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Accuracy monitoring and task demand evaluation in aphasia

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Abstract

This study investigated possible underlying sources of resource allocation deficits in aphasia. The ability to rate one's own accuracy, as well as to evaluate task difficulty, were examined in aphasic individuals and normal, control subjects as they performed a lexical decision listening task alone and in competition with two distractor tasks. The aphasic subjects were as precise as control subjects in monitoring the accuracy of their lexical decisions. Despite greater error rates and slower reaction times, aphasic individuals' perceptions of task difficulty did not differ significantly from those of the control subjects. Therefore, resource allocation deficits in aphasia may reflect inadequate evaluation of task demands rather than poor self-monitoring of accuracy.

Introduction

Over the past 15 years there has been growing interest in the integrity of resource capacity and allocation in aphasia (Cohen *et al.* 1981, Haarmann *et al.* 1996, Robin and Rizzo 1989). This interest has arisen from the proposition, as advanced by McNeil and colleagues (McNeil 1982, 1983, McNeil and Kimelman 1986, McNeil *et al.* 1991), that aphasic performance deficits may reflect attention or resource allocation rather than linguistic impairments. Several studies support this contention, indicating that not only do aphasic individuals display decrements of resource capacity or its allocation, but also that these decrements may negatively affect both their receptive and expressive language skills (Arvedson and McNeil 1986, Murray 1994, Murray *et al.* 1995, 1996, Tseng *et al.* 1993). However, the sources of resource allocation impairments in aphasia have not yet been determined.

Limited capacity theories of resource allocation specify the existence of one or more pools of attentional or processing resources[1] that are quantitatively limited but can be flexibly and simultaneously distributed to one or more activities (Kahneman 1973, Navon and Gopher 1979, Wickens 1984, 1989). The amount of resources invested in a specific cognitive task is dependent on the task demands or the processing resources necessary to ensure successful completion of that task. When subjects complete concurrent or dual tasks, performance decrements for one

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or both tasks are predicted only if there is task competition for the same limited-capacity resources; the more tasks share resources, the greater the competition, and thus interference expected during dual-task performance. Further interference may occur if these limited, shared resources are inefficiently or inappropriately distributed between competing tasks.

Aphasic individuals may fail to allocate sufficient effort or attentional resources because they have difficulty monitoring their accuracy. For example, LaPointe and Erickson (1991) interviewed aphasic subjects about their perceptions of task difficulty and their accuracy in performing the tasks employed in a dual-task paradigm. The paradigm required subjects to listen to word lists and identify target words while sorting cards from the Wisconsin Card Sorting Test (Grant and Berg 1981). Whereas the aphasic subjects reported that the dual-task condition was more difficult than performing the listening task by itself, they failed to acknowledge their decreased accuracy during the more difficult condition. Likewise, there have been several reports of aphasic patients demonstrating lack of awareness of their own speech–language errors (Kinsbourne and Warrington 1963, Lebrun 1987, Maher *et al.* 1994).

Another possibility, as suggested by Clark and Robin (1995), is that resource allocation deficits following brain damage reflect poor evaluation of task demands. Given that perceptions of task difficulty or 'sense of effort' have been equated with task resource requirements, it is expected that increased effort will be reported as task complexity, and thus task demands are increased (Gopher and Braune 1984, O'Donnell and Eggemeier 1986, Yeh and Wickens 1988). Based upon this premise, Clark and Robin (1995) required brain-damaged subjects to rate their own sense of effort while completing reading tasks that required lexical decisions under non-degraded- and degraded-image conditions. They found that brain-damaged individuals and non-brain-damaged control subjects reported similar sense of effort ratings, despite the brain-damaged subjects' slower reaction times. Furthermore, the brain-damaged subjects showed decreased sensitivity to task complexity; for example, only 50% of the brain-damaged subjects reported higher sense of effort for degraded versus non-degraded conditions.

