Xjenza

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Cover Picture:
The small internal combustion
engine car converted to work off
batteries. This has been test
driven over a four year period.

Malta
Chamber *of*
Scientists

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Editorial

Ecologically Friendly Transport

Heavy traffic on our island is contributing, among other factors, to the poor air quality in Malta. The news of the battery-operated car built and introduced in Malta (refer to p22) spells hope for our air-pollution problem. Statistics have shown that there are far too many cars on our roads, and the situation seems to be getting worse annually. To counteract this ever-increasing problem, it is a culture change that is required first and foremost, especially our lifestyle by which we expect to travel a few yards by private car. For many people the car is the status symbol and it is hard to imagine where the battery-operated car will fit into all this. Consumers will not necessarily take to the battery-operated car seeing that it lacks the power, speed and class of other cars.

The environmentally - conscious amongst us are very few and far between. Even our youngsters seem to be ignoring the problems with air pollution. In a recent report on the Environment in Malta, it has been reported that levels of nitrogen dioxide, ozone, benzene and benzopyrene are very high especially in areas where traffic is heavy. All these emissions are toxic and affect our health in several ways. Benzene is known to be a carcinogen, and benzene pollution in Malta is amongst the highest in Europe.

Battery-operated cars would reduce air pollution drastically. This could bring a healthy respite to the many asthma sufferers and people with respiratory problems. Research has shown that the number of people, especially children, with respiratory problems seems to be on the increase due to the poor air quality. The direct effect of air pollutants on the incidence of cancer is as yet unknown.

Another advantage of the electric car is reduction in noise pollution, so much a requirement on our island. Perhaps some might argue that the electric car is too silent, presenting a danger on the road to children, the elderly or people with hearing impairment. However, the electric car might not be as dangerous as conventional cars since it lacks the high speed.

One of the major problems associated with the electric car is the charging of the battery every 80 kilometres or so. In Malta, this problem is minimised since distances travelled are relatively short, making the electric car quite feasible as a means of transport.

The Government has introduced incentives to change to battery-operated cars (the reduction in registration tax is a step in the right direction) for privately - owned cars. Probably as a start the most viable use of electric cars is in carrying out services in different localities in Malta, as has been done in Italy, for example in post collection, public transport, rubbish collection etc.

The Maltese Government should encourage the use of electric cars as part of a programme to safeguard the environment, by setting an example and giving more incentives to people who use electric vehicles.

Angela Xuereb
Editor

Research Article

The National Adult Reading Test (NART) – A preliminary validation study on a Maltese tertiary education population

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Summary: *The popularity of the National Adult Reading Test (NART) and the North American Adult Reading Test (NAART) as measures of pre-morbid intellectual ability and as accurate estimates of IQ in healthy samples evoked an interest to conduct this preliminary validation study to assess how a Maltese tertiary education population faired on these tests. The National Adult Reading Test-revised (NART-R; Crawford, 1990) or the North American Adult Reading Test (NAART; Blair & Spreen, 1989) was administered on a randomly allocated sample of Maltese tertiary education students and graduates (N=50). The Extended River Mead Behavioural Memory Test (ERBMT) was used as a baseline test to allow for comparisons between the two groups. The results yielded a significant difference in performance between the two NART/NAART groups with a greater number of errors resulting from the NAART group. Comparisons on the overall performance between groups on the ERBMT and on one of the subtests of the ERBMT reflecting semantic memory, yielded no significant difference, indicating that the NART/NAART performances were not a result of pre-existing intellectual group differences. Conversion of NART/NAART scores into WAIS-r IQ's revealed a lower mean IQ than that estimated for tertiary education students or graduates. This observation raises the question of whether the two forms of NART correctly reflect the performance capacity of Maltese graduates and students.*

Keywords: National Adult Reading Test

Introduction
The validity of a test concerns what the test measures and how well it does so. The validity of a test must be established with reference to the particular use for which it is being considered. In the Standards for Educational and Psychological Testing (AERA, APA, NCME, 1985), the specific procedures for determining test validity are grouped under three categories, namely content-related, criterion-related and construct-related. Messick, (1980b) has argued convincingly that the term validity, insofar as it designates the interpretive meaningfulness of a test, should be reserved for construct validity.

When carrying out a validation study on a test that has been standardized on a different population one cannot dismiss the cross-cultural element involved in validating the test for a new population. Examination of the construct validity of a test provides evidence concerning the appropriateness and fairness of the *use* of the test. Comparability of factor analysis results for different groups and the degree to which the results of the factor analysis are consistent with the major scores and common interpretations of the test are necessary conditions for fairness in use of the test with culturally diverse persons. Indeed, if a test is not measuring the same underlying abilities or if the commonly used scores from the test represent varying abilities depending on group membership, then use of the test with culturally different persons is probably inappropriate and unfair, and the predictive validity of the test is likely to be lower for specific groups (Hambleton, 1994).

The attainment of equivalent measures is perhaps the most central issue in cross-cultural/language comparative research. If the basis of comparison is not equivalent across different groups, then valid comparisons across these groups cannot be made. Consonant with the unified conceptualization of validity, assessment bias is regarded as differential construct validity that is addressed by the question: To what extent is the assessment task measuring the same construct and hence has similar meaning for different populations? The presence of bias invalidates score inferences about target constructs because of irrelevant, non-target constructs that affect performance differently across groups (Messick, 1989). These irrelevant constructs are related to characteristics such as gender, ethnicity, race, linguistic background, socioeconomic status (SES), or other conditions that define the groups.

The National Adult Reading Test (NART)
The National Adult Reading Test (NART) is a highly respected measure of pre-morbid intelligence and gives an accurate measure of IQ by assessing the ability to read non-phonetic words – an intellectual function which remains intact after dementia, strokes or head injury. The development of the NART was based on the finding that reading ability is highly correlated with general IQ in the normal population but is maintained at or near its pre-morbid level in patients with dementia.

Since it's publication in 1982, the information about the NART's reliability and validity as a measure of current and premorbid intelligence has become more available.

It is a test that can be administered by both experienced as well as inexperienced clinicians (O'Carroll, 1987; Schlosser & Ivison, 1989), and has shown to be a valid measure of general intelligence in the normal population (Crawford et. al., 1989b) as well as having a potentially wide range of applicability in organic and functional disorders (Nelson & O'Connell, 1978).

Some studies have indicated that NART scores may be only relatively resistant to the effects of progressive dementia in organic disorders (Stebbins et. al., 1990b; Grober & Sliwinski, 1991). Other studies have reported no apparent effect on reading ability in a range of dementing conditions, including dementia of Alzheimer type (DAT), multi-infarct dementia, alcoholic dementia, head injury and AIDS (Crawford et. al., 1988a) As a measure for detecting and assessing the extent of intellectual deterioration, the studies reviewed above suggest that the NART may underestimate premorbid IQ levels only in the more severely demented subject or in those subjects with a more pronounced language deficit and there is no evidence to suggest that the NART does not give a true estimate of premorbid IQ in mildly dementing subjects (Nelson & Willison, 1991). The NART has achieved popularity as a measure of pre-morbid intellectual ability based on the premise that pronunciation of irregular words is unaffected in many clinical disorders and that performance is highly correlated with general intellectual ability (O'Carroll et. al., 1992). Rather, the most common problem with the NART seems to revolve around its insensitivity in estimating intelligence levels above the normal/bright range (Nelson & Willison, 1991).

The original NART standardization study used the Wechsler Adult Intelligence Scale (WAIS) as the test of intelligence; hence, the IQ equivalents of NART scores are WAIS IQ's. With the ever-increasing popularity of the Wechsler Adult Intelligence Scale – Revised (WAIS-R), it became desirable to restandardise the NART against the WAIS-R so that NART scores could be converted directly to WAIS-R IQ's and give a more accurate indication of intelligence level relative to today's population. The restandardisation was based on 182 people aged 18 to 70 years, including volunteers, non-neurological hospital in-patients and other normal subjects. The ability of the NART (Nelson and Willison, 1991) and the revised NART (NART-r), (Crawford et. al., 1990) to estimate IQ was examined in 47 healthy subjects using the Wechsler Adult Intelligence Scale-Revised (WAIS-R) scores as the criterion. The NART-r showed to have significantly higher correlations with Full Scale and Verbal IQ than the NART. Published reports indicate that the NART-r can be used reliably with people aged up to 84 years (Nelson & Willison, 1991).

To examine the relationship between NART performance and demographic variables, Nelson's (1982) original report of the NART's split-half

reliability was re confirmed in a study where performance and demographic variables were examined. This study, which used subjects free of neurological or psychiatric disorder, reported that the NART estimated IQ was significantly correlated with education, social class and age (Crawford et al., 1988b)

The NART was originally designed to provide a means of estimating the pre-morbid intelligence levels of adults suspected of intellectual deterioration. Performance depends more on previous knowledge than on current cognitive capacity (Nelson & O'Connell, 1978). The value of the test lies in the high correlation between reading ability and intelligence in the normal population (Crawford et. al., 1988b). Nelson developed the test in England for use with the WAIS. Recently, in 1991, Nelson and Willison restandardised the test on a British sample making it possible to convert NART-R scores directly to WAIS-r scores (Nelson and Willison, 1991).

Description of the NART
(National Adult Reading Test)

A list of 50 words printed in order of increasing difficulty is read aloud by the examinee. Each word is relatively short and irregular in terms of common rules of pronunciation, in order to minimize the possibility of reading by phonemic decoding rather than word recognition. From the reading error scores obtained, verbal, performance and full-scale IQ scores can be predicted to approximate closely the pre-morbid IQ level. Restandardised (based on 182 people aged 18-70yrs), and drawing on many studies of reliability and validity published over almost a decade, the test provides:

- Predicted scores for the WAIS-R
- Improved large print materials for use with people who are partially sighted, mentally frail of who have dementia.
- Improved sensitivity at higher IQ levels.
- A range of new validation studies

Blair and Spreen (1989) modified the test for use with American populations. The North American Adult Reading Test (NAART) has been validated against the WAIS-R. The NAART consists of 61 irregular words printed in 2 columns, and is administered and corrected in the same way as the English NART-R. In a study comparing the NAART and the Wide Range Achievement Test – Revised (WRAT-R) on neurologically impaired patients, Johnstone et. al. (1996) reported that although both tests were equivalent and accurate estimates of average verbal IQ level, the WRAT-R had superior normative data and a less restricted range and standard deviations equal to that of the WAIS-R than the NAART (Johnstone et. al. 1996).

The Extended Rivermead Behavioural Memory Test (ERBMT)

The Extended Rivermead Behavioral Memory Test (ERBMT) is a test, which is used to assess every day memory. Most clinical memory tests are extensions of laboratory tests, and do not as such map directly onto memory problems encountered by patients in their everyday lives. The Rivermead Behavioral Memory Test (RMBT) was devised to solve this problem (Wilson, B.A. et. al., 1989). It consists of a number of subtests each attempting to provide an objective measure of one of a range of everyday memory problems. It has been validated using the observation of memory lapses in a sample of 80 brain-damaged patients observed over an average of 55 hours each. It proved to have a high correlation with observed lapses and to have high inter-rater reliability. Four parallel version of the test are available and are applicable to a wide range of environmental settings, making the RBMT a short, reliable and valid test of everyday memory problems. The RBMT, however, was originally designed as a screening test and thus is insufficiently sensitive to detect mild deficits, whether due to brain damage or to the introduction of a drug or stressor. Therefore, the RBMT was extended to provide a sensitive measure of memory within the normal range.

The Extended Rivermead Behavioral Memory Test (ERBMT) increases the level of difficulty by doubling the amount of material to be remembered, by combining material from Forms A and B and forms C and D of the original test to produce 2 parallel versions of the new extended test. The sensitivity of the ERBMT was assessed by comparing the performance of a middle-aged man and an elderly group of normal subjects, who would be expected to show modest differences in memory performance. The subtests varied in their sensitivity to this small age difference, but when performance was assessed in terms of scale scores that allow an overall combined measure of memory performance to be calculated, the test proved sensitive and free of ceiling and floor effects. (Wilson, B.A. et al., 1989). It has been suggested that the ERBMT provides a promising measure of everyday memory in normal adults. With regards to ecological validity of the test, it has been argued that the ERBMT has higher ecological validity than other memory tests (De Wall, C. et. al., 1994), as it was initially based on contrasting groups for whom everyday memory problems were or were not prominent and subsequently was validated against many hours of careful observation to finally being used effectively to predict the capacity of patients to cope independently. What may be arguable is the ecological validity of each of the subtests to detect the milder deficits in everyday memory performance, a factor that could extend the use of the test across an even wider range of situations.

Materials and methods

Participants
Participants (N=50) aged between 18 and 37 were selected for the study. All participants were recruited randomly by word of mouth over a period of 2 months. They were selected so that personal characteristics (e.g. age, gender and education) in each of the experimental groups were matched. The participants used for this study were either university students or university graduates. Criteria of exclusion included non-English speakers.

Materials
The Extended Rivermead Behavioural Memory Test (ERBMT) was used as a baseline memory test to allow for comparison between the 2 groups. This test fulfills criteria required for the experiment and is a reasonably sensitive, validated and culture-fair everyday memory test (de Wall, C., Wilson, B., & Baddeley, A. 1994).

Either the National Adult Reading Test NART (UK) or the North American Reading Test NAART (US) was administered to each participant either directly before or directly after the administration of the ERBMT.

Test Procedure
Two experimental groups were randomly assigned to NART (UK), (n=25) and NAART (US), (n=25) conditions. Each experimental group was further divided in two sub groups according to the sequence of administration of tests.

Exp. group 1. (NART) (UK)		Exp. Group 2. (NART) (US)	
Group A	*Group B*	*Group A*	*Group B*
NART	ERBMT	NART	ERBMT
ERBMT	NART	ERBMT	NART

The four groups were balanced to eliminate performance variance as a result of motivation and/or subjective difficulty on either one of the tests. Age and gender were also balanced across the different conditions. Before the commencement of tests each participant was debriefed on the procedure of the tests and asked to read and sign a Consent For. The duration of the tests was approximately 40 minutes per person.

Scoring
The results of the tests were scored using the standardized scoring sheets accompanying each test. The raw data was processed and analysed using SPSS version 10.0. NART/NAART scores were converted into WAIS-R full and verbal IQ scores (Wechsler, D. 1981).

Results
Analyses of the results demonstrated that the sample population (N=50) used for this study performed better on the NART (National Adult Reading Test) then on the NAART (North American Adult Reading Test). The

descriptive statistics for the participants are given in Table 1.1 and Figure I below.

Table 1.1: Descriptive statistics of subjects used in the validation study (N=50)

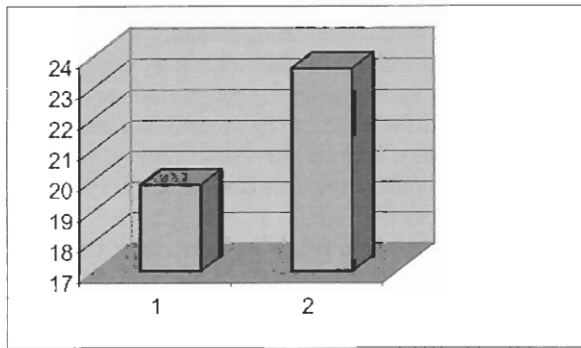|	N	Min.	Max.	Mean	Std. Dev.
NART	25	11	32	19.88	5.11
NAART	25	15	38	23.64	5.85

Fig.1 Mean error scores of Group 1 (NART) 19.88 compared to Group 2 (NAART) 23.64

The error scores on both the NART and NAART groups was obtained and converted into the WAIS-R predicted Full Scale IQ (Table 1.2)

Table 1.2: The WAIS-R Full Scale and Verbal IQ's predicted from range of errors made.

	Error Scores	Means
Range IQ	117 – 91	106.1
NART	11 – 32	20
Range IQ	112- 84	101.0
NAART	15 – 38	24

Comparison of NART and NAART means using an Independent Samples T-Test showed that there was a significant difference in errors made between the two experimental groups t (48) = -2.42, p<.01. In order to verify that this difference was not attributed to IQ differences between the two groups, an Independent Samples T-Test was administered between the two groups on their performance on the ERBMT baseline test. The results of this test showed that there was no significant difference between the 2 groups on the ERBMT t(48) = 1.06, p>.05, thus eliminating intelligence level as possible explanation for the significant difference between the two groups.

Further analysis on one of the sub-tests of the ERBMT;

the 'immediate' and 'delayed' recall of a 'story' which taps the use of semantic memory was carried out between the NART and NAART groups. The Mean scores on performance in this subtest were compared between the groups (Table 1.3) and the results from an Independent Samples T-Test used for this analysis showed no significant difference between the two groups, both on 'immediate' recall of the story t(48) = -0.169 p>0 .05, as well as on 'delayed' recall t(48) = -0.926 p>0 .05.'

Table 1.3: Comparison of Mean scores from the 2 groups on ERBMT Story Recall

		N	Mean	Std. Dev.	Std. Error Mean
Story 1	NART	25	2.24	0.88	0.18
	NAART	25	2.28	0.79	0.16
Story 2	NART	25	1.6	0.87	0.17
	NAART	25	1.8	0.65	0.13

Story 1 = Immediate Recall; Story 2 = Delayed Recall

Furthermore, scores obtained from the NART/NAART were correlated with scores obtained from both the 'immediate' as well as the 'delayed' recall of the ERBMT story. A Pearson's Correlation between NART/NAART scores and 'immediate' recall scores showed no significant difference r = -0.18, p>.05. Similarly, the NART/NAART and 'delayed' story correlation also yielded no significant difference r = -0.06, p>.05.

A further analysis to check the validity of transforming the NART/NAART scores into WAIS-R IQ scores was made. A correlation was made between NART/NAART converted Full and Verbal IQ scores and ERBMT overall performance. A Pearson's Correlation was administered and yielded a significant correlation between both Full IQ scores and ERBMT overall scores, r = .436, p<.01 as well as Verbal IQ scores and ERBMT overall scores, r = .436, p<.01.

An Independent Samples T-Test was carried out to see whether there were any gender differences in performance on the NART/NAART. Analysis of the results yielded no significant difference t(48) = -0.382, p>.05.

Discussion
The NART group in the study committed less pronunciation errors than the group allocated to the NAART, indicating that performance ability on the NART was greater than that for the NAART. This observation was further confirmed by the results obtained from comparisons on performance between the two groups on the ERBMT baseline memory test and on

the ERBMT semantic memory sub-test, which as explained previously, yielded no significant difference between the two groups on either of the comparisons.

The sample used in both groups for this study was homogeneous with regards to age, sex, education and social background; therefore none of the above confounding variables could be attributed to the observed differences in performance between the two groups. With regards to age and sex, Crawford et. al., (1988b), have reported that the two variables have little effect on performance and that an age-related increase in *correct* NAART scores only appears to emerge when a wide range of persons are studied (well-educated healthy individuals aged 16-84). In this study, the range of age of persons used was between 18 years and 37 years, also the educational background of the participants was similar. However, the type of course that a person had frequented or was reading at the University might have had an influence to prior knowledge of certain words, for example the word *leviathan* for philosophy students.

A relevant factor which merits mention with regards to the differences in performance observed between the two NART groups is that Maltese schooling is based on a British style of education and therefore the Maltese students' exposure to English words is more congruent with the NART than the NAART. This observation could contribute to one of the explanations related to the better performance achieved from the NART as compared to that achieved from the NAART.

Comparisons of the overall performance on the ERBMT between the NART and NAART groups were made to justify the results observed in the NART/NAART tests. The ERBMT has been validated across the normal range and has shown to be a reliable and sensitive measure of memory within this range (de Wall et. al.. 1994). The results from these comparisons showed no significant differences in the performance levels on the ERBMT between the two NART and NAART groups and therefore the differences observed in performance between the NART and the NAART cannot be attributed to intellectual differences between the two groups. The fact that both groups also showed no significant differences in the semantic memory 'immediate' and 'delayed' *story recall* of the ERBMT further highlighted this assumption.

A point of interest with regards to this study is that the average predicted Full Scale IQ obtained from performances in the NART/NAART was that of 100. Although this is an average score it is lower than the estimated IQ for tertiary education students or graduates, which ranges between 110 and 120. This observation raises the question of whether the two forms of NART correctly reflect the performance capacity of Maltese graduates and students. A sample of 50 persons is too small to arrive at any solid conclusions with

regards to this observation; however, this could be a starting point for a series of future validation studies of the NART/NAART on the Maltese population using a larger sample of same education / social background participants which, depending on the type of results obtained, may or may not lead to further studies on a wider more heterogeneous sample. The interesting point in question that emerges from this study is whether or not the NART/NAART can be validated and used reliably on the Maltese population. Furthermore, the results obtained from this study could be indicative as to which test, the NART or the NAART could be more appropriate for the Maltese population, if at all.

References

Crawford. JR; Parker, DM. Besson, JAO (1988a). Estimation of premorbid intelligence in organic conditions. *British Journal of Psychiatry*, **153**, 178-181.

Crawford. JR. Stewart. LE, (1988b). Garthwaite. PH, Parker, DM, Besson. JA. The relationship between demographic variables and NART performance in normal subjects. *Br J Clin Psychol* **27** (Pt 2): 181-182.

Crawford. JR. Stewart. LE. Cochrane. RHB. Parker, DM, Besson. JAO (1989a). Construct validity of the National Adult Reading Test: A factor analytic study. *Personality and individual differences*, **10**, 585-587.

Crawford. JR. Allan. KM, Cochrane, RHB, Parker, DM (1990). Assessing the validity of the NART-estimated premorbid IQs in the individual case. *British Journal of Clinical Psychology* **29**, 435-436.

