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Hand Movement Speed and Accuracy in Detoxified Alcoholics

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Detoxified alcoholics (n = 192) were found to be 9.3% slower than age-matched controls (n = 112) with regard to the composite speed (movement time, MT) with which they were able to strike targets of various sizes and distances with a hand-held stylus at onset of a light stimulus (Fitts's Task). Females (n = 102) were 8% slower than males (n = 202), and blacks (n = 103) about 15.6% slower than whites (n = 201). Gender was the only significant factor with regard to errors (target misses), with women committing 28% fewer errors than men. Women, in contrast to men, appear to trade speed for accuracy in this task. Favorable socioeconomic/medical status and target misses were directly related to movement speed. Thus, when the MT data were corrected for lifestyle variables, the significance of the alcohol effects on MT disappeared, but gender differences persisted. The alcohol effect became statistically significant, the ethnic group differences remained statistically significant, and the gender effect became insignificant when MT scores were corrected for accuracy of performance (target misses). The slope of the linear function relating MT to target difficulty was similar for all subgroups. Prior knowledge of the direction of movement was found to affect MT performance more in white than in black subjects. With regard to reaction times, ethnic group and alcohol use effects remained statistically significant after corrections for lifestyle and errors were made, with values for blacks about 5% slower than values for whites, and values for alcoholics about 4.6% slower than those for controls. Prior knowledge of the direction of movement significantly improved (shortened) reaction time in all subgroups (14%–19%).

Key Words: Motor Performance, Reaction Time, Race, Gender, Alcoholism.

ALTHOUGH ALCOHOLISM has been associated with a variety of movement disorders, only the most severe syndromes have been given adequate research attention. Tremors of the limbs and disturbances in posture or gait are probably the most common movement disorders observed in severely affected alcoholics.[1] The more severe and longlasting movement disorders are often linked to the hepatic encephalopathy accompanying alcoholism in patients with liver disease.[1] Pathology of the basal ganglia has been implicated in these movement disorders by the pattern of symptomatology and by the findings of decreased cholinergic receptor density in the putamen of deceased alcoholics.[1,2]

Knowledge regarding the capabilities of detoxified alcoholics to perform simple work-related or recreation-related motor performance tasks is also needed in order to understand the full spectrum of alcohol toxicity. Research regarding the prevalence of "subclinical" movement disorders in alcoholics also has obvious implications with regard to the development of treatment, rehabilitation, and occupational programming for affected individuals. One research approach has involved the documentation in alcoholics of motor skills that have a cognitive component.[3-5] Evidence regarding the existence of a subacute neurophysiological syndrome of intermediate duration in healthy alcoholics has recently been presented.[6,7] The present research focuses upon psychomotor performance in alcoholics who do not have a major medical problem. Thus, the goal has been to uncover possible direct toxic effects of alcohol, effects not attributable to, or complicated by, a medical condition accompanying alcoholism.

Our previous research indicated that the nature of the psychomotor performance deficit in male alcoholics is different from the deficit observed in female alcoholics when a reciprocal tapping task[8] was employed. That task measured both the speed and accuracy of small amplitude movements of the hand, as subjects tapped back-and-forth between two targets. Male alcoholics tended to sacrifice accuracy in favor of speed, whereas female alcoholics displayed slower speeds than controls.[5] Our goal in the present study was to investigate the performance of alcoholics using a similar, but more complicated, task that simultaneously assessed reaction time, as well as movement time in a discrete response task. Moreover, the interaction of ethnicity (black vs. white) with the effects of alcohol was assessed to investigate the hypothesis that blacks may be more vulnerable to the toxic effects of chronic alcohol consumption.[9]

METHODOLOGY

Subjects

Alcoholic subjects (ages 20–59) were recruited from five local alcoholism treatment programs in Western New York. The programs spanned a wide range of clientele, ranging from derelict alcoholics in a county-supported unit to employed, socially stable alcoholics in a private program. To obtain volunteers, a member of the research team made monthly visits to the treatment facilities and described the study orally to the clients. Subjects were also given a handout (consent form) that described the procedures, risks, reimbursements, and confidentiality safeguards. The clients were informed that in order to participate they must be healthy and not be suffering from a multiple addition. Sign-up cards

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were then distributed and collected and the list of volunteers was given to a designated employee at the treatment facility to screen out volunteers who were suffering from polydrug abuse or from a major medical condition (e.g., emphysema, epilepsy, cirrhosis of the liver, cardiovascular or heart disease, high blood pressure, severe arthritis, diabetes, nervous system disorders). Thus, the subjects admitted into the study comprised a group of rather healthy alcoholics. Only about 20%–25% of the clients met the criteria for participation. Those who qualified were given a packet of questionnaires (described below) to fill out and a date (4–7 weeks postdetoxification) to report for testing at the Research Institute on Alcoholism. Testing was conducted at a mean of 35.4 days after drinking had been discontinued in alcoholic subjects.

Nonalcoholic individuals with lifestyles somewhat similar to those of alcoholics were chosen as controls. This was done to minimize the influence of lifestyle variables upon performance measures. To this end, alcoholic subjects were required to recruit a nonalcoholic person (friend, acquaintance, relative, co-worker, neighbor) to participate in the study as a control. Some control subjects for "homeless" alcoholics were recruited from a local shelter for homeless individuals. With the exception of this group of homeless subjects, control subjects usually reported for testing at the same time as their alcoholic acquaintance. All subjects were given breathalyzer tests (Alco-Sensor III, Intoximeter, Inc.) to ensure their sobriety when they reported for testing. During the same session, subjects also participated in a protocol established to measure the performance of muscles in the arms and legs (to be reported elsewhere).

Physical Measures

Data on height and weight were obtained using a HealthoMeter physician's scale. Percent body fat and lean body mass were estimated by means of bioelectric impedance methodology (RJL Systems Body Composition Analyzer, see Ref 10 for details). Blood pressure and heart rate were measured with a Takeda Medical digital blood pressure meter (average of three readings).

