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Dysarthria predicts poorer performance on cognitive tasks requiring a speeded oral response in an MS population

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Dysarthria is a common symptom of multiple sclerosis (MS). To examine its impact on tests requiring speeded oral responses, 97 MS patients and 27 controls were administered the Controlled Oral Word Association Test, the Visual Elevator (VE), and the Symbol Digit Modalities Test (SDMT). Regression analyses revealed that dysarthria significantly predicted patient performance on the SDMT and VE. When dysarthria was controlled for, patient status no longer accounted for a significant amount of the variance in predicting VE performance; the contribution of patient status to SDMT variance was also reduced substantially, though still statistically significant. These results suggest that the poor performance of MS patients on some tasks that require oral responses is partially due to dysarthria.

Motor speed and coordination are frequently impaired in neurological populations, though many widely used neuropsychological tests require a written response. Impaired graphomotor speed or upper extremity motor problems may affect performance on these tests. To mitigate this concern, many researchers and clinicians select tests that require an oral, rather than written, response in cases where motor impairment is suspected. However, such attention has not been paid to the influence of slowed oral-motor speed, or dysarthria, though this impairment also occurs frequently in neurological populations such as patients with Parkinson's disease (Hartelius & Svensson, 1994; Ho, Iansek, Marigliani, Bradshaw, & Gates, 1998–1999; Sapir et al., 2001), Huntington's disease (Hartelius, Carlstedt, Ytterberg, Lillvik, & Laakso, 2003), stroke (Kent & Kent, 2000), and multiple

sclerosis (Darley, Brown, & Goldstein, 1972; Hartelius, Runmarker, & Andersen, 2000a; Hartelius, Runmarker, Andersen, & Nord, 2000b; Tröster & Arnett, 2006). Therefore, in attempting to control for the influence of impaired graphomotor speed, examiners may be exchanging one confound for another as slowed speech may affect performance on tasks requiring a speeded oral response.

Motor problems such as impaired graphomotor and oral-motor speed are common symptoms of multiple sclerosis (MS), a frequently occurring neurodegenerative disorder. If dysarthria affects performance on cognitive tasks requiring a speeded oral response, MS patients might have particular difficulty with such tasks. Using a large sample of patients with MS and control participants, the present study examines both the

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prevalence of dysarthria and the effect of dysarthria on performance on cognitive tests requiring a speeded oral response. It is hypothesized that observer ratings of dysarthria will be higher for MS patients than for controls and that MS patients will perform more poorly on the cognitive tests than will control participants. Additionally, we hypothesize that dysarthria ratings will be correlated with performance on neuropsychological tests requiring a rapid oral response. Finally, we predict that differences between MS patients and controls on neuropsychological tests requiring a speeded oral response will be reduced when the impact of dysarthria on test performance is statistically controlled.

Dysarthria

Dysarthria is more accurately described as a group of motor speech problems that result in slurred or poorly articulated speech (Beeson & Rapcsak, 1998). As early as 1877, Charcot described dysarthria (or “scanning speech”) as one of the three characteristic neurological symptoms of MS, along with intention tremor, and nystagmus (Charcot, 1877; Darley et al., 1972). Charcot believed scanning speech to be a hallmark of disseminated sclerosis (as MS was termed at the time) and reported that it was observed in 22 of the 23 cases he had examined. He suggested “. . . the words are as if measured or scanned; there is a pause after every syllable, and the syllables themselves are pronounced slowly” (p. 192).

While Charcot’s (1877) claims regarding the widespread nature of dysarthria in MS may no longer be accurate, a significant percentage of patients with MS demonstrate observable problems with speech. Hartelius et al. (2000a) report that prevalence levels of dysarthria in MS populations range from 40–55%. Difficulties include problems with articulation and slowed speech rate (Darley et al., 1972; Hartelius et al., 2000a; Hartelius et al., 2000b). Research has suggested that dysarthria in MS is not correlated with age or duration of illness, though speech problems have been found to be positively correlated to neurologic disability (Darley et al., 1972; Hartelius et al., 2000a) and course type (Hartelius et al., 2000a). Regarding the latter, it has been found that secondary and primary progressive patients display greater levels of dysarthria than do relapsing–remitting patients. Hartelius and Svensson (1994) found that 16% of a sample of 200 patients with MS rated their speech disturbances as one of their greatest problems. However, despite this evidence

