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ALCOHOLISM: CLINICAL AND EXPERIMENTAL RESEARCH

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Motor Performance in Detoxified Alcoholics

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Detoxified male and female alcoholics (aged 20–49 years) and age-matched controls performed a series of 15-sec target-tapping tasks in which they alternatively marked two target strips with a felt marker as rapidly and as accurately as possible. Consistent with "Fitts' Law" (Fitts PM: J Exp Psych 47:381–391, 1954), a highly linear relationship between movement time and task difficulty was observed in all four groups. Overall, the alcoholics were slower and made more errors than the controls, although the pattern of deficit differed for males and females. Accuracy, but not speed, was impaired in male alcoholics. The production of undershoot errors was increased more in alcoholics than nonalcoholics in targets of narrower width, whereas the production of overshoot errors was increased more in alcoholics as target separation decreased. Female alcoholics displayed impairment in speed of movement, but not accuracy. However, both alcoholic groups displayed elevated error rates for the more difficult targets. It is thus possible that detoxified alcoholics might mimic the speed functions of nonalcoholic individuals at the occasional cost of an erroneous response at a difficult target.

ALCOHOLISM has been associated with dysfunction in a variety of psychomotor and behavioral tasks.[1,2] Performance deficits may persist for weeks, months, or years after alcohol use is discontinued. Recovery of function with prolonged abstinence may be taken as strong evidence of the reversible toxic effects of alcohol. The persistence of deficits for long periods after abstinence may be related either to irreversible toxic effects of alcohol or to inherited deficiencies that may have antedated alcohol use in alcoholics.[3] Only prospective studies are guaranteed to provide unambiguous answers to these questions. However, more information is needed at this time in order to identify and categorize the deficits that are present in recovering alcoholics, thus providing a focus for prospective studies.

Although neuropsychological performance has been extensively studied in alcoholics, only a few studies have addressed the specific impact of alcoholism on related motor movement control functions, despite the implications of this research for occupational functioning, as well as for treatment and rehabilitation programming. One noteworthy study demonstrated that detoxified alcoholics were deficient in their ability to modulate the speed at which they turned a knob when instructed to turn it as slowly as possible.[4] A deficit in motor inhibitory control functions was suggested by the authors as one possible explanation for the performance of alcoholic subjects. This deficit is considered to be distinct from the lack of behavioral inhibitory control reported in alcoholics.[5] Little research has been performed to further probe and extend these original and provocative observations and to further define the meaning of "motor inhibitory control."

Notably lacking is information with regard to the persisting effect of excessive alcohol intake on fine movement functions of the hands. In normal subjects, hand movement speed has been found to be linearly related to target difficulty when small amplitude movements of the hand are used in a reciprocal tapping task. This relationship, known as "Fitts' Law,"[7] may be summarized by the equation:

$$\text{Movement time} = a + b \log_2 \frac{2D}{W}$$

where a and b are constants and D and W refer to movement distance and target width, respectively. The expression

$$\log_2 \frac{2D}{W}$$

was defined by Fitts[7] as the "index of difficulty" (ID), or the difficulty encountered in making a quick hit on a target. Fitts' Law has been found to accurately describe hand motor control functions across a broad age range in normal males and females.[7] An attractive feature of Fitts' task is that it involves the type of visually guided motor response that is a critical component of a wide variety of everyday work- and recreation-related skills.[6]

The purpose of the present study was to determine if the information processing characteristics of the motor system (as assessed by Fitts' Task) in alcoholics obeys the same principles that apply to normal subjects. In particular, Fitts' Task allows for the determination of speed-for-accuracy tradeoffs which may be deficient in alcoholics and may reflect disrupted inhibitory motor control functions. Inasmuch as some of the health consequences of alcoholism may be gender specific, both male and female subjects were examined in this study.