Assessment of Drinking History and Lifestyle Characteristics

Subjects accepted into the study were given or mailed questionnaires to complete before reporting to the laboratory for psychomotor performance testing. The questionnaires provided information regarding subject characteristics that might be related to performance. For instance, the level of physical activity (exercise) typically expended in work, leisure, and sport activities was assessed using the 16-item self-administered form developed by Baecke et al.[11] The Health and Daily Living Questionnaire[12] was used to characterize subjects with regard to major medical problems. An index of socioeconomic status (SES) was calculated for each subject from information on occupation and formal education using the Hollingshead and Redlich[13] "two-factor" index of social position. The Alcohol Dependency Scale (ADS)[14] was used to obtain information regarding the severity of alcohol dependency, as reflected in psychological, physical, or social dysfunction during the 12 months preceding testing.

When subjects reported to the laboratory for testing, lifetime alcohol consumption was assessed by means of a structured interview.[15] Quantity, frequency, and type of beverage, as well as the influence of life events on drinking behavior, were recorded for each phase of the subjects' drinking career beginning with the period in their life in which they first began drinking at least one drink per month. Data from individual phases were summed to obtain lifetime drinking measures.

Psychomotor Testing

Our motivation in the present study was to expand upon findings previously obtained using a reciprocal tapping task[5] by using instead a discrete trial target-striking task that incorporated a reaction time element and allowed for the assessment of the influence of prior knowledge of movement direction upon task performance. To this end, a modification of the apparatus and procedure described by Fitts and Peterson[16] was used. Essentially, subjects were required to strike quickly and accurately at a target with a hand-held stylus. The major variables in this task were the distance of the target from the start position, the size (width) of the target, the direction of movement (left or right), and foreknowledge or ignorance of the direction of movement prior to the initiation of a trial. The important measures were movement speed and accuracy. This choice of psychomotor tasks derived from the 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.

Fitts's procedure has revealed a lawful relationship between hand movement speed and a measure of the size and separation (index of difficulty) of targets that are to be hit with a hand-held stylus. As such, Fitts's 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. Fitts's task involves the type of visually guided motor response (eye-hand coordination) that is a critical component in many work/recreation related tasks.[17]

All targets were 4-inch high brass rectangles that varied in width, distance from "start" button, and "index of difficulty" as outlined in Table 1. The index of difficulty (ID) is a measure of the difficulty encountered in making a quick "hit" on the target with a hand-held stylus. Thus, ID was directly related to distance (D) and inversely related to target width (W) according to the equation $ID = \log_2 \times 2D/W$.[8] In turn, movement time (MT) has been found to be directly related to ID in the straight line equation $MT = a + b \log_2 2D/W$.[8] Plug-in targets of four different widths (0.125, 0.25, 0.5, 1.0 inches) were presented at each of three distances (3, 6, 12 inches) from the start button by plugging them into the appropriate distance setting on the target board. Thus, a total of 12 targets (Table 1) were presented in which the subject was required to move to the right of the start button. In addition 12 trials required movement to the left upon onset of the stimulus light. The 12 trials to the right were interspersed with the 12 trials to the left using a Latin square design to balance for possible order effects of task presentation. This design, which balanced for both the sequence of task presentation and the position of the task, was created by first constructing a simple Latin square design and then reversing the position of adjacent columns, two at a time.

The target board (20 × 30 inches) was similar to that described by Fitts and Peterson[16] and contained two signal lights (7.5 watts) mounted 3 inches above the target strip, one light located 4 inches to the right of the start button and another light located 4 inches to the left of the start button. Subjects were seated in front of the apparatus and were required

Table 1. Target Dimensions and Distances

Target	Target Width (Inches)	Target Distance (Inches)	Index of Difficulty
A	1.0	3	2.58
B	0.5	3	3.58
C	0.25	3	4.58
D	0.125	3	5.58
E	1.0	6	3.58
F	0.5	6	4.58
G	0.25	6	5.58
H	0.125	6	6.58
I	1.0	12	4.58
J	0.5	12	5.58
K	0.25	12	6.58
L	0.125	12	7.58

All targets were 4 inches high. The widths of the targets were 1.0, 0.5, 0.25, and 0.125 inches, and their distance from the start button 3, 6, or 12 inches. Index of difficulty (ID) is directly related to distance (D) and inversely related to width (W) according to the equation: $ID = \log_2 \times 2D/W$.

to prepare for a trial by placing the metal stylus in contact with a metal "start button" located midway between two targets of the same dimension. Subjects were instructed to execute the task in the direction in which the light came on (left or right), as soon as they saw the light. Subjects were instructed to move as quickly as possible to the target, but to make sure that they hit the target each time. Reaction time was taken as the time elapsing between the onset of a stimulus light and the removal of the tethered metal stylus from the metal start button. This value was recorded automatically by means of customized computerized software and timers (Apple IIe computer, Timemaster II H.O. software and I.O. 32 Interface Board, Applied Engineering, Carrolton, TX). Contact of the metal stylus with the metal target (or a miss to the metal surface on either side) was also electronically recorded as movement time. Most of the testing was administered by a white female research assistant.

Experimental Design and Statistical Analyses

Movement time and reaction time data were analyzed using a multivariate analysis of covariance with repeated measures (SPSSPC MANOVA software). The analysis utilized a 4-way full factorial design, with three between subjects measures (ethnicity, gender, alcohol use) and one within subjects measure (known versus unknown direction of movement). This was a true multivariate analysis, with the three dependent variables (movement time, reaction time, errors) yielding individual (univariate) and joint (multivariate) significance tests. Lifestyle variables (socioeconomic status, physical activity, nutrition index, and medical scores) were entered as covariates. A separate analysis was also performed with errors entered as a covariate, along with the other lifestyle variables. Data pertaining to subject characteristics were analyzed using a 3-way ANOVA (race × sex × alcohol use, Number Cruncher Statistical Package). Degrees of freedom varies somewhat because all measurements were not always available on all subjects.