The purpose of the present study was to determine whether difficulty in monitoring one's own accuracy, difficulty in evaluating the resource demands of a particular task, or both, are associated with the resource allocation deficits of individuals with aphasia. Aphasic individuals and normal, control subjects rated their accuracy and the difficulty of a lexical decision listening task performed alone and in competition with two distractor tasks. Task demands, and possibly perceptions of accuracy and task difficulty, were manipulated in two ways. First, a distractor task was introduced: in comparison to completing the lexical decision task by itself, focused attention conditions required resistance to distraction and selective dedication of limited resources to the lexical decision task, whereas divided attention conditions required efficient distribution of limited resources to both the lexical decision and distractor tasks (Kahneman 1973). Secondly, processing similarities between the lexical decision and distractor tasks were increased: the degree of task competition for shared resources was predicted to be greater between the lexical decision task and a verbal distractor task than between the lexical decision task and a non-verbal distractor task (Tsang and Wickens 1988, or both tasks are predicted only if there is task competition for the same limited-capacity resources; the more tasks share resources, the greater the competition, and thus interference expected during dual-task performance. Further interference may occur if these limited, shared resources are inefficiently or inappropriately distributed between competing tasks.

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1. Do aphasic and control individuals differ in their perceptions of self-accuracy? Does the relationship between perceived and actual accuracy differ for aphasic and control individuals?
2. Do aphasic and control individuals differ in their perceptions of task difficulty? Does the relationship between perceived task difficulty and reaction time or accuracy differ for aphasic and control individuals?

Method

Subjects

Participants included 16 subjects with stroke-induced aphasia and eight control subjects matched for age ($t(22) = 0{\cdot}064, p = 0{\cdot}950$), education ($t(22) = 1{\cdot}083, p = 0{\cdot}291$), and estimated IQ (Barona *et al.* 1984) ($t(22) = 1{\cdot}558, p = 0{\cdot}133$). Table 1 displays the groups' characteristics. Based on subject interviews and review of aphasic subjects' medical records, the first author determined that all subjects had negative histories for head trauma; alcohol or substance abuse; pre-existing communication, memory, neurological, or psychiatric problems. As determined by pure-tone air-conduction hearing screening, all subjects had hearing thresholds (aided or unaided) of 35 db HL or better at 0·5, 1·0 and 2·0 kHz in at least one ear. Additionally, subjects were required to pass the speech discrimination subtest of the Arizona Battery for Communication Disorders of Dementia (Bayles and Tomoeda 1991), and a visual discrimination (line-drawing matching task) screening test.

Aphasic subjects had suffered a left hemisphere stroke (as documented by CT or MRI scan report), were minimally 6 months post-stroke, and were initially diagnosed with aphasia by licensed speech–language pathologists. The first author administered the Aphasia Diagnostic Profiles (ADP) (Helm-Estabrooks 1992) to confirm the diagnosis of aphasia and to assess each subject's current language skills (see Table 1). To avoid confounding apraxic errors on computer key responses, all aphasic subjects were given the Limb Apraxia subtest of the Apraxia Battery for Adults (Dabul 1979); all subjects achieved a perfect score and no instances of searching behaviour were observed.

Procedures

Subjects completed a lexical decision task alone and in competition with a non-verbal (tone discrimination) or verbal (semantic judgement) distractor task. Specific conditions included: (a) isolation—subjects completed the lexical decision task without distraction, (b) focused attention—lexical and distractor task stimuli were presented simultaneously but subjects completed only the lexical decision task, and (c) divided attention—lexical and distractor task stimuli were presented simultaneously and subjects attended and responded first to the distractor task and second to the lexical decision task. Order of distractor task type was counter-balanced with subjects completing the lexical decision task in competition with the non-verbal versus verbal distractor on separate days (average length of time between testing sessions was 7 days with a range of 1–15 days). Conditions were completed in the order presented above, which reflected our hypothesized hierarchy of difficulty. Condition order was restricted so as to circumvent confusion over task and condition requirements.

Table 1. Group characteristics

Group	Age (years)	Education (years)	Estimated pre-morbid IQ	Post-stroke (months)	ADP Standard Scores: Aphasia severity†	ADP Standard Scores: Auditory comprehension‡
Aphasic (n = 16)						
M	63·00	13·88	115·63	26·63	113·75	13·63
SD	13·20	3·16	7·67	21·56	6·42	1·75
(*Range*)	(36–79)	(8–20)	(104–126)	(6–75)	(103–124)	(11–17)
Control (n = 8)						
M	62·63	15·25	120·30			
SD	14·24	2·38	4·99			
(*Range*)	(39–76)	(12–19)	(107–126)			

ADP = Aphasia Diagnostic Profiles (Helm-Estabrooks 1992).
† Aphasia Severity Standard Score with *M* = 100, SD = 15, based on standardization sample of 222 stroke patients.
‡ Auditory Comprehension Standard Score with *M* = 10, SD = 3, based on a sample of 140 right-handed patients with left-hemisphere stroke.