De Wall. C. Wilson. BA, Baddeley. AD (1994). The Extended Rivermead Behavioural Memory Test: A measure of everyday performance. *In Memory*, MRC Applied Psychology Unit. Cambridge, 149-166.

Grober. E. Sliwinski. M (1991). Development and validation of a model for estimating premorbid verbal intelligence in the elderly. *Journal of Clinical and Experimental Neuropsychology*, **13**, 933-949.

Hambleton. RK (1994). Guidelines for adapting educational and psychological test: A progress report. *European Journal of Psychological Assessment*, **10**, 229-244.

Johnstone. B. Callahan. CD, Kapila. CJ. Bouman, DE (1996). The comparability of the WRAT-R reading test and the NAART as estimates of premorbid intelligence in neurologically impaired patients. *Archives of Clinical Neuropsychology*, **11**, 513-519.

Messick S (1989). Validity. In Linn R (Ed.), *Educational Measurement*, New York: Macmillan Publishing Company, 221-262.

Nelson. HE. Willison. JR. (1991). National Adult Reading Test (NART): *Test Manual. Second Edition*. Windsor, UK: NFER Nelson.

Nelson. HE. O'Connell, A (1978). Dementia: The estimation of premorbid intelligence levels using the new adult reading test. *Cortex*, **14**, 234-244.

O'Carroll, R (1987). The Inter-rater reliability if the National Adult Reading Test (NART): a pilot study. *Br J Clin Psychol*: 229-230.

O'Carroll, R, Walker, M, Dunan, J, Murray, C, Blackwood, D, Ebmeir, KP, Goodwin, GM (1992). Selecting controls for schizophrenia research studies: the use of the NART is a measure of premorbid ability. *Schizophrenia Research*, **8**, 137-141.

Schlosser, D, Ivison, D. (1989). Assessing memory deterioration with the Wechsler Memory Scale, the National Adult Reading Test, and the Schonell Graded Word Reading Test. *Journal of Clinical and Experimental Neuropsychology*, **11**, 785-792.

Stebbins, GT, Wilson, RS, Gilley, DW, Bernard, BA, Fox, JH (1990b). Use of the National Adult Reading Test to estimate premorbid IQ in dementia. *The Clinical Neuropsychologist*, **4**, 18-24.

Wechsler, D (1981). *Wechsler Adult Intelligence Scale – Revised: Manual.* New York: The Psychological Corporation.

Wilson, B, Cockburn, J, Baddeley, A (1985). *The Rivermead Behavioural Memory Test.* Bury St. Edmunds, England: Thames Valley Test Company.

Research Article

Differences in attention between methadone patients and abstinent problem heroin drug users frequenting a drug rehabilitation programme.

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Summary: *Cognitive deficits of attention have been associated with substance abuse. The present study assessed the degree to which the ability to concentrate and to sustain and shift attention is impaired in methadone patients and recovering heroin addicts who were all frequenting the same drug rehabilitation programme but were at different levels of their rehabilitation process. Test scores indicated a decrease in the ability to shift attention and to focus and tap on a sequential display of digits in the IED subtest and the RVIP subtest respectively of the Cambridge Automated Neuropsychological Test Battery (CANTAB) in the methadone group. Additionally, this decrease in performance ability was also visible in the more recently heroin addicts compared to the group who had been abstinent for a longer period of time. These findings indicate a progressive improvement in selective attention functions relative to drug-state and length of abstinence.*

Keywords: Attention, cognitive functions, methadone, heroin, abstinence

Introduction
Poly-drug use and abuse is a major societal problem. The cognitive deficits associated with the chronic abuse of drugs have important theoretical and clinical significance. They reflect changes in underlying cortical, sub-cortical and neuromodulatory mechanisms that underpin cognition and consequently have an impact on rehabilitative programs. (Rogers and Robbins, 2001).

Cognitive Impairment and different drugs of abuse
Chronic misuse of stimulant drugs, such as cocaine or amphetamine, or of opiates such as heroin has been shown to lead to long-lasting impairments in brain function (Ricaurte et al. 1984; Miller 1985). Heavier use of opiates in long-term users has been shown to be associated with greater likelihood of neuropsychological impairment when assessed by a battery including the WAIS, aphasia tests, and the Halstead battery (Grant et al. 1978).

Hill and Mikhael (1979) who studied opiate abusers with an almost exclusive drug preference for heroin found that they were impaired on Tactual Performance for memory and location and Tapping Tests, but not on the Category Test, a measure of abstract reasoning ability. They concluded that, since performance on the Category Test is thought to be related to damage to the frontal lobes, this brain region might be less affected by opiate abuse. This conclusion is supported to some extent by results from studies that have failed to detect a difference between opiate users and controls on other

measure of neuropsychological functioning thought to correlate with frontal lobe damage (Bruhn et. al., 1975; Rounsaville, 1982).

Several studies have assessed cognitive function in stimulant (cocaine) abusers (Washton and Gold 1984; Ardila et al. 1991; Mittenberg and Motta 1993). In an extensive study of cocaine abusers and poly-abusers, Rosselli and Ardila (1996) found significant impairments in short-term memory and attention. Abstracting ability as tested by the Wisconsin Card Sorting Test and non-verbal short-term memory, were less impaired, while verbal fluency and long-term memory were un-impaired. Test scores were found to correlate with lifetime cocaine abuse, suggesting a relationship between drug abuse and cognitive dysfunction.

Although a substantial amount of evidence strongly indicates the impairment of cognitive functioning in different types of substance abusers, the specific type of cognitive impairment varies according to the type of drug used, the amount used per day, the duration of use and the recency of use. A 1992 study comparing twenty chronic cocaine abusers with age and education matched controls using standardized neuropsychological assessment procedures showed that in the cocaine abuser sample, neuropsychological performance was related to the amount and recency of cocaine use, suggesting a direct role of cocaine on cognitive functioning (O'Malley et. al., 1992). Additionally, a report published in the Journal of Neuropsychiatry and

Clinical Neurosciences (1999) revealed that heavy cocaine users show slower reaction times, more problems with attention and concentration, and perform worse on tests of mental flexibility and planning. The author attributed the amount and the recency of use as being the factors most closely related to a poor performance (Bolla, 1999).

A comparison of the cognitive functioning between amphetamine and heroin abusers and age- and IQ-matched control subjects, found qualitative differences, as well as some commonalities, in the profile of cognitive impairment between groups (Ornstein et. al., 2000). The chronic amphetamine abusers were significantly impaired in performance on the extra-dimensional shift task (a core component of the Wisconsin Card Sort Test) whereas in contrast, the heroin abusers were impaired in learning the normally easier intra-dimensional shift component. Whereas both groups were impaired in some tests of spatial working memory the amphetamine group, unlike the heroin group, was not deficient in an index of strategic performance on this test. The two groups were profoundly, but equivalently impaired on a test of pattern recognition memory sensitive to temporal lobe dysfunction. The results of this study support current literature and are indicative of chronic drug use leading to distinct patterns of cognitive impairment, with differences in the exact nature of the cognitive deficit according to the type of drug used (Ornstein et. al., 2000).

Current trends in research on other stimulants such as ecstasy have resulted in the growing evidence of chronic, heavy, recreational use of ecstasy being associated with sleep disorders, depressed mood, persistent elevation of anxiety, impulsiveness and hostility, and selective impairment of episodic memory, working memory and attention (Morgan, 2000). A study by Parrott et al. (1998) reported that light to moderate ecstasy users whilst exhibiting selective deficits in memory performance, did not show impairments in other aspects of cognitive functioning, such as, simple reaction time, choice reaction time, vigilance performance and Sternberg task reaction time. In a recent study, (Gamma, et. al., 2000), mood and regional cerebral blood flow (rCBF) profiles between regular polytoxic Ecstasy users and Ecstasy-naive controls were compared. Brain activity was measured during cognitive activation by an attentional task using positron emission tomography (PET) and [H2(15)O]. Statistical parametric mapping revealed that brain activity did not differ between the two groups and. Significantly higher levels of depression were found in the Ecstasy-using subjects, however, both groups also performed equally on the cognitive task requiring sustained attention (Gamma, et. al., 2000).

The attentional aspect of cognitive impairments observed in drug abusers has also been investigated independently in a study comparing recently recovering substance abusers and subjects with attention deficit-hyperactivity disorder (Hoegerman, et. al., 1993). The results of this study showed intriguing educational and therapeutic implications of the similarities between cognitive impairments of newly sober substance abusers and adults with persistence of attention deficit-hyperactivity disorder (ADHD). In another study using only adolescent female substance abusers and female non-substance abusers as controls, the findings suggested that the female substance abuse group performed deficiently on tests requiring language skills, sustained attention and perceptual efficiency and scored lower than controls on standardized tests of intelligence and academic achievement (Tarter, et. al., 1995).

Similar to the effects observed in other drugs of abuse, methadone, an opiate, has also been found to exhibit a wide range of cognitive deficits. In a study comparing methadone patients with ex-substance abusers, poorer performance in tests of learning and recall were found in the methadone group compared to the abstinent ex-substance abuser group (Gritz et. al., 1975). In a more recent study by Darke et. al., (2000), the cognitive functioning between methadone-maintenance subjects and naïve controls was compared. The results of this study clearly show that almost half of the subjects in the methadone-maintenance group demonstrated to have cognitive impairment in the severely impaired range and moderate deficits were seen in both information processing and problem solving (Darke, S, et. al., 2000). The function of attention in methadone patients is illustrated in a study using a series of cognitive psychomotor performance tests to compare the ability of a number of cognitive functions between methadone patients and naïve controls. The results of this study demonstrated a decrease in performance ability especially on the attention tasks with the methadone group compared to controls (Specka et. al., 2000).

CANTAB - The Cambridge Neuropsychological Test Automated Battery

The Cambridge Neuropsychological Test Automated Battery (CANTAB), firstly developed by CeNeS in 1987, is a computerized battery of neuropsychological tests. It has been shown in more than 100 published studies to be sensitive to cognitive changes in a variety of brain disorders and normal subjects. Twelve tests form its 'Attention Battery', 'Visual Memory Battery' and 'Working Memory and Planning Battery'. It provides for the assessment of a variety of cognitive functions, including working memory, attention, learning and problem solving, as well as tests of executive function and vigilance (Pantelis & Maruff, 1988). CANTAB also has four Parallel Batteries where different versions of the tests in the main batteries can be used.

CANTAB is very easy to administer, running DOS 6.0 on a 486DX processor with 4MB RAM, using a touch

screen or a mouse. The version used in this study is version 2.35 released by CeNeS Cognition in August 1998. All twelve tests are language free, making CANTAB highly suitable in multinational studies. Data is stored automatically and then analysed and summarized in a simple easy-to use format.

CANTAB is especially sensitive to cognitive changes even when traditional cognitive measures have proven insensitive (Robbins, 1998). It can be used across all ages, with psychiatrically disturbed or dementing subjects, but also with normally healthy individuals (Harrison, 1998).

CANTAB has been used and validated in hospitals and neuroscientific research groups across four continents. Over 2,000 subjects have been tested with CANTAB and their data has been used to determine norms for both patients and normal control subjects. The norms commonly used are given by age, gender, and IQ (CeNeS Cognition, 1998). The major division is by age, with bands for subjects less than 35, age from 35-49, then by decade up to 70 and a band for 70 and over. In this research the participants all fell under the –under 35 age bands.

Within the different age bands, the norms are divided into three bands of IQ: less than 110, 110 to 119 and 120+. In the standardized norms, IQ is estimated form the National Adult Reading Test (NART). This test would have proved inappropriate for this sample since most of the participants were not English speaking (but see accompanying paper). The minor division within each age/IQ band is gender. CANTAB tests, with the exception of some spatial measures have been shown to be insensitive to gender, however in this particular experiment only males were used. CANTAB has been shown to have test-re-test reliability and therefore the battery is reliable over time (Shah, 1998).

The two tests selected for this study were extracted from the Attention Battery section of the CANTAB:

1. The Intra/Extra Dimensional Shift (IED)
The IED is a test that measures the subject's ability to attend to the specific attributes of compound stimuli and to shift that attention when required. Two artificial dimensions are used in this test, colour-filled abstract shapes and white lines. Simple stimuli are made of just one of these dimensions, whereas compound stimuli are made-up of both, namely white lines overlying colour-filled shapes. Participants progress through the test by satisfying a set criterion of learning at each of nine stages (six consecutive correct responses). If at any stage the participant fails to reach this criterion after 50 trials, the test is terminated (CeNeS Cognition, 1998a).

2. The Rapid Visual Information Processing (RVP)
The RVP is a test of sustained attention with a small working memory component. This test has a 2-minute

training period before the actual 4-minute test is run. On both training and actual test a white box appears in the center of the computer screen, inside which, digits from 2-9 appear in a pseudo-random order, at the rate of 100 digits per minute. Participants are required to monitor the changing digits for pre-defined number sequences and to respond by pressing a button at the presentation of the final digit of the sequence. The reaction time is not measured (CeNeS Cognition, 1998a).

Method and Materials

Participants
Participants (N=30) aged between 18 and 27 were selected from a drug rehabilitation programme (San Blas Therapeutic Community, Caritas, Malta). All participants were male, had a history of heroin drug use and had been or were currently being detoxified by use of methadone. Exclusionary criteria included those people who were currently on prescribed psychiatric medication and who had a psychiatric history. All the participants came from the same social background and none had completed secondary school education. Females were not used in this study because the available number of female problem heroin drug users was deemed to be too small to effectively have sufficient numbers in each of the different groups.

Procedure
Following a screening procedure where all participants were formally assessed on their drug-use history with a personal details questionnaire and a general drug use questionnaire resulted in three groups with ten participants in each group. Group 1 consisted of 'ex-problem heroin users who were currently on methadone'; Group 2 consisted of 'ex-problem heroin users who had been detoxified by use of methadone 1-3 months ago'; and Group 3 consisted of 'ex-problem heroin drug users who had been detoxified by use of methadone 6-12 months ago. All groups were matched according to age, social class and education. Prior to the experimental sessions, all the participants were debriefed together on the experimental procedure and were given a consent form to read and sign.

Experiment
The experiment was conducted in a room allocated for the test within the rehabilitation building. Testing was carried out on an individual basis, over four consecutive days, with a random allocation of participants to time of testing. Prior to each experiment, standardised instructions were used to explain each test . The sequence in which the two tests were administered was balanced between the groups to eliminate performance variance as a result of motivation and/or subjective difficulty on either one of the tests

The duration of each experiment was approximately 30 minutes. Testing commenced at 9.00am and the last test

on each day was conducted by not later than 3.00pm.

Materials

The Intra/Extra-Dimensional Shift and the Rapid Visual Information Processing tests from the Attention Battery section of The Cambridge Neuropsychological Test Automated Battery (CANTAB) were administered to each participant. These tests were selected for their accuracy in measuring the particular cognitive function (attention) relevant for this study and also for their avoidance of 'floor' and 'ceiling' effects.

Scoring

The main data items following each test from the CANTAB were automatically recorded and summarised. A summary table is given for each test where the score, standard score (Z score) and percentile of the main items being measured. In the Intra/ Extra Dimensional Shift Test the data items recorded were:

- Stage reached (maximum 9)
- Total errors
- Errors at ED-shift
- Errors up to ED-shift

In the Rapid Visual Information Processing Test, the data items recorded were:

- Probability of hit – this is the probability of the subject responding correctly, equal to the hits / (hits and misses).
- Probability of false alarm – this is the probability of a false alarm, equal to false alarms / (false alarm and correct rejection).

Data Analysis

The scores obtained from the CANTAB tests and the information obtained from the participants' checklist - age and type of group (1, 2 or 3) were inputted into a data file for SPSS Version 10.0 analysis.

Results

Analysis of the results revealed differences in attention and concentration between the three groups. In the IED subtest, the capacity to shift attention was poorest in the methadone group (Group 1). This capacity progressively improved between the 1-3 month group (Group 2) and the 6-12 month (Group 3) respectively. In the 'probability of a hit' task from the RVIP sub test, a similar progression in improvement in performance was observed. The three groups, however, did not differ significantly in the sustained attention task of the IED sub test. A table of means for all three groups (Table1.1 and figure 1) illustrate the differences in Group 2 (1-3 months 'clean') compared to Group 1 (methadone group) and similarly in Group 3 (6-12 months 'clean') compared to both Group 2 and Group 1.

Table 1.1: Comparison between groups on subtests.

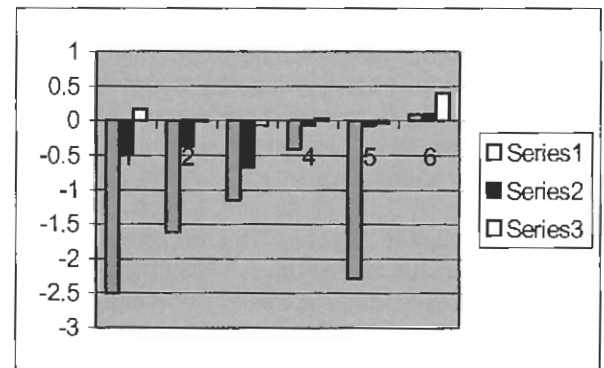| Sub-tests	Group	Mean	Group	Mean	Group	Mean
Stage	1	-2.5	2	-0.5	3	0.17
Total Errors	1	-1.61	2	-0.37	3	-0.01
At ED	1	-1.15	2	-0.67	3	-0.065
Up to ED	1	-0.41	2	-0.068	3	0.033
Prob. of Hit	1	-2.28	2	-0.067	3	-0.037
Prob. of FA	1	0.1	2	0.1	3	0.4

Fig.1.　　Series 1 = Group 1 (Methadone Group)
Series 2 = Group 2 (1-3 month Group)
Series 3 = Group 3 (6 month+ Group)

A multivariate ANOVA was used to reveal the differences between the three groups in some attention aspects of the sub-tests (table 1.2)

Table 1.2: Differences between groups on sub-tests

	df	F	Sig.
Stage	2	3.687	.038
Total Errors	2	5.438	.010
At ED	2	1.193	.319
Up to ED	2	0 .474	.628
Probability of a hit	2	12.599	.000
Probability of false alarm	2	0.309	.737

A series of Independent Samples T-test were used to investigate the differences between the groups. A comparison between the methadone group and the 1 to 3 months group, (Table 1.3), on the 'total errors' on the IED subtest and the 'probability of a hit' on the RVIP subtest reached significance t (18) = -2.11, p< .05; t (18) = -4.94, p< .01 respectively.

Table 1.3: Comparison on subtests between methadone group and 1-3 months group.

Subtests	T	df	Sig. (2-tailed)
Stage	-1.597	18	0.128
Total errors	-2.111	18	0.049
At ED	-0.58	18	0.569
Up to ED	-7.93	18	0.438
Probability of a hit	-4.943	18	0
Probability of F.Alarm	0	18	1.000

The same comparisons between the methadone group and the 6-12 months group, (Table 1.4) also yielded a significant difference t (18) = -3.16, $p<.01$; t (18) = -4.04, $p<.01$.

Table 1.4: Comparison on subtests between methadone group and 6-12 months group

Subtests	T	df	Sig. (2-tailed)
Stage	-2.279	18	0.035
Total errors	-3.159	18	0.005
At ED	-1.643	18	0.118
Up to ED	-0.719	18	0.481
Probability of a hit	-4.042	18	0.001
Probability of F. Alarm	-0.617	18	0.545

Comparisons between the 1-3 months group and the 6-12 months group, (Table 1.5) on the 'Total Errors' made on the IED subtest also revealed significant differences between the two groups, t (18) = -0.86, $p< .05$; however no significant difference was found between the two groups in the performance on the RVIP 'Probability of a hit' t (18) = 0.603, $p>.05$.

Table 1.5: Comparison on subtest between 1-3 months group and 6-12 months group

Subtests	T	df	Sig. (2-tailed)
Stage	-1.5	18	0.151
total error	-0.865	18	0.398
at ED	-0.991	18	0.335
up to ED	0.088	18	0.931
Probability of a hit	0.603	18	0.554
Probability of F. Alarm	0.847	18	0.408

Discussion

The results obtained from this study show a progressive improvement in specific attention functions between Group 1 (methadone group) and Group 2 (1-3 months 'clean') and between Group 2 and Group 3 (6-12 months 'clean') respectively, both in the IED sub test as well as in the RVIP sub test. In the IED subtest the main difference observed between the groups was that of shifting attention when the rule of a given sequence was changed, reflected by the 'total errors' made, with Group 1 demonstrating to have the most problems. No differences however emerged in the IED sustained attention task between all the three groups. With regards to the 'probability of a hit' in the RVIP subtest, which is also reflective of sustained attention, the differences were significant between the methadone and the 1-3 months and the 6-12 months group respectively, however, there was no significant difference in this task between the 1-3 months group and the 6-12 months groups.

Research on methadone-maintenance patients' highlights the observation that these people show cognitive impairments in the moderate to severe range (Darke, 2000). The results that emerge from this study seem to reflect similar observations with the methadone group demonstrating a decreased capacity to shift attention and poorer concentration levels than the 1-3 months abstinent group and the 6-12 months abstinent group. On the other hand, the IED measure of sustained attention which showed no significant difference between groups has yielded similar results in other studies using matched controls and 3-5 week abstinent drug abusers, alcoholics, cocaine abusers (Beatty et. al., 1995) and ecstasy users (Gamma et. al., 2000).