that dysarthria is a prominent symptom of MS, as far as we have been able to determine, discussion of the impact of dysarthria on test performance is largely absent from neuropsychological reference texts and empirical study. Spreen and Strauss (1998) caution that dysarthria might impact performance on the Paced Serial Addition Test (PASAT), also cited by Lezak (Lezak, Howieson, & Loring, 2004), but this reference is based on an unpublished doctoral thesis. Notably, Tröster and Arnett (2006) and Benedict et al. (2002) both suggest that dysarthria might impact MS patients’ performance on tests requiring a speeded oral response.

Neuropsychological testing in MS

Neuropsychological testing has been demonstrated to be relevant in MS because about half of all individuals with MS experience cognitive deficits. These deficits are often severe enough to impact their day-to-day functioning (Bobholz & Rao, 2003; Brassington & Marsh, 1998; Rao, Leo, Bernardin, & Unverzagt, 1991a; Rao et al., 1991b). Research has revealed that the domains most commonly affected include memory, conceptual reasoning, speed of information processing, attention, concentration, and executive functioning (Bobholz & Rao, 2003; Brassington & Marsh, 1998; Tröster & Arnett, 2006).

Because MS can result in a wide variety of cognitive deficits, a battery approach is often used in evaluating this population. Two of the most commonly used test batteries developed to be sensitive to the cognitive deficits most frequently seen in MS populations are the Brief Repeatable Battery (BRB; Rao & the Cognitive Function Study Group of the National Multiple Sclerosis Society, 1990) and the Minimal Assessment of Cognitive Function in MS (MACFIMS; Benedict et al., 2002). Both the BRB and the MACFIMS recommend that oral forms of widely used tests (such as the Symbol–Digit Modalities Test) be used in order to minimize the impact of impaired graphomotor and upper extremity speed. However, these test forms are susceptible to the influence of dysarthria, which has been demonstrated to be present in about half of all MS patients. Therefore, these speech problems may be inflating estimate rates of cognitive impairment in these patients. In the present study, guided by the hypotheses stated earlier, we empirically examined the influence of oral-motor slowing on key tests from the MACFIMS and BRB batteries using examiner ratings of dysarthria.

METHOD

Participants

The participants for this study were recruited from a local MS society in the mid-Atlantic United States as a part of a larger study of cognitive and emotional functioning in MS. Eligibility was determined through a phone screening interview completed by clinical psychology graduate students or undergraduate laboratory assistants. Exclusion criteria included a history of or current substance abuse, nervous system disorder other than MS, severe motor or visual impairment that would interfere with cognitive testing, premorbid history of a learning disability or attention-deficit/hyperactivity disorder (ADHD), severe physical or neurological impairment that made testing at the university location impossible, or inability to come to the university location due to distance. A total of 101 individuals with MS and 27 controls completed the testing. A total of 4 MS participants were excluded from the data analysis for the following reasons: MS diagnosis could not be verified (1), history of electroconvulsive therapy (1), history of stroke (1), and history of significant loss of consciousness following a motor vehicle accident (1).

All participants provided informed consent (reviewed and approved by the Institutional Review Board), were treated in accordance with the Ethical Principles of the American Psychological Association, and were paid \$75 for their participation. All participants were also provided with written neuropsychological evaluations of their performance as well as verbal feedback at the completion of their participation. Each MS participant's diagnosis was verified by a board-certified neurologist as definite or probable MS using Poser et al.'s (1983) criteria. Disease course was classified according to Lublin and Reingold's (1996) suggested criteria. No MS participants were experiencing an exacerbation at the time of testing (as determined through the initial phone screening and then reconfirmed at the time of testing).

The demographic and disease characteristics of the participants are depicted in Tables 1 and 2. The majority of the MS patients were rated (using the scale described below) as having normal speech (65, 67%). Of the 32 patients who were rated as demonstrating some level of dysarthria, 28 were rated as mildly dysarthric (28.9%), 3 were rated as mildly to moderately dysarthric (3.1%), and 1 was rated as moderately dysarthric (1%). No MS participants were rated as severely dysarthric. Only 1 control participant was rated as having impaired speech and was rated as mildly dysarthric. The majority of control participants were rated as having normal speech (26, 96.3%).