METHODOLOGY

Subjects and Procedure

Male and female subjects (ages, 20–49 years) were recruited from the general population (nonalcoholics) and from three local alcoholism treatment programs. The three programs included a state-operated, a county-operated and a privately operated unit. Although data on socioeconomic status were not collected, control subjects were usually working class individuals recruited from the staff of the Research Institute on Alcoholism and neighboring office buildings. Subjects in treatment pro-

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grams could also be classified as working class, and were tested during their fourth week of admission. Subjects volunteering for the study were screened for polydrug abuse and for severe medical conditions such as hepatitis, pancreatitis, history of head injury or seizures, organic brain disease, and emphysema. Subjects were not screened specifically for indications of peripheral neuropathy or myopathy, thus the possible contribution of these conditions to the performance measures cannot be ruled out.

Alcoholic subjects who were accepted (about 40% of those volunteering) were given Health, Activity, and Alcohol Dependency questionnaires[8] to fill out and bring with them when reporting for testing. Upon reporting to the Research Institute on Alcoholism, subjects were interviewed using the Lifetime Drinking History Questionnaire[9] and then took the movement time test, as described below. Alcoholic subjects were considered to be alcohol free for at least the 3-week period postdating admission to the treatment program. Most subjects had been drinking immediately prior to admission. All subjects were instructed not to consume alcohol or mind-altering drugs 24 hr prior to the test session. Control subjects with a history of alcoholism were not included in the study.

Apparatus

Our choice of psychomotor tasks derived from our hypothesis that the ability to regulate speed in order to maintain precision in motor tasks of varying difficulties may be a function that is impaired in alcoholics. A reciprocal tapping task requiring speeded, accurate movements of the favored hand was used to assess motor system performance. This procedure, developed by Fitts[7] in 1954, has revealed a lawful relationship between hand movement speed and a measure of the size and separation ("difficulty") of "targets" that are to be hit with a marking pen by means of back-and-forth movements of the favored hand.[10,11] As such, Fitts' Task allows for the quantitative variation of sensory motor task difficulty while holding relatively constant the overall cognitive and motivational contributions to task performance. Thus, an uncontaminated internal measure of performance as related to task difficulty is obtained. The linear relationship between movement time and Fitts' Index of Difficulty provides for a pure measure of performance, including slope parameters. Because the task required that subjects pay attention to both speed and precision of hand movements, it allowed for the evaluation of possible speed-for-accuracy tradeoffs.

Subjects were presented with a total of 12 target pairs, each pair drawn on a piece of unruled legal sized paper. Targets were all 4-inch tall rectangles which ranged in width from 0.25 to 1.0 inches, and were always presented in identical pairs separated by a distance (target center to center) of 3, 6, or 12 inches. The index of difficulty for each target pair is shown in Table 1. Note that a number of the target pairs have identical ID values, created by a trading off of width for distance in the expression $\log_2 \frac{2D}{W}$.

Table 1. Target Dimensions and Separations

Target pair	Target separations (in.)	Target width (in.)	ID
J	3	1.0	2.58
G	3	0.5	3.58
D	3	0.25	4.58
A	3	0.125	5.58
K	6	1.0	3.58
H	6	0.5	4.58
E	6	0.25	5.58
B	6	0.125	6.58
L	12	1.0	4.58
I	12	0.5	5.58
F	12	0.25	6.58
C	12	0.125	7.58

All targets were 4" high and were presented as pairs separated (center to center) by 3, 6, or 12 inches. All 12 target pairs (A–L) were presented to all subjects. The order of target presentation was balanced among comparison groups using a Latin Square Design.

The order of target presentation for subjects was determined using a Latin Square Design such that the serial position of target pairs as well as the order of presentation were approximately balanced among the populations studied.

Subjects were instructed to move as rapidly as possible back-and-forth from target to target, making a mark each time with a marking pen during 15-sec test periods. The instructions stressed that subjects should make sure that they hit the target each time. This procedure minimized the occurrence of errors and thus gave a more comparable estimation of movement time among subjects. The number of marks was divided into 15 for the calculation of movement time. The number of misses (undershoot or overshoot errors) made by each subject on each target pair was also recorded.