The progressive improvement in performance on certain elements of the attention subtests with the 1-3 month group and the 6-12 month group respectively, compared to the methadone group, seems to demonstrate the increasing capacity of the recovering drug addict to concentrate, focus and shift attention to relevant cues with increasing drug-free time. This improvement is also highlighted by the fact that in the 'probability of a hit' RVIP subtest, no significant differences in performance emerged between the 1-3 months and the 6-12 months abstinent groups. Studies that have highlighted deficits in mental flexibility and attention and concentration problems in drug addicts have also found a relationship between the degree of cognitive impairment and the amount and recency of drug use (O'Malley, 1992; Bolla, 1999).

The results from this experiment, especially evident in the methadone group, translated into everyday function, may be reflected in slowness of response, failure to grasp the meaning of complex or rapid instructions and difficulty in shifting attention when necessary. These factors may be reflected as difficulties in thinking of adaptive solutions to problems that crop up in everyday routines, slowness in learning, and a tendency to fixate

on a pattern of events rather then shifting attention to other occurrences. Cognitive impairments may contribute to continued misuse and addiction in at least 2 ways. They may increase the likelihood of drug-seeking behaviour as a result of failure to control impulses, for example and in addition they may also interfere with the users capacity to assimilate and participate effectively in rehabilitation programs that often have an educational and cognitive component (Mc Crady et al., 1986). This finding is important for out-patient clinics or rehabilitation programmes that support a methadone-maintenance programme as non-compliance on the part of the patient or client with clinic routines and instructions may, therefore, reflect inability rather than motivational or personality characteristics.

Due to the methadone component in this study, no conclusions can be generated as to whether attention function improves as a result of the elimination of the methadone variable or as a result of the improved cognitive function due to drug abstinence in general. The only indications that may be drawn up from the results of this study are that ex-problem heroin users currently on methadone seem to show a decreased capacity in shifting attention and concentration relative to those who have been detoxified from methadone. This change is also progressive and improves as the time frame between methadone withdrawal and abstinence increases.

A methodological shortcoming in the study is the non-inclusion of a naïve control group which would have provided the possibility of comparing the performance between the 6-12 month abstinent group and the control group and thus enabling us to make inferences on the extent to which certain elements of attention improve in the abstinent problem heroin drug user compared to a the drug naïve person.

The possibility of pre-existing differences in individual cognitive capacity or intelligence cannot be ignored. Although the participants in this study all came from the same educational and social background and these two variables were balanced across all the three groups, this alone is not sufficient to ensure that the group is really homogeneous with regards to this factor. In addition to this, one cannot exclude the possibility that exposure to certain groups, educational courses and learning situations, which form part of the treatment in rehabilitation programmes, could have in some ways contributed to the improved capacity in certain attention functions with the 1-3 months group and even more so with the 6-12 months group.

A suggestion for future research would be to perform a longitudinal study on the same sample to re-assess and compare the performances across the different groups. Additionally, a baseline IQ test should also be administered to enable a correlation between

performance and intelligence, thus eliminating pre-existing cognitive ability and intelligence as confounding variables. The addition of a group of naïve controls would introduce the possibility of investigating and comparing attention levels between the drugs exposed groups and the drug naïve group over the time frame in question.

References

Ardila, A, Rosselli, M. Strumwasser, S (1991). Neuropsychological deficits in chronic cocaine abusers. *Intl J Neurosci* 57,73-79.

Beatty, WW, Katzung, VM, Moreland, VJ, Nixon, SJ (1995). Neuropsychological performance of recently abstinent alcoholics and cocaine abusers. *Drug Alcohol Depend* 37(3), 247-53.

Bolla, K (1999). Dose related cognitive effects of drug abuse. *Journal of Neuropsychiatry and Clinical Neurosciences.*11:361-369.

Bruhn. P, Maage, N (1975). Intellectual and neuropsychological functions in young men with heavy and long term patterns of drug abuse. *Am J Psychiatry.* 132, 397-401.

Cairns. E. Cammock, T (1978) Development of a more reliable version of the matching familiar figures test. *Dev Psychol,* 13, 555-560.

CeNeS Cognition, (1988a). *CANTAB user manual: The Parallel Batteries,* 36-37; 40-41. Cambridge, UK.

Darke. S. Sims. J, McDonald, S, Wickes, W. (2000). Cognitive impairment among methadone maintenance patients. *Addiction,* 95(5),687-695.

Gamma A. Buck A. Berthold T. Vollenweider FX. (2000). No difference in brain activation during cognitive performance between ecstasy (3,4-methylenedioxymethamphetamine) users and control subjects: a [H2(15)O]-positron emission tomography study. *J Clin Psychopharmacol,* 1, 66-71.

Grant, I. Adams. KM. Carlin, AS. Rennick. PM. Judd. LL, Scheof, K (1978). Collaborative neuropysiological study of polydrug users. *Arch Gen Psychiatry,* 35,1063-1074.

Haarhoff. G. London. M (1995). A comparative study of injecting opiate and amphetamine users in a sural area. *Addict. Res* 3(1),33-38.

Harrison. (1998). *CANTAB: A battery for all seasons.* Paper presented at the CANTAB conference. Glasgow, Scotland.

Hill, SY. Michael, M.A. (1979). Computerised transaxial tomographic and neuropsychological evaluations in chronic alcoholics and heroin abusers. *Am J Psychiatry* 136, 598-602.

Hoegerman. GS, Resnick. RJ. Schnoll, SH (1993). Attention deficits in newly abstinent substance abusers: childhood recollections and attention performance in thirty-nine subjects. *J Addict Dis,* 12(1). 37-53.

Miller. L (1985). Neuropsychological Assessment of substance abusers: review and recommendations. *J Subst Abuse Treat* **2**,5-17.

Mittenberg, W. Motta. S (1993). Effects of cocaine abuse on memory and learning. *Arch Clin Neuropsychol* **8**, 477-484.

Morgan. MJ (2000). Ecstasy (MDMA): a review of its possible persistent psychological effects. *Psychopharmacology*, **152**, 230-248.

Morgan. MJ (1998). Recreational use of ecstasy (MDMA) is associated with elevated impulsivity. *Neuropsychopharmacology*, **19**, 252-264.

Pantelis & Maruff. (1988). *The assessment of executive function using CANTAB: Examples from the study of neuropsychiatric disorders*. Papers presented at the CANTAB conference. Glasgow. Scotland.

O'Malley. S. Adamse. M, Heaton. RK. Gawin. FH (1992). Neuropsychological impairment in chronic cocaine abusers. *Am J Drug Alcohol Abuse* **18**(2),131-44.

Ornstein, TJ, Iddon. JL, Baldacchino. AM, Sahakian BJ, London. M.. Everitt. B.J.. Robbins. T.W. (2000). Profiles of cognitive dysfunction in chronic amphetamine and heroin abusers. *Neuropsychopharmacol* **23**(2),113-26.

Parrott, AC. Sisk. E. Turner, JJD (1998). Cognitive performance in recreational users of MDMA or 'Ecstasy': evidence for memory deficits. *J Psychopharmacol*, **12**. 79-83.

Robertson. IH et al. (in press).The structure of normal human attention: The Test of Everyday Attention. *Journal of the International Neuropsychological Society*.

Rosselli. M, Ardila. A (1996). Cognitive effects of cocaine and polydrug abuse. J Clin *Exp Neuropsychol* **18**,122-135.

Rounsaville, BJ (1982). Neuropsychological functioning in opiate addicts. *Journal Nerv Mental Dis* **170**(4), 209-216.

Ricaurte. GA, Schuster, CR. Seiden, LS (1984). Further evidence that amphetamines produce long-lasting dopamine neurochemical deficits by destroying dopamine nerve fibers. *Brain Res*, **303**, 359-364.

Robbins, (1998). *The use of CANTAB in psychopharmacology*. Paper presented at the CANTAB conference, Glasgow. Scotland.

Rogers, RD. Robbins. T.W. (2001) Investigating the neurocognitive deficits associated with chronic drug misuse. *Current Opinion in Neurobiology* **11**, 2, 250-257.

Shah. (1998). *Test-retest reliability: CANTAB tasks-how do they do?* Paper presented at the CANTAB conference, Glasgow, Scotland.

Specka, M. Finkbeinder, T, Lodeman, E. Leifert. K. Kluwig. J, Gastpar, M. (2000). Cognitive-motor performance of methadone-maintained patients. *Eur Addict Res*, **6** (1). 8-19.

Tarter. RE. Mezzich, A.C.. Hsieh, YC. Parks, SM (1995). Cognitive capacity in female adolescent substance abusers. *Drug Alcohol Depend* **39**(1).15-21.

Research Article

Bouncing Liquids and Flowing Solids

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Summary: *Many materials, such as blood, emulsion paints, modern lubricating oils, plastics of all kinds, and so on, have properties which are different from those of ordinary liquids and solids. The response to stress of some of these materials can be spectacularly different from that of viscous liquids and elastic solids; they can exhibit behaviour which cannot be adequately explained by the simple mathematical laws of classical theories. This behaviour is the concern of rheologists.*
The unusual behaviour of these materials is discussed and a brief review is made of some fairly recent developments in the formulation of mathematical equations which can explain such behaviour.

Keywords: *Rheology, deformation, flow, stress, strain, non-Newtonian liquids, non-Hookean solids*

Introduction

The best example of a bouncing object is a rubber ball or a billiard ball. Both these are made of solid material and can be classified as *bouncing solids*. On the other hand, water and beer are good examples of *flowing liquids*. This 'normal' behaviour of solids and liquids can be mathematically explained by the classical theories of **solid deformation** (Hooke's law of elasticity) or **liquid flow** (Newton's law of viscosity). Here we exclude gaseous materials.

However, the behaviour suggested by the title of this article is rather different from that of our daily experience. Indeed many modern materials exhibit behaviour which cannot be adequately explained by any of the classical theories of solid deformation or liquid flow. The field of study which deals with such behaviour is **rheology**. The word rheology comes from the Greek $\dot{\rho}\epsilon\iota\nu$ meaning 'to flow' and it is applied to the study of deformation and flow of materials *which do not conform to simple mechanical laws*. In rheology we generally distinguish between liquids and solids as those materials which change, or do not change, their shape continually when subjected to forces however small; that is, *a liquid is one which changes, while a solid is one which does not change, its shape under its own weight*; thus, for example, ordinary table jelly is a solid, though when shaken it shows the appearance of a mobile liquid. Here we are in a field where the boundary between liquids and solids is not very sharp. Indeed certain materials exhibit some of the properties of ordinary solids and some of the properties usually associated with ordinary liquids – they have both elasticity and viscosity in varying degrees.

Rheological Study Cycle

Our aim is to construct precise unambiguous statement of all the deformation and flow properties of real physical continuous materials which ideally describe the behaviour of the material under all conditions of motion and of stress. One way of achieving this is to combine the effort of the experimental and the theoretical rheologists working in close collaboration in a study cycle consisting of four important linked stages:

(i) Observation of behaviour of material experimentally;

(ii) Formulation of mathematical laws to explain observed behaviour;

(iii) Use of formulation to predict behaviour under new conditions of stress;

(iv) Back to the laboratory to confirm (or otherwise) predicted behaviour.

Prediction should be the basis on which crucial experiment is planned to test the validity of the new formulation. Any discrepancy between prediction and experimental observation requires a repetition of the cycle according to the following flow diagram:

Study Cycle

Experimental   Observation of behaviour $\longleftarrow$ Confirmation of predictions

Theoretical   Formulation of Mathematical laws $\longrightarrow$ Prediction of new behaviour
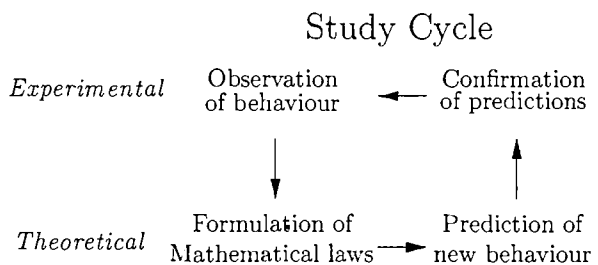
Idealized Materials with Simple Properties

In our day to day experience with ordinary liquids and solids we observe behaviour which lead to the formulation of simple mathematical laws known as the *equations of state* for the materials.

Liquids

- Flow or change shape under their own weight. They need to be kept in containers;
- Do not have inherent elasticity;
- When disturbed they settle down slowly while the applied energy is dissipated into heat;
- Easily divided into parts or droplets which do not show sharp edges.

Equation of state is Newton's law of viscosity *stress $\propto$ rate-of-strain* or

$$p = \eta e , \qquad (1)$$

if incompressible, where η is the (constant) coefficient of viscosity.

Solids

- Do not flow but keep their shape, and do not deform under their own weight;
- Elastic – some very extensible (rubber), some not very extensible (steel);
- Spontaneously resume their shape after dilatation. The applied energy is stored as elastic energy and is recovered immediately;
- When broken by large forces, they show sharp edges (bottle neck effect);

Equation of state is Hooke's law of elasticity *stress $\propto$ strain* or

$$p = \mu E , \qquad (2)$$

where μ is the (constant) modulus of elasticity.

Three Dimensional Stressing

In general, we take a set of Cartesian coordinate axes Ox_1, Ox_2, Ox_3 using suffixes $1, 2, 3$ instead of writing Ox, Oy, Oz (see, for example, *Vector Analysis*, Camilleri, 1994) to combine the different equations corresponding to shearing in different planes and write invariant equations involving the stress tensor p_{ik} ($i, k = 1, 2, 3$) and the rate-of-strain tensor e_{ik} or strain tensor E_{ik}.

Equations of state (1) and (2) then take Cartesian tensor form

$$p_{ik} = \eta e_{ik} \qquad \text{and} \qquad p_{ik} = \mu E_{ik} . \qquad (3)$$

In both cases the equations of state are *linear algebraic* relations involving second-order symmetric ($p_{12}=p_{21}$, etc.) tensors and physical constants. Hence each of relations (3) represent nine equations, of which only six are different. Using these simple equations engineers have managed over the years to build ships, bridges, dams, cathedrals, towers, etc.

Materials with Complicated Properties

There are other materials whose behaviour under stress is spectacularly different from that of classical idealized materials. The following are a few examples of easily observed violations of the more familiar behaviour.

(a) Blood is non-Newtonian
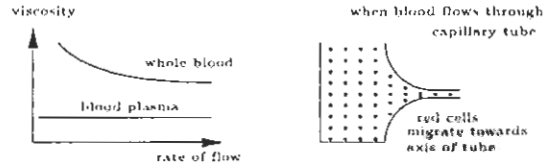
(b) Merrington Effect (c) Weissenberg Effect
Rubber Solution is non-Newtonian

(a) While the viscosity of blood plasma is constant for all rates of flow, the *viscosity of "whole blood" is not constant but decreases as the rate of flow increases*. Also, when blood flows through a capillary tube the red cells migrate towards the axis of the tube reducing the effective viscosity. This is very fortunate indeed, otherwise we would need far more powerful heart pumps.

(b) Merrington (1943) observed that *rubber solution 'swells radially outwards' on emerging from a capillary tube* whereas Newtonian liquids exhibit the opposite effect known as 'vena contracta'.

(c) Weissenberg (1947, 1948, 1950) observed that *when certain liquids* (such as sweetened condensed milk) *are sheared between rotating coaxial cylinders they tend to migrate towards the inner cylinder* resulting in a higher level there. When stirred with a rod condenced milk tends to 'climb' the rod; it has been suggested to use condensed milk to catch mice, since the poor mouse which finds itself in a shallow pool of such a liquid would get more entangled the harder it tries to get away. On the other hand, when a Newtonian liquid is stirred with a rod it tends to move away from the rod leaving a hollow there.

(d) Again *when the stirring rod is removed certain liquids, such as polymer solutions, tend to 'recoil back' and part of their deformation is gradually recovered* – they are said to have **an elastic memory**. Newtonian liquids would continue to rotate until all energy is dissipated into heat.

(e) A material known as 'bouncing putty' looks and feels very much like ordinary plasticine. Yet it is mobile enough to flow under its own weight and must therefore be classified as a liquid. A piece of this material flows into a pool with a smooth upper surface within minutes of being placed on a table, yet it may be bounced on the table like a rubber ball with no visible flattening at its point of contact with the table. *It shows very different response to slow and to rapid shearing*; when handled slowly it flows even through a fine mesh, but when snapped suddenly it feels elastic and shows sharp edges (bottle neck effect) where it breaks.

In fact we have a whole spectrum of materials which exhibit both viscous and elastic properties in varying degrees. In formulating the equations of state, here we consider a model of the material called a **disperse system** which in the simplest form consists of two uniform component materials.

Disperse Systems Model
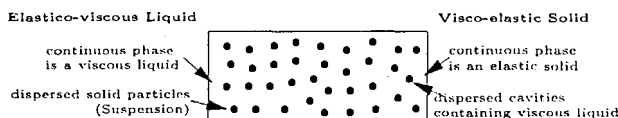
The first material, the disperse phase, which may be solid or liquid, is made up of small bits dispersed at random in the second, the continuous phase, which may also be liquid or solid and which fills all the space between the dispersed bits of the first phase. If both phases are liquid they are taken to be immiscible, one of which or both having elastic properties and the dispersion is referred to as an **emulsion**.

If the continuous phase of the dispersion is a liquid and the dispersed phase consists of solid particles it is referred to as a **suspension**. In this case the dispersion as a whole is essentially a liquid and we talk about an **elastico-viscous liquid**. On the other hand, if the continuous phase of the dispersion is a solid with dispersed cavities filled with viscous liquid, the dispersion as a whole is essentially a solid and we talk about a **visco-elastic solid**.

Elastico-Viscous Liquids

For our purpose here it easiest to consider mainly dipersions having continuous liquid phase i.e. elastico-viscous liquids. The case of essentially solid dispersions or visco-elastic solids follow analogous arguements.

Slow, Steady Rates of Deformation

Einstein (1906, 1911) considered a suspension of *inelastic* solid spherical particles, of concentration c, in a Newtonian liquid of viscosity η and found that

at *very small, steady (time-independent)* rates of shear it behaves as a liquid of viscosity η_0 given by

$$\eta_0 = \eta(1 + 2.5c). \qquad (4)$$

Taylor (1932) found that, again at *very small, steady* rates of shear, the viscosity of an emulsion of liquid droplets of viscosity η', with concentration c, in a liquid of viscosity η is

$$\eta_0 = \eta\left(1 + \frac{\eta + 2.5\eta'}{\eta + \eta'}c\right). \qquad (5)$$

The equation of state for these 'hypothetical liquids' is

$$p_{ik} = 2\eta_0 e_{ik}, \qquad (6)$$

which is still a linear algebraic equation and the liquids are characterized by *one* physical constant η_0 which is, of course, a function of the constants of the component materials and the concentration c. Note that (4) is a special case of (5) as $\eta/\eta' \to 0$. The models of Einstein and Taylor exhibit no elasticity of shape at all (all component materials assumed inelastic) so that when all deforming forces are suddenly released such materials retain their shape without recoil.

Small, Variable Deformation

Fröhlich and Sack (1946) considered a suspension of Hookean elastic solid spheres of elastic modulus μ uniformly dispersed in a Newtonian liquid of viscosity η, and showed that, at *small variable* rates of shear, the equation of state relating the viscous stress p_{ik} to the rate-of-strain e_{ik} takes the form

$$\left(1 + \lambda_1 \frac{\partial}{\partial t}\right) p_{ik} = 2\eta_0 \left(1 + \lambda_2 \frac{\partial}{\partial t}\right) e_{ik} \qquad (7)$$

with $(\lambda_1 > \lambda_2 > 0)$, where $\eta_0 = \eta(1 + 2.5c)$,

$$\lambda_1 = \frac{\eta(3 + 5c)}{2\mu}, \qquad \lambda_2 = \frac{\eta(3 - 7.5c)}{2\mu}.$$

It is to be noted that the equations are now *linear differential* equations involving rate-of-change with respect to time, i.e. they are time-dependent. The class of liquids characterized by (7) are referred to as **liquids of type 1** since the equation involves *first* derivatives. It is characterized by *three* physical constants; a relaxation time λ_1, a retardation time λ_2, and viscosity η_0. These materials exhibit both viscous and elastic properties. On the application of external stresses the suspended elastic particles will now be deformed absorbing some energy, but the deformation requires time which depends on the viscosity of the continuous liquid phase. On removal of the external stress, the particles require time to recover their undeformed shape and release the stored elastic energy.

Oldroyd (1953) showed that the properties of an idealized dilute emulsion with liquid droplets replacing the elastic spheres are quantitatively the same

as for the corresponding suspension. The investigations were extended by Oldroyd (1955) to include the effect of an interfacial film everywhere between the boundaries of the two phases, such as that introduced when a trace of stabilizer is added to an emulsion. He found that, if the film has any inherent elasticity, the equation for p_{ik} (again for slow, variable deformation) takes the form

$$\left(1 + \lambda_1 \frac{\partial}{\partial t} + \nu_1 \frac{\partial^2}{\partial t^2}\right) p_{ik} = 2\eta_0 \left(1 + \lambda_2 \frac{\partial}{\partial t} + \nu_2 \frac{\partial^2}{\partial t^2}\right) e_{ik} \tag{8}$$

possibly with more additional derived terms on each side. The class of liquids characterized by (8) are referred to as **liquids of type 2** since the equation involves *second* derivatives. These liquids are characterized by 5 physical constants $\lambda_1, \lambda_2, \nu_1, \nu_2$ and η_0. Liquids characterized by an equation of the form

$$\left(1 + \alpha_1 \frac{\partial}{\partial t} + \alpha_2 \frac{\partial^2}{\partial t^2} + \ldots + \alpha_N \frac{\partial^N}{\partial t^N}\right) p_{ik}$$

$$= 2\eta_0 \left(1 + \beta_1 \frac{\partial}{\partial t} + \beta_2 \frac{\partial^2}{\partial t^2} + \ldots + \beta_N \frac{\partial^N}{\partial t^N}\right) e_{ik}, \tag{9}$$

where the constant η_0 is the limiting viscosity at small rates of shear and $\alpha_1, \beta_1 \alpha_2, \beta_2, \ldots, \alpha_N, \beta_N$ are constants such that α_N and β_N do not both vanish, are referred to as **liquids of type N**. Oldroyd (1962) showed that in general, a dilute emulsion consisting of a liquid of type M dispersed in a liquid of type N, with constant interfacial tension between the two components is an elastico-viscous liquid of type (at most) $1 + 2M + 3N$.