Procedure

Participants received a packet of questionnaires approximately one week prior to their scheduled testing day. This packet included a self-report version of the Kurtzke Extended Disability Status Scale (EDSS; Kurtzke, 1983) used in our prior work (Arnett, Higginson, & Randolph, 2001). Prior to any test administration on the day of testing, all participants were interviewed by trained clinical psychology graduate students, under the supervision of an experienced clinical neuropsychologist (P.A.), who completed a brief psychosocial interview that included the 4-point dysarthria rating scale anchored with descriptors. Following this interview, participants completed the Controlled Oral Word Association Test (COWA), the Symbol-Digit Modalities Test-oral form (SDMT), the Visual Elevator (VE), and the Shipley Institute of Living Scale. The tests were administered as a part of a larger testing battery in four different, alternating orders to control for fatigue and administration order effects on test performance.

Dysarthria rating

The dysarthria ratings were conducted as a part of a psychosocial interview that was administered prior to any of the cognitive tests. The ratings were

TABLE 1
General demographic data

	<i>N</i>	<i>Sex:</i> <i>No. of women</i>	<i>Age^a</i>	<i>Race:</i> <i>No. of Caucasians</i>	<i>Education^a</i>	<i>Handedness:</i> <i>No. right-handed</i>	<i>Marital status:</i> <i>No. married</i>
MS	97	80 (82.5%)	47.34 (<i>SD</i> = 8.95)	97 (100%)	14.28 (<i>SD</i> = 2.01)	76 (78.4%)	68 (70.1%)
Controls	27	22 (81.5%)	45.63 (<i>SD</i> = 12.46)	26 (96.3%)	15.07 (<i>SD</i> = 2.13)	21 (77.8%)	16 (59.3%)

Note. MS = participants with multiple sclerosis.

^aIn years.

TABLE 2
Demographic data: Disease variables

<i>Symptom duration^a</i>	<i>Diagnosis duration^a</i>	<i>Course type (No. in each)</i>	<i>EDSS</i>
14.97 (<i>SD</i> = 8.76)	10.77 (<i>SD</i> = 7.85)	74 (76.3%) RR 18 (18.6%) SP 4 (4.1%) PP 1 (1%) PR	4.57 (<i>SD</i> = 1.56)

Note. RR = relapsing–remitting; SP = secondary progressive; PP = primary progressive; PR = progressive–relapsing. EDSS = Extended Disability Status Scale.

^aIn years.

based on a 4-point scale anchored with descriptors (e.g., 1 = normal: nothing unusual about participant's speech; 2 = mildly dysarthric: participant's speech generally normal, but some words slurred/difficult to understand, or speech notably slow; 3 = mildly/moderately dysarthric: more than a few words difficult to understand/slurred with occasional requests for repetition, or speech very slow; 4 = moderately dysarthric: frequent requests for repetition are necessary because of difficulty understanding participant's speech, or speech extremely slow). Due to the fact that very few participants were rated at 3 or higher, for the purposes of this study these ratings were dichotomized into "normal speech" (score of 1) and "dysarthria" (scores of 2–4).

Disability measure

The EDSS, a rating scale derived from a standard neurological examination, is the most commonly used measure of disease severity in MS (Lezak et al., 2004). The EDSS provides a 0–10 rating of disability due to MS, ranging from no disability to death due to MS in half-point increments (Kurtzke, 1983). Higher scores indicate more significant impairment. A score of 5 would indicate that the participant is able to walk for about 200 meters without aid or rest, but the disability is severe enough to impair full daily activities. For this study, the EDSS was converted into a self-rated questionnaire in consultation with a board-certified neurologist. Participants were asked to rate for symptoms of ambulation difficulties, motor-related problems, bowel and bladder dysfunction, and visual, oral, and sensory functioning on a 4-point scale. The EDSS rating was then determined by an experienced clinical neuropsychologist (P.A.) with expertise in MS. The EDSS was included in the present study to assess the relationship between dysarthria and general physical/neurological disability.

