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WHOLE-BODY VIBRATION EFFECTS ON HUMAN PERFORMANCE: MECHANICAL OR MENTAL?

J. C. Guignard, A. C. Bittner, Jr. and M. M. Harbeson

Naval Biodynamics Laboratory, New Orleans, Louisiana, U.S.A.

INTRODUCTION

Disruption and degradation of human performance by low frequency oscillatory motion and vibration aboard naval ships and aircraft is of continuing concern to the Navy and to kindred agencies both in the United States and in other maritime countries. Modern air and sea defense operations, relying on sophisticated technology demanding a high and consistent degree of human skill, leave little room or time for crew redundancy or human performance impairment. Adverse effects of ship motion and vibration on human performance, safety and wellbeing are with mounting urgency being recognized as frequently the limiting factor in naval operations and mission effectiveness. In the naval forces of the 1980's, this problem is being intensified by technological, political and economic constraints resulting in a trend to equip the fleet with smaller ships (accordingly subject to higher motion and vibration levels at sea), more complex and operationally critical on-board systems, and relatively smaller crews than of yore, so that any disruption or impairment of crew performance by adverse environmental and human factors becomes more critical to the mission.

Human performance during whole-body oscillatory motion and vibration* has been investigated in the laboratory and occasionally in field studies since the early years of this

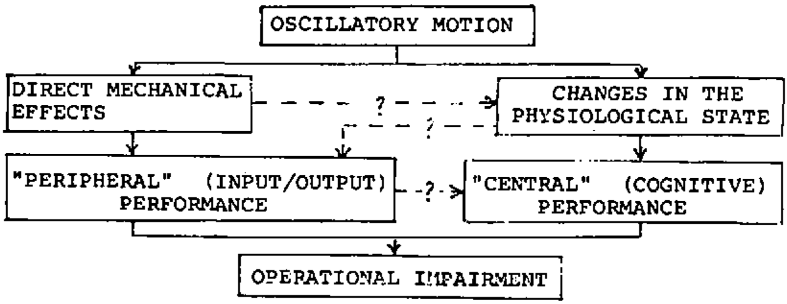
* "Vibration" commonly means oscillation at frequencies above 1 Hz, associated with mechanical resonance phenomena in the body, while "ship motion" generally means oscillation below 1 Hz, associated mainly with seasickness.

century. The research effort has risen steeply in recent decades since World War II, largely promoted by developments in modern high-performance aerospace and military technology and operations: by the mid-1970's a substantial body of literature had been published, and collated in various reviews (1-3), on this topic. Certain deficiencies have, however, limited the applications of much of the published work to practical ends, which include the formulation of valid and reliable engineering design criteria, specifications, and standards intended to serve as guidelines in the practice of vibration control to preserve human performance, safety and well-being in the oscillatory motion environment. In the domain of human performance measurement during vibration, some of the deficiencies have been methodological, for example, the use of experimental designs marred by a multiplicity of uncontrolled variables; lack of proven stability, reliability, validity or real-world applicability of many of the tasks used; and inadequate safeguards against motion artifact in some tasks. Another important deficiency historically has been the restriction of most investigations of vibration effects to short-term exposures, in which only the immediate mechanical effects of the oscillatory motion could be observed.

Time-dependent effects on sustained cognitive performance, such as vigilance cannot be investigated using short-term exposures (4): yet much of the published work cited has been based on exposures of substantially less than one hour. Current national and international standards purporting to provide guidelines to the evaluation of vibration exposure effects on human performance as a function of exposure duration (5) are based on essentially speculative extrapolations from short-term exposure data. Yet we learn, if only anecdotally, from experience at sea and in the air that it is frequently the cumulative effect of rough motion in a complex amalgam of workload and environmental stress that wears down crew and the safety and efficiency with which they perform their mission (6-8).

MECHANISMS OF HUMAN PERFORMANCE EFFECTS OF VIBRATION

A simple model of probable mechanisms by which oscillatory motion or vibration may disrupt or degrade human activity and performance is shown in the following diagram:



Vibration as a unique physical agent may act either to disrupt or impede mechanically the acquisition of (particularly visual) information on the input side of the task and the speed or precision with which the task is executed on the output or motor side; or, in a less specific manner, as a stressor impairing central processing (cognitive function).

As a rule, the direct mechanical interference with peripheral (input/output) mechanisms of task-performance is apt to be immediate, persistent during the vibration exposure, and strongly dependent on the vibration frequency and amplitude; whereas the centrally acting effect upon cognitive function (somewhat akin to the "distracting" effect of noise on performance postulated by Broadbent) may possibly be more generally related to the overall severity of the vibration exposure (a complex function of exposure duration and strength of the vibratory motion). This central action is less immediate in its impact, rather developing cumulatively with the passage of time, and is less clearly related to the frequency of oscillation (2). It may moreover be postulated, and at least for very low-frequency (<1.0 Hz) motion it has been demonstrated experimentally, that oscillatory motion or vibration can act by indirect mechanisms to induce alterations in the physiological state (eg, motion sickness; sopite syndrome; hyperventilatory syndromes; fatigue) that secondarily degrade or disrupt performance (8, 9).

A taxonomy of motion-induced performance degradation is needed; and in both future research and standardization efforts in this area, the question of time-dependent mechanisms must be addressed.

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DISCLAIMER

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