Linear differential equations of the forms (7) to (9) may also be simulated by mechanical models consisting of springs and dashpots in series and in parallel – see, for example, *Hydrodynamics of Elastico-Viscous Liquids*, Camilleri (1965).

It is noted that for *slow steady* shearing equations (7) to (9) would reduce to the Newtonian viscosity relation (6).

Finite Rates of Deformation

In obtaining the equations of state (7) to (9) we restricted attention to *small* variable rates of deformation and it is found that these equations are not adequate to describe behaviour at finite rates of deformation. Any quantity associated locally with a fluid, such as the temperature of the fluid, or a stress or rate-of-strain component, changes in general at a different rate according to whether we measure it at a fixed point in space over an interval of time, or measure it in a certain macroscopic element of fluid (which is moving in space) over the same instant of time. In ordinary hydrodynamics we distinguish between the rate of change with respect to time at a fixed point $(\partial/\partial t)$ and the rate of change with respect to time following the material particle (D/Dt).

Thus for the scalar density ρ we have

$$\frac{D\rho}{Dt} = \frac{\partial \rho}{\partial t} + v_i \frac{\partial \rho}{\partial x_i}, \tag{10}$$

where v_i $(= v_1, v_2, v_3)$ is the velocity of the element and summation is understood over the repeated suffix i according to the usual summation convention.

The derivative D/Dt measures the rate of change with respect to time relative to a *moving coordinate system* whose origin is moving with the material particle. It allows for the translation of the material element and is sufficient when differentiating scalar quantities. When it comes to vector or tensor quantities (which are associated with directions) we must take a rate of change of the components relative to a *rotating coordiate system* which is moving and rotating with the material element.

A time derivative of a tensor p_{ik} that corrects for the translation as well as the rotation of the fluid element is **Oldroyd material derivative $\mathcal{D}/\mathcal{D}t$**, given by (Oldroyd, 1958)

$$\frac{\mathcal{D}}{\mathcal{D}t} p_{ik} = \frac{\partial}{\partial t} p_{ik} + v_j \frac{\partial}{\partial x_j} p_{ik} + \omega_{ij} p_{jk} + \omega_{kj} p_{ij} \tag{11}$$

where the linear motion of the fluid element is accounted for by its velocity vector v_i and the angular motion by the vorticity tensor ω_{ik} measured by

$$\omega_{ik} = \frac{1}{2}\left(\frac{\partial v_k}{\partial x_i} - \frac{\partial v_i}{\partial x_k}\right). \tag{12}$$

A time derivative of a tensor p_{ik} relative to a *convected coordinate system* which moves, rotates and deforms with the material is **Oldroyd convected derivative $\mathcal{V}/\mathcal{V}t$**, defined by (Oldroyd, 1950)

$$\frac{\mathcal{V}}{\mathcal{V}t} p_{ik} = \frac{\mathcal{D}}{\mathcal{D}t} p_{ik} + e_{ij} p_{jk} - e_{kj} p_{ij}. \tag{13}$$

This corrects also for the *straining* of the material which is measured by the rate-of-strain tensor

$$e_{ik} = \frac{1}{2}\left(\frac{\partial v_k}{\partial x_i} + \frac{\partial v_i}{\partial x_k}\right). \tag{14}$$

For a tensor p_{ik}, the derivative $\mathcal{V}/\mathcal{V}t$ differs from $\mathcal{D}/\mathcal{D}t$ only in the addition of simple products of p_{ik} and e_{ik}. It can be shown (see *Tensor Analysis*, Camilleri, 1999) that we may obtain universally valid constitutive equations of state – that is, equations with a physical significance for the material independent of any particular frame of reference and independent of the motion of the material as a whole in space – if we replace the partial time-derivative $\partial/\partial t$ in equations of state (7) to (9) by the convected time-derivative $\mathcal{V}/\mathcal{V}t$ or the material time-derivative $\mathcal{D}/\mathcal{D}t$, both of which are eligible for inclusion into

constitutive equations. The simplest possible generalization of equation (9) which is valid for all conditions of motion and stress takes the form

$$\left(1 + \alpha_1 \frac{\mathcal{D}}{\mathcal{D}t} + \alpha_2 \frac{\mathcal{D}^2}{\mathcal{D}t^2} + \ldots + \alpha_N \frac{\mathcal{D}^N}{\mathcal{D}t^N}\right) p_{ik}$$

$$= 2\eta_o \left(1 + \beta_1 \frac{\mathcal{D}}{\mathcal{D}t} + \beta_2 \frac{\mathcal{D}^2}{\mathcal{D}t^2} + \ldots + \beta_N \frac{\mathcal{D}^N}{\mathcal{D}t^N}\right) e_{ik} .$$

$$(15)$$

The equations of state (7) to (9) are linear differential equations and liquids characterized by them are often referred to as **linear** elastico-viscous liquids. But, in view of relation (11), the material derivative destroys the linear nature of equation (15). The first material derivative involves simple contracted products of the rate-of-strain with itself and with stresses, and higher material derivatives involve products of higher degree in stress and rate-of-strain taken together. Other generalizations of equation (15) involve such products of degree up to $(N + 1)$. In particular the most general constitutive equation of state for liquids of type *1* is

$$\left(1 + \lambda_1 \frac{\mathcal{D}}{\mathcal{D}t}\right) p_{ik} + \kappa_1 e_{ik} p_{jj} + \kappa_2 (e_{ij} p_{jk} + e_{kj} p_{ij})$$

$$+ \kappa_3 e_{jn} p_{jn} \delta_{ik}$$

$$= 2\eta_0 \left(e_{ik} + \lambda_2 \frac{\mathcal{D}e_{ik}}{\mathcal{D}t} + 2\kappa_4 e_{ij} e_{jk} + \kappa_5 e_{jn} e_{jn} \delta_{ik}\right) ,$$

$$(16)$$

first suggested by Oldroyd (1958), which involves *eight* physical constants characterizing a wide spectrum of materials. The corresponding generalization for liquids of type *2* which include third-order products in stress/rate-of-strain taken together was obtained by Camilleri (1965) and involves no less than *thirty* physical constants.

The class of liquids characterized by constitutive equations of state (16) are capable of exhibiting the kind of non-Newtonian behaviour that is often observed in real liquids as, for example, a variation of apparent viscosity with the rate of steady shearing (Oldroyd, Strawbridge & Toms, 1950), the Weissenberg climbing effect (Lux-Weiner & Scoenfield-Reiner, 1952), a distribution of normal stresses corresponding to an extra tension along the streamlines (Roberts, 1954), and secondary transverse circulatory flow in the section between non-intersecting cylinders of various shapes (Camilleri & Jones, 1965, 1966).

Visco-Elastic Solids

In an analogous way, dispersions which are essentially solid, having a solid continuous phase in which spherical cavities, filled with liquid or with solid of another material, are characterized by a single shear modulus μ_0 if examined in equilibrium or at sufficiently small rates of shear.

Mackenzie (1950) considered the case of a continuous phase with shear modulus μ and bulk modulus

κ and found that the presence of scattered small holes results in a disperse system of shear modulus

$$\mu_0 = \mu \left[1 - \frac{5(3\kappa + 4\mu)c}{9\kappa + 8\mu}\right] .$$

Hashin (1955) considered the presence, instead, of scattered small rigid spherical inclusions which resulted in an increased shear modulus

$$\mu_0 = \mu \left[1 + \frac{5(3\kappa + 4\mu)c}{6(\kappa + 2\mu)}\right] .$$

Oldroyd (1956) found that for small variable rates of shear the equation of state for visco-elastic disperse systems is of the form

$$\left(1 + \alpha_1 \frac{\partial}{\partial t} + \alpha_2 \frac{\partial^2}{\partial t^2} + \ldots + \alpha_N \frac{\partial^N}{\partial t^N}\right) p_{ik}$$

$$= 2\mu_o \left(1 + \beta_1 \frac{\partial}{\partial t} + \beta_2 \frac{\partial^2}{\partial t^2} + \ldots + \beta_N \frac{\partial^N}{\partial t^N}\right) E_{ik} ,$$

$$(17)$$

replacing the equation $p_{ik} = \mu_0 E_{ik}$, representing Hooke's law, which in this system is valid only in equilibrium. Equation (17) may be generalized to a universally valid constitutive equation by replacing the partial derivatives with the material or convected derivatives, the simplest generalization being

$$\left(1 + \alpha_1 \frac{\mathcal{D}}{\mathcal{D}t} + \alpha_2 \frac{\mathcal{D}^2}{\mathcal{D}t^2} + \ldots + \alpha_N \frac{\mathcal{D}^N}{\mathcal{D}t^N}\right) p_{ik}$$

$$= 2\mu_o \left(1 + \beta_1 \frac{\mathcal{D}}{\mathcal{D}t} + \beta_2 \frac{\mathcal{D}^2}{\mathcal{D}t^2} + \ldots + \beta_N \frac{\mathcal{D}^N}{\mathcal{D}t^N}\right) E_{ik} ,$$

$$(18)$$

To conclude, we shall expect a wide range of materials to be characterized by differential constitutive equations of the form (15) representing what is fundamentally liquid behaviour, or of the form (18) representing basically solid behaviour. The physical constants in the equations will distinguish between different materials of the same class. In *steady* flow at small rates of shear or at *constant* small shear (that is, at constant shear stress in either case), the differential equations will reduce to those for the corresponding classical idealized material.

References

Camilleri C J, *Hydrodynamics of Elastico-Viscous Liquids*, Thesis, University of Wales (1965).

Camilleri C J, *Vector Analysis with a gentle introduction to Cartesian Tensors*, Malta University Press (1994).

Camilleri C J, *Tensor Analysis with applications to Geometry and Continuum Mechanics*, Malta University Press (1999).

Camilleri C J & Jones J R, *Zeitschrift fur Angewandte Mathematik und Physik*, Volume 16 (1965) page 582.

Camilleri C J & Jones J R, *Zeitschrift fur Angewandte Mathematik und Physik*, Volume 17 (1966) page 78.

Einstein A. *Annalen der Physik, Leipzig*, Volume 19 (1906) page 289.

Einstein A, *Annalen der Physik, Leipzig*, Volume 34 (1911) page 591.

Fröhlich H & Sack R, *Proceedings of the Royal Society of London*, Series A, Volume 185 (1946) page 415.

Hashin Z, *Bulletin of the Research Council of Isreal*, Series C, Volume 5 (1955) page 46.

Lax-Weiner K & Scoenfeld-Reiner R, *Bulletin of the Reserch Council of Israel*, Volume 2 (1952) page 66.

Mackenzie J K, *Proceedings of the Physical Society*, Series B, Volume 63 (1950) page 2.

Merrington A C, *Nature*, Volume 152 (1943) page 663.

Oldroyd J G, *Proceedings of the Royal Society of London*, Series A, Volume 200 (1950) page 523.

Oldroyd J G, *Proceedings of the Royal Society of London*, Series A, Volume 218 (1953) page 122.

Oldroyd J G, *Proceedings of the Royal Society of London*, Series A, Volume 232 (1955) page 267.

Oldroyd J G, *Deformation and Flow of Solids*, Berlin: Springer (1956).

Oldroyd J G, *Proceedings of the Royal Society of London*, Series A, Volume 245 (1958) page 278.

Oldroyd J G, *Proceedings of Internation Union of Theoretical and Applied Mechanics Symposium*, Haifa, Israel (1962).

Oldroyd J G, D.J. Strawbridge & B.A. Toms, *Proceedings of the Royal Society of London*, Series B, Volume 64 (1950) page 44.

Roberts J E, *Proceedings of the 2nd International Congress on Rheology*, Ed. V.G.W. Harrison (London: Buttersworths) (1954) page 91.

Taylor G I, *Proceedings of the Royal Society of London*, Series A, Volume 138 (1932) page 41.

Weissenberg K, *Nature*, Volume 159 (1947) page 310.

Weissenberg K, *Proceedings of International Congress on Rheology*, Holland, Volume 1 (1948) page 29.

Weissenberg K, *Proceedings of the Royal Society of London*, Series A, Volume 200 (1950) page 183.

Research Article

An Electric Vehicle as a Commuter Car

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Summary: *A small internal combustion engined car converted to work off batteries was test driven over a four year period. Intensity of use was about half that of conventional cars, the main vocation of the vehicle being a commuting one. Despite the lack of regenerative energy recovery, the EV proved capable of journeys of 50-60 km length on full charge, even when numerous gradients were involved. Energy consumption under a wide range of traffic conditions was about 0.1 that of an ICE car considering only on-board energy. For the total fuel cycle the EV consumed 0.4 of the ICE car; this figure would drop to 0.3 with regenerative energy recovery and to 0.26 with the best available generating efficiency. For purely mains charging, EV $CO2$ emissions are 50% of an ICE car. However it was shown that significant amounts of charge could be obtained from small PV installations, in which case average CO_2 emissions could be as low as 15% of those from an ICE car.*

Legal problems with EV registration were finally solved in an ad hoc fashion. Revision of registration criteria for electric vehicles is urgently required.

Keywords: electric vehicle, energy consumption.

Introduction
The internal combustion engine is at serious disadvantage in present road traffic conditions. As car numbers on roads and urban sprawl have increased, average journey speeds have gone down. At low speeds, fuel consumption will be far from optimum, with large increases in the emission of certain pollutants. Where catalytic converters are in use, short journeys may prevent them from reaching their working temperature, allowing pollutants to filter through at low conversion rates. Cooling systems may overheat in slow traffic, particularly in summer, with indiscriminate use of car air conditioners. In such situations a battery-powered car can offer significant advantages.

Local conditions
Local conditions correspond essentially to european urban driving at best, and in town and village cores, with speed limits of 25kph, to inner city or city centre conditions on a much reduced physical scale. In March 2001, the number of licensed motor vehicles exceeded 248,000. There were 43,200 commercial vehicles and 183,400 private cars, among which were some 7000 cars with engine capacities above 2 litres (NSO, 2001). These latter are rather unsuited to local roads, where there are few stretches that are at all safe at speeds above 120kph. With 260km of arterial road we have some 1.4m of road per car, without allowing for other types of road vehicle. Congestion may therefore be acute on main roads at rush hours, particularly where roadside parking is allowed.

For an assessment of the usefulness of an electric vehicle (EV) as a commuter vehicle it is worthwhile to look at mode and intensity in local use of cars. There is as yet no very comprehensive source of such information. What follows draws on 1996 observations of the Traffic Section of the Planning Authority (PA); on results of the 1998 household travel survey conducted by the PA; on answers (52) to a questionnaire circulated by students from James Madison University (Abbott et al., 1999); on answers (75) to a questionnaire circulated among university staff (Mallia, 2000).

While the PA 1998 survey is by far the most statistically significant, the other sources contain some information which is particularly relevant to our purposes, even if the weight that can be given to them is limited because of the small sample size.

The JMU and university staff surveys suggested that mean distance covered in a year was close to 10,000km, with 75% of respondents covering between 15km and 40km every day in some 3-4 journeys per day. There was some ambiguity in the responses relating to this last parameter simply because respondents did not always make clear if "journey" meant single or return.

Average speed information was and still is rather sparse. Short time sequences (PA, 1996) for a main road through Mosta gave 27kph, comparable to the 30kph mean speed in European cities (MEET, 1997). On the other hand, along Aldo Moro Road, linking Marsa with Paola and Luqa, average speeds were close to 50kph, even if there were cross-roads (now controlled by traffic lights) at one end and a roundabout at the other end just 1km away.

The Electric Vehicle (EV).
In original form the test vehicle was a small, four seat petrol-engine car (704cc) of 1989 vintage with rear wheel drive. The petrol engine, mounted at the rear of the car, was replaced by a 6kW (8 HP) DC series motor run at 60V. Despite some loss in efficiency, the original

gear box with stick shift was retained for two reasons. The 6kW motor with only the gear ratio in the differential would be unable to carry the vehicle up the steepest local gradients with two passengers and a 240kg battery load. That would have imposed significant limitations on the car's area of use. In practice the car ran in second and third gear; first was only used for steep gradients and top not at all because of insufficient motor torque. In this respect the electric motor, with high torque at low RPM, behaves differently from the internal combustion engine (ICE). Top speed on the flat was 65kph.

Retention of the gear box also greatly simplified coupling of motor to drive, requiring just a faceplate and motor-gear box shaft connection, with the motor itself fixed to the engine mounting bracket (see Figure 1). The original flywheel was retained with rebalancing, after some 20% of its mass was removed by cutting out annular sectors. No changes were made to the rear suspension (coil springs); the front suspension was strengthened with an extra leaf after the successive destruction of two front traction batteries by heavy vibration from poor road surfaces. Out of a total of Lm120 spent on maintenance over the four-year running period, most went into strengthening suspension and brakes. Consumption of gear box oil amounted to 4*l*.

A total of five 12V 110Ah gas-recombination Pb-acid batteries with a nominal 6.6kWh and a realizable 5.2kWh to 80% depth of discharge (DOD), provided the traction energy. One battery was accommodated at the front and four in place of the rear seats. Placed in the car boot, these batteries would have been outside the line of the rear axle; 192kg in that position would have made the steering dangerously light and put excessive weight on the rear wheels. For almost all of the test period, one of the rear traction batteries doubled as services battery. Two 15Wp PV panels connected in parallel and bolted on the car roof rack supplied small amounts of extra charge to the services battery. For the final ten months of the test period this arrangement was substituted by a DC/DC converter delivering 13.2V with a 48-65V input from the battery pack.

The motor controller did not cater for regenerative current, and there was no on-board charger. This required some care in undertaking specific trips, a concern that would not be present in a properly designed commuter vehicle. Battery charging could draw on three different sources: a standard voltage-regulated charger (600W) working off the mains; photo-voltaic (PV) installations of 250Wp and 330Wp; static battery packs charged by the PV panels when the vehicle was on the road.

Electric Vehicle Use
Over a calendar period of 4 years which included 44 motoring months, the EV covered a total of 16,378km, which suggests an intensity of use lower than normal for a private car. The strongly-commuter nature of the use

TB: Traction Battery
C: Controller
A: Accelerator
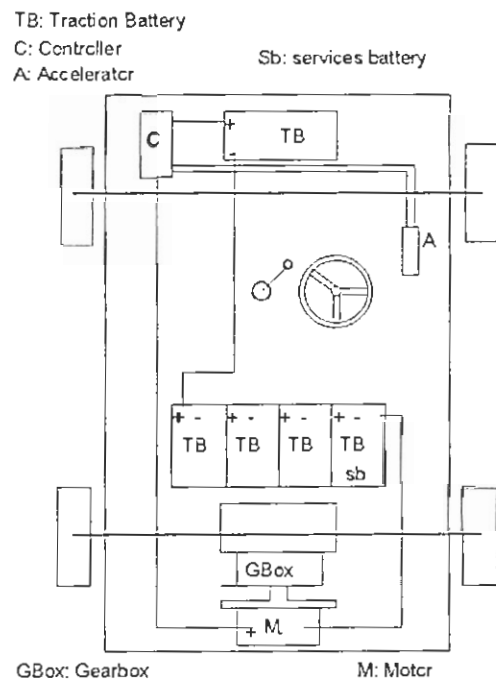Sb: services battery

GBox: Gearbox   M: Motor

Figure 1

can be seen from Figures 2 and 3: the one-way journey to the university campus was 5.9km long.
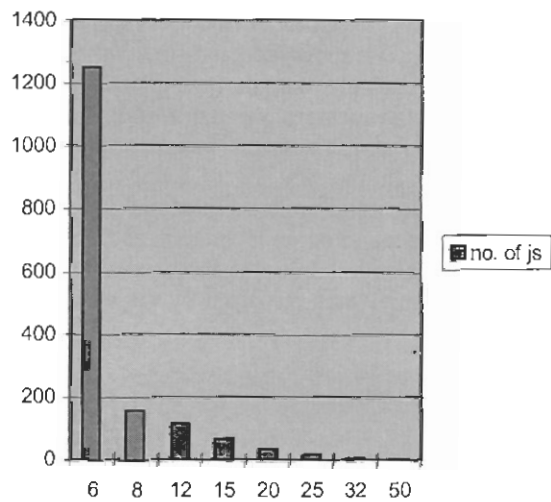

Figure 2

Over half (53%) of the total distance covered during the test period was generated in journeys of 6km or under. The next three journey lengths– 8km, 12km and 15km – combined provided a quarter (25.6%) of the distance covered. These proportions reflect the central position of Campus and Attard in relation to the south and south east of Malta, where most social facilities in everyday use are situated.

There was at best only a very minor influence on the journey pattern from the limited range of the EV. The journey pattern for the 1738km covered with solar charging, when one would expect the general level of

battery charge to be lower   than with mains charging, is very similar to the general pattern (Figure 4); so is the daily travel distance: 12km/day for the whole of the test period and 13km/day for the "solar" period.