Cognitive measures

The Shipley Institute of Living Scale is an easily administered paper-and-pencil test of vocabulary and verbal abstraction (Lezak et al., 2004; Zachary, 1986). Scores on the Shipley are highly correlated with Wechsler Adult Intelligence Scale–Revised (WAIS–R) IQ. In the present study, the Shipley was used to control for the influence of general cognitive ability on test performance.

All other cognitive measures employed in this study are widely used tasks that require a speeded oral response. The Visual Elevator (VE) is a subtest of the Test of Everyday Attention (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994), which measures attentional switching and cognitive flexibility. Participants are presented with a series of pictures of elevators and arrows pointing up or down and are asked to count out loud what "floor" they are on as quickly as possible. There are 10 trials, and the raw score for this test is the number of correct "switches" (changes in elevator direction) made per second. The COWA is a measure of verbal association fluency (Spren & Benton, 1969), which is a component of the BRB (Rao & the Cognitive Function Study Group of the National Multiple Sclerosis Society, 1990) and the MACFIMS (Benedict et al., 2002). Though the number of words produced in three 60-s trials is typically the index score for this measure, we also examined the number of words produced within the first 15 s of each trial, due to the increased verbal output in this portion of the test. The SDMT is a widely used adaptation of the Wechsler Digit Symbol Test (Wechsler, 1981), which measures complex scanning and visual tracking (Lezak et al., 2004) as well as working memory (Smith, 1982). Although both written and oral forms are available, the oral form of this measure is typically used in clinical and research applications in which the patient population is suspected of having motor-writing difficulties. Only the oral form was used in the present study, as is recommended by manual of the BRB (Rao & the Cognitive Function Study Group of the National Multiple Sclerosis Society, 1990) and the MACFIMS (Benedict et al., 2002).

RESULTS

The data were initially examined for outliers within the MS sample. Z-scores for the VE, COWA, and SDMT were calculated using the MS participants as a reference group in order to ensure that data labeled as outliers were, in fact, unusual for the sample and did not represent real differences between the control and MS groups. The determination

of outliers was based on a cutoff of 3 standard deviations above or below the mean (Ratcliff, 1993). Using this method it was determined that there was an outlier in the COWA and the VE scores. These two cases were removed from the analyses in which these tests were the dependent variables and in the calculations of group means. The results for both analyses remained significant when completed with the outliers included. Unfortunately, we were not able to include four cases in our analyses of the 15-s COWA due to experimenter error in recording the timing.

The following analyses were completed with the MS participants only, in order to illustrate the impact of dysarthria in that population. The relationship between dysarthria and several demographic variables was examined with Spearman's rank-order correlations, due to the skewed nature of the dysarthria ratings, with many more participants rated as having normal speech than dysarthric speech. To test whether age and dysarthria were related in this sample, though they have not been found to be in previous samples, these variables were correlated. As expected, this correlation was not significant. However, unlike previous findings, in our sample neurological disability (as measured by the EDSS) and dysarthria were not significantly correlated, whereas dysarthria was correlated with symptom duration and diagnosis duration ($\rho = .26, p < .05$; $\rho = .35, p < .01$).

The relationship between age and performance on the cognitive tests was also examined, using Pearson's correlations. It was found that, although the correlation between age and the COWA (both the 15-s and the standard versions) was not significant, age and the SDMT ($r = -.35, p < .001$) and the VE ($r = .21, p < .05$) were significantly correlated.

Chi-square analysis revealed that significantly more MS participants than control participants were rated as dysarthric, $\chi^2(1, N = 124) = 9.28, p < .005$, as was predicted.

To test the prediction that dysarthria would be negatively associated with performance on tests requiring a speeded oral response, hierarchical linear regressions were conducted on the SDMT, COWA, and VE. All test variables were *z*-scored, using the control group as the reference group. In the regressions, the SDMT, COWA, and VE were predicted by the Shipley total score and the dysarthria score. The Shipley total score was entered first in order to assure that any variance accounted for by the dysarthria rating was not due to differences in general cognitive ability. In the regressions using the SDMT and the VE as the dependent variables, age was also entered as a predictor variable

before the dysarthria rating because it was found to be significantly correlated with test performance for these measures.