Stimuli for the lexical decision task consisted of 10 real words and 10 non-words randomized and then recorded by a male speaker. Across lists (a different list for each condition described above), real words were matched in terms of syllable length, part of speech, and frequency (Kucera and Francis 1982). Pronounceable non-words were derived by changing one letter in a real word. The non-verbal distractor task required the identification of 10 high (2 kHz) and 10 low (0·5 kHz) tones presented in a random order. The verbal distractor task required subjects to make semantic judgements about 10 in-class exemplars (Battig and Montague 1969) and 10 out-of-class concrete nouns. In- and out-of-class stimuli were randomized and then recorded by a female speaker; different stimuli lists were used for the focused attention and divided attention conditions (target categories—'tools' and 'body parts', respectively).

PsyScope software (Cohen *et al.* 1993) was used to present stimuli (free field presentation), and to record accuracy and reaction times. Subjects were instructed to respond as quickly and as accurately as possible using a YES/NO (for lexical decision and verbal distractor tasks) or HIGH/LOW (for non-verbal distractor task) computer key-press response. A more detailed description of tasks, stimuli, and procedures can be found in Murray (1994).

At the completion of each condition, subjects rated their accuracy and task difficulty by marking a 100 mm visual analogue scale. Reliability has been found to be higher for ratings at the end of each condition versus at the end of each trial (Yeh and Wickens 1988). Anchors for the perceived accuracy scale were 'All Wrong' and 'All Correct', and anchors for the perceived task difficulty scale were 'Difficult' and 'Easy'. Both written and spoken instructions were provided. Subjects were allowed to see their ratings of previous conditions, a technique recommended to reduce variance around change scores (Guyatt *et al.* 1985). Numerical values for the ratings were determined by measuring from left to right for perceived accuracy and right to left for perceived task difficulty. Because the lexical decision task was completed in isolation on both testing days (once prior to completing conditions with the competing non-verbal distractor task and once prior to completing conditions with the competing verbal distractor task), two sets of visual analogue ratings were available to calculate test–retest reliability. Reliability correlation coefficients for perceived accuracy and task difficulty ratings, respectively, were $r = 0.853, p < 0.001$ and $r = 0.911, p < 0.001$ for the aphasic group, and $r = 0.772$, $p < 0.05$ and $r = 0.813, p < 0.05$ for the control group. All coefficients exceeded Cohen and Cohen's (1982) 0·75 criterion level for acceptable reliability.

Each of the dependent measures (perceived accuracy, perceived task difficulty, accuracy, RT) was analyzed separately using repeated-measures ANOVAs with group (aphasic, control) as the between-subjects factor and condition (isolation, focused attention, divided attention), and distractor type (non-verbal, verbal) as within-subjects factors; Tukey *post-hoc* pairwise comparisons ($\alpha < 0.01$) were completed as needed. To meet the ANOVA assumption of homogeneous variances, accuracy data were arcsine transformed and reaction time data were logarithmically transformed (Keppel 1991). The relationship between actual and perceived performance was examined via Pearson product moment correlations and via ratios (i.e. change in actual performance[2] to change in perceived performance across conditions or distractor types). Prior to calculating any correlations, scatter diagrams, residual means, and residual plots were examined (Verran and Ferketich 1987). Overall, the data adhered to the linear model assumptions with few observed outliers. However, for the few cases in which outlying values were found to be influential, correlations calculated with and without extreme data points are reported.

