different solutions examined and decisions made on their implementation. To model the human performance aspects of the MI operation, the factors influencing the insertion and on-target phases need to be quantified. The initial strategy of evaluation should include, a formal Task Analysis, to assess the potential degradation to performance and operational effectiveness. The ability to model these inter-related human, environmental and equipment factors provides the ability to develop effective solutions to reduce performance degradation and enhance operational effectiveness.

4.1 Factors Limiting Human Performance in Maritime Interdiction Operations

The basic model (Figure 2) has been expanded to illustrate how various behavioural and environmental factors may adversely influence performance and operational effectiveness. Using the work of Hyde et al. [28] as a basis, the more detailed factorial model is shown below in Figure 5.

5.0 DEVELOPMENTAL REQUIREMENTS

The development of the MI human performance model will support the enhancement of operational effectiveness by providing a greater understanding of how the environmental stressors, engineering systems, the human operatives, and their interaction, influence performance and operational effectiveness. The following areas are highlighted for enhancing operational effectiveness and/or the maintenance of performance.

5.1 Development Areas

5.1.1 Equipment

5.1.1.1 Insertion Phase

- HSC – a User-Centred approach to HSC design provides enhancements in system effectiveness and reliability [15, 16]
  - Shock mitigation – assists in the maintenance of performance [9] and reduces the risk of acute and chronic injuries [7]
  - Command & Control (C2) – essential for effective operations [23]
- Individual equipment
  - PPE – required to ensure the safety and performance of personnel
    - Reduced weight – reduces exercise intensity and therefore enhances performance potential and reduces the risk of fatigue and injury.
    - Improved mobility – increased limb range of motion and agility
    - Thermoregulation – improved safety and performance by reducing the degradation effects of cold and heat exposure