For the SDMT, dysarthria ratings significantly predicted performance even after controlling for general intellectual ability and age in the first step of the analysis (adjusted $r^2 = .351, r^2$ change = $.051, F$ change = $7.50, p < .01$). Again, for the VE, dysarthria ratings significantly predicted performance even after controlling for general intellectual ability and age in the first step (adjusted $r^2 = .380, r^2$ change = $.034, F$ change = $5.13, p \leq .05$). Dysarthria did not significantly predict standard COWA performance. However, dysarthria did significantly predict 15-s COWA performance (adjusted $r^2 = .178, r^2$ change = $.049, F$ change = $5.49, p < .05$; see Table 3).

Dysarthria group means were calculated for the neuropsychological tests to ensure that dysarthria was associated with test performance in the direction hypothesized. It was found that the dysarthria group performed consistently worse than the normal speech group on all three tests studied: SDMT, $F(1, 95) = 12.73, p \leq .001$; the VE, $F(1, 93) = 11.95, p \leq .001$; and both versions of the COWA: standard, $F(1, 94) = 4.31, p < .05$; 15-s, $F(1, 91) = 9.69, p < .005$ (see Table 4).

TABLE 3
Regression analyses

	Step		Δr^2	ΔF	<i>p</i>
SDMT-Oral	1	Shipley total, age	.321	22.22	<.001
	2	Dysarthria rating	.051	7.50	<.01
VE	1	Shipley total, age	.365	26.49	<.001
	2	Dysarthria rating	.034	5.13	<.05
60-s COWA	1	Shipley total	.159	17.74	<.001
	2	Dysarthria rating	.017	1.89	<i>ns</i>
15-s COWA	1	Shipley total	.146	15.61	<.001
	2	Dysarthria rating	.049	5.49	<.05

Note. SDMT = Symbol Digit Modalities Test. VE = Visual Elevator. COWA = Controlled Oral Word Association.

TABLE 4
Group means: Dysarthria versus normal speech

<i>Z</i> -score		<i>N</i>	<i>M</i> (<i>SD</i>)	<i>F</i>	<i>p</i>
SDMT	Normal speech	65	-0.88 (1.13)	12.73	$\leq .001$
	Dysarthria	32	-1.84 (1.14)		
VE	Normal speech	63	-0.44 (1.34)	11.95	$\leq .001$
	Dysarthria	32	-1.67 (2.10)		
60-s COWA	Normal speech	64	-0.39 (0.84)	4.31	<.05
	Dysarthria	32	-0.80 (1.03)		
15-s COWA	Normal speech	63	0.16 (1.14)	9.69	<.005
	Dysarthria	30	-0.61 (1.07)		

Note. SDMT = Symbol Digit Modalities Test. VE = Visual Elevator. COWA = Controlled Oral Word Association.

For the following analyses, both MS and control data were analyzed in order to test the hypothesis that performance differences between MS patients and controls will be reduced when the impact of dysarthria on test performance is statistically controlled. In order to establish performance differences between MS participants and controls, univariate analysis of variance (ANOVA) tests compared the groups on performance on the SDMT, VE, and the COWA. The results revealed that MS participants performed significantly worse than the controls on the SDMT, $F(1, 122) = 19.26, p < .001$, the VE, $F(1, 120) = 6.00, p < .05$, and the standard COWA, $F(1, 121) = 6.60, p \leq .01$. However, the groups were not significantly different based on their performance on the 15-s COWA (see Table 5).

Next, regression analyses were completed for the SDMT, VE, and 15-s COWA (see Table 6). The

standard COWA was not analyzed here because it was not significantly associated with dysarthria in our earlier analyses. The test z -scores were entered as dependent variables, and two sets of regressions were completed. In one set of regressions, the Shipley total score and age (for the SDMT and VE only) were entered as the first step, the dysarthria rating was entered at the second step, and the group variable (MS vs. control) was entered at the third step. In the other regression set, the Shipley total score and age (for the SDMT and VE only) were entered at the first step, the group variable was entered at the second step, and the dysarthria rating was entered at the third step. For the SDMT, it was found that both the dysarthria rating and group variable remained significant regardless of which was entered first. However, although the group effect for the SDMT remained significant after the dysarthria rating was entered, the group effect was reduced by about 4% of the variance (from 10% to about 6% of variance accounted for). For the VE, the group variable was no longer significant when dysarthria was entered at Step 2, though the dysarthria variable remained significant regardless of whether it was entered at Step 2 or 3 of the regression. For the 15-s COWA, the group variable was not significant whether it was entered at Step 2 or 3, though the dysarthria variable remained significant.