Results

Perceived accuracy

Table 2 provides group means and standard deviations for all dependent measures. Analysis of the perceived accuracy data revealed that all main effects, and the condition by group and condition by distractor interactions were significant (see Table 3). The perceived accuracies of the control group were significantly greater than those of the aphasic group except during the isolation condition in which there were no group differences. For both subject groups, perceived accuracies were higher when: (a) the lexical decision task was performed by itself (i.e. isolation condition) versus in competition with a distractor task (i.e. focused and divided attention conditions), and (b) the lexical decision task was performed in competition with the non-verbal versus verbal distractor task.[3]

The results of the accuracy analysis were similar to those of the perceived

[2] The ratio of change in reaction time to change in perceived task difficulty was adjusted so that group differences in speed of responding were addressed. That is, for each subject a proportionalized reaction time difference score was calculated in which the change in reaction time (across conditions or distractor types) was divided by the subject's reaction time for the non-verbal distractor task in isolation. This proportionalized difference score was then entered as the numerator of the reaction time/perceived task difficulty ratio.

[3] It should be noted that analysis of the condition by distractor interaction for all data sets (perceived accuracy, accuracy, perceived task difficulty, and reaction time data) indicated that there was no significant difference between ratings or performances of the two isolation conditions (one completed prior to focused and divided attention conditions in which the distractor was non-verbal and one completed prior to focused and divided attention conditions in which the distractor was verbal). This lack of significance was expected given that, during isolation conditions, the lexical decision task was presented without competing stimuli.

Table 2. Group means, standard deviations, and ranges for perceived accuracy (mm), perceived difficulty (mm), accuracy (%), and reaction time (ms) data

			Non-verbal distractor			Verbal distractor		
Data	Group		Isolation	Focused attention	Divided attention	Isolation	Focused attention	Divided attention
Perceived accuracy	Aphasic	*M*	80·75	68·31	59·31	75·25	40·25	21·69
		SD	13·92	17·86	17·64	14·72	16·43	13·05
		(*Range*)	(54–99)	(35–98)	(27–83)	(54–98)	(9–67)	(4–50)
	Control	*M*	84·13	81·75	80·63	77·50	59·00	36·88
		SD	9·95	9·36	10·35	10·18	10·28	13·99
		(*Range*)	(65–98)	(68–97)	(62–94)	(59–93	(47–81)	(19–58)
Perceived difficulty	Aphasic	*M*	20·94	27·94	39·63	26·13	58·38	76·50
		SD	15·73	14·14	17·88	17·18	17·86	17·06
		(*Range*)	(1–47)	(3–53)	(7–70)	(7–53)	(20–86)	(36–97)
	Control	*M*	19·38	27·88	32·25	21·88	56·38	82·00
		SD	10·07	13·84	13·58	13·11	16·92	11·60
		(*Range*)	(4–32)	(5–46)	(10–52)	(6–43)	(36–82)	(66–97)
Accuracy	Aphasic	*M*	92·8	82·2	78·8	89·2	60·3	55·6
		SD	6·0	8·8	8·9	5·4	9·1	8·6
		(*Range*)	(80–100)	(65–95)	(60–95)	(80–100)	(50–80)	(35–75)
	Control	*M*	95·0	89·4	91·9	93·8	75·9	68·7
		SD	4·6	4·2	3·7	5·2	5·5	4·7
		(*Range*)	(85–100)	(85–95)	(85–95)	(85–100)	(70–85)	(65–80)
RT†	Aphasic	*M*	1632	1738	3686	1488	1905	4636
		SD	367	397	853	242	556	1180
		(*Range*)	(1149–2347)	(1159–2299)	(2029–5249)	(1136–2069)	(1419–2432)	(3201–7544)
	Control	*M*	1339	1366	2427	1292	1331	3241
		SD	107	240	427	235	139	551
		(*Range*)	(1088–1408)	(1091–1860)	(1782–3107)	(904–1590)	(1059–1485)	(2052–3769)

† Group means and standard deviations reflect RTs from correct responses only.