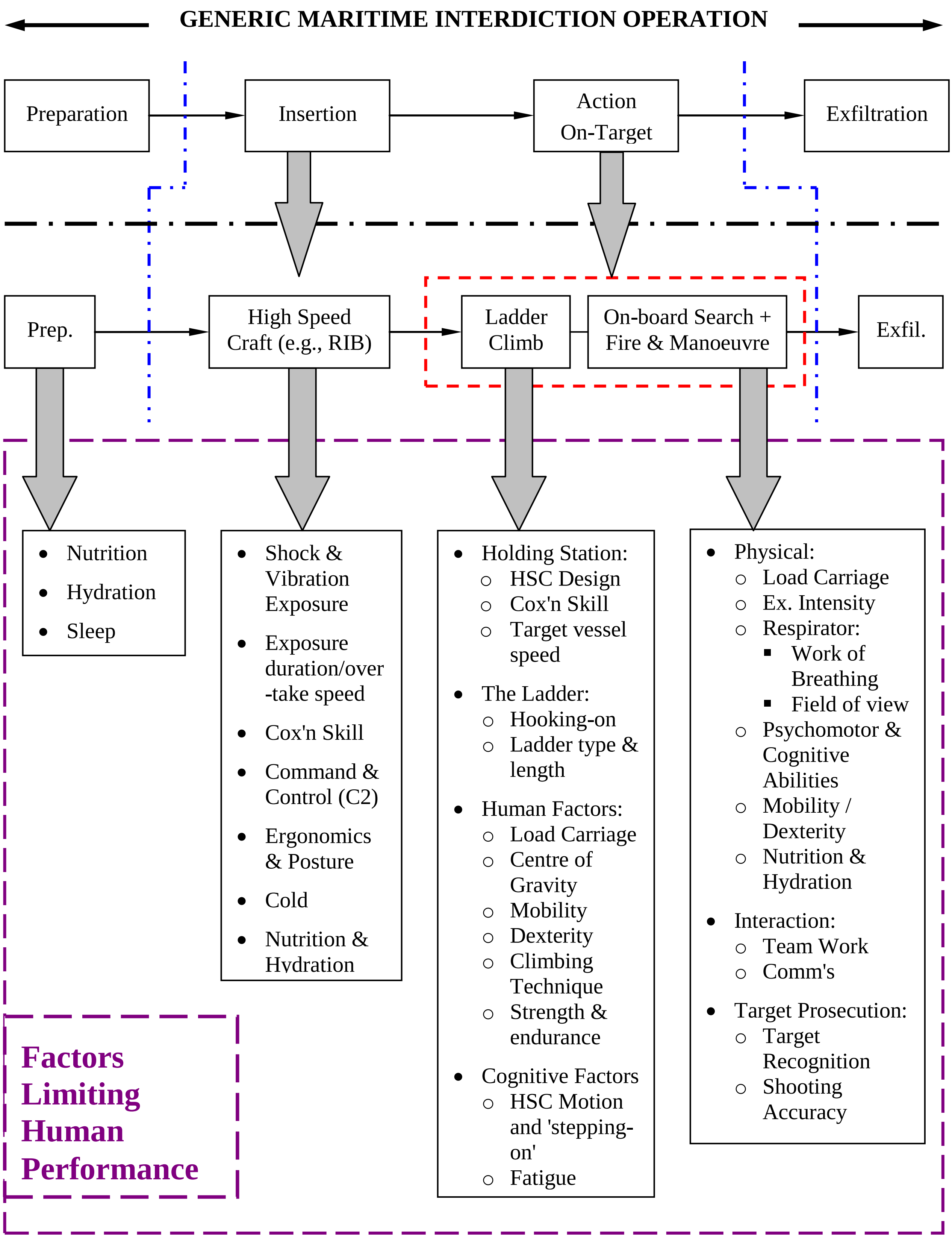

Figure 5: A Model of the Human Factors Implications on Performance in Maritime Interdiction Operations.

5.1.1.2 Action on Target

- Ladder climb
    - Hook placement – improved ability to manoeuvre equipment at height and accuracy of placement
    - Ladder design – improved biomechanics and speed of climb
- On-board Search + Fire & Manoeuvre
    - PPE – required to ensure the safety and performance of personnel
        - Reduced weight – reduces the exercise intensity and therefore enhances performance potential and reduces the risk of fatigue.
        - Improved mobility – increased limb range of motion and agility
        - Thermoregulation – improved safety and performance by reducing the degradation effects of cold and heat exposure

5.1.2 Standard Operating Procedures (SOPs)

The development of SOPs is recognised as essential for enhancing and maintaining operational effectiveness. Their development is beyond the scope of this paper.

5.1.3 Training

Training is an inherent foundation of military operations. The essential issue is the effectiveness of the prescribed training, and thus metrics are required to assess this effectiveness. It should be recognised that some training enhanced skills/competencies are related to operational effectiveness but are difficult to quantify, therefore the issue of the transfer of training needs to be understood and addressed.

The following factors are highlighted as being essential elements within the MI operation that must be addressed by the appropriate training and assessment programme.

5.1.3.1 Skill and Technique

- HSC Coxswain
    - The coxswains and crew must receive high levels of training and experience. An example of how professional coxswain training may be achieved is described by Hill et al. [14] with the appropriate specific MI training being undertaken to develop the required level of competence in the full range of environmental conditions.
- Ladder climbing
    - The climbing of caving ladders, particularly in the maritime environment, where the climbers may have endured many hours of exposure to an environment including RS, WBV, and the cold and wet environment, all of which degrades climbing ability [19] before embarking on the climb. It is essential that good technique is taught to ensure that climbing effectiveness is developed and maintained with the PPE and operational equipment carried.
- On-board Search + Fire & Manoeuvre
    - The repeated-sprint nature of MOUT-type operations, combined with the specific demands of ship-borne operations, requires specific training to deal with the demanding environment. Representative environments are required to ensure that boarding teams have the appropriate level of experience and competency to undertake operations with the required level of effectiveness.