DISCUSSION

Consistent with our hypothesis, impaired oral-motor speed was found to be more prevalent in our

TABLE 5
Group means: MS vs. controls

Z-score		N	M(SD)	F	p
SDMT	MS	97	-1.20 (1.31)	19.26	<.001
	Controls	27	0.00 (1.00)		
VE	MS	95	-0.85 (1.72)	6.00	<.05
	Controls	27	0.00 (1.00)		
60-s COWA	MS	96	-0.53 (0.93)	6.60	<.01
	Controls	27	0.00 (1.00)		
15-s COWA	MS	93	-0.09 (1.17)	0.12	ns
	Controls	27	0.00 (1.00)		

Note. SDMT = Symbol Digit Modalities Test. VE = Visual Elevator. COWA = Controlled Oral Word Association. MS = participants with multiple sclerosis.

TABLE 6
Regression analyses

	Regression	Step		Δr^2	ΔF	p
SDMT-Oral	1	1	Shipley total, age	.270	22.39	<.001
		2	Dysarthria rating	.080	14.73	<.001
		3	Group variable	.064	12.94	<.001
	2	1	Shipley total, age	.270	22.39	<.001
		2	Group variable	.101	19.18	<.001
		3	Dysarthria rating	.043	8.72	<.005
VE	1	1	Shipley total, age	.317	27.62	<.001
		2	Dysarthria rating	.053	9.86	<.01
		3	Group variable	.012	2.33	ns
	2	1	Shipley total, age	.317	27.62	<.001
		2	Group variable	.028	5.12	<.05
		3	Dysarthria rating	.037	6.92	$\leq .01$
15-s COWA	1	1	Shipley total	.145	20.03	<.001
		2	Dysarthria rating	.037	5.29	<.001
		3	Group variable	.002	0.25	ns
	2	1	Shipley total	.145	20.03	<.001
		2	Group variable	.000	0.17	ns
		3	Dysarthria rating	.039	5.49	<.05

Note. SDMT = Symbol Digit Modalities Test. VE = Visual Elevator. COWA = Controlled Oral Word Association.

MS participants than in our control participants. Also in agreement with our predictions, our MS participants as a whole performed more poorly on the cognitive tests (with the exception of the 15-s COWA) than did the control participants. Within the MS group, dysarthria was found to be significantly negatively associated with test performance on three tests requiring a speeded oral response measured in this study, as predicted. Participants' general intellectual abilities accounted for the bulk of the variance in performance on the cognitive tasks, as was expected. However, r^2 change indices indicated that dysarthria had a small to moderate effect and was associated with worse performance on the SDMT, VE, and 15-s COWA, even after controlling for these general abilities and age. When examined further, it was found that the group variable was no longer a significant predictor of VE performance if it was entered after the dysarthria rating. Additionally, the group effect for the SDMT was reduced by more than a third when the dysarthria rating was entered first in the regression. This finding suggests that the differences between the MS and control groups on the VE are not due to higher level cognitive dysfunction in the MS group, but are significantly impacted by oral-motor speed impairment. It also suggests that MS impairments on the SDMT, though not entirely accounted for by dysarthria, are inflated by MS patients' differential problems in this rudimentary motor domain. Surprisingly, the MS and control groups were not significantly different based on their scores on the 15-s COWA, though within the MS group, the participants with dysarthria scored significantly worse than the participants with normal speech.

These results have significant implications for both clinical and research applications of these measures. They suggest that when cognitive deficits are measured by the SDMT and VE, level of cognitive impairment may be overestimated in individuals who are experiencing dysarthria, and, indeed, with the VE, performance differences between MS and control groups may be solely due to oral-motor speed slowing in the MS group. It may be that, in our efforts to avoid motor impairment confounds due to writing task demands, we are introducing confounds due to oral response task demands.