The test period stretched from   November 1997 to November 2001. Over this interval the major use of the vehicle was for normal commuting needs. Over September- October 1998 and April-May 1999 an extensive series of commuter journeys were monitored in detail.   These provided determinations of energy consumption and range of the EV under local driving conditions.   In addition there were two journeys of 50km (Campus – Cirkewwa return) spaced by two years to test battery ageing, as well as a set of some 50 test trips in the period December 1999 to March 2000. These latter also involved direct comparisons with a petrol-engine version of the EV.

The monitoring system underwent some development during the test period. In the first version, battery and motor voltages, motor current and motor and controller temperatures were sampled every second and average values for 10-second periods were stored. Combined with ear odometer readings, these data were used to work out energy consumption and average speeds over sections of journeys and over whole journeys. For the 1999 – 2000 test runs, instantaneous speed was added to the recorded data – while retaining the analogue indication of the normal car speedometer. The speed data could be combined with the sampling time to provide another measure of total or partial distance covered.   Data were recorded and stored at 1s intervals after it was found that during periods of strong acceleration 10s averages were distorting the current-time curve. As a result, instantaneous power and total energy values in the first set of monitored journeys contained systematic underestimates of up to 8-10%, actual values depending on magnitude and frequency of acceleration episodes. Initially, the maximum length of monitored journey was restricted by the 40-minute life
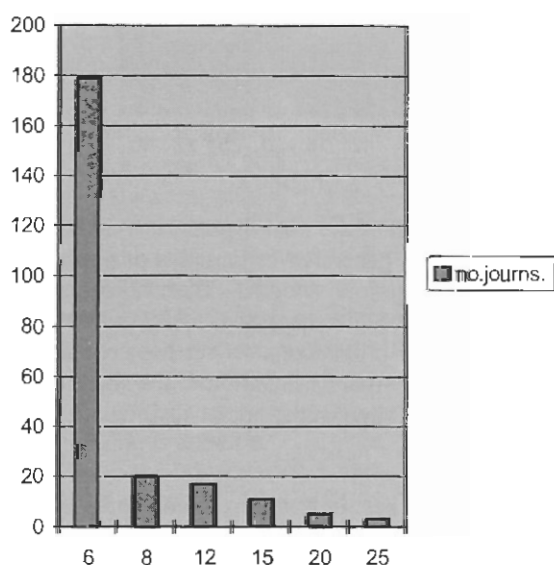

Figure 4

of the computer battery. With use of two batteries, up to 90 minutes of recording was possible, allowing monitored return journeys to the northern and southern ends of the main island from the university campus (sample trace shown in Figure 5).

Capacity tests on the surviving four rear-mounted batteries were run during February 2000, after 27 months and 9200 km of running. It was not possible to compare the bench results with those expected from cycle life specifications provided by the makers. The batteries were seldom fully discharged; while opportunities for solar charging were hardly ever missed. That style of use, imposed to a large extent by the commuting vocation of the vehicle, does not allow a credible estimate of number of cycles the batteries have been put through.

Nichrome wire (SWG 8) was used as load, with a length chosen to obtain a current of about C/5 (22A) from a fully charged battery. Measurement of current and terminal p.d. was continued until the latter reached 10.2V, which eorresponded to 80% DOD according to specifications.   The capacity under these conditions was found to lie between 100Ah and 105Ah; the batteries had lost up to 10% of nominal capacity. Some warping of the outer casing, which must reflect internal plate buckling, was also evident.

Motor maintenance was restricted to occasional removal of graphite dust from brush erosion. At the end of May 2001, the brushes had eroded by about 2mm in 32mm. The original set were left in place. During the four year test period, there were no motor or controller failures.

Energy Consumption

The nominal energy content of the 240kg battery pack was 6.6kWh, of which 5.3kWh were available by 80% DOD. This energy content is equal to that of 0.57*l*. gasoline (Goodger, 1982). After a period of two months running, the batteries were drained and then slow-charged over a period of 22 hr. The mains wattmeter registered 7.9kWh, which indicated a transfer of 5.1kWh into the batteries (see below). The vehicle was then driven for a period of 6 days without further charging. The trips included a 21km run (Campus-Marsaxlokk-Campus):two   journeys   Attard-Mosta-Campus; two Attard-Campus return. After the final return to Campus, individual battery voltage was close to 11.0V. This represented a residual range of about 5km, which could only be covered at low speed. The total distance actually covered was 73km, giving a specific energy consumption of 0.07 kWh/km.

For practical purposes the range with full charge was taken to be 65km. This served not only to lessen the risk of getting caught on the road with exhausted batteries, but also to have a minimal hill climbing ability in reserve, as one of the approaches to Campus involved a climb out of Msida Valley. In fact the longest journey undertaken was Campus-Cirkewwa return (56km); the
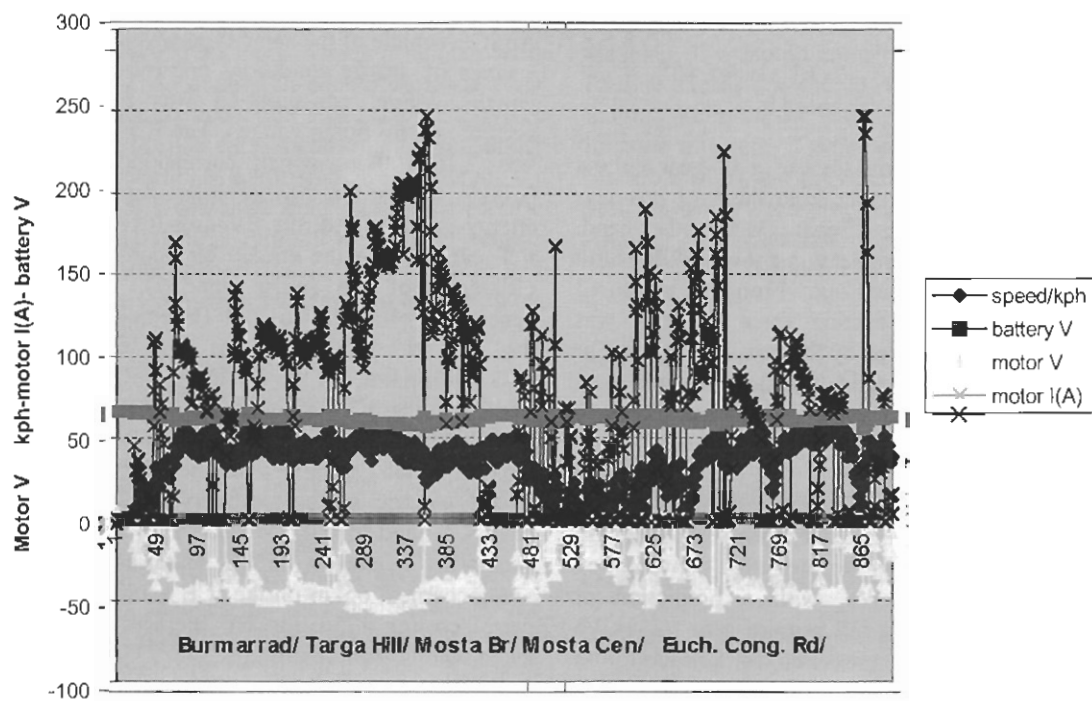
St.Paul's Bay to Mosta

Figure 5

second longest was a circular run from Campus to Hal Far to Gudja (Airport). to Attard and back to Campus (43km), with significantly fewer hills than the first.

In general the specific energy consumption (SEC) is dependent on style of driving. on average speed, on gradients and on car occupancy. On strictly commuter trips, usually during morning and evening rush hours, average speeds were low for two reasons. Part of the route ran through narrow village streets with a 25kph limit; while the numerous roundabouts on the Birkirkara by-pass obstructed free flow. Average speeds were below 30kph, compared to 40kph for Sunday trips over the same stretch. However. superposed on average speed are the effects of the detailed driving cycle. For instance, in steady slow (28kph) and fast (43kph) runs on the Birkirkara by-pass at times of low traffic, SEC ranged from 0.027kWh/p.km to 0.045kWh/p.km. The latter, though representing a high-speed run. is at the lower end of SEC for commuter trips. where average speeds were below 25kph but acceleration episodes were much more frequent. This situation would have been modified if regenerative braking were available. but it is unlikely to have been reversed. Urban driving cycle ranges for current EVs are invariably shorter than country cycle ones. On the other hand, the use of super capacitors as a buffer between batteries and motor, with increased energy recovery from regenerative braking and the batteries spared the current peaks required for acceleration (Mestre and Astier, 1998), could have a major effect in improving SEC in urban driving.

The longer runs with full occupancy show off the EV at

its best in terms of SEC. Over journeys of more than 15km without long gradients, average SEC was 0.032kWh/p.km. which is close to the SEC of a manual bicycle (Lincoln. 1973). but over twice that of an electric bicycle (Wegmann, 1998). For the longest runs: Campus-Cirkewwa return, with just driver on board, SEC ranged from 0.065kWh/p.km to 0.083kWh/p.km. The increase from the average quoted above was caused by the number of hill climbs along the route. By way of comparison. the SEC for electric cars (Peugeot 106, Citroen Saxo) in long term use in the hilly district of Mendrisio. southern Switzerland, was 0.24kWh/km (Wegmann, 1998). Taking these EVs as typical in terms of annual distance covered (12,000km) and energy consumed (2400kWh). 7500 EV would account for 1% annual electricity production (Enemalta. 2000), which is well within the recent 4.5% annual increase in consumption (Fsadni and Mallia, 1999). Overnight (2300-0700hr) charging of half this number of EVs would provide Enemalta with significant load levelling.

Predictions of energy consumption on gradients or on the flat could be made after determinations of the vehicle drag (C_d) and rolling friction (C_r) coefficients. For determination of C_r. the vehicle, with a 2.3bar tyre pressure, was pulled at a steady speed on the flat while recording the traction force on a spring balance; air drag is insignificant at such low speed.

The second method involved timed decelerations over the speed ranges 50kph to 40kph and 40kph to 30kph. Both coefficients were calculated from timed decelerations. with a first assumption that $C_d \gg C_r$.

The values finally adopted were C_d = 1.25 and C_r = 0.01. For running on the flat the power required could then be estimated as

$$P(kWh/s) = 9 \times 10^{-6} v^2 - 2 \times 10^{-5} v + 9 \times 10^{-5}$$
with v being the car speed in m.s^{-1}.

From deceleration times with the car in 3rd gear and out of gear, the retardation arising from the gear box was deemed to be negligible in 3rd gear. On the other hand, for use on long or steep gradients, unpowered downhill runs in 1st gear were carried out. From the measured average acceleration, a friction force of 95N was calculated as being produced by the box in 1st gear. For use on gradients the weight of the car with two passengers and the height rise were combined to determine the energy expended.

The usefulness of the above energy estimates can be seen from a number of examples. For the short steep hill between Attard and Zebbug the measured consumption in first gear was 0.20kWh, with a prediction of 0.19kWh; for Santa Lucija hill in third gear 0.31kWh predicted against 0.29kWh measured; for Selmun hill in first gear, a measured value of 0.37kWh against a prediction of 0.34kWh; for the climb from sea level at Ghadira to Mellieha by-pass in second gear a measured energy consumption of 0.41kWh against a calculated value of 0.40kWh for third gear.

The two Campus-Cirkewwa return journeys spaced by two years clearly demonstrate battery ageing. In April 1998, the return leg ended at Attard (48.5km), with the battery voltage at 59.8V, and was then continued to Campus the following morning without recharging, battery voltage being at 59.0V on arrival. In the April 2000 run, battery voltage had dropped to 55V at Bugibba (39.5km), with values as low as 35V while running uphill into old St.Paul's. In fact the run was terminated at Bugibba and the batteries recharged overnight before continuing to Campus.

For a complete estimate of energy consumption, a measure of the charging efficiency has to be obtained. The energy input into the charger was read off a standard mains wattmeter, while energy transferred to the batteries was measured by an integrating power meter. A series of 47 monitored mains charges gave a value of 0.67±0.06 rms for the mains charging efficiency. Towards the close of the test period a pulse charger was installed, working at a frequency of 6Hz with peak current pulses of 14A. Apart from a doubling of the charge transfer rate, the charging efficiency increased to 0.8.

The intensity of use of the EV did not require daily charging. However, with charging facilities at home and on the university campus, any time the EV was parked at either station it was put on charge: mains, direct solar or indirect solar through storage batteries. With a developed infra-structure for Evs, work places could

have charging points; house charging points could be an ordinary mains power socket in a garage.

An ICE vehicle of the same type was used for a week in a range of traffic conditions and over various journey lengths. Fuel consumption was measured on the accurate petrol pump gauges. The ICE car consumption was 7.16*l*/100km, which corresponds to a SEC of 0.33kWh/p.km for two persons. As far as on-board energy is concerned, the EV uses 0.1-0.2 of that of the ICE car. Getting the energy on board with a charging efficiency of 0.8 (pulse charger), together with a generation efficiency of 0.3 (Enemalta, 2000), leaves the EV at 0.133kWh/p.km and the ICE car at 0.337kWh/p.km, i.e. the EV has a SEC of less than half (0.40) of the ICE car. The EV SEC would drop to 0.102kWh/p.km with the installation of regenerative braking which capitalizes on one of the major strengths of the electric motor (recovery of 30% of available energy), and to 0.07kWh/p.km for the best available generating efficiency (45%). As far as actual fuel costs are concerned, 65km on the ICE vehicle require 4.5*l* of petrol costing 175c; the EV requires 8kWh which, if taken wholly from mains cost 36c.

From the point of view of CO_2 emissions, the transferred emissions from the EV depend on the source of electricity or more precisely on the source mix. Clearly a solar or wind source is essentially emission-free. In our national mix, an average fuel consumption of 0.3kg/kWh generated would carry a penalty of 120g/ p.km of CO_2 for the EV. The ICE counterpart would produce about 230g CO_2/p.km. This CO_2 cut-back factor (0.52) for the EV can be compared with a value of 0.35 for European city driving and generation mix (Lestienne and Vergels, 1998) and with 0.5 for the US situation (Mackenzie, 1994).

In our case mains charging was supplemented by PV charging to a varying extent, depending on weather and on travel requirements. Over the period May to November 2000, for instance, the EV covered 1700km. with PV charging only. Transferred emissions were essentially zero. On the other hand, from January to June 2001, 2046km were covered on a mix of mains and solar charging. With a mains contribution of 94kWh, CO_2 emissions were down to around 40g/km, less than a third of the value for mains-only charging. As for other important pollutants from car emissions, the mitigation of these by EV use has been discussed elsewhere (Mallia,1999).

Legal aspects
Throughout most of the test period, the EV was registered under its original ICE guise. The car register required engine power and capacity; the motor has no analogue of the latter parameter. The 'solution' finally adopted was to translate motor power into 'engine capacity' via the equivalence 0.75kW = 100cc and using 'electric' as the fuel. Sometime after the registration of the car as an EV, the registration tax for new (battery)

cars was reduced from the 65% for ICE models to 16.5%. Hybrids, of which there is at least one on the road, do not qualify for this reduction. On the other hand, electric motor scooters, of which a number have been sold locally, do qualify. It should be made clear however, that this tax reduction still leaves EV prices well above those for ICE cars. A car selling at just under Lm4000 in a petrol ICE version was offered for Lm10,000. Vehicles designed from scratch for electric drive still cost 20%-50% more than an ICE vehicle offering comparable space. This cost disadvantage can be mitigated by fiscal measures related to import duties and registration tax.

Engine capacity should be removed from the car registration form, leaving just engine/motor power in kW. However, if that parameter is retained, the equivalence formula should be revised. As it stands, there is a strong discrimination against EVs, both converted and intrinsic. For instance, conversion of a 1100cc ICE to a 15kW electric motor gives a 2000cc equivalence. This changes the road tax bracket of the car in an upward direction. The same handicap would operate against an electric version of a 1000cc ICE with a 15kW motor. Such discrimination goes against any policy of favouring EVs for their environmentally friendly qualities. In France for instance, where there is the largest EV fleet in Europe, EVs are registered as motorcycles, irrespective of motor power.

Conclusion

Under local traffic conditions a small EV provides a number of advantages for use as a commuter vehicle. With short distances, low average speeds and a number of short journeys every day, the EV has been shown to offer a flexible alternative to present ICE cars. As it combines low running and maintenance costs with reduced and transferred emissions of most traffic-related pollutants and low specific energy consumption, the EV is particularly suited to congested urban driving conditions. Transferred emissions can be reduced further through utilization of renewable energy sources. On the other hand, capital costs are still daunting for most available models. Low volume production is a principal cause; while other than lead-acid – with low cycle life, and low power and energy density—most battery types are still expensive. Another aspect of capital cost, which has not been treated here, lies in the choice between DC and AC drive systems. While the latter offer the highest efficiencies, they introduce high cost elements like inverters. At the present stage of the market, capital cost rather than relatively small gains in efficiency and range, may control the growth of numbers.

References

Abbott S. Creswick B, Horvath E, Ritter M, Walsh B (1999) A Feasibility Assessment of Implementing Sustainable Transportation in Malta.

James Madison University-Institute of Energy Technology Report.

Enemalta Corporation (2000) Annual Report.

Goodgere EM (1982) Liquid Fuels for Transport in *Progress in Energy and Combustion Science* **8**, 233-240.

Lincoln GA (1973) Science 180 155.

Mackenzie JJ (1994) The keys to the Car: *Electric and Hydrogen Vehicles for the 21st Century.* World Resources Institute, Baltimore, 128pp.

Mallia EA (2000) Questionnaire on car use among University staff.

Mallia EA (1999) *Xjenza* **4** no. 1, 19-21.

Mallia EA and Fsadni M (1999) Energy: Transformation, Use and Environmental Impact in State of the Environment Report Environment Protection Department.

MEET (1997) Methodologies for Estimating Air Pollutant Emissions from Transport: Draft Final-Report to EC.

Mestre P and Astier S 1998 Application of Ultracapacitors and Influence of the Drive Control Strategies on the Performance of an Electric Vehicle Proceedings of the 15th International Electric Vehicle Symposium and Exhibition.

National Office of Statistics Bulletin (2001).

Planning Authority (1998) Household Travel Survey

Stafrace L (1996) Private Communication.

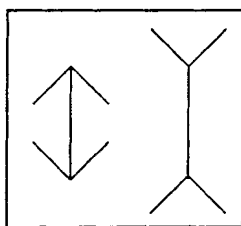Wegmann S (1998) Mobile Autumn 1998 **4**, 10-11 AVERE, Brussels.

Article

Trains of Clinical Thought
- with special reference to Practical Reasoning

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Summary: *In the last two decades clinical reasoning has attracted the attention, not only of pure academics but also of practicing clinicians. This has followed a long period of neglect, when, discussion on such subjects was limited to few people, mostly speaking from their easy-chairs. The various philosophical processes utilized in methods of reaching a diagnosis and decision making in a clinical setting are portrayed. Special reference is made to Aristotelian Practical Reasoning, which though frequently used by most clinicians has not been given its due importance in the medical and to some extent even in the philosophical literature.*

Optimal decisions result from the application of a statistical decision – rule to data, as usually occurs in mathematics. Other methods, including clinical decision-making are considered sub-optimal because clinical practice is inherently uncertain and most processes probabilistic. Expertise in clinical reasoning thus depends both on mastery of logical rules and accumulation of experience. The importance of the latter factor is not surprising since one's very interpretation of external environment is moulded by previous experience. This is not only a philosophical consideration but has also been shown experimentally using illusions. Using the classical Muller Lyer illusion, the vertical line on the right appears to be longer than the one on the left though one can easily ascertain that their lengths are equal on measurement. This is probably because the mind interprets the two-dimensional diagrams as three-dimensional, with the left diagram as the outside edge of a corner coming towards us and the right as the inside of a corner going away from us. It is illuminating that this illusion does not work on Zulus who traditionally live in round houses. Categories and concepts, even such high-level concepts as disease, depend on our previous experience and training. The observation that the trained mind is better equipped to solve problems may seem commonplace, but it has been formally proposed in psychology under the term "plasticity", i.e. the interaction between the environment and the brain. This effect as applied to the clinical process, has also been demonstrated experimentally by practical research. All this leads to the conclusion that understanding of thought processes involved in the clinical processes as well as the experience which is necessary to mould the expertise, are both vital to planning of medical curricula.
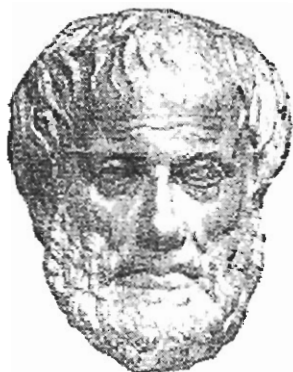
Diagnosis involves opinion revision with imperfect information. The mental processes, used may include, pattern recognition or categorization, prototypes, practical reasoning, generating competing hypothesis (hypothesis testing) and algorithms. These methods are not necessarily mutually exclusive. Since medicine is a highly visual as well as an intellectual discipline, pattern recognition combined with a personal template of the norm is often used especially in typical cases e.g. syndromes. This is however not applicable in the significant proportion of cases which are not typical.

The clinician has traditionally combined the science and the art (in different proportions) and in the same way combines discursive (logical) reasoning and intuitive reasoning into a synthesis. This is applicable to diagnosis, choices in clinical management and in predicting outcomes. Unfortunately intuitive reasoning suffers from several biases and there have been precious few studies investigating the effectiveness of clinical decision making based on intuitive thought.

The traditional ways of reaching a diagnosis are:

- Taxonomy – one decides whether the disease is congenital inflammatory, traumatic, degenerative or neoplastic. One then narrows down on the more specific pathological mechanism e.g. an acute abdominal emergency may be due to obstruction of a hollow viscus, peritoneal irritation or haemorrhage.