RESULTS

Sample Characteristics

The data presented in Tables 2 and 3 serve to define the populations of alcoholics and nonalcoholics included in this study in terms of physical, lifestyle, and alcohol consumption variables.

Physical Measures. The mean ages for the eight subpopulations were quite similar. Heights were relatively uniform within the four female subpopulations and within the four male subpopulations. Weights of alcoholic subjects were slightly less than those of the appropriate controls. In female alcoholics, the percentage of body fat was also less in the alcoholic subjects. Nutritional indices for all subgroups were within the normal range specified by the manufacturer of the body composition analyzer (values in excess of 1.22 reflect malnutrition), although values for whites, alcoholics, and females were significantly greater (in the direction of malnutrition) than values for blacks, controls, and males, respectively ($p < 0.003$ for all comparisons). The significance of the body composition measures in terms of the nutritional status of alcoholics has been discussed in another report.[10]

Heart rates were significantly higher in alcoholic subjects, particularly males (82.7 ± 1.3 vs 75.1 ± 1.6 for controls, $F(1,139) = 11.51$; $p < 0.001$). Higher heart rates present in all alcoholic subgroups may be related to a higher prevalence of smoking in alcoholic populations, or reduced vagal tone.[18] The low diastolic and systolic blood pressures in black alcoholics (particularly females) are noticeable, and seem to suggest a tendency for alcohol to act to lower blood pressures in black populations, possibly by facilitating renal sodium excretions.[19,20] The 3-way ANOVA (race × sex × alcohol) indicated a significant interaction of race × alcohol use for both systolic ($F(1,276) = 4.55$; $p < 0.03$) and diastolic ($F(1,276) = 7.15$; $p < 0.008$) measures. In general, however, heavy alcohol use has been associated with hypertension in both black and white populations.[21] Decreased adiposity probably does not explain the lower blood pressures in black alcoholics because white alcoholics also exhibited decreased adiposity, but have blood pressures comparable with controls.

Lifestyle Measures. One goal of the subject recruitment procedures was to obtain comparison (control) groups that were generally similar to alcoholic subjects in lifestyle characteristics. This was done to minimize the possibility that lifestyle differences in comparison groups might confound interpretations of group performance differences, although statistical means were also used to determine and control for the influence of lifestyle variables. The socioeconomic status of subjects in this study was lower than average. All three factors (race, sex, alcohol use) were found to be significantly related to socioeconomic status, with blacks ($F(1,296) = 16.40$; $p < 0.001$), women ($F(1,296) = 8.53$; $p < 0.003$) and alcoholics ($F(1,296) = 14.19$; $p < 0.001$) reporting lower SES values than whites, men and controls, respectively. There were no significant interaction effects. Only sex was found to be significantly related to activity scores, with women reporting lower scores than men ($F(1,296) = 11.59$; $p < 0.001$). Both alcoholics ($F(1,296) = 13.79$; $p < 0.001$) and women ($F(1,296) = 9.24$; $p < 0.002$) reported more medical problems than nonalcoholics and males, respectively. The overall incidence of major medical problems was rather low in all groups, owing to the screening procedures used in this study.

Alcohol Consumption Measures. Scores on the Alcohol Dependency Scale (ADS) indicated high levels of alcohol-related problems with physical dependency likely[14] for all alcoholic subjects. Scores for controls were quite low. White alcoholics reported higher ADS scores (more severe alcoholism) than did black alcoholics (race × alcohol use interaction, $F = (1,296)\ 7.92$; $p < 0.005$). Alcoholics reported longer drinking "careers" than did controls, indicative of an early starting age for regular drinking (at least once per month criteria) in alcoholics. Total lifetime alcohol consumption was in excess of 10 kg ethanol/kg lean body weight in all alcoholic subpopulations, nearly 10 times the amount reported by control subjects. Alcohol consumption measures have been normalized by expressing them in terms of the lean body mass (LBM), the volume into which ethanol is distributed. This measure is arguably more closely related to ethanol toxicity than is total body weight. Alcohol consumption and ADS values

Table 2. Female Subject Characteristics

	Black		White	
	Alcoholic (N = 20)	Nonalcoholic (N = 12)	Alcoholic (N = 36)	Nonalcoholic (N = 34)
Physical measures				
Age	35.1 (1.2)	32.8 (1.3)	34.2 (1.2)	35.4 (1.6)
Height (cm)	164.1 (1.2)	162.6 (2.6)	162.5 (1.1)	162.8 (1.0)
Weight (kg)	61.6 (2.3)	76.5 (6.0)	61.6 (2.3)	67.9 (2.3)
%Fat	29.8 (0.8)	35.0 (2.0)	29.9 (0.9)	34.4 (1.2)
Nutrition index	104.0 (2.0)	94.0 (2.0)	110.0 (2.0)	102.0 (1.0)
Systolic BP	104.7 (2.6)	117.6 (4.0)	111.1 (2.0)	112.0 (2.7)
Diastolic BP	68.7 (2.0)	78.1 (2.4)	72.2 (1.7)	71.7 (1.6)
Heart rate	83.4 (3.0)	80.7 (3.4)	84.2 (2.9)	77.5 (3.0)
Lifestyle measures				
Activity score	8.1 (0.4)	7.1 (0.5)	7.1 (0.3)	7.8 (0.2)
SES	59.7 (2.7)	51.7 (4.4)	50.1 (2.3)	43.1 (3.2)
Health score	0.7 (0.2)	0.3 (0.1)	0.8 (0.2)	0.3 (0.1)
Alcohol consumption measures				
Years of drinking	17.6 (1.4)	11.8 (1.6)	18.5 (1.1)	15.2 (1.4)
Lifetime drinking days	3433 (363)	536 (127)	4267 (319)	1160 (273)
Drink days/drink career days	0.53	0.12	0.63	0.21
Lifetime drinking total* (kg/kg LBM)	11.2 (1.5)	1.0 (0.4)	17.1 (2.3)	1.6 (0.4)
Lifetime daily average† (g/kg LBM/day)	1.84 (0.30)	0.23 (0.11)	2.66 (0.37)	0.26 (0.04)
Lifetime drinking day‡ average (drinks/day)	10.6 (1.6)	5.4 (1.3)	11.6 (1.0)	4.3 (0.6)
Lifetime drinking day§ average (g/kg LBM/day)	3.4 (0.4)	1.7 (0.5)	3.72 (0.33)	1.38 (0.2)
ADS Score	20.1 (1.6)	2.5 (1.3)	29.0 (1.5)	2.0 (0.6)