Dysarthria was not found to be significantly associated with standard COWA performance. However, an examination of the first 15 s of the task revealed that dysarthria accounted for a significant amount of variance in task performance, while group status (MS vs. control) did not. Although the first 15 s of performance on the

COWA may be affected by motor speed impairment more than cognitive dysfunction, these effects may be largely washed out by the end of a 60-s trial. It may be that performance on the first portion of this task is more automatic and dependent on motor speed, while the latter portion is based on higher order executive functions involving verbal fluency. Though the first 15 s of the COWA are rarely used independently in a clinical setting, this finding offers an interesting clue as to different aspects of task demand.

As has been found previously, dysarthria in the present sample was not correlated with age. However, in contrast to previous findings, dysarthria was found to be significantly correlated with diagnosis duration and symptom duration and was not significantly correlated with a measure of general physical/neurological disability. Additionally, relatively fewer participants were judged to be experiencing dysarthria in the present study than in previous studies. This may be due to the measurement technique used (examiner ratings vs. speech measurements) or the sample characteristics. It is difficult to compare the present sample to the Darley et al. (1972) sample due to the fact that sample characteristics in the latter study were not reported in detail. However, compared to Hartelius et al. (2000a), our sample was less impaired overall. For example, our sample had been experiencing MS symptoms for approximately half the length of time of the participants in Hartelius et al., who were also significantly older than the participants in the present study, with a mean age of 66.6 years. Additionally, the majority of Hartelius et al.'s sample was diagnosed with a progressive course of MS, while the majority of the participants in the present study were diagnosed with a relapsing-remitting course, which is typically associated with less disability than are the progressive forms. These comparisons suggest that our sample represents a fairly mild manifestation of dysarthria and that our results might have been more dramatic in a more impaired population.

Limitations

There are a number of limitations to the conclusions that can be drawn from the current study. Chiefly, it is important for these results to be replicated using a more sophisticated measure of dysarthria. The method used to determine impaired speech in our study has potential for inaccuracy due to the relatively subjective nature of the ratings. Though the speech ratings were made prior to the administration of cognitive tasks, it is possible

that factors beyond speech quality, such as perception of overall disability, affected examiner ratings. However, the fact that EDSS scores were not found to be correlated with dysarthria ratings argues against this. Nonetheless, examiners' perceptions of cognitive disability during the interview when dysarthria ratings were made may have influenced these latter ratings. Future research using more valid measurements of oral-motor speed based on performance, such as the oral diadochokinesis tasks recommended in the MACFIMS (Benedict et al., 2002), may further elucidate this question. Additionally, the use of this method would provide more statistical power to the analyses because they would provide a continuous, rather than dichotomous, measure of oral-motor speed.

Another area for future research to address would be examining other widely used tests in the MS literature requiring speeded oral responses, such as the PASAT, which may be affected by dysarthria. As the question of the impact of dysarthria on testing is further explored, it will be important to assess the extent of its association with a variety of tests in order to obtain a more accurate picture of cognitive impairment in neurological patients experiencing dysarthria.

This report was unable to address whether a more generalized motor slowing including dysarthria and manual motor impairment influenced the MS patients' performance on the cognitive tests. Future research should address this question as it applies to the correlation between dysarthria, motor tasks, and performance on neuropsychological tests.

The results of this study are limited in their generalizability in that only MS patients were included. Dysarthria is an important clinical problem in Parkinson's disease, Huntington's disease, and stroke as well as MS. As such, it will be important to examine whether our results apply to other neurological populations as well. Additionally, as described previously, the majority of our participants had relapsing–remitting MS. Future research might examine whether these results are generalizable to more impaired MS populations.

CONCLUSIONS

Our data show that dysarthria, although not as prevalent in this sample as in some previously reported samples (Hartelius et al., 2000a), is significantly negatively associated with performance on two tests requiring a speeded oral response and on a portion of a third. Additionally, our results show

that when dysarthria is controlled for, no significant performance differences emerge on the VE between MS and control participants, and group differences are reduced by a little more than a third on the SDMT. Future research could examine whether the poorer performance of MS patients than of controls on other higher level cognitive tasks that require rapid oral responses is due, at least in part, to patients' slowed speech. If this is the case, it would indicate that tasks requiring a speeded verbal response may overestimate some patients' cognitive impairment, a finding with significant implications for assessing cognitive functioning in MS patients, as well as other neurological populations.

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