- Differential diagnosis – One produces a list of possible pathological conditions which correspond to symptoms and signs through a process of eliminations with the help of special investigations, narrow options to the correct diagnosis. This is an inductive process of reasoning on the basis that similar symptoms and signs should lead to the corresponding diagnosis.

- Goal-seeking (Heuristic) attitude - Heuristic reasoning is not synonymous with intuitive thought. The former, which literally means 'aiming at discovery', has as its primary goal the choice between alternative actions (in the way of algorithms) and is not so much concerned with arriving at absolute truths. Formal science, research and analysis improve the reliability of the premises, which are channelled into a utilitarian (goal-seeking) thought process. One develops short lists of important data, which allow decision as to the next step, forming a working hypothesis, which may be changed on the way, without assuming that this is necessarily the final pathological diagnosis. Because clinical decisions are often taken in close-call situations, the latter method is very useful. Though often described as a hypothetico–deductive process of logic this is really an application of Aristotelian "Practical Reasoning" (a situation which leads to a logical action) in contradistinction to Theoretical Reasoning (a collection of true facts which necessarily lead to a conclusion). Practical reasoning may be considered as a utilitarian approach, finding the options to maximize utility. The importance of practical reasoning to human sciences has been compared to that of deductive process in the natural sciences and merits further consideration.

Aristotle: 384 - 322 BC

The division of reasoning into "theoretical" and "practical" was proposed by Aristotle. Unfortunately, later philosophers, with a few exceptions e.g. Hegel, Kant and Wittgenstein, concentrated on theoretical reasoning, ignoring the latter. The logical nature of practical reasoning is less clear than inductive, deductive, or even hypothetico-deductive forms of theoretical reasoning. There is a difference of form between reasoning leading to action (practical reasoning) and reasoning leading to a truthful conclusion (theoretical reasoning). Basically, in practical reasoning, the first premises mentions an end to an action and the second premises some means to this end.

eg   I want to attain E
      Unless I perform action A, I shall not attain E
      Therefore I shall do A

The hallmark of practical reasoning is that the end is at a distance from the immediate action, the latter being a means to attain an end. The following is a clinical example:

1. I want to prevent this patient with right iliac fossa pain from developing peritonitis.
2. To achieve this I must explore or laparoscope the patient's abdomen, to investigate whether he has appendicitis and treat it.
3. Therefore prepare this patient for operation.

Clearly, though it may be in the patient's best interest, the argument itself is not logically conclusive. For example, the causative pathology of the right iliac fossa pain may not lead to peritonitis. In addition, the clinician concerned may not have the necessary expertise to operate the patient. In the latter event the patient may be better off if he is not prepared for the operation.

Practical reasoning may either look to the past for motivations for previous actions (retrospective use), or to the future for actions (prospective use). In the retrospective application one starts from the conclusion and reconstructs the premises. This happens when we justify our actions eg:

1. The patient had to have endotrachial intubation
2. The patient had glottic spasm
3. Patients with glottic spasm may need endotrachial intubation.

In the prospective use, one sets out from the premises and the conclusion follows eg:

1. This patient has suffered blunt abdominal trauma and has developed hypovolaemic shock from haemoperitoneum.
2. To save his life I need to explore his abdomen surgically (laparotomy) to stop the bleeding whatever the source.
3. Therefore prepare the patient for laparotomy.

Clinical decision-making is based on different degrees of evidence, values (or preference) and circumstances. It is also influenced by bias, which is consequent on the different ways we see things. Several 'aids' have been proposed to render the decision-making process more accurate e.g. multivariate equations, decision analysis, information technology, patient data banks, artificial intelligence, clinical problem analysis, mechanistic case diagramming and algorithms.

To discuss these in any detail would be outside the scope of this essay., but it is important to note that all these methods involve the use of the thought processes previously described.

Conclusion

Practical reasoning is used very frequently in the clinical process, though almost invariably this is not done consciously. Furthermore, the diagnostic process may involve several logical processes and perspectives [13] (e.g. inductive, deductive, hypothetico-deductive and
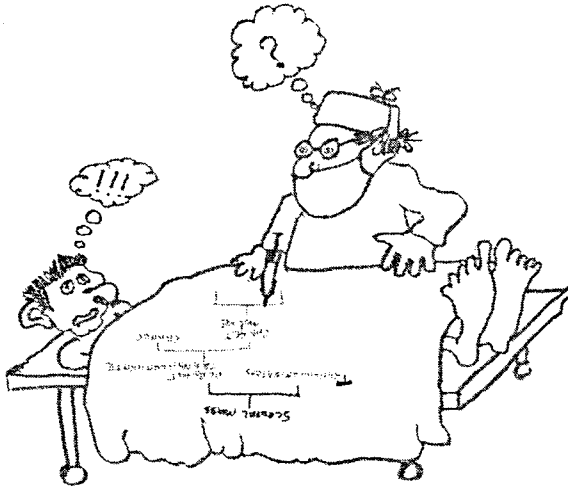
practical reasoning. as well as pattern recognition, heuristic application and priority setting, in different degrees, and with varying frequency and emphasis. In a clinical scenario characterized by estimates of probabilities, close-calls and balancing trade-offs, clinicians use both formal and informal (intuitive) strategies. As the proportion of 'certainties' becomes progressively more consistent, the need for intuitive thought decreases, and science would be expected to encroach upon (but not eliminate) the art.

To recognize, dissect and analyse these processes may be more than a pedantic academic exercise. It is a first step towards appreciation, formal teaching and conscious application of such methods. It also highlights one aspect of the clear influence of many disciplines on clinical practice and the need for a multi-disciplinary approach to medical education.

References

Ascombe Gem (1978) On practical reasoning: practical reasoning, p33-45.

Black Dak (1986) The logic of medicine: Diagnosis. 29-57. Oliver and Boyd Publishers.

Cox K (1999) Doctor and patient: Exploring clinical thinking. New South Wales University Press.

Deregowski JB (1974) Illusion and Culture, in Gregory RL Gombrich EH (eds). Illusion in nature and art. New York: Scibner.

Elstein AS (2000) Clinical problem solving and decision psychology: Comment on "The epistemology of clinical reasoning". *Academic Medicine*, **75.10**. 134-136.

Gregory RL (1996) Eye and brain: The psychology of seeing. Weidenfield and Nicholson Publishers. London UK.

Gross R, Lorenz W (1990) Intuition in surgery as a strategy for surgical decision making. *Theoretical Surgery*, **5**, 54-59. Springer Verlag Publisher.

Hobsley M (1986) The nature of clinical acumen. Theoretical Surgery, p10-18. SpringerVerlag Publisher.

Hobsley M (1984) Pathways in Surgical Management. Edward Arnold Publisher.

Norman GR (2000) The epistemology of clinical reasoning: Perspectives from philosophy, psychology and neuroscience. *Academic medicine*, **75.12**. 1199-1205.

Rosch E (1973) Natural categories. *Cogn. Psychology*, **4**. 328-350.

Rosen MP, Sands DZ, Morris J, Drake W, Davis RB. (2000) Does a physician's ability to accurately suspect the likelihood of pulmonary embolism increase with training? *Academic Medicine*, **75.10**. 127-133.

Wittgenstein L (1953) Philosophical investigations. Blackwell Publisher.

Abstracts

THE PROTECTIVE EFFECT OF OPUNTIA EXTRACT AGAINST STRESS IN FISH

Joseph Abela Medici

The aim of this dissertation was to show that fish treated with TEX-OE®, a locally prepared extract, survived harsh stressful conditions to a greater extent than non-treated fish and that TEX-OE® induces an increased heat shock response immediately after a stressor is applied as opposed to that in non-treated fish when a similar response is induced 2 hours following the stress incident.

Heat shock proteins (Hsp's) are proteins that have been highly conserved throughout the course of evolution in all species from bacteria to man. These proteins appeared at the dawn of life on earth when oxygen began to accumulate in the atmosphere. Their role is to preserve molecule structures under oxidative stress (similar to the prevalent conditions at the start of evolution of life on the planet). Under adverse conditions, poikilothermic animals suffer the consequences of stress to a greater degree than homoeothermic organisms. These include reduced growth rates and even death. The fish farming and ornamental fish industry continuously subject fish to potentially stressful operations such as fish movements, confinement to restricted spaces, and rapid changes in osmotic pressure. However, environmental stressors such as seasonal variations in temperature, salinity, oxygen, water movements etc., also come into play.

TEX-OE®, a natural active extract derived from the fruit of Prickly pear (Opuntia ficus-indica) was exposed to a variety of fish species stressed in various ways under experimental conditions. More specifically, the fish were subjected to transport in restricted space and confined conditions and sudden extended heat changes. TEX-OE® has been shown to induce a rapid response under conditions of stress. It brings about a much faster rate of synthesis of Hsps' and a prolonged elevated level of Hsps' in fish tissues. This preconditioning helped the treated fish survive heat shock better than non-treated (control) fish. The guppies (Poecilia reticulata) tested resulted in an average 3-fold difference in mortality between treated fish and control fish whilst a 2-fold difference resulted in Angelfish (Pterophyllum scalare). Immunofluorescent antibody labelling of treated and control guppy tissue were analysed for a quantitative analysis of the Hsps' present in both tissues. This resulted in a much higher expression of Hsps' in the treated tissues analysed. Statistical analysis of the results obtained has confirmed that there is a significant difference between control and treated fish. TEX-OE® is therefore a very good fish stress protector. It increases the chances of survival under stressful conditions such as exposure to chemicals, sudden changes in temperature, transport, etc., and it helps reduce loss in fish stock.

A VEGETATION SURVEY OF THE NUFFARA AREA (GOZO)

Rita Buttigieg

Nuffara located between Nadur, Xaghra and Xewkija, consists of a rocky steppe Upper Coralline limestone plateau surface, surrounded by maquis, rupestral, disturbed and agricultural areas. The aims of this study were to make a species list of the flora occurring naturally in the area, to investigate the plant species composition and distribution in the various habitats present, to determine whether any factors are influencing their occurrence and to see if conservation strategies are needed in this area. This was done through observation and the use of ecological census techniques between July 2000 and April 2001.

Quadrat sampling was used for the steppe, maquis, disturbed and clay slope areas, and percentage coverage values were used to determine the relative abundance of each species. Four line transects were laid out across the inland cliff areas and their immediate plant communities; while boulder and rubble wall species were studied by recording presence or absence of species. Chemical and physical analyses were carried out on thirteen soil samples that were taken from the different habitats in the study site. A total of 148 species belonging to 44 families were identified and the families containing the highest number of species were the Fabaceae, Asteraceae and Poaceae, which are also the families containing the highest number of species in the Maltese islands. This investigation indicated that the dominant species in the area is the invasive alien weed Oxalis pes-caprae which, together with Acanthus mollis, Psoralea bituminosa, Stipa capensis, Ferula communis and Urginea pancration, is responsible for more than half of the vegetation cover of Nuffara.

Maquis communities are characterised by Acanthus mollis, while the characteristic species in the steppe communities is Stipa capensis. It was also noted that approximately 75 % of the species present in the area

are ruderals. These include opportunistic (natives and normal components of typical natural habitats but which are resilient where disturbance occurs and thus tend to be favoured by disturbance in relation to non resilient species) and weedy (invasive and generally also occur on disturbed ground even in non-rural areas) species, and indicate that the area is quite disturbed.

The trees and large shrubs present were mapped out individually. The dominant tree species was the Almond tree *Prunus dulcis*. An interesting observation was that the uncommon lichen *Ramalina durieui* extensively covers the majority of trees in the area. A high population of the Prickly Pear shrub, *Opuntia ficus-indica*, which seems to be on the increase, was also present.

Factor analysis indicated that the species were distributed randomly throughout the area and that there seemed to be no high relationship between any of the species present. This was attributed mainly to the high disturbance that is present and to the fact that the majority of species are ruderals. The cluster analysis indicated that the highest similarity is found between the maquis and disturbed habitats, indicating that maquis communities are considerably disturbed. This study also suggests the importance of abiotic factors like soil, rainfall, wind, and sunlight on the occurrence, abundance and distribution of species. Biotic factors also seem to affect the vegetation. These include herbivorous organisms like the grey wild rabbit *Oryctolagus cuniculus*, as well as other floral interactions that seem to be taking place, like the parasitic relationship between *Oxalis pes-caprae* and *Orobanche muteli*. Anthropogenic disturbances in the area include illegal scrambling, especially on the clay slope, planting of *Eucalyptus* trees, trampling by local farmers and by hunters and the construction of hunting/trapping hides.

The rare species *Hymenocarpus circinnatus*, last recorded in Nuffara, seems to have disappeared and is now probably extinct from the Maltese islands. Several species of ecological importance were observed. During this study, a population of *Centaurea acaulis* was discovered on the Nuffara Coralline Limestone Plateau rocky steppe area. This is a Tunisian/Algerian endemic, previously recorded outside North Africa only in Lampedusa and Northern Spain and this was the first time that it has been recorded as occurring naturally in the Maltese islands. Other important species that are present include *Darniella melitensis, Ononis natrix* subsp. *ramosissima, Atractylis cancellata, Scorzonera laciniata* and *Vitex agnus-castus*. This area should be protected not simply for the fact that it supports species of conservation interest but also for the natural habitats it contains and conservation strategies should be implemented and enforced before it is too late

CLONAL AND SANITARY SELECTION OF MALTESE CLONES OF THE EUROPEAN GRAPEVINE (*VITIS VINIFERA*)

Lenox Cilia

The primary aim of Clonal and Sanitary selection is to improve the sanitary level of local fruit trees. This process became imperative to safeguard the native varieties both from being totally replaced by modern imported varieties and from deteriorating due to various viral diseases.

Field surveys were conducted in the Summer months, during the periods of highest symptom expression. Data was collected on the various clones of *Vitis vinifera*, and field symptomatological studies were performed. The clones Tax-Xitwa and Damaskina were selected for further study. Cuttings were taken from these clones and were propagated in different rooting media in order to have a stock of plants available in the greenhouse which could be used for the Indexing tests. Indexing tests (Serological test: ELISA) and dsRNA and RT-PCR analysis (which were used when ELISA gave dubious results) were performed using tissue samples from the stock plants to identify the presence of any viruses in the grapevine tissues. The grapevines were all found to be infected by viruses and so all had to undergo sanitation. Sanitation of the grapevines was performed by *in vitro* meristem tip culture, where the shoot apical and lateral meristems were cultured on a modified semi-solid MS medium, and the cultures were maintained in a temperature and photoperiod-controlled growth room.

During the field surveys performed, it was noticed that many local grapevine varieties are in a highly degraded state with low fruit production, and the majority are not used for commercial purposes. When performing the Indexing tests, the ELISA test confirmed the presence of viruses in the grapevine tissues. ELISA gave a dubious result on the presence of grapevine virus D in the clone Tax-Xitwa 1 and thus to confirm its presence, dsRNA followed by RT-PCR were performed and gave a negative result to the presence of Grapevine virus D. Sanitation involving Meristem tip culture was then performed to produce virus free plants, however since the time period available was not sufficient to perform the whole process, only initaition and multiplication steps could be performed. Laboratory work was performed at the Plant Biotechnology Centre, Lija.

HARMFUL ALGAL BLOOMS IN MALTESE COASTAL WATERS – A PRELIMINARY STUDY

Sarah Debono

The main objective of the study was to identify toxic and harmful phytoplankton species and to detect any harmful algal blooms occurring within Marsamxett and Grand Harbours, two moderately eutrophied areas in the Maltese Islands. When certain conditions prevail in the marine environment, such as high nutrient levels accompanied by warm, calm weather, dense population explosions of phytoplankton occur. These phenomena, 'blooms', range from high cell concentrations that discolour the water, to dilute, often inconspicuous concentrations of cells noticed only because of the harm caused by their highly potent toxins. Such events are called Harmful algal blooms (HABs) and can be defined as events where the concentration of one or several harmful algae reaches levels that can cause harm to other organisms in the sea, or cause accumulation of algal toxins in marine organisms that will eventually harm other organisms who will consume the toxic species. There is no general rule to define the cell concentrations at which an algal bloom would have harmful effects. The concentration of cells in a HAB is said to be species specific. HAB impacts include mass mortalities of wild and farmed fish and shellfish, human illness and death from contaminated seafood, death of marine organisms and alterations of marine habitats.

Surface seawater samples were collected monthly between August 2000 and January 2001, from six fixed stations: Sliema Point (reference site), Sliema Creek, Msida Creek, Pieta' Creek, Marsa (Menqa) and Dockyard Creek in Vittoriosa. Taxonomic identification focussed on two of the main phytoplankton groups, **diatoms** and **dinoflagellates**, down to species level. A list of 66 species that were the most easily identifiable was obtained. Environmental data for each location were also recorded, including: air and sea surface temperatures, salinity, nitrates, phosphates and faecal coliforms. Monthly wind speed and direction and rainfall data as recorded at Malta Weather Station, Balzan were also used.

Different sampling methods were evaluated to determine the most feasible way in which not only quantitative results can be obtained, but also detailed phytoplankton presence or absence data. The main sampling method involved the use of a phytoplankton net. Such a net makes it easier to filter large volumes of water and thus concentrate the organisms. Sampling a larger volume of seawater makes the collection of a rare or non-abundant species more possible. Samples were concentrated in the laboratory by the Utermöhl settling technique and observed with an inverted microscope, using settling chambers with a glass bottom of a coverslip thickness to examine a sample.

A high proportion of toxic and harmful phytoplankton species, as classified by UNESCO, were found in all locations, with higher percentage relative abundances in Marsamxett than in the Grand Harbour. Comparable species distributions can be found in the southern Adriatic Sea and Eastern Mediterranean regions as given in published literature. The presence of particularly toxic species, such as *Dinophysis* spp., *Gonyaulax* spp., *Gymnodinium* spp. and *Pseudonitzschia* spp., is a cause for concern since cases of shellfish poisonings to humans and higher animals can result with cell concentrations of less than 1,000 cells/L, as reported in international publications (see Table 1). The monthly concentrations of these, and other toxic species recorded in this study, were highly variable. The highest concentration of *Dinophysis* spp. (which causes Diarrhetic Shellfish Poisoning) was recorded at Sliema Creek in August 2000 with 1.7×10^5 cells/L. The presence of *Pseudonitzschia* spp. (which causes Amnesic Shellfish Poisoning) was recorded at significant concentrations every month of the study period.

Algal blooms were recorded for *Ceratium furca* and *Pseudonitzschia* spp. in Marsamxett Harbour, and for *Skeletonema costatum* in both harbours. The highest concentration was recorded for *S. costatum* as 3.3×10^6 cells/L in August at Msida Creek. The highest recorded concentration of *Pseudonitzschia* spp. was 2.0×10^6 cells/L, and for *C. furca* this was 3.0×10^4 cells/L, both were recorded in Sliema Creek. The significant quantities of nutrients in both harbours, combined with their limited seawater circulation, enabled and supported the development of these blooms.

Diatom blooms are more common in winter. *Pseudonitzschia* spp. bloomed in December, coinciding with sharp drops in salinity and sea surface temperature. Dinoflagellate blooms, however, appear more commonly in the warmer seasons, during stagnant meteorological conditions. The *C. furca* bloom was centred around Sliema Creek in November, where cell counts of 3×10^4 cells/L were recorded and the percentage abundance was 99 %. *C. furca* is known to be harmful due to its long horns that can cause physical damage to marine life. Two members of the *Ceratium* genus are also known to produce toxins. The presence of high concentrations of the opportunistic, fast-growing diatom, *S. costatum*, were indicative of sewage pollution, since it is one of those species that respond quickly to new inputs of nutrients by sewage discharge or agricultural runoff. A consistent feature occurring when blooms were recorded was a prevailing onshore wind, which could be regarded as a cell-concentrating mechanism.

Cluster analysis was used to indicate the degree of similarity between the six locations according to the

species composition and abundances. Results have shown high similarities between the Marsamxett locations, which proved to be distinct from the two highly similar locations within the Grand Harbour. Increases in cell concentrations for some species occurred whenever a number of factors were optimal for the growth of that particular species. Principal component analysis revealed that not all species achieved high concentrations when high levels of nitrates and phosphates were available. Sewage pollution in both harbours had both positive and negative correlations with the occurrence of different species.

Although similarity of results cannot be applied with certainty for predictive purposes, due to the complexity of factors involved, the data obtained in the present study shows that there is a higher possibility of algal blooms in Marsamxett Harbour than in the Grand Harbour. This is because, whenever algal blooms were recorded, lower concentrations and lower relative abundances of the bloom species were recorded in the Grand Harbour. The probable causative organisms for future algal blooms in the areas investigated, would be *Ceratium furca*, *Prorocentrum* spp. or *Dinophysis* spp. for summer blooms, and *Pseudonitzschia* spp. for winter blooms.

A STUDY OF THE DISTRIBUTION AND ABUNDANCE OF THE SUPRALITTORAL MACROFAUNA OF FOUR MALTESE SANDY BEACHES

Alan Deidun

The sandy beaches of Gnejna and White Tower Bay on Malta and Xatt L-Ahmar and Ramla on Gozo were sampled for macrofauna during the summer of 2000. Depending on the size of the beach, two or three transects were laid at each location. Each transect spanned from mean sea level to the unvegetated limit of the beach — i.e. in the supralittoral. Each transect was then divided into a wet zone (from the strandline to the foredune) and a dry zone (from the strandline to mean sea level).