Data were obtained from the procedures described in "Methods." Values in parentheses are standard errors of the mean. SES = socioeconomic status. Blood pressure (BP) and heart rate (HR) measurements were performed on a subset of subjects (N = 19 BP, N = 10 HR black alcoholics; N = 12 BP, N = 9 HR black nonalcoholics; N = 34 BP, N = 17 HR white alcoholics; N = 32 BP, N = 16 HR white nonalcoholics).

* Ethanol (kg) consumed per kilogram of lean body mass (LBM) over the duration of the drinking career (years of drinking). LBM = body weight − (% Fat × body weight).

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

‡ Average number of drinks consumed on days that drinking took place (one drink = 14.0 g ethanol = 12 oz. beer (5%) = 1.5 oz. liquor (40%) = 5 oz. wine (12%).

§ Refers to g of ethanol consumed per kg LBM on days when drinking occurred.

reported here are similar to those reported for alcoholics recruited in a similar manner for an earlier study.[5]

With regard to gender comparisons, the average ADS score for female alcoholics was similar to that for male alcoholics. Yet, the women alcoholics reported a slightly shorter duration of drinking career (18 vs. 20.4 years) and lifetime alcohol consumptions ("lifetime drinking total") of about 70% of the value for men (20.4 vs. 14.1 kg/kg LBM; $T = 2.70$; $p < 0.007$ post hoc contrast, Fisher's least significant difference test followed by specific user Number Cruncher Statistical Package version 5.01). When alcohol consumption was expressed in terms of amount consumed on drinking days as a function of the lean body mass, the values for women more closely approximated those for men (3.83 ± 0.17SE g/kg LBM for males vs. 3.5 ± 0.27 for women), perhaps indicating that women alcoholics titrated their alcohol consumption in accordance with an increased bioavailability (decreased volume of distribution). This practice may result in peak blood alcohol levels quite similar to those achieved by male alcoholics during drinking episodes, an observation also made in female social drinkers.[22] Adding to this effect, lower levels of gastric alcohol dehydrogenase in women may also contribute to the achievement of blood alcohol levels that approximate those achieved in male alcoholics during drinking episodes.[23] Also indicated in Tables 2 and 3 is the finding that women alcoholics drank less often than male alcoholics (a smaller proportion of days in the drinking career, 60% for women, 70% for men). A similar gender difference also appeared among controls.

With regard to race comparisons, black alcoholics (both male and female) reported lower alcohol intakes then did white alcoholics in terms of total lifetime consumption values (30% lower than white alcoholics) and consumption values for drinking days (24% lower than whites). Although the drinking careers were of similar duration (years) for black and white alcoholics, the number of drinking days, drinking day average intake and ADS scores were slightly smaller for blacks, but the differences were not statistically significant.

Scores on the ADS scale indicated that the black and white male alcoholics in this study suffered psychological, social and physical dysfunction to a similar extent (8% smaller for blacks), yet those problems were related to nearly 25% smaller lifetime alcohol intakes in black males (17.7 kg/kg LBM) than in white (23.6 kg/kg LBM) male alcoholics (Table 3), although the differences were not statistically significant. Both groups reported a drinking career of about 20 years duration. Thus, smaller alcohol intake by blacks appeared to produce a syndrome of problems similar in extent to that produced by a larger alcohol intake in whites. This suggests that black males may be more susceptible than whites to the untoward consequences of alcohol intake measured by the ADS

Table 3. Male Subject Characteristics

	Black		White	
	Alcoholic (*N* = 52)	Nonalcoholic (*N* = 19)	Alcoholic (*N* = 84)	Nonalcoholic (*N* = 47)
Physical measures				
Age	35.5 (0.7)	34.8 (1.6)	35.3 (0.8)	34.2 (1.1)
Height (cm)	171.2 (1.1)	173.3 (1.9)	174.2 (0.6)	175.5 (1.2)
Weight (kg)	75.7 (2.3)	7.91 (3.0)	79.6 (1.8)	83.2 (2.7)
%Fat	21.7 (1.0)	20.6 (1.4)	21.2 (0.9)	21.9 (1.1)
Nutrition index	93 (1)	88 (2)	92 (2)	90 (1)
Systolic BP	121.3 (3.0)	127.4 (3.1)	124.2 (1.5)	125.2 (1.6)
Diastolic BP	73.0 (1.3)	77.6 (1.8)	76.6 (1.2)	77.1 (1.3)
Heart rate	81.3 (2.5)	69.0 (2.4)	82.1 (2.3)	72.8 (2.8)
Lifestyle measures				
Activity score	8.0 (0.3)	8.2 (0.3)	8.1 (0.2)	8.0 (0.3)
SES	61.5 (1.0)	55.8 (2.9)	56.6 (1.3)	50.8 (2.0)
Health score	0.3 (0.1)	0.0 (0.0)	0.4 (0.1)	0.2 (0.1)
Alcohol consumption measures				
Years of drinking	20.0 (0.7)	15.0 (2.1)	20.8 (0.9)	16.8 (0.2)
Lifetime drinking days	4747 (288)	2078 (526)	5282 (302)	1709 (203)
Drink days/drinking career days	0.65	0.38	0.69	0.28
Lifetime drinking total* (kg/kg LBM)	17.4 (1.7)	2.6 (0.8)	23.6 (2.4)	2.2 (0.4)
Lifetime daily average† (g/kg LBM/day)	2.35 (0.20)	0.39 (0.09)	2.98 (0.31)	0.38 (0.06)
Lifetime drinking day‡ average (drinks/day)	14.8 (1.0)	4.9 (0.8)	17.7 (1.3)	5.3 (0.5)
Lifetime drinking day§ average (g/kg LBM/day)	3.5 (0.2)	1.1 (0.2)	4.2 (0.34)	1.2 (0.1)
ADS Score	23.8 (1.3)	1.6 (0.5)	25.7 (0.9)	2.2 (0.4)