Health, Activity, and Alcohol Use Assessment

Three self-administered forms were given to subjects in order to obtain information regarding characteristics that might be related to task performance. A Health questionnaire (form developed by Dr. David Pendergast, Department of Physiology, SUNY at Buffalo. Copies and scoring guide available upon request.) contained questions regarding current and past medical problems, current medications, and physical symptomology. An Activity questionnaire (form developed by Dr. David Pendergast, Department of Physiology, SUNY at Buffalo. Copies and scoring guide available upon request.) contained questions regarding the type and intensity of recreational, home, and work-related physical activities engaged in by subjects. Each item on the Health and Activity questionnaires was given a score depending, respectively, upon the severity of the symptoms or illness and upon the amount of energy expended. Thus, higher scores represented greater levels of physical activity (Activity questionnaire) and better health (Health questionnaire).

The Alcohol Dependence Scale (ADS)[8] contained 25 questions related to the extent of psychological, physical, and social dysfunction resulting from alcohol use during the 12 months preceding testing. Scores on this form may range from 0 to 47 and may be interpreted to reflect the level of physical or psychological dependence on alcohol.

The Lifetime Drinking History questionnaire[9] is a structured interview employed to document alcohol consumption throughout the subject's drinking career, starting with the age at which regular drinking (once per month) began. Quantity, frequency, and type of beverage, as well as the influence of life events on drinking behavior were recorded for each phase of the subject's drinking career. Data from the individual phases were summed to obtain lifetime drinking measures.

RESULTS

Sample Characteristics

The data in Table 2 depict questionnaire scores for the samples studied. Although the number of subjects in each subgroup varied considerably, the mean age for the four groups was quite similar. The small number of female alcoholic subjects is the result of the low representation of that gender (approximately 20%) found in the alcoholic treatment programs participating in our study. The ADS scores for the male and female alcoholics were, as expected, markedly different from those of their nonalcoholic counterparts. Scores in the 22 to 30 range are indicated by the authors of the ADS scale to reflect a "substantial level of alcohol dependence, with physical dependence likely.[8]" Scores for nonalcoholic subjects were quite

low. Scores on the Health questionnaire were approximately 4% lower for alcoholic subjects (both males and females) than for nonalcoholic subjects. Within each sex no statistically significant differences between alcoholic and nonalcoholic subjects was discernible with regard to physical activity scores.

Alcohol Consumption Patterns

The values found in Table 2 were obtained from the Lifetime Drinking History interview.[9] The number of years since regular drinking (at least once per month) began was observed to be slightly greater (not statistically significant) in the alcoholic populations. The number of days upon which drinking occurred (Lifetime drinking days) was, as expected, greater (nearly 3 times) for alcoholic subjects than for controls. Total alcohol consumed since the beginning of regular drinking (Lifetime Drinking Total and Lifetime Daily Average) were nearly seven times greater in alcoholic subjects than in controls. On days that drinking did occur (Drinking Day Average), alcoholic subjects consumed nearly three times as many drinks as nonalcoholics. Not shown in the Table is the finding that, of beer, wine, or liquor, the greatest proportion of total ethanol consumed came from beer in males (43 and 58%, respectively, alcoholics versus nonalcoholics) and from liquor in females (53 and 51%, respectively, alcoholics versus nonalcoholics).

Hand Movement Speed

The data in Fig. 1 illustrate the relationship between movement time and the ID of target pairs. The main effect of the increasing ID value on movement time was highly significant for subjects of each sex [alcoholics and nonalcoholics combined, $F(11,58) = 179.6$ $p < 0.001$ for males and $F(11,32) = 56.1$, $p < 0.001$ for females, repeated measures analysis of variance], using individual data from all 12 targets in ascending index of difficulty.

The correlation coefficients were similar and were approximately 0.90 for all four subpopulations, indicating a good fit of the data to a straight-line function. The slope of the regression line did not differ significantly between alcoholics and nonalcoholics of the same sex. These data were in harmony with the finding of a nonsignificant interaction of index of difficulty by group (alcoholic versus nonalcoholic, SPSSX MANOVA) with regard to the speed of movement. The performance of female alcoholics was noticeably slower than the performance of female nonalcoholics across the full range of 12 targets [$F(1,42) = 5.87$, $p < 0.02$]. This difference was reflected in the large Y intercept value for female alcoholics and a large value for Mean Movement Time (performance on all 12 targets combined).