Macrofauna was sampled using pitfall trapping, standardized searching and the sieving of core samples for the first three beaches, but only pitfall trapping was used for Ramla as the other two collecting techniques had already been used in a previous study by Sammut (1995). Core samples for sieving were collected from stations spaced at regular intervals along each transect. Standard searches were made for a single station in the wet zone and another in the dry zone of each transect, while similarly, for each transect, a constellation of

pitfall traps was placed in the wet zone and another in the dry zone. A box corer of area 0.15m x 0.15m was used to collect sediment from the upper 30cm which was then sieved through a 0.5mm mesh. Searches, made to collect mobile epifauna, consisted of searching 5m x 3m rectangular areas for 10mins and collecting fauna using a pooter. Pitfall traps were used to collect nocturnal, burrowing fauna, and consisted of constellations of five plastic cups in a cross-pattern arranged such that the surface of each cup was flush with the sand surface. The cups were connected by thin strips of wood serving as walkways to enhance the sampling efficiency.

For the first three beaches, the temperature, water content, percent organic carbon, pH, salinity and grain-size distribution of the sand were measured. The depth of the anoxic zone, when present, was also determined. At Ramla, only the organic content was measured, as good data on the other parameters were available from the study by Sammut (1995). These parameters were measured for stations arranged along the shore-normal transects.

For each beach, the slope and the exposure to wave action were estimated, using the Thomas Index for the latter. The beach occupancy by human users for different summer months was also estimated to give an index of anthropic disturbance.

A total of 1584 individuals from 39 species of macrofauna were collected from the four beaches by the three sampling techniques combined. The great majority of individuals (93.06 %) were collected by pitfall trapping. The number of individuals and the number of species collected per cubic metre by sieving ranged from zero to 147.10 and from zero to 58.58 respectively. The number of individuals and the number of species collected per square metre by standard search ranged from zero to 70.00 and from zero to 0.29 respectively. The number of individuals and the number of species collected per trap ranged from 7.00 to 199.00 and from 2.50 to 5.50 respectively.

Fauna collected consisted mainly of Coleoptera (Tenebrionidae, Anthicidae and Carabidae, Hymenoptera (Formicidae, Sphecidae and Vespidae) and Crustacea (Amphipoda and Isopoda). Functionally, the species collected consisted mainly of detritivores and scavengers, with only low numbers of predators and herbivores being recorded.

No correlation was found between faunal abundances and physical parameters, except for salinity. ANOVA indicated that only faunal abundances estimated by pitfall trapping differed significantly from beach to beach. Both cluster analysis and NMDS indicate that, in spite of their geographical proximity, each of the beaches studied had a distinct faunal composition, with White Tower Bay and Ramla being the most dissimilar.

Zonation studies carried out indicate that amphipods, (*Talitrus saltator*), isopods (*Tylos europaeus*), the tenebrionid genus *Phaleria* and the wasp *Polistes omissus* dominated the wet zone of the beaches studied, whilst the dry zone was dominated by *Phaleria*, the ant *Camponotus barbaricus* and the bee *Bembix oculata*. Compared with other Mediterranean beaches, the four Maltese beaches had an impoverished supralittoral fauna, both in terms of species richness as well as abundance of most species.

Some possible reasons for the impoverished fauna and low population densities reported, such as human disturbance, marine pollution, inadequate sampling and beach sediment physical parameters were all excluded, whilst an explanation based on seasonally biased sampling was partly accepted. From this study, it emerged that a lack of recruitment of sandy beach fauna, due to the Maltese Island's physical isolation from any major landmass, may be one explanation of the results obtained, although this possibility requires further study.

A STUDY ON THE USE OF EMPTY TERRESTRIAL SNAIL SHELLS (GASTROPODA) AS A RESOURCE

Karl A. Ebejer

Snail shells have been documented as a source of calcium for certain species including passerine birds and terrestrial gastropods, as well as shelters for organisms small enough to fit inside them. Such organisms include terrestrial hermit crabs (Paguridae), spiders, ground beetles, mason bees, caddis-flies and a variety of other arthropods. In spite of numerous mentions of shell-use in the literature, little appears to be known about the value of the snail shells as a resource.

This pilot study aimed to evaluate descriptively the empty shells of terrestrial gastropods as a resource in the Maltese environment. Snail shells were not believed to play a significant role as a source of calcium in Malta, given that calcium carbonate is readily available in Maltese soils. For this reason, the study focused solely upon shell-users found inside the shells.

Shells were collected from two sites along the coast: Qrejten Point and Slugs Bay. Coastal sites were selected because it was initially believed that the shell resource at these sites would be more limiting. This was found not to be the case due to the fact that empty snail shells are preserved very well in limey, dry environments where dissolution or transport by water is minimal. The abundance of the shell resource suggested that a wide variety of organisms might make use of the shells. This hypothesis was tested through identification of any

organisms, or fragments of organisms, found inside the shells collected. Shell parameters including height, width and reflectance were measured before the shells were broken open and their macroscopic faunal contents were examined.

The most frequent occupants were spiders, beetles, flies and ants. The spiders were commonly represented by their exuvia in a silken nest inside shells, suggesting that the shells were used as shelters during moulting.

The beetles found belonged to at least four species, two of which are known to have relationships with snails. One species, *Staphylinus olens*, is recorded to attack the gastropod *Helix ericetorum*, a close relative of *Cantareus aspersus*, which is a common local species. However, the single specimen of *S. olens* found in this study was taken from the gastropod *Eobania vermiculata* and was incomplete, suggesting that the beetle may have died inside the shell whilst sheltering.

A second interesting beetle collected from the snail shells was a member of the Drilidae, probably *Drilus flavescens*. This beetle occurred only in shells from Qrejten and was represented by the exuvia of the larvae and, in one case, by a live larva that was successfully reared to the adult. *Drilus flavescens* is a well-known predator of snails belonging to the familiy Helicidae. In this study, however, the majority of the *Drilus* specimens were not collected from Helicidae.
A particularly interesting find was that of the polyxenid millipede *Polyxenus macedonicus* (Diplopoda: Polyxenidae). In the Maltese Islands, polyxenids had previously been found on only three occasions (Enghoff & Schembri, 1989), always in leaf-litter collected from under shrubs. The finding of aggregations of these millipedes in snail shells strongly suggested a unique value of the empty snail shells as roosts and possible breeding grounds for the species.

The use of empty snail shells is related to both the properties of the shells and to the biology of the shell-users. The results of the study indicated that some of the shell-users showed preferences for particular snail species. It is believed that the most likely reason for this preference was the relationship between the size of the shell and the size of the potential shell user. In many cases, shell occupants were probably just visiting the shell, but in others, occupants were nesting, either for breeding or for moulting purposes. For all snail species, the presence of a large proportion of shells void of living occupants or their remains suggested that the shell resource was not limiting.

ZONATION PATTERNS ON EXPOSED AND SHELTERED SHORES AT SLIEMA (MALTA) AND THE EFFECT OF SEWAGE ON THE SHELTERED BAY.

Helena Ferro

During the period July - October 2000, the benthic shore communities of two sites along the Sliema shore were investigated in relation to a number of environmental parameters. These included exposure to wave action, which was quantified using the Thomas Exposure Index, slope of shore, pH, salinity, temperature, nitrate and phosphate levels and microbiological pollution.

The continuous belt transect method was used to sample the areas chosen. For the supralittoral and infralittoral zones $0.25m^2$ quadrats were used while for the mediolittoral zone a smaller quadrat of area $0.025m^2$ was used. Macroalgae were recorded as percentage area coverage while macroinvertebrates were counted individually. From the raw data obtained, species richness, species abundance and relative abundance, species diversity and R/P ratios were calculated. The results of cluster analysis and of the tests carried out by the SPSS statistical software package were used to determine the zonation patterns of macroalgae and thus to characterize each of the two sites in relation to position of algal species on the shore.

59 algal and 12 macroinvertebrate species were identified in total. In terms of area coverage, rhodophytes were found to be equally abundant on the two shores whilst phaeophytes dominated the exposed shore and chlorophytes were dominant in the sheltered bay. The dominant macrophytes were Cystoseira amentacea, Jania rubens and Cystoseira compressa on the exposed shore and Jania rubens, Ulva laetevirens and Corallina elongata in the sheltered bay. The macroinvertebrates Melarhaphe neritoides and Chthamalus stellatus were abundant in the exposed site. The distribution of species on the exposed and sheltered shores was notably different. The high degree of exposure of the exposed shore shaped the communities of the site while the intense anthropogenic pressure, which included the flow of raw sewage, greatly influenced the community structure of the sheltered bay. The sheltered bay was found to be more homogenous than the exposed shore and this was shown by the zonation patterns which were more evident on the exposed shore

BIOLOGICAL EFFECT OF THE THERMAL EFFLUENT FROM THE DELIMARA POWER STATION: A THIRD STUDY

Mark Alan Micallef

The aim of this project was to study the impact that the thermal effluent from the Delimara power station is having on the shallow benthic ecosystem at Il-Hofra z-Zghira, by comparing it to a control site (Il-Hofra l-Kbira) and with previous studies made in 1995 and 1996. A control site had to be used since no studies were made on the Il-Hofra z-Zghira site before the power station started to discharge cooling water.

Temperature, dissolved oxygen concentration, conductivity, pH and current speed at the surface and at 1.3m depth were monitored in both bays. Readings were taken at stations spaced 25m apart along eleven 250m long transects. Readings were taken every 3 weeks for six months to investigate any seasonal variations. The current direction was measured by releasing drifters at the mouth of the discharge tunnel. Samples of biota, mainly of the seagrass Posidonia oceanica, were collected and analysed in the laboratory. For the sea grass samples, shoot density, number of leaves per shoot (from which total number of leaves per metre squared was calculated), leaf dry mass per shoot, dry mass of epiphytes per shoot, leaf length and leaf width were measured. Benthic habitat maps of both bays were made by recording depth, distance from the discharge tunnel, substratum type and major biotic assemblages present every 5m along carefully 250m-long transects placed on the bottom.

On average, Il-Hofra z-Zghira was found to be 1-2°C warmer than the control site, and a definite temperature gradient was observed along the discharge plume, with temperature being high near the mouth of the discharge tunnel and decreasing with distance. The western part of Il-Hofra z-Zghira had a higher temperature than the southern area. During summer the temperature was higher then in the winter in both bays. At Il-Hofra z-Zghira, temperature was only high enough to potentially affect the sea grass in summer, especially in front of the discharge tunnel and on the western part of the bay.

The dissolved oxygen concentration was about 0.1ppm lower at Il-Hofra z-Zghira compared to Il-Hofra l-Kbira, but no hypoxic conditions were observed. Il-Hofra z-Zghira was slightly hypersaline in the immediate vicinity of the discharge tunnel and on the western part when compared to the control site; pH was constant in the two bays. During the sampling sessions, the current speed was below the detection limit of the meter used at Il-Hofra l-Kbira and also at Il-Hofra z-Zghira except in front of the discharge tunnel where the current speed was high (a maximum speed of $1.51ms^{-1}$ at the surface

was measured) and decreased with distance from the tunnel. The current was faster at the surface than at 1.3 m depth, showing that the effluent is buoyant.

The *Posidonia oceanica* in front of the discharge tunnel and on the western part of Il-Hofra z-Zghira appeared to be stressed, most probably due to the thermal effluent. Shoot density, dry leaf biomass, total number of leaves, leaf length and leaf area index, were found to be lower in the western part of Il-Hofra z-Zghira when compared to the rest of Il-Hofra z-Zghira and to Il-Hofra l-Kbira.

Comparison of maps of the benthic assemblages made during this study with those made in 1996 showed that in the immediate vicinity of the discharge tunnel, *Posidonia oceanica* no longer exists and that new patches of photophilic algae and of the pioneering seagrass *Cymodocea nodosa* have replaced *Posidonia oceanica* in the western part of Il-Hofra z-Zghira. The southern part of Il-Hofra z-Zghira seems not to have been affected by the thermal effluent. A large area of bare rock is present near the discharge tunnel at Il-Hofra z-Zghira most likely due to scouring of sediment from the seabed by the thermal effluent jet.

From this study it could be concluded that at Il-Hofra z-Zghira the biota is affected negatively in the immediate vicinity of the tunnel and on the western part of the bay. The reason for this degradation cannot be attributed to a single physicochemical parameter but to a combination of high temperature, salinity, current and turbidity. Should the Delimara powers station be upgraded and the volume of thermal effluent increases, the results of the present study should prove useful for any Environment Impact Assessment that is carried out, as well as for monitoring the impact of any increase in the volume of effluent discharged.

MEDIOLITTORAL SANDY BOTTOM MACROBENTHIC ASSEMBLAGES OF MALTESE BEACHES

Stephen Saliba

The present work aims to determine the diversity, abundance and distribution of mediolittoral and upper infralittoral macrofaunal species on contrasting sandy shores in the Maltese Islands.

Sandy bottom macrobenthic assemblages from the mediolittoral and uppermost regions of the infralittoral were sampled from nine different beaches along the Maltese coast. The sandy beaches investigated were: Ramla l-Hamra and Xatt l-Ahmar (Gozo), Ghajn Tuffieha and a nearby beach henceforth referred to as Small Bay, Gnejna Bay, White Tower Bay, Ghadira,

Paradise Bay and Qarraba Bay (Malta).

Two types of sampling were used: core and hand-net sampling. For core sampling, a metal cylinder 90cm in length and 20cm diameter was forced into the sand. Sand was then scooped from the open end of the corer and sieved through a 1mm mesh. The fauna retained was identified as far as possible and counted. Nighttime standardised collecting using a hand-net of mouth area $0.097m^2$ and mesh size 0.5mm was used in the uppermost regions of the infralittoral zone (water ca 1m deep) of five beaches (Ramla, Ghadira, Golden Bay, Ghajn Tuffieha and Qarraba). The net was swept gently from side to side for 20 minutes as the handler slowly walked parallel to the shore along each beach. This sampling technique was designed to collect upper infralittoral burrowing infauna that emerged to swim in the water column at night. The degree of exposure of the beaches studied was assessed and the organic content and the particle size distribution of sand samples collected from all beaches studied were determined.

The only correlation found between species richness and abundance with the physical parameters determined, was between organic content of the sediment and the number of individuals collected using the hand-net. More species were collected using the hand-net then by coring, but the reverse was true for the number of individuals – 99 individuals comprising 12 species were collected by hand-net and 159 individuals comprising 7 species were collected by core sampling. Polychaetes were only collected by core sampling. Only the isopod *Eurydice* was sampled by both methods. The polychaete *Ophelia bicornis* and the mysid *Siriella* sp. were the most abundant species collected using core and net sampling respectively. Bivalves, which are common inhabitants of sandy beaches, were almost totally absent. Comparing these results with similar studies carried out on other Mediterranean coasts, it was evident that Maltese beaches were relatively poor of ‚intertidal macrofauna in terms of both species richness and abundance. In fact most of the beaches studied were almost barren of biota. Diversity was even lower than on the Mediterranean coastlines of Israel (Dexter, 1986/87) and Egypt (Dexter, 1989), which are the least productive regions in the Mediterranean.

One reason for the impoverished fauna of Maltese beaches could be that local beaches are very small. Abel & Walters (1979) suggest that many of the differences in diversity reported in the marine literature can be well explained by a species-area relationship. One expects greater number of species in habitat types that are geographically more extensive.

Human impact might also be a factor affecting sandy beach assemblages; for example, Ramla l-Hamra has a relatively high species richness and it is also the least disturbed of all the sandy beaches studied. However this does not seem to be the major cause of depauperate

beaches. The fact that the Maltese archipelago is isolated from the nearby mainlands might suggest a recruitment problem. Unfortunately there is not enough information to test such a hypothesis.

MEASURING THE GENETIC VARIABILITY OF *PATELLA RUSTICA* IN THE MALTESE ISLANDS

Karen Sapienza

Allozyme electrophoresis was used to investigate the population structure of the limpet *Patella rustica* Linnaeus 1758 (= *P. lusitanica* Gmelin) around the Maltese Islands. Allozymes refer to enzymes coded for by different alleles of a particular gene locus. The amino acid sequences of proteins are changed by mutations in the encoding DNA locus. Such mutations may alter the shape and net charge as well as catalysis efficiency and stability of the enzyme. The method of allozyme electrophoresis takes advantage of the fact that proteins with different net charge migrate at different rates through the gels to which an electric current is applied. A histochemical stain is applied to the gel after electrophoresis to single out the products of particular genes.

The limpet *P. rustica* is found on temperate rocky shores and has a marked influence on community structure and is thus of great ecological significance. Thirteen sites were sampled covering the north and south of Gozo and Malta. Four putative loci were resolved and analysed for each site.

Nei's (1972) Genetic Identity (I) and Genetic Distance (D) were calculated to determine the degree of genetic variation. These values showed no difference between the exposed and less exposed sites, (I values ranged from 98.87×10^{-2} to 100.07×10^{-2} and D values ranged from 0.07×10^{-2} to 1.13×10^{-2}). It is thus suggested that *P. rustica* settles opportunistically within its physiological tolerances and responds morphologically to localised environmental conditions. All the sites sampled in Malta and Gozo were grouped respectively; the values of I (99.29×10^{-2}), and D (0.01×10^{-2}), showed that the samples were closely related. The sample sites were then grouped into four areas, representing the north, south, east and northeast of the Maltese Islands. The largest D values were obtained between the individuals at the pairwise site, which includes Ghar Lapsi. There was a cline of larger D values between the individuals sampled at Ghar Lapsi and those at each site moving northwards. The largest D value was between Ghar Lapsi and Reqqa Point (D = 0.74×10^{-2}). It is suggested that there is a slight restriction in larval pattern distribution between the north and south of the Maltese

Islands. This may also account for the higher levels of heterozygosity and polymorphism obtained at Qawra and Ghar Lapsi.

The population seems to be one breeding group and shows high levels of gene flow, leading to genetic homogeneity. The levels of heterozygosity and polymorphism in the Maltese population studied in the present project were lower than the Italian population, investigated by other researchers. This could suggest that limpets from the Maltese Islands cannot exchange larvae freely with the neighbouring Italian populations, leading to the isolation of the Maltese population.

The null hypothesis of the project is based on the single panmictic unit and thus states that, 'there is no difference in allele frequency between the limpet population of *P. rustica* in the areas sampled.' A single panmictic unit model occurs when there is random mating and thus the distribution of genotypes throughout a population is random and the chances of mating with an individual of a particular genotype are equal to the frequency of that genotype in the overall population. Through the results obtained in this study the null hypothesis cannot be rejected and the population on the Maltese Islands seems to be a single panmictic unit. Further genetic studies will corroborate these results.

Knowledge of the genetic structure of the natural population leads to the identification of genetic stocks, which is essential for effective management in conservation biology and sustainable development as one can maintain the highest levels of genetic differentiation. It gives insight to how the population will be effected by changes in the environment. It also reveals the extent of genetic variation and thus shows the level of heterozygosity or homozygosity in the population.

A CHITON AS A BIOINDICATOR OF HEAVY METAL POLLUTION

Ramona Scerri

Various molluscs are currently being used as bioindicator species for heavy metal pollution in coastal waters. These generally include *Mytilus galloprovincialis*, and, to a lesser extent, *Patella rustica*. It has been shown that a range of heavy metals readily induce the production of metallothionein proteins in such species. The extent of induction of such proteins is then used as an index of environmental exposure to heavy metals.

In view of the unavailability of such species in a number of areas, efforts are being made to find suitable alternatives. Such areas include the local harbours, which are exposed to significant contamination by

heavy metals. The present study investigates the possibility of using a chiton for such a purpose.

Chitons of the species *Lepidochitona corrugata* were collected from various places around the Maltese Islands with special emphasis on the Grand Harbour and Marsamxett Harbour areas. Specific tissues were dissected and their metallothionein content analysed spectrophotometrically using the analytical technique of Viarengo (1997) based on Ellman's reagent. Total lead, copper and zinc were also analyzed in tissues and in samples of seawater collected from the same sites. Samples were collected in summer 2000 and winter 2001.

During both seasons, specimens collected from all sites showed elevated levels of metallothionein induction relative to the reference site. Induction of metallothioneins was overall higher in winter. The degree of induction varied from one site to another, possibly indicating a varying degree of heavy metal insult in different areas. The highest level of induction was obtained from specimens collected in the vicinity of Malta's major solid waste landfill in summer, while in winter highest induction was obtained from specimens collected from Ta' Xbiex, a large and enclosed yacht marina.

All metals tested showed a higher concentration in tissues than in the surrounding water. In the case of lead, a non-essential heavy metal, this indicates bioaccumulation of lead in the organism. In the case of zinc and copper, both being essential heavy metals, this is attributed to both bioaccumulation and to their natural occurrence within the organism.

There was a marked difference in the results obtained for the reference site when compared to results from other sites; in the absence of other influencing factors such as size of the organism. This suggests that methallothionein induction in this species is related to the levels of heavy metals, and as such might be good candidate for future biomonitoring work.

MONITORING OF OIL POLLUTION IN MALTA: FURTHER STUDIES

Charmaine Vassallo

The Mediterranean is well known as a high-risk zone as regards oil pollution. In fact, local coastal waters may be exposed to various sources of oil contamination, including oil bunkering, discharges of ship bilge waters, as well as normal operations of small water craft. Once oil is released in the marine environment, a portion of it may reach the superficial benthic sediments. In fact, oil levels in such sediments have proved to be highly reliable data to indicate trends and levels of oil pollution in coastal waters.

In this project, superficial sediments from 41 fixed stations from Malta, Gozo and Comino were sampled twice over the period July 2000/March 2001, so as to find out if there is any seasonal variation in the levels of petroleum hydrocarbons. Hydrocarbons from the sediments were extracted using methanolic refluxing followed by hexane extraction, concentration, and separation. Hydrocarbons were subsequently quantified using UV-spectrofluorimetry and chrysene standards. Synchronous scans for all samples were carried out in order to obtain some information about the composition of the extracted hydrocarbons. The sediment particle size composition and its organic content were also determined in order to find out if there was any correlation with the hydrocarbon levels.