Data were obtained from the procedures described in "Methods." Values in parentheses are standard errors of the mean. SES = socioeconomic status. Blood pressure (BP) and heart rate (HR) measurements were performed on a subset of subjects (*N* = 49 BP, 27 HR black alcoholics; *N* = 74 BP, 35 HR, white alcoholics; *N* = 19 BP, 11 HR, black controls; *N* = 45 BP, 22 HR white controls).

* Ethanol (kg) consumed per kilogram of lean body mass (LBM) over the duration of the drinking career (years of drinking). LBM = body weight − (% Fat × body weight).

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

‡ Average number of drinks consumed on days that drinking took place (one drink = 14.0 g ethanol = 12 oz. beer (5%) = 1.5 oz. liquor (40%) = 5 oz. wine (12%).

§ Refers to g of ethanol consumed per kg LBM on days when drinking occurred.

scale. The same logic cannot be applied to a distinction between black and white female alcoholics, as lower ADS score in black females would be expected from lower alcohol intakes in that group.

Reaction Time Performance

Inasmuch as variations in the index of difficulty had no significant effect upon reaction time scores, a mean of the 12 trials (12 to the left, as well as 12 to the right) was used as the representative value for each subject. Table 4 presents a breakdown of the reaction time performance when the direction of movement was either known or was unknown to the subject prior to the initiation of the trial. Reaction times were quite similar regardless of whether the target was located to the right or to the left of the start button. The data also reveal that reaction times were 40 to 55 msec longer (13%–15%) when the direction in which the response was to be made was not known prior to the trial. All subgroups benefitted similarly from knowledge of the direction in which movement was to be made. That is, prior knowledge of direction of movement did not interact with ethnic group, gender, or alcoholic status. Gender had no significant effect on reaction time performance. The main effects of alcohol status and of ethnic group, however, were found to be statistically significant, with the reaction times for alcoholics being about 4.6% slower than those for controls and the reaction time for blacks being about 5% longer than those for whites. The difference persisted for responses to the left or right, under known or unknown conditions. and remained statistically significant after corrections for lifestyle variables and accuracy (Table 6). The only significant interaction was ethnic group by sex (after corrections for all covariates) with black males exhibiting longer reaction times than black females ($F = 5.125$; *df*, 1312; $p < 0.02$, univariate analysis).

Table 4. Reaction Time (msec) in Alcoholics and Controls

		Known		Unknown	
		Right	Left	Right	Left
Alcoholics					
Males	Black	297 (10)	301 (10)	341 (8)	351 (9)
	White	281 (6)	281 (6)	321 (6)	330 (6)
Females	Black	309 (11)	298 (12)	355 (13)	369 (12)
	White	285 (8)	284 (7)	332 (5)	318 (11)
Controls					
Males	Black	305 (14)	302 (12)	346 (9)	344 (11)
	White	266 (5)	272 (5)	315 (6)	320 (6)
Females	Black	266 (9)	270 (8)	314 (10)	313 (16)
	White	278 (5)	275 (5)	328 (6)	308 (7)

Reaction times are reported for movements to targets located to the left and to the right of the start button, under conditions when the direction of movement was known or was unknown to the subject prior to the onset of the stimulus light. Values represent the mean of the reaction times to the 12 target configurations outlined in Table 1, with standard errors in parentheses.

Movement Time Performance

The data in Figs. 1 and 2 represent movement time (MT) performance as influenced by the index of difficulty

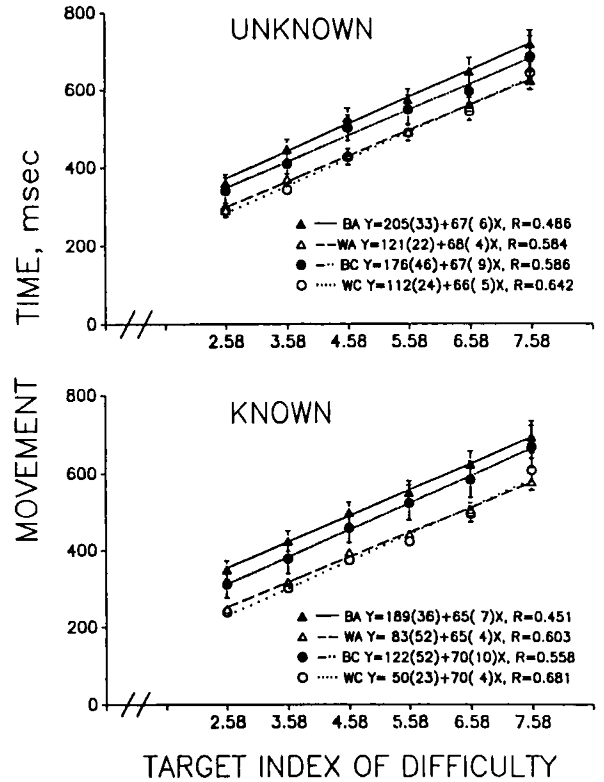

Fig. 1. Movement time as a function of target index of difficulty in men. Performance on the 12 targets (Table 1) was measured when subjects had prior knowledge (known) or no prior knowledge (unknown) of the direction (left or right) in which movement was to take place at onset of light stimulus. Because direction of movement had no discernable influence on movement time, data from the 12 movements to the left were pooled with data from 12 movements to the right. Regression lines and equations were calculated using the Number Cruncher Statistical Package. Key: BA, black alcoholic; WA, white alcoholics; BC, black controls; WC, white controls. Brackets and values in parentheses indicate standard errors of the mean.