The movement time values (means ± SEM) obtained for each target pair (in alcoholics and nonalcoholics of both sexes) are depicted in Table 3. The data in Table 3 also provide information with regard to the influences of target separation and target width upon the movement time performance of male and female alcoholics and nonalcoholics. Increasing the distance by which targets were separated did not differentially influence the speed of performance of alcoholics versus nonalcoholics of the same sex. Variations in target width were also found to have a similar influence (nonsignificant interaction of width with alcoholic status) on movement time performance in all groups. The main effects of both target width and target separation on movement time were highly significant ($p < 0.001$) in all four groups studied.

Accuracy of Performance

The overall error rates were relatively low for all four groups of subjects: male alcoholics, 4.1%; male nonalcoholics, 1.6%; female alcoholics, 1.8%; female nonalcoholics, 1.2%; and were comparable to the value of 1.3% in college men reported by Fitts.[7] These low rates indicate that subjects were, in general, attempting to adjust their

Table 2. Sample Characteristics

Measure	Males		Females	
	Alcoholic ($N = 41$)	Nonalcoholic ($N = 29$)	Alcoholic ($N = 11$)	Nonalcoholic ($N = 33$)
Age	34.7 (6.8)	32.8 (7.6)	34.4 (8.3)	34.9 (8.0)
ADS Score*	25.4 (8.8)	2.9 (4.0)	28.0 (10.0)	1.6 (2.3)
Health score	215.0 (16.0)	225.0 (11.0)	210.0 (18.0)	221.0 (15.0)
Activity score	3637 (4003)	3468 (4286)	830 (762)	1018 (987)
Years of drinking	18.4 (6.1)	15.4 (7.5)	16.8 (6.2)	15.6 (8.4)
Lifetime drinking days	14656 (8914)	2265 (4265)	7810 (4648)	882 (1693)
Lifetime* drinking total† (g/kg)	4346 (1907)	1661 (1387)	2989 (1088)	829 (776)
Lifetime* daily average‡ (g/kg/day)	2.12 (0.98)	0.39 (0.64)	1.30 (0.63)	0.14 (0.24)
Lifetime* drinking day average§ (drinks/day)	14.8 (5.2)	5.5 (3.9)	9.4 (3.8)	3.2 (2.4)

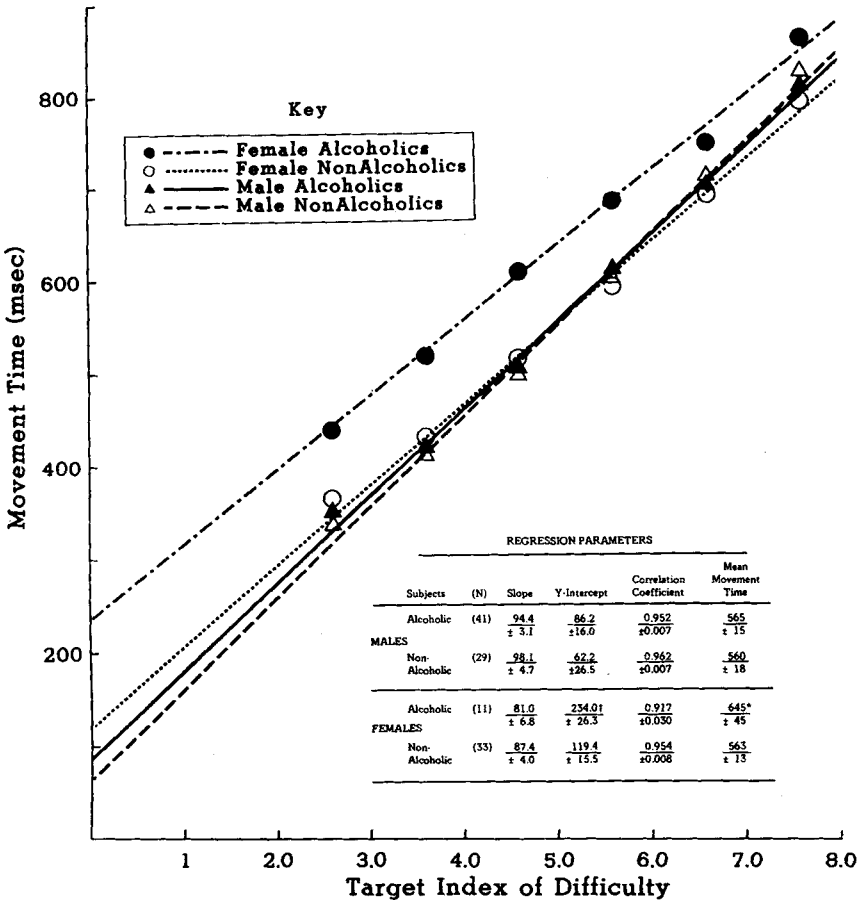
Subjects were given Health, Activity, and Alcohol Use (ADS) questionnaires to self administer, as described in "Materials and Methods." Alcohol consumption data was obtained by use of the Lifetime Drinking History questionnaire. Values in parentheses indicate standard deviations. *N* values were slightly less than those indicated for Health and Activity score data, as all subjects did not return these questionnaires.