The study showed that stations may be classified in three separate categories, as follows:

- Reference areas which are not expected to be exposed to oil pollution exhibit baseline hydrocarbon levels of up to 0.5μg CE/g DW;
- Areas which are exposed to low levels of oil pollution may exhibit up to 10μg CE/g DW.
- Areas which are exposed to high oil pollution exhibit more than 10μg CE/g DW.

Stations within Grand harbour and Marsamxett harbour always exhibited values greater than 10μg CE/g DW. However, the hydrocarbon levels of Marsamxett harbour where always lower than the levels of the Grand harbour.

When compared with previous archived data (starting from 1990), the present study has shown that in general, for most stations being monitored, there has not been any dramatic increase in the levels of oil pollution over the past two-three years. Complex and different trends in the levels of oil pollution were identified in different localities.

Synchronous scanning has shown that the composition of hydrocarbons from the polluted areas was different from the other sampled sites. One distinguishing feature was the prominence of fluorescence by polyaromatic structures consisting of five rings or more in the former.

STUDY OF THE GROSS MORPHOLOGY OF SPARUS AURATA (L.) AND DICENTRARCHUS LABRAX (L.) FOR THE DEVELOPMENT OF A GRADING SYSTEM

Patrick J. Vella

In farmed fish, growth is variable due to biological and behavioural differences between individuals. This will result in a non-normal distribution of the weight at the end of the on-growing period. The weight differential will cause losses in production quantity and quality. Uniformity in size increases the marketing value of the fish because buyers normally want animals for a specific purpose. and only animals within a particular size range are acceptable. Prices for fish outside of the required range will usually be less favourable. Thus grading will aid in the economical management of the fish and provides a better quality stock at harvest. This practice is also necessary to obtain a higher growth rate, to reduce cannibalism among cultured fish, and to make it easier to calculate the amount of feed to be used.

Frequent grading is limited by the complexity of the equipment available and also due to the stress incurred on the fish. The construction of a simple grading net was studied, using measurements of total length, maximum body thickness, maximum body depth and weight from samples of *Sparus aurata* (Gilthead sea bream) and *Dicentrarchus labrax* (European sea bass) from two different fish farms in Malta.

Since the fattening periods of the two samples studied were different. the condition factor was used to determine in what way would a long on-growing period influence the efficiency of growth. The condition factor for one fish farm (F1) was 1.94 times larger than that at the other farm (F2). Therefore a longer fattening period (in the case of F2) will result in inefficient growth since the length of the fish was found be large but the mass was smaller then expected.

Several regression methods were used to produce the best prediction model for the dimensions of the fish morphological parameters from its weight. This would help the constructor of the grader to produce the desired grading grids at the required grading dimensions. A program code was written in Visual Basic 6 using the best two fitting models to the data sampled (logarithmic and power). This consisted of a weight input parameter with the total length, maximum body depth and maximum body thickness output parameters from both fish species.

The data collected was then used to predict the grading efficiency of a theoretical grading grid. Several weight data points were taken through the range of samples and then the whole sample was graded at these points. Grading was defined as the selection of smaller fish from larger fish in a group of individuals. The selection was based on the body depth and the body thickness, so at a grading mass, m, a specific value for the depth and for the thickness had to be found (the size of the grid). This was then compared to the other depths and thickness from the total range, and selection was achieved by using this logical reasoning:

- Grading mass, m, is equivalent to depth, i, and thickness, j.
- A rectangle (grid) is produced from i and j.
- Selection occurs on the fish passing or not through the grid.
- Since i and j correlate to the fish mass, then selection of the fish is ultimately for its mass.

The effect of deformed fish and starved fish was also studied by conducting simulations of such cases and then measuring the grading efficiency with these groups of fish.

Theoretically, the grading efficiency of the system could reach up to 93.41% and 91.09% for the market weights of the sea bream and sea bass (250g and 350g) respectively.

AN INVESTIGATION OF POTENTIAL ANTHROPOGENIC IMPACTS ON A MAERL GROUND OFF NORTH-EASTERN MALTA

Miraine Rizzo

Maerl beds are characterised by accumulations of live and dead free-living coralline algae that form nodules known as rhodoliths. These grounds provide isolated habitats of high benthic biodiversity and support many rare and unusual species. Maerl beds have only recently (1993) been discovered in Maltese waters: the largest maerl bed known to date occurs between Ras il-Qala on the southeastern tip of Gozo and St. George's Bay on the northeastern coast of Malta at depths between 45m and 100m, and occupies about 20km^2 of the bottom.

Two sites within this maerl bed were studied: one site, designated the impacted site. was potentially subject to anthropogenic impact by otter trawling. The other site, designated the control, on the other hand was relatively pristine. Seasonal samples were collected from each site by means of a van Veen grab over a period of two years (1996-1998). Measurement of physico-chemical parameters of the water column overlying the maerl beds was also carried out throughout the two-year

sampling period. The effect of trammel net (*parit*) fishing on local maerl beds was assessed by fishing experimentally on both beds.

The sediment, live rhodoliths and the biota (animals and non-coralline algae) collected in the grab samples were analysed; 155 species of animals and 75 species of algae (excluding the rhodolith-forming algae) were identified from both control and impacted sites combined. This high biodiversity is attributed to the complex architecture of the rhodoliths, which provides a wide range of organisms with food and shelter. Most species associated with the maerl beds are actually interstitial species living between the rhodolith branches.

The sediment and rhodolith characteristics at the two sites indicated that the impacted site was subject to higher degrees of disturbance than the control site. However, the source of this disturbance is not certain and it can be attributed to three main factors: bottom currents, bioturbation and trawling activities. Whichever the source, this disturbance does not seem to have a detrimental effect on the rhodolith cover of the impacted site, since rhodoliths at this site attained larger sizes than those at the control site.

Differences in species composition at the control and impacted sites, although not very significant, may be attributed to differences in the microhabitats available at the two sites, including the gross morphology of the rhodoliths and the sediment composition. The chlorophyte *Flabellia petiolata* and the rhodophyte *Womersleyella setacea* were consistently the dominant algal species present on the maerl ground. Both species tend to bind the surface maerl layer creating a semi-hard substratum and thus stabilising the bottom. *Womersleyella setacea* was more abundant at the control site, which consequently showed a greater degree of sediment binding and stability. Macroalgae were not very abundant at the impacted site, again indicating the possible higher degrees of disturbance at this site. Species that are characteristic of maerl communities were also not very abundant at the impacted site. This site was, on the other hand, characterised by the dominance of two species, the gastropod *Bittium latreillii* and the hermit crab *Cestopagurus timidus*, which occur commonly in other benthic assemblages.

A functional group analysis was carried out for the animal biota. Ten distinct trophic groups were identified. The deposit feeders constituted the dominant group at both sites. This indicates that energy transfer from the primary producers to the higher trophic levels occurred mainly via detritus. The predators were represented by a large number of species, although they were not very abundant. These invertebrate predators, which are sheltered from the super-predators by the rhodolith branches, maintain their prey populations below the threshold of competitive exclusion enabling

the coexistence of a large number of species. Multifunctional feeders, which were represented by only 9 species, were very abundant. This indicates the success of organisms that are able to utilise a wide range of food resources.

Although there is no evident impact of otter trawling on the maerl beds, the impacts of trammel nets are quite evident. Large rhodoliths (up to 85.9mm longest diameter in the experimental fishing carried out in this study) get entangled with the nets and are removed and destroyed. Thus this type of fishing definitely depletes the slow-growing rhodoliths and can therefore have a severe impact on the maerl beds in the long term.

THE ARCHAEOGASTROPODA (MOLLUSCA: PROSOBRANCHIA) IN MALTESE COASTAL WATERS: A COMPUTERISED MULTIPLE ENTRY KEY AND BIOGEOGRAPHICAL REVIEW

Michael J. Sant

A total of 84 species belonging to the Superorder Archaeogastropoda (Mollusca: Prosobranchia) have been recorded from the coastal waters of the Maltese Islands (Central Mediterranean). Certain species, for example those belonging to the Trochidae, are important and sometimes abundant components of various marine ecosystems. Six species are doubtful records; of the latter, three are species alien to Mediterranean waters.

The Archaeogastropoda occuring in Maltese waters are reviewed in terms of the diversity of their shell morphology and their biogeographic affinities. Data on shell morphology, ecology and biogeography were collected for all species, both from detailed examination of an extensive collection of reference specimens and from the literature. The data collected were organized into a computer database format.

The accurate identification of molluscs is a critical problem frequently encountered in ecological and conservation research. Consequently, the shell morphology data was analysed and organized according to quality and reliability (in terms of usefulness for identification). A major difficulty in the choice of shell character is the intraspecific variety of shell forms. For example, shell colour is usually a highly variable character in most species, but may be an important diagnostic character distinguishing between certain species (for example, *Gibbula divaricata* and *G. rarilineata*). The practical difficulties in the identification of Archaeogastropod shells are discussed.

Given that unique diagnostic shell characters are frequently not available, the use of a combination of shell characters is rendered possible by the use of a multiple entry key. The advantages and limitations intrinsic to the use of multiple entry keys (in contrast to dichotomous keys) are analysed in terms of practicality and ease of use.

Identification software is a useful tool facilitating the identification of species for ecological and conservation applications. The identification software Linnaeus II^C (version 2.1 for Windows), provided by the Expert Center for Taxonomic Identification (ETI) of the Biodiversity Center, University of Amsterdam was customised to allow the generation of a multiple entry key for Maltese archaeogastropods, using the shell morphology data collected.

The biogeographic affinities of Archaeogastropod species occurring in Maltese waters were analysed using the Linnaeus II^C software. The local archaeogastropod fauna is shown to be derived from that of the western Mediterranean; the difference between archaeogastropod diversity in Maltese waters and that of the eastern Mediterranean is significant. As suggested by the literature reviewed, the Mediterranean archaeogastropod fauna is shown to be almost entirely derived from that of the Lusitanian province.

A REVIEW OF THE FISH FAUNA OF MALTESE WATERS BASED ON FIELD DATA

Titian Schembri

This mainly taxonomic study was the result of four years of field and laboratory work on the fish fauna of the Maltese Islands. Specimens were obtained from the local fish markets or were collected by the author from coastal waters. Other material used included photographs taken by fishers, cuttings from the local papers reporting particular catches and specimens preserved in private collections. The fish collected were preserved in 10% formally in seawater. All fish were identified to species using standard guides, monographs, and the primary literature. In some cases, an analysis of the stomach contents was carried out.

This work resulted in the identification of 30 species of sharks from 12 families, 10 species of rays from 6 families and 117 species of bony fish from 46 families. Five species, *Apterichthus anguiformis*, *Belone svetovidovi*, *Dentex macrocannus*, *Lobotes surinamensis*, and *Pagellus belotti belotti*, are new records for the Maltese Islands. Illustrated dichotomous keys for distinguishing between sharks, rays and bony

fish, and for the identification of species within each group were constructed.

For each species identified, previous records from the Maltese islands, the material examined during the present study, local names, maximum length, and ecological data from the literature as well as from the author's fieldwork are given together with notes on the diagnostic features required for accurate identification. Habit drawings, based on actual specimens studied by the author, and diagrams showing details of important diagnostic features are also included (see figure).

Previous compilations by contemporary authors are analysed and compared to the data collected in this study. It was found that these publications include a number of species that are not strictly part of the local fauna. This is partly a result of old records that have been cited from one publication to another for decades while actually having been confirmed. Such records need to be reviewed and confirmed, as the species concerned may no longer occur in the Maltese Islands, if they ever did at all.

A detailed analysis of the shark species that visit or reside in local waters was also made. The data collected from the local fishers and fishmarkets by Ian K. Fergusson in 1990 is reviewed and updated.

An analysis of the landings of commercially important fish over the last 40 years was also made. Data were obtained from the National Statistics Office and from the Department of Fisheries and Aquaculture. An estimation of Catch per Unit Effort was made and the general trends for fish landings (in kg) were analysed. Overall, there is a decreasing trend in fish catches, especially since the mid-seventies. Reasons for this are unclear and a number of possibilities are discussed. However, these estimates are not accurate due to inadequate records collected by the authorities, and this is also discussed.

The species recorded are compared to records from other parts of the Mediterranean. namely the Sicilian coast, the Far and Near Eastern Mediterranean and the Western Mediterranean. This was done to study the biogeography of the species recorded. It was found that a great part of the fish fauna recorded for the Maltese Islands is also found in the Western Mediterranean, but that the overlap with the Eastern Mediterranean is less. This is attributed to a number of physical and biogeographical factors and to the colonisation of the Far Eastern Mediterranean by Lessepsian migrants. To date, only four Lessepsian species have been recorded in the Central Mediterranean. Temperature remains the most significant barrier that separates the Eastern and Western fish faunas of the Mediterranean.

MULLUS SURMULETUS AS A MULTIPLE BIOMARKER FOR MARINE POLLUTION

Amanda Stafrace

The use of bioindicators to evaluate the effects of chemical pollutants on marine organisms constitutes a relatively new and efficient tool in the monitoring field. In the last two decades great advances have been made in this regard and various biomarkers have been determined as being ideal for pollution monitoring. However, due to species-specific differences in biological responses to different types of marine contaminants, very few studies have investigated the possibility of using a single species as a multiple biomarker of pollution. The present study has investigated the feasibility of using the fish *Mullus surmuletus* as such a multiple biomarker for organic as well as heavy metal contaminants.

Fish were sampled from different sites on a seasonal basis over a period of one year starting in May (Spring) 1999 till March (Winter) 2000. The biomarkers investigated where EROD activity and MT induction. *Mullus surmuletus* proved to have a high response factor both in what regards EROD and MT monitoring. Choice of this species was based on its habitat preference (which is in-shore and thus close to the point of coastal pollution). When sampling was carried out in spring (the reproductive season), immature individuals were used so that sex-related fluctuations were avoided. The sites monitored included: Xghajra, which is exposed to pollution from Malta's major sewage outfall throughout the year; St.Paul's Bay, which is a touristic area exposed to potential marine contamination risks, especially during the summer months; St.Thomas Bay, which is a relatively clean area and only occasionally threatened by marine contaminants.

Numerous studies before this have demonstrated the strong correlation of mixed function oxidase activity (and indicated through EROD activity) and polyaromatic hydrocarbons (PAHs) or polychlorobiphenyls (PCBs) in the environment. Similarly, other studies have also noted the elevated levels of MT (above normal homeostatic levels) when heavy metal pollution is present in the environment.

Biomonitoring results in the present study have confirmed Xghajra as a site of both organic and heavy metal pollution. EROD activities in liver of fish sampled, were expressed in terms of two indices: Specific EROD activity (RP1), which measures the level of inducible proteins per mg of microsomal protein; and Total EROD activity (RP2) which measures the level of inducible proteins per mg of total liver tissue.

The highest specific EROD activity value was recorded for fish sampled from Xghajra during the summer season. Such samples had a mean Specific EROD activity value of 258.48 ± 90.70 pmoles/min/mg protein. The lowest values recorded was 4.18 ± 1.71 pmoles/min/mg protein. Such a value was recorded for samples obtained from the reference site (St.Thomas Bay). RP2 proved to have higher percentage induction than RP1. Hence, there is an indication that RP2 can be a better biomonitoring parameter than RP1 for organic pollution monitoring. Studies on this matter are almost non-existent and this has to be confirmed by further studies.

Highest MT induction levels were also recorded for samples obtained from Xghajra. Such fish were collected during the winter season and had an MT level of 403.5 ± 42.9 µgMT/gFW. The lowest MT level was (as expected) recorded for fish sampled from the reference site during the winter season. Such samples exhibited an MT level of 92.5 µgMT/gFW. An apparent trend in MT induction levels was obtained for fish sampled at St.Paul's Bay. This trend is possibly related to seasonal pollution that may be occuring at this site.

The ecological significance of these results as well as the merits of using a single fish species as a multiple biomarker of pollution, are discussed.

THE STATUS OF MALTESE SAND DUNES AND THEIR FLORA AND VEGETATION, WITH A CASE STUDY ON THE VEGETATION OF RAMLA L-HAMRA (GOZO, CENTRAL MEDITERRANEAN)

Darrin T. Stevens

The aim of this study was to analyse and assess the status of Maltese sand dunes and their flora and vegetation. This involved the analysis of various publications starting from the 17th century and field visits carried out during the period 1998-2001.

Results indicate that sand dune ecosystems in the Maltese Islands were definitely known from at least 19 localities: 14 from Malta, 4 from Gozo, and 1 from Comino. Of these, based upon ecological and geomorphological criteria, only 8 sites (42%) are considered extant, of which only one locality in Gozo, Ramla l-Hamra (l/o Xaghra and Nadur), still supports a fairly complete sand dune vegetation, with a relatively complete zonation pattern.

Other sandy beaches known to have housed or are housing sand dune vegetation have also been assessed; a minimum of 27 such areas have been found, although the past extent of the dune vegetation in some of these is not well known. 33% (9 out of 27 areas) of these sites are either heavily eroded or have been totally obliterated as a result of human influence.

With respect to the plant species reported from local sand dunes, 84 species were found to be important or characteristic of Maltese dunes. The distribution of each of these species was assessed and their IUCN threat status and trend in distribution since the earliest reliable records were determined. 48% (41 species) of the dune flora fall within the IUCN threat status categories (i.e. rare, vulnerable, endangered, possibly extinct, extinct), of which 15% (13 species) are extinct or possibly so.

Of these 84 plant species, 29 species were found to be exclusive to sand dunes. 24% (7 species) of these dune-exclusive flora are extinct or possibly so, and an impressive 62% (18 species) are vulnerable or endangered, leading to a total of 86% of the species within IUCN threat status categories.

When studying differences in distribution range and extent, the results also show that as much as 94% (27 out of 29 species) of the dune-exclusive plant species are declining.

The vegetation of the Maltese dunes was in turn assessed via the methods of the Zurich-Montpellier School of phytosociology, and a preliminary list of the main community types observed produced for the first time. The distribution and the threat status of these communities is also provided.

The extant sand dunes were hence surveyed in order to identify the main threats, most of which are essentially due to human influence, mainly because of the high population density of the Maltese Islands and the lack of environmental awareness and education amongst the general public. These have led to various activities which have resulted in the degradation, reduction or loss in habitat for dune species, and the invasion of allochthonous species, of which the Great Reed [Arundo donax, Maltese: Qasba], the Kaffir Fig [Carpobrotus edulis, Malt.: Swaba' tal-Madonna/Xuxett San Gwann], the Grape Vine [Vitis vinifera s.str., Malt.: Dielja], the Tree Mallow [Lavatera arborea, Malt.: Hobbejza tas-Sigra/Hobbejza Franciza] and the Cape Sorrel [Oxalis pes-caprae, Malt.: Haxixa Ngliza] are a few examples.

A vegetation survey carried out at Ramla l-Hamra as a case study is also presented. The study was based on observation, on three line-intercept transects and a combination of stratified and random sampling via quadrats. Quadrat size was determined via the Wiegert's method, and the coverage-abundance of each species observed was sampled via a modified Braun-Blanquet Cover-Abundance Index in the case of quadrats or frequency of occurrence for the line-intercept transects. Species dominance was also analysed through rank-abundance curves, and the effects of soil on the vegetation composition was also studied. The community structure was in turn analysed via cluster analysis and ordination methods, through the use of the Principal Components Analysis. A vegetation map was also produced and compared with older aerial photographs and vegetation maps.

Results indicate a zonation pattern both land-wise and wind-wise, with typical Central Mediterranean zonation patterns, including the Centaureo-Ononidetum ramosissimae fixed dune communities, which are reported from Malta for the first time.

The sand dunes of the area are negatively affected by human influence, which has led to the proliferation of the *Brometalia* and *Malcolmietalia* vegetation, typical of more disturbed dunes, and via the invasion of a number of allochthonous species, especially *Arundo donax*, *Oxalis pes-caprae* and *Vitis vinifera*. *Arundo donax* has increased its extent considerably since 1994, and engulfed many *Elytrigetum* and *Ononidetum* communities, and is the main threat to the last complete dune vegetation of the Maltese Islands.

A species list for *Ramla l-Hamra* was also produced, increasing the number of vascular species known from the area from 103 to 227 species, of which 151 (67%) occur in sand dunes. The following 8 new records are added amongst the threatened species: the Sea Purslane [*Atriplex portulacoides*, Malt.: Bjanka tal-Bahar], the Sea Club-Rush [*Bolboschoenus maritimus*, Malt.: Bordi Skars], the Maltese Star-Thistle [*Centaurea melitensis*, Malt.: Centawrja Rqiqa], the Ice-Plant or Crystal-Plant [*Mesembryanthemum crystallinum*, Malt.: Kristallina], the Cliff Groundsel [*Senecio leucanthemifolius*, Malt.: Kubrita ta' l-Irdum] and the Sea Radish [*Raphanus maritimus*, Malt.: Ravanell tal-Bahar], together with *Cardaria draba* (unpublished record of J. Timothy Tabone) and the Gum-Chicory or Rush-Leaved Sow-Thistle [*Chondrilla juncea*, Malt.: Tfief tar-Ramel/Tfief ta' l-Ghadira] (unpublished record of Michael Briffa), previously unreported for the area.

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Felice AE (1992) Molecular Epidemiolgy of Haemoglobin, and the Molecular biology of Normal and Abnormal Globin gene expression. In: *Collected Papers* (Eds R Ellul- Micallef and S Fiorini), pp. 357-391. University Press, Malta.

David Rawn J (1989) *Biochemistry*. Neil Patterson Publishers, North Carolina

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