(ID) of targets. Note that, from Table 1, only one target has an ID of 2.58, or an ID of 7.58, whereas two each have IDs of 3.58 and 6.58, and 3 each have IDs of 4.58 and 5.58. Thus, the values indicated for ID 3.58 through 6.58 in Figs. 1 and 2 represent a mean MT on the two or three targets at that particular ID. The "least squares" straight line fits to the data were generated by the Number Cruncher Statistical Package.

In both men and women, movement time values were larger (slower) for alcoholics than for controls of the same race. Moreover, alcoholics and controls slowed down in similar manners when confronted with tasks of increasing difficulty. This is revealed by visual inspection (parallel lines) and by the similar slope values in the equations describing the straight lines. MT values of blacks were consistently larger than those for whites (also reflected in Y intercept value). This conclusion is also evident when the performance is expressed as an average of the 12 tasks outlined in Table 1. These values (referred to as mean movement time, Table 5) are approximately 16% lower (faster) in white males.

Socioeconomic status, medical problems, and accuracy (target misses) were variables found to be significantly

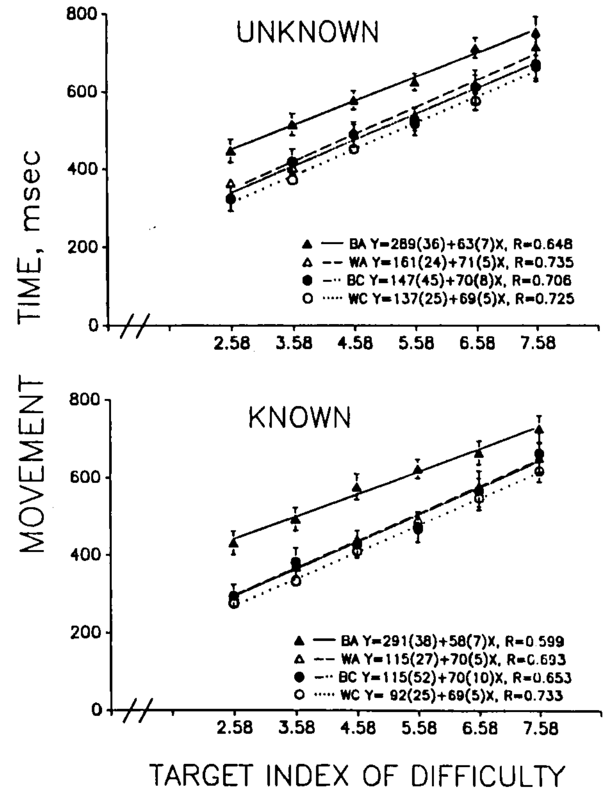

Fig. 2. Movement time as a function of target index of difficulty in women. Legend and key are the same as for Fig. 1.

Table 5. Movement Time and Errors in Alcoholics and Controls

		Mean Movement Time (msec)		Errors	
		Known	Unknown	Known	Unknown
Alcoholics					
Males	Black	514 (25)	531 (23)	4.61 (0.66)	4.49 (0.51)
	White	415 (15)	463 (16)	5.87 (0.55)	5.99 (0.47)
Females	Black	589 (26)	607 (24)	2.70 (0.54)	3.15 (0.49)
	White	470 (15)	521 (16)	3.97 (0.44)	3.61 (0.40)
Controls					
Males	Black	488 (41)	516 (34)	4.72 (1.07)	4.39 (0.72)
	White	402 (16)	455 (18)	4.64 (0.65)	5.40 (0.60)
Females	Black	464 (37)	510 (35)	4.83 (1.2)	4.08 (0.89)
	White	441 (17)	484 (16)	3.06 (0.40)	3.72 (0.45)

Mean movement time values represent the average movement time for the 24 target configurations (12 to right, 12 to left). "Errors" refers to total errors (misses committed by subjects on the 24 target attempts). Each variable was recorded when the direction of movement was known or unknown prior to the initiation of the trial. Values in parentheses are standard errors.

correlated with mean movement time scores (Table 6). When the MT data were corrected for the influence of lifestyle variables, the significance of the alcohol effect disappeared, but gender and race effects persisted. When the MT scores were corrected for errors, as well as lifestyle variables (Table 6), the alcohol effect became statistically significant, the racial differences remained statistically significant, and the gender effect became nonsignificant.