* $p < 0.001$ alcoholics versus nonalcoholics of each sex, *T* tests.

† Ethanol (g) consumed per kilograms of body weight over the duration of the drinking career (years of drinking).

‡ Ethanol (g) consumed per kilogram of body weight across the drinking career.

§ Average amount (no. of drinks) consumed on days that drinking took place (one drink = 14.0 g ethanol = 12 oz. beer (5%), 1.5 oz. liquor (40%), and 5 oz. wine (12%).



REGRESSION PARAMETERS

Subjects	(N)	Slope	Y-Intercept	Correlation Coefficient	Mean Movement Time
MALES					
Alcoholic	(41)	94.4 ± 3.1	86.2 ±16.0	0.952 ±0.007	565 ± 15
Non-Alcoholic	(29)	98.1 ± 4.7	62.2 ±26.5	0.962 ±0.007	560 ± 18
FEMALES					
Alcoholic	(11)	81.0 ± 6.8	234.01 ± 26.3	0.917 ±0.030	645* ± 45
Non-Alcoholic	(33)	87.4 ± 4.0	119.4 ± 15.5	0.954 ±0.008	563 ± 13

Fig. 1. Movement time as a function of index of difficulty. Twelve different target pairs with varying indices of difficulty (abscissa) were presented to subjects in a 15-sec reciprocal tapping task (see "Materials and Methods"). Movement time (ordinate) refers to mean time required to move from one target pair to the other. Regression lines and parameters were calculated using the SPSSX PLOT (least squares) program. Mean Movement Time was calculated by summing movement times for the 12 target pairs and dividing by 12. Errors refer to total number of undershoots and overshoots for all 12 target pairs. Values following ± signs indicate standard errors of the mean. $*p < 0.03$, $\dagger p < 0.001$, as compared to nonalcoholics of the same sex.

speed of performance in order to meet the demands of the different task conditions. Although the movement time performance for male alcoholics was similar to that of nonalcoholics, total errors (undershoots plus overshoots) committed by male alcoholics across all 12 targets were far in excess of those committed by nonalcoholics (13.1 ± 2.9 SEM versus 5.1 ± 1.2. $p < 0.03$, t test). Elevated overall error rates were also observed in female alcoholics (5.3 ± 2.7 versus 3.8 ± 1.5 for nonalcoholics), but the difference was not statistically significant. Proportionally more errors were committed on targets of higher ID by alcoholics than by male nonalcoholics (Fig. 2), but the interaction (group X ID) was not statistically significant.

Errors on the target-tapping task are the result of either "overshooting" or "undershooting" the target area, actions which may reflect qualitatively different perturbations in the motor performance systems. The total number of undershoot errors did not differ significantly from the number of overshoot errors within any of the four groups studied (data from all 12 targets combined).

Although the errors were more common in the direction of the dominant hand for all four groups studied, the differences were not large enough to be statistically significant. Errors committed when movements were made in the direction of the dominant hand comprised the following percentages of the total errors: alcoholic males, 58% nonalcoholic males, 59%; alcoholic females, 63%; and nonalcoholic females, 72%. The occurrence of left-handedness among alcoholics subjects (22% of the males, 9% of the females) was greater than that among controls (13% of the males, 6% of the females).