Table 3. Summary of statistical analyses

Source†	Dependent variable	SS	d.f.	MS	*F*	Post-hoc comparisons
Group	PA	4908·75	1	4908·75	9·29*	C > A
	PD	82·35	1	82·35	0·10	NS
	AA	0·80	1	0·80	12·81*	C > A
	RT	0·45	1	0·5	18·01*	C < A
Condition	PA	19057·13	2	9528·57	68·97**	1 > 2 > 3
	PD	27182·63	2	13591·32	117·46**	1 < 2 < 3
	AA	3·54	2	1·77	146·50**	1 > 2 = 3
	RT	3·60	2	1·80	548·00**	1 = 2 < 3
Condition × group	PA	1491·05	2	745·52	5·40*	For 1: C = A For 2, 3: C > A
	PD	24·63	2	12·32	0·11	NS
	AA	0·08	2	0·04	3·21*	For 1: C = A For 2, 3: C > A
	RT	0·05	2	0·02	7·02*	For C: 1 = 2 < 3 For A: 1 < 2 < 3
Distractor	PA	18512·09	1	18512·09	81·70**	NV > V
	PD	20842·01	1	20842·01	102·70**	NV < V
	AA	1·97	1	1·97	97·09**	NV > V
	RT	0·03	1	0·03	5·154*	NV < V
Condition × distractor‡	PA	6423·42	2	3211·71	31·99**	For 1: NV = V For NV: 1 > 2 = 3 For V: 1 > 2 > 3
	PD	8583·88	2	4291·94	44·89**	For 1: NV = V For NV: 1 < 3 For V: 1 < 2 < 3
	AA	0·46	2	0·23	23·20**	For 1: NV = V
	RT	0·11	2	0·06	11·24**	For 1, 2: NV = V

PA = Perceived accuracy; PD = perceived difficulty; AA = actual accuracy; RT = reaction time; C = control group; A = aphasic group; NS = no significant effect; 1 = isolation condition; 2 = focused attention condition; 3 = divided attention condition; NV = non-verbal distractor; V = verbal distractor.

* $p < 0{\cdot}05$; ** $p < 0{\cdot}001$.

† Interaction effects not listed in this table were not significant for any data set.

‡ Lack of significance was expected during condition 1 (isolation) given that, during this condition, the lexical decision task was presented without competing stimuli.

accuracy analysis: all main effects, as well as the interaction effects of condition by group and condition by distractor, were significant (see Table 3). Accuracy and perceived accuracy *post-hoc* comparisons also revealed similar findings. The control group achieved greater accuracy than the aphasic group during all conditions except the isolation condition, for which no group differences were observed. Furthermore both groups demonstrated greater performance accuracy during the isolation condition compared to focused and divided attention conditions, and during competing task conditions in which the distractor was nonverbal versus verbal.

The positive relation between perceived and actual accuracy was confirmed by consistently positive correlations and ratios (change in accuracy to change in

Table 4. Pearson product moment correlations between perceived and achieved accuracies (PA/AA), between perceived task difficulty and reaction times (PD/RT), and between perceived task difficulty and achieved accuracies (PD/AA)

		Condition			Distractor	
Relationship	Group	Isolation	Focused attention	Divided attention	Non-verbal	Verbal
PA/AA	Aphasic	0·434*	0·597**	0·736**	0·474*	0·754**
	Control	0·522*	0·854**	0·881**	0·437*	0·837**
PD/RT	Aphasic	0·136	0·094†	0·324	0·447*	0·610**
	Control	0·541*	−0·108	0·647*	0·560*‡	0·711**
PD/AA	Aphasic	−0·339	−0·638**	−0·694**	−0·489**	−0·699**
	Control	−0·212	−0·524*	−0·933**	−0·457*§	−0·828**

* $p < 0{\cdot}05$; ** $p < 0{\cdot}001$.
† After removing the influence of one extreme outlier; computing with the outlier, $r = 0{\cdot}302$.
‡ After removing the influence of one extreme outlier; computing with the outlier, $r = 0{\cdot}318$.
§ After removing the influence of one extreme outlier; computing with the outlier, $r = -0{\cdot}267$.

perceived accuracy) (see Tables 4 and 5, respectively). A prevalence of small ratios (i.e. ratio < 1·00) indicated that small changes in accuracy were rated as large changes in perceived accuracy, and suggested that both groups tended to underestimate their abilities; this underestimation may reflect increased test anxiety or decreased self-confidence that reportedly accompany ageing in general (Ryan 1995). Ratio magnitudes of the two groups were also similar (i.e. 95 % confidence intervals of the aphasic and control groups consistently overlapped). Therefore, the aphasic subjects were as precise as control subjects in monitoring the accuracy of their lexical decisions across conditions and distractor types.