In women, performance of black alcoholic subjects was noticeably slower than that of the other subgroups, although this effect did not show up as a significant interaction term. The performance of black controls was indistinguishable from the performance of white alcoholics and

Table 6. Multivariate Analysis of Covariance

Independent Variables	Dependent Variables: Multivariate F-Sequential (All Dep Var)	df	Univariate F-Sequential: RT	MT	Errors	df
Fixed Factors						
Alc/Con†	4.28**	3,311	4.37*	1.53	1.97	1,313
	(5.40**)	(2,311)	(5.27**)	(9.57**)		(1,312)
Ethnicity	11.47***	3,311	16.32***	19.23***	0.33	1,313
	(17.03***)	(2,311)	(15.92***)	(30.61***)		(1,312)
Gender	4.39**	3,311	0.19	6.99**	12.03***	1,316
	(0.59)	(2,311)	(0.66)	(0.10)		(1,315)
Condition	214.30***	3,314	621.60***	101.50***	1.42	1,316
	(319.34***)	(2,314)	(619.12***)	(136.10***)		(1,315)
Covariates						
Covariates	2.44**	9,939	2.65*	5.96**	1.68	3,313
	(29.22***)	(8,624)	(3.53**)	(81.51***)		(4,312)
SES	3.64**	3,315	2.42	10.32***	2.78	1,317
	(5.20**)	(2,316)	(2.42)	(10.32***)		(1,317)
Activity	1.18	3,313	3.15	0.02	0.05	1,315
	(1.77)	(2,314)	(3.15*)	(0.02)		(1,315)
Medical	2.52*	3,315	1.86	7.31**	2.35	1,317
	(3.69*)	(2,316)	(1.86)	(7.31**)		(1,317)
Total errors	(169.60***)	(2,317)	(6.68**)	(311.90***)		(1,318)

SPSS PC "MANOVA" software was used. Dependent variables were reaction time (RT), movement time (MT), and errors (target misses). A mean value for performance on all 12 targets was used as the MT or RT measure. "Condition" refers to a repeated measures (within subject) factor in which the direction of movement was either known or unknown prior to the initiation of the trial. The joint significance of independent variables to all dependent variables is indicated by the multivariate *F*-sequential. Values in parentheses are the results of a separate analysis in which errors was also entered as a covariate. Values were processed in the order of their listing.

† SES, socioeconomic status; Alc/Con, alcoholic/control.

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; 2-tailed test.

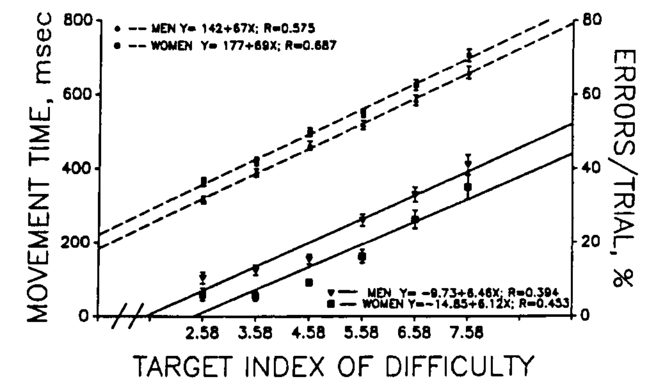

Fig. 3. Target misses (dotted lines) and movement time (solid lines) as a function of target index of difficulty in men (n = 202) and women (n = 100). Errors/trial refers to the probability of an error (target overshoot or undershoot) on a single trial. The straight line equations and correlation coefficients (movement time in lower right corner, errors in upper left corner) were calculated using the Number Cruncher Statistical software. Brackets indicate standard errors of the mean. The data are not corrected for the influence of covariates. These data were generated under the "unknown" condition, i.e., the direction in which movement was to be made was not known prior to the initiation of the trial. Nearly identical data were also generated when the target direction was known prior to the trial.

their controls. Overall, the mean movement times of women (511 ± 9 SE) were significantly slower than those for men (473 ± 7, Table 5), even after correction for lifestyle variables (Table 6). The differences became non-significant when MT performance was corrected as well for the number of target misses (errors, Table 6), illustrating the reciprocal relationship between speed and accuracy in this task.

Prior knowledge of the direction in which movement was to be made improved the movement times of Whites more than it improved the movement times of blacks (race × condition interaction, Table 6, $F = 9.61$; *df*, 1315; $p < 0.002$, univariate task).

Accuracy of Performance. The data in Table 5 reveal that women committed only about 70% as many errors as men (3.6 ± 0.27 SE for women vs. 5.0 ± 0.20 for men). The effect of gender was the only significant factor in error performance when the data were corrected for the influence of lifestyle variables (Table 6). There were no significant interactions of the fixed factors with regard to the number of errors. The rate of errors was not related to testing condition (known or unknown), but was highly related to target index of difficulty (Fig. 3). The slope of the linear regression was quite similar for men and for women. The correlation between index of difficulty and errors was higher for women than for men. In general, however, the distribution of errors among the various targets was similar for men and women, and the slopes generated by each of the eight individual subgroups were similar to those in Fig. 3. Also depicted in Fig. 3 are the movement time scores for the same subjects (dotted lines). The movement time scores taken together with error scores reveal the speed-for-accuracy tradeoff involved in Fitts's Task.

DISCUSSION

The findings reported here extend and, to some extent, corroborate the observations reported earlier[5] in which a reciprocal tapping task without a reaction time component was employed. In the earlier reciprocal tapping task, male alcoholics were found to have movement times (MT) similar to those of controls, but the error rate was a factor of about 1.7 times that of controls. A similar finding was observed in the present study, with the exception that the error performance of alcoholic males was a factor of about 1.25 times that of nonalcoholic males, and the difference was not statistically significant. The slower movement times for alcoholic subjects (9.3%) became statistically significant when the multivariate analysis of covariance included a correction for the number of errors committed, an illustration of the reciprocal relationship between speed and accuracy embodied in this task. It is important to point out that controls in the 1988 study[5] were not matched as closely to alcoholics with regard to lifestyle variables, nor was that data corrected for lifestyle variables. As a point of reference, a simple 2 × 3 ANOVA performed on the MT data contained in Table 5 yielded highly significant effects ($p < 0.001$) of alcohol on MT.