DISCUSSION

Alcohol consumption measures as determined by the Lifetime Drinking History interview clearly establish the excessive intake of alcohol in the alcoholic subjects recruited for this study. Their scores on the Alcohol Dependence Scale, indicating a substantial level of alcohol dependence with physical dependence likely,[8] are in harmony with the alcohol consumption estimates. Values in this range are comparable to values generally obtained from subjects enrolled in public alcoholism clinics.[12] Conversely, low levels of alcohol consumption and alcohol problems were observed in the nonalcoholic comparison groups. The health scores of the alcoholic subjects suggest that our screening procedures for eliminating volunteers with major health problems were successful. Moreover, no appreciable differences between alcoholics and nonalcoholics in the physical activity measures were discernible. The relatively low scores for female subjects on the activity questionnaires reflect the low involvement of females in recreational activities given heavy representation on that questionnaire.

Table 3. Movement Time as a Function of Target Separation, Width, and Subject Group

Target separation	Males		Females	
	Nonalcoholics ($N = 29$)	Alcoholics ($N = 41$)	Nonalcoholics ($N = 33$)	Alcoholics ($N = 11$)
Three inch				
1.0 (J)	337	354	366	441
0.5 (G)	422	425	438	532
0.25 (D)	510	521	516	589
0.125 (A)	617	633	623	693
	472 ± 60	483 ± 60	486 ± 55	564 ± 53
Six inch				
1.0 (K)	409	417	423	511
.5 (H)	499	495	506	612
0.25 (E)	594	608	590	652
0.125 (B)	704	704	707	763
	552 ± 63	556 ± 63	556 ± 60	634 ± 52
Twelve inch				
1.0 (L)	498	505	519	635
0.5 (I)	594	599	581	709
0.25 (F)	715	714	691	747
0.125 (C)	827	814	797	862
	658 ± 72	658 ± 67	647 ± 61	738 ± 47
Target width	Mean effect of width			
1.0	415 ± 47	425 ± 44	436 ± 45	529 ± 57
0.5	505 ± 50	506 ± 50	508 ± 41	618 ± 57
0.25	606 ± 60	614 ± 55	599 ± 51	662 ± 46
0.125	716 ± 61	717 ± 53	709 ± 50	773 ± 40

Targets are designated by capital letters in parentheses and correspond to those listed in Table 1. The mean values ± standard errors for each cluster of targets are also presented and represent the mean of four and three performances, respectively, for target separation and target width.

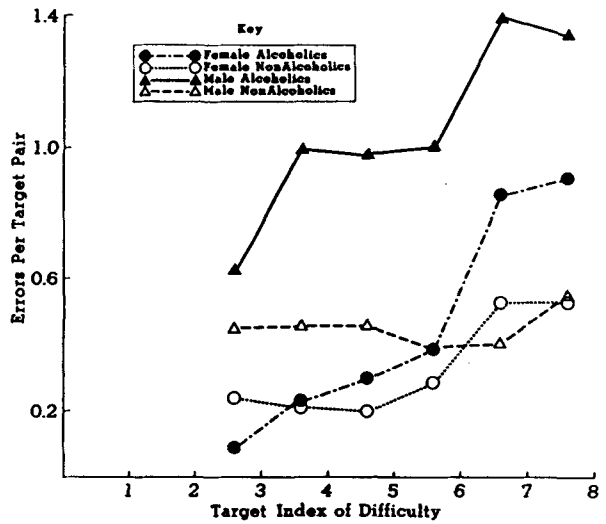


Fig. 2. Errors as a function of index of difficulty. Total errors (ordinate) were determined for target pairs of differing Indices of Difficulty (abscissa), as listed in Table 1. This figure represents the apportionment of total errors per subject presented in Fig. 1. Note that ID values of 3.58 and 6.58 represent the mean for two target pairs, and ID values of 4.58 and 5.58 represent the mean for three target pairs (Table 1).