5.1.3.2 Physical Fitness

- Operational Fitness
  - As described above (Section 3.1.1.1) MI personnel require both high levels of general and task specific fitness. Research into training programmes for enhancing tactical occupational tasks has shown that combined resistance and endurance training proved enhancement in both strength and endurance without compromising either [29].
  - Relatively simple methodologies are being developed to reduce the risk of injury in Special Operations Forces [30], pre-participation screening techniques such as mobility, stability, agility, endurance, and strength using functional clinical tools such as Functional Movement Screen (FMS), dynamometer grip strength, timed running tasks, balance tests appear to provide a methodology for identifying individuals at-risk of injury and developing intervention plans for reducing the risk of injury.
- Specific Fitness
  - HSC transits: The harsh motion of the insertion craft requires the occupants to cope with the repeated eccentric contractions required for the vertical impacts. These eccentric contractions during HSC transits have been shown to result in elevated levels of muscle damage markers [6]. Therefore specific eccentric training may assist in coping with the RS exposure. The required postural stability to cope with the lateral accelerations means that the individuals require an enhanced level of core stability and isometric strength/endurance.
  - Ladder climbing: Anecdotal reports of climbing training support the need for upper body strength and endurance, but it should be noted that upper-body strength will, in the majority of circumstances, not cope with the weight of the equipment that the boarding team personnel carry onto the target vessel. Therefore the appropriate technique must be practiced in addition to developing the specific strength and endurance requirements.
- Physical Performance Assessments
  - Baseline pre-participation assessments should be conducted upon entrance to a command/division/unit etc. Such an assessment enables operators to identify deficiencies, and for individualised training programme to be developed to address them. Quarterly or yearly updates of some subcomponents should be assessed for evaluation of progress.
  - The tracking of injury and physical performance metrics should be conducted on a regular basis. Normative data and pass/fail criteria should be established to allow for remediation to be recommended and initiated. Individual assessments conducted in a group environment with computer tracking should be implemented to allow for individuals to view their status and progress allowing for targeting individual and group goals.
  - The implementation of validated questionnaires related to general health and joint specific problems (e.g., neck disability index or international knee documentation committee) should be completed at baseline entrance to command and subsequently yearly follow-ups should be completed to evaluate potential musculoskeletal degradation due to job task demands [7].

6.0 CONCLUSION

It is anticipated that further development of the MI human performance model will help enhance operational effectiveness by providing a greater understanding of how environmental stressors and, engineering systems interact with human operatives to influence performance. In support of the performance modelling it is recommended that a formal Task Analysis (TA) and Training Needs Analysis (TNA) be undertaken. It is recognised that although there is no typical MI operation, it is essential that a generic operation be defined to support the development and assessment of solutions that have the potential to either enhance performance, or reduce performance degradation. It is therefore recommend that the proposed model of MI human performance is developed to promote a better understanding of operator performance in extreme maritime environments.

NMIOTC, using modern training facilities and techniques (including real platforms and high-fidelity simulations), is providing realistic MI training to International Naval Units/personnel, thus assisting in the development of their capability to confront a range of different scenarios within the MI operational environment. By facilitating this coordination and training, NMIOTC supports the increasing recognition of the MI Sector, and adds value to the continuing NATO efforts of assisting with the development of anti-piracy and related operations.

7.0 REFERENCES

[1] http://www.nmiotc.gr Accessed August 2010

[2] McLellan R. (2010) **Improving Advanced Interdiction Tactics, Techniques, and Procedures**, In: *High Speed Boat Operators Forum, Gothenburg*, Sweden.

[3] Zhang N., Liu H-T. (2008) **Effects of sleep deprivation on cognitive function**. *Neurosci Bull*, 24(1) 45-48.

[4] Haslam DR. (1984) **The military performance of soldiers in sustained operations**. *Aviat Space Environ Med*, 55(3):216-221.

[5] Myers SD., Dobbins TD., Dyson R. (2006) **Motion induced fatigue following exposure to whole body vibration in a 28ft rigid inflatable boat (RIB).** In: *ABCD meeting Human Performance at Sea: Influence of Ships Motions on Biomechanics and Fatigue*. Panama City, FL, USA.

[6] Myers SD., Dobbins TD., Hall B., Ayling R., Holmes SR., King K., Dyson R. (2008) **Muscle damage: a possible explanation for motion induced fatigue following transits in small high speed craft**. In: *Pacific 2008 International Maritime Conference*. Sydney, Aus.

[7] Ensign W., Hodgdon J., Prusaczyk WK., Ahlers S., Shapiro D., Lipton M. (2000), **A survey of self-reported injuries among special boat operators**; *Naval Health Research Centre*, Tech Report 00-48.

[8] Hodgdon JA., Walsh BJ., Hackney AC. (2004) **Microhematuria associated with a special operations craft mission**. In: *RTO-MP-AVT-110 Habitability of Combat and Transport Vehicles: Noise, Vibration and Motion, NATO Research and Technology Organisation*. Prague, Czech Republic..

[9] Myers SD., Dobbins TD., King S., Hall B., Gunston T., Holmes SR., Dyson R. (2008) **The effectiveness of shock mitigation technology in reducing motion induced fatigue in small high speed craft**. In: *Pacific 2008 International Maritime Conference*. Sydney, Aus.