In earlier studies,[5,24] measuring reciprocal tapping performance, nonalcoholic females performed similarly to nonalcoholic males in MT, but females committed only about 60% as many errors as males. In the present study, females (all) committed only about 70% as many errors as males, but their movement times were also about 8% slower than that for males. The tradeoff of speed-for-accuracy (females) or accuracy-for-speed (males) is evident here, as well as in earlier studies.[5,24] As expected, the statistical significance of the longer movement times in females disappeared when correction for total errors was made. The impact of the correction for errors emphasizes the need to consider both accuracy (errors), as well as speed in the interpretation of findings.

Among female alcoholics, only the black subgroup displayed the impairment in speeded (MT) performance that was characteristic of the racially mixed group of female alcoholics in the 1988 study. (The performances of black and white alcoholics were similar in the 1988 study.) The findings of the present study utilizing discrete tapping performance suggests that blacks (particularly females) may be more vulnerable than whites to a toxic effect of chronic alcohol on speeded measures, although the statistical analyses did not indicate a significant interaction for ethnic group and alcohol use, or for ethnic group × sex × alcohol use. A separate ANOVA performed only on the female subgroups revealed a significant interaction of race by alcohol use ($p < 0.05$) for both MT and RT, but the statistical significance disappeared when a correction for errors was made. Thus, alcohol use in black females appears to result in a dramatic tradeoff of speed for accuracy.

In general, reaction times for alcoholic subjects (males and females) were only slightly slower (approximately 5%) than those for controls, but the differences remained statistically significant after corrections for lifestyle variables and errors were made. Others have also reported slightly larger simple reaction times in alcoholics than in controls,[4,25,26] but such studies did not employ corrections for lifestyle variables. In some respects, the MT findings appear to be in harmony with those of Grant and coworkers (1984) who report that education and medical problems (not drinking history) were related to psychomotor slowing on the Halstead Reitan battery. The findings on RT and MT support the notion of a persisting subclinical neuropsychological deficit in detoxified alcoholics. The deficits were not large, probably owing, in part, to the relatively stringent screening criteria used for subject selection in the present study.

Another noteworthy, but unexpected, finding was that the reaction times and movement times for black subjects were significantly lower (slower) than those for whites, even after the correction for covariates. The ethnic/racial difference in performance was about the same magnitude in alcoholics as in controls. Reaction times under unknown conditions were about 18% longer than under known conditions for both whites and blacks, but movement times (MT) improved more in white subjects when the testing condition was changed from unknown to known. The longer movement time in black males may be partially attributed to a more careful approach to the task on the part of blacks, evidenced by lower error scores than for whites. However, the ethnic difference still prevailed even after mean movement time scores were corrected for errors, socioeconomic status, activity scores and health scores. The generalization of these findings to the general population are limited, of course, owing to the absence of random, general population sampling procedures employed in this study. The possibility of the unknown influence of other ethnic-related variables in this sample cautions against the use of these observations as support for true race differences. Moreover, motivational or cultural biases in the testing cannot be entirely ruled out.

One interpretation is that data such as these are a reflection of a generally poorer living condition in the United States for blacks as compared to whites. For instance, the longevity of blacks in the United States is approximately 6 years shorter than that for whites,[27] and diseases commonly associated with aging, such as hypertension, also develop at an earlier age in blacks than in whites.[28] Some, but not all, of the ethnic differences in longevity and disease prevalence has been explained by lower socioeconomic status in blacks,[29] presumably reflecting a life style or standard of living less advantageous to good health in blacks. A recent study suggests that stress among blacks of lower socioeconomic status may be a variable related to health status differences between blacks and whites.[29] The residual variance in MT and RT unexplained by the lifestyle variables measured in this study, thus, may not be a true racial difference, but may derive from other ethnicity-related factors not measured or controlled for in this study. The impact of these ethnicity-related factors have a net effect that appears somewhat as if blacks were aging at a faster rate than whites. For instance, the magnitude of the difference in MT performance between blacks and whites in this study is roughly similar to the magnitude of the difference observed between the MT performance of subjects in their 30s and 40s in the reciprocal tapping task.[24] However, somewhat parallel linear regressions were generated by plotting the MT performance of blacks and whites across the ages of subjects, suggesting that the ethnic differences appear at an early age.

Some important basic differences exist between the present findings and the findings reported by Fitts and Peterson,[16] one of the few studies that used procedures very similar to ours. Error rates were higher in the present study, with subjects missing the target on approximately 20% of their responses, as compared to 10% reported by Fitts and Peterson.[16] Movement times and reaction times in the present study were, in general, larger (slower) than those reported by Fitts and Peterson.[16] Variations in the target index of difficulty had little effect upon reaction time in the present study, a finding also reported by Fitts and Peterson. However, the goodness of fit of the present data to the straight line equation (MT vs. ID) was not as good as that reported by Fitts and Peterson, who reported correlations in the 0.90s for individual subjects. Correlations in the 0.60s and 0.70s were typical for individual subjects in the present study. The correlations for groups of subjects also was typically in the 0.60s and 0.70s (Figs. 1 and 2). The higher correlations obtained by Fitts and Peterson may be explained, in part, by the greater amount of practice that they gave their subjects before testing. The lower error rate and the high correlations (0.90s) between ID and MT found when a reciprocal tapping task is used[5,8,24] may derive from the repetitive nature of the task, which provides a practice effect. In agreement with the findings of Fitts[8] (reciprocal tapping) and Fitts and Peterson[16] (discrete responses), our studies[5,24] (present study) have also observed the slope of the function to be less steep for discrete than for serial responses. Unlike Fitts and Peterson,[16] who reported that the effect of uncertainty regarding direction of movement was almost entirely on reaction time, we observed that both reaction time and movement time were lengthened to a similar extent in all subjects when they did not have prior knowledge of the direction in which movement was to be made. Moreover, we were not able to find evidence supporting the claims of others[25,30] that alcoholics may be less capable of utilizing information that structures or "regularizes" a simple reaction time task.

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