The values we report for movement time are slightly larger than those reported in other studies,[7,13] probably owing to minor variations in materials and procedures. However, the motor performance of alcoholics and nonalcoholics of both sexes displayed a highly linear relationship (correlation coefficient approximately 0.90) between task difficulty and movement time, thus extending to alcoholic populations the findings previously reported for normal males and females on Fitts' task.[7,10,11,13-15] Although movement time parameters were very similar for alcoholic and nonalcoholic males, alcoholic males committed significantly more errors (roughly three times as many) than did nonalcoholic males. Thus, a speed-for-accuracy tradeoff appeared to be operating in male alcoholics. The underlying basis for the tradeoff of accuracy in favor of speed may be related to some fundamental deficits in alcoholic subjects which will be probed systematically in future studies.

Owing to the small number of female alcoholic subjects, caution must be exercised in the generalization of these findings to other populations of female alcoholics. Notwithstanding this caution, the performance of female alcoholics in this study suggests that the speed of information processing in the motor system is compromised,[16,17] as the movement time performance of female alcoholics was slower across the full spectrum of targets tested. Although the temporal performance of female alcoholics was similar in many respects to the performance of nonalcoholic septuagenarians we have studied,[18] we caution against a premature aging interpretation of dysfunction.[19] Error scores for female alcoholics were higher than those for nonalcoholics, but the difference was not statistically significant, as it was for males. A trend in the direction of more errors on the most difficult targets (ID = 6.58, 7.58) is visually discernable from the data in Fig. 2. If confidence can be placed in the self-reports of lifetime alcohol consumption presented here,[20] it is clear that female alcoholics have consumed far less ethanol (only 62%, roughly, of the total amount consumed by males) yet are more impaired on the speeded movement measure, and appear to be equally impaired with regard to health and alcohol dependency (ADS) scores. In this respect, then, this information is in harmony with other studies suggesting a greater susceptibility of females to some of the untoward consequences of excessive alcohol consumption.[21-23] Even this conclusion must remain tentative, however, owing to other possible alternative explanations. For instance, a lessened accessibility to treatment programs for female alcoholics may bias that population such that only highly impaired subjects tend to enter the programs.[24]

Several possibilities exist with regard to the stages of sensorimotor system functioning that may be impaired in alcoholics. We have adopted an approach to this problem that takes the form of classical views regarding the stages in information processing involved in the selection and execution of responses to environmental stimuli.[25,26] Our data could be interpreted to suggest that the mental "set," or program, used in the target-tapping task may be different in alcoholics and may also vary depending upon the sex of the subject. For instance, the instructions, "make as many marks as possible, but make sure you hit the target each time" invariably presents subjects with a di-

lemma, to which they often respond, "Which is more important, speed or accuracy?" In spite of the experimenter's attempts to clearly present these instructions, subjects seem to make a personal decision regarding how many errors they are willing to accept in their performance. It is possible that, owing to sex-related psychological or socialization differences, men and women alcoholics respond differently to the same fundamental toxicity insult, with women slowing down to ensure accuracy, but with men attaching relatively greater importance to speed and accepting losses in the area of accuracy.

The Fitts' tapping task reflects a constellation of abilities and it will be important to determine whether some of the present findings are task-specific or will generalize to other psychomotor tasks. Other specific hypotheses regarding the performance of male alcoholics that can be tested more directly in appropriately designed studies include: (*a*) a deficit in the ability to make fine motor movements[27,28]; (*b*) a more general breakdown in inhibitory motor processes which would normally operate to modulate speed in order to insure accuracy[5]; (*c*) failure to effectively use visual feedback (as opposed, for instance, to auditory feedback) regarding errors to modulate performance. The importance of this issue to the performance of other visually guided tasks involved in work, recreation, or motor vehicle operation can be readily appreciated.[6] The issue of whether these deficits are a direct consequence of alcohol toxicity or antedated alcohol abuse cannot be determined from these data. Although the etiology may not be clear at this time, a better understanding of psychomotor deficits in alcoholics is needed and should be considered in the total approach to alcoholic rehabilitation.[29]