[10] McMorris T., Myers S., Dobbins T., Hall B., Dyson R. (2009) **Seating Type and Cognitive Performance After 3 Hours Travel by High-Speed Boat in Sea States 2-3**. *Aviat Space Environ Med*, 80(1):24-28.

[11] Dobbins T, Myers S, Dyson R. (2009) **Marine High-speed Craft Coxswain Workload**. *Med Sci Sports Exerc* 2009, 41(5):58-59.

[12] Nieuwenhuis, M. (2005) **The ultimate performance of fast RIBs – An experimental investigation into the influence of the helmsman**. In: *Rigid Inflatables. Royal Institution of Naval Architects*. Cowes, UK.

[13] Dobbins, T., Myers, S., Dyson, R. (2009) **High Speed Craft Coxswain Workload**. In; *Royal Institution of Naval Architects, SURV 7 - Surveillance of Search & Rescue Craft.* Poole, UK.

[14] Hill, J., Dobbins, T., Myers, S. (2009) **Advanced Coxswain Training**. In: *Royal Institution of Naval Architects, SURV 7 - Surveillance of Search & Rescue Craft*. May 2009. Poole, UK.

[15] **High Speed Craft Human Factor Engineering Design Guide**. ABCD-TR-08-01 v1.0. www.highspeedcraft.org.

[16] ASTM F1166 - 07 **Standard Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities**.

[17] Dobbins TD. (2004). **High speed craft design from a human factors perspective**. In: *The Royal Institution of Naval Architects Surv 6 - Surveillance Pilot & Rescue Craft*. London, UK.

[18] Myers SD., Withey WR., Dobbins TD., Dyson R. (2009) **Effect Of Cold On Post-transit Run Performance Of Marine High-speed Craft Passengers**. *Med Sci Sports Exerc* 2009, 41(5):58.

[19] Myers S. and Dobbins T. (2010) Unpublished data.

[20] Grandjean AC., Grandjean NR. (2007) **Dehydration and Cognitive Performance**. *J Am Coll Nutr*, 26(suppl_5):549S-554.

[21] Sawka MN., Toner MM., Francesconi RP., Pandolf KB. (1983) **Hypohydration and exercise: effects of heat acclimation, gender, and environment**. *J Appl Physiol*, 55(4):1147-1153.

[22] Buskirk ER., Iampietro PF., Bass DE. (1958) **Work performance after dehydration: effects of physical conditioning and heat acclimatization**. *J Appl Physiol*, 12(2):189-194.

[23] Dobbins T., Dahlman J., Stark J. (2009) **High Speed Craft Command & Control - A Preliminary Model**. *Conference Proceedings, European Human Factors & Ergonomics conference*. Linkoping, Sweden.

[24] Pandolf KB., Givoni B., Goldman RF. (1977) **Predicting energy expenditure with loads while standing or walking very slowly**. *J Appl Physiol*, 43(4):577-581.

[25] Johnson JL. (2010) **Force and the Fatigue Threshold: The Point of No Return**. *AELE Mo. L. J.* 2010(6):501-508.

[26] Caretti, DM. and Whitely, JA. (1998) **Exercise performance during inspuratory resistance breathing under exhaustive constant load work**. *Ergonomics*. 41(4):501-511.

[27] Kleider HM., Parrot, DJ., King TZ. (2010) **Shooting Behaviour: How Working Memory and Negative Emotionality Influence Police Officer Shoot Decisions**. *Appl Cognit Psychol.* 24(5):707-717.

[28] Hyde D., Thomas JR., Schrot, J., Taylor, W.F. (1997) **Quantification of special operations mission-related performance: Operational evaluation of physical measures**. *Naval Medical Research Institute,* NMRI 97-01.

[29] Hendrickson NR., Sharp MA., Alemany JA., Walker LA., Harman EA., Spiering BA., Hatfield DL., Yamamoto LM., Maresh CM., Kraemer WJ., Nindl BC. (2010) **Combined resistance and endurance training improves physical capacity and performance on tactical occupational tasks**. *Eur J Appl Physiol*. 109(6):1197-208.

[30] Strock, M. and Burton, L. (2007) **Functional Testing of Military Athletes**. *J. Special Operations Medicine.* 7(2):104-108.