Perceived task difficulty

For the analysis of perceived task difficulty, all main effects except group and the condition by distractor interaction were significant (see Table 3). These results indicated that perceptions of task difficulty were similar between aphasic and control groups. For both groups, perceptions of task difficulty tended to parallel manipulations of task difficulty: (a) competing task conditions were perceived as more difficult than isolation conditions, and (b) completing the lexical task in competition with the verbal distractor was perceived as more difficult than completing the lexical task in competition with the non-verbal distractor.

In contrast to these findings for perceived task difficulty, analysis of reaction time demonstrated that all main effects and both the condition by group and condition by distractor interactions were significant (see Table 3). The control group made lexical decisions more quickly than the aphasic group, regardless of condition or distractor type. The two groups also responded differently to condition manipulations: whereas the aphasic group's reaction times progressively increased as condition complexity increased, the control group's reaction times significantly increased during divided attention conditions only (i.e. no significant difference between reaction times for isolation conditions compared to focused attention conditions). For both groups a differential effect for distractor type was found only

Table 5. **Group mean ratios (and 95 % confidence intervals) of change in achieved performance to change in perceived performance across conditions and distractor types**

Ratio	Group	Isolation—divided attention: Non-verbal distractor	Isolation—divided attention: Verbal distractor	Non-verbal distractor—verbal distractor: Isolation	Non-verbal distractor—verbal distractor: Focused attention	Non-verbal distractor—verbal distractor: Divided attention
Achieved accuracy: Perceived accuracy	Aphasic	0·657	0·699	0·944	0·657	0·778
		(0·335)	(0·181)	(1·109)	(0·994)	(0·322)
	Control	0·334	0·696	1·210	0·614	0·622
		(0·519)	(0·166)	(1·786)	(0·174)	(0·160)
Reaction time: Perceived task difficulty	Aphasic	0·176	0·112*	0·048	0·059*	0·089
		(0·099)	(0·045)	(0·070)	(0·050)	(0·071)
	Control	0·094	0·050	0·006	0·003	0·020
		(0·116)	(0·012)	(0·018)	(0·005)	(0·009)
Achieved accuracy: Perceived task difficulty	Aphasic	−0·939	−0·776*	0·319	−1·04	−0·792
		(0·784)	(0·242)	(0·881)	(0·654)	(0·317)
	Control	−0·341	−0·423	−0·276	−0·426	−0·494
		(0·443)	(0·045)	(0·490)	(0·169)	(0·103)

* Indicates that the aphasic group's 95 % confidence interval did not overlap with that of the control group.

during divided attention conditions; for these conditions, reaction times were longer when completing the lexical decision task in competition with the verbal versus the non-verbal distractor.

Therefore, despite longer reaction times, the aphasic group reported similar, or sometimes lower, perceptions of task difficulty than the control group (see Table 2). For example, during the divided attention condition in which the distractor was verbal, ratings of task difficulty for six aphasic subjects (group mean = 76·50) fell below 66 mm, the lowest task difficulty rating of the control group (group mean = 82·00). Correlational and ratio data also highlighted the discrepancy between the aphasic group's reaction times and perceptions of task difficulty. First, the aphasic group's correlations for the isolation ($r = 0{\cdot}136$), focused attention ($r = 0{\cdot}094$), and divided attention ($r = 0{\cdot}324$) conditions failed to reach significance (see Table 4). In contrast, the control group's correlations for both the isolation ($r = 0{\cdot}541$) and divided attention ($r = 0{\cdot}647$) conditions were significant at the $p < 0{\cdot}05$ level. Secondly, Table 5 shows that ratios (change in reaction time to change in perceived task difficulty) for the aphasic group tended to be larger than those of the control group; in fact the control group's 95% confidence interval fell below that of the aphasic group for one across-condition ratio (control ratio = 0·05, aphasic ratio = 0·11) and one across-distractor ratio (control ratio = 0·003, aphasic ratio = 0·059). These findings indicate that aphasic subjects did not change their ratings of task difficulty, despite their large increases in reaction time.

To determine whether or not aphasic subjects placed greater emphasis on accuracy than on speed, the relationship between accuracy and perceived task difficulty was also explored