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REFERENCES

1. Tarter RE: Psychological deficits in chronic alcoholics: A review. Int J Addict 10:327–328, 1980

2. Tarter RE, VanThiel DH: Alcohol and the Brain: Chronic Effects. New York, Plenum Press, 1985

3. Tarter RE, Alterman AI: Neuropsychological deficits in alcoholics: Etiological considerations. J Stud Alcohol 45:1–19, 1984

4. Parsons OA, Tarter RE, Edelberg R: Altered motor control in chronic alcoholics. J Abnorm Psychol 80:308–314, 1972

5. Tarter RE, Alterman AI, Edwards KL: Vulnerability to alcoholism in men: A behavior-genetic perspective. J Stud Alcohol 46:329–356, 1985

6. Wickens CS: Engineering psychology and human performance. Columbus, Charles E. Merrill, 1984

7. Fitts PM: The information capacity of the human motor system in controlling the amplitude of movement. J Exp Psychol 47:381–391, 1954

8. Skinner HA, Horn JL: Alcohol Dependence Scale (ADS): Users Guide. Toronto, Addiction Research Foundation, 1984

9. Skinner HA, Sheu WJ: Reliability of alcohol use indices: The lifetime drinking history and the MAST. J Stud Alcohol 43:1157–1170, 1982

10. Bainbridge L, Sanders M: The generality of Fitts' law. J Exp Psychol 96:130–133, 1972

11. Fitts PM, Petersen JR: Information capacity of discrete motor responses. J Exp Psychol 67:103–112, 1964

12. Ron MA: The alcoholic brain: CT scan and psychological findings. Psychological Medicine Monograph Supplement 3. Cambridge, UK, Cambridge University Press, 1983

13. Welford AT: Ageing and Human Skill. Oxford, UK, Oxford University Press, 1958

14. Morikiyo Y, Nishioka A: An analysis of the control mechanism on simple movement of hand. J Sci Labour (Japan) 42:238–243, 1966

15. Welford AT, Norris AH, Schock NW: Speed and accuracy of movement and their changes with age. Acta Psychol 30:3–15, 1969

16. Parsons OA. Cognitive dysfunction and recovery in alcoholics. Subs Alcohol Actions Misuse 4:175–190, 1983

17. Tarter RE, Jones BM: Motor impairment in chronic alcoholics. Dis Nerv Syst 32:632–636, 1971

18. York JL, Biederman I: Hand movement speed and accuracy as a function of gender, alcohol abuse, and aging (Astract). Alc Clin Exp Res 10:103, 1986

19. Ryan C, Butter N: Alcohol consumption and premature aging: A critical review, in Galanter M (ed): Recent Developments in Alcoholism, vol 2, 1984, pp 224–250

20. Sobell LC, Sobell MB: Can we do without alcohol abusers' self reports? Behavioral Therapist 9:141–146, 1986

21. Hill SY: Biological consequences of alcoholism and alcohol-related problems among women, in Alcohol and Health Monograph, no 4: Special Population Issues. Rockville, MD, U. S. Department of Health and Human Service, 1982, pp 43–76

22. Blume S: Women and alcohol. A review. J Am Med Assoc 256:1467–1470, 1986

23. Gallant P: The female alcoholic: Early onset of brain damage. Alcohol Clin Exp Res 11:190, 1987

24. Beckman LJ, Amaro H: Patterns of womens use of alcohol treatment agencies, in Wilsnack SM, Beckman LJ (eds): Alcohol Problems in Women. New York, Guilford, 1984, pp 318–348

25. Stelmach GE: Information Processing in Motor Control and Learning. New York, Academic Press, 1978

26. Welford AT: Motor performance, in Birren JE, Schaie KW (eds): Handbook of the Psychology of Aging. New York, Van Nostrand, 1977, pp 450–496

27. Kish GB, Cheney TM: Impaired abilities in alcoholism measured by the general aptitude test battery. Q J Stud Alcohol 30:384–388, 1969.

28. Vivian TN, Goldstein G, Shelly C: Reaction time and motor speed in chronic alcoholics. Percept Mot Skills 36:136–138, 1973

29. McCrady BS, Smith DE: Implications of cognitive impairment for the treatment of alcoholism. Alcohol Clin Exp Res 10:145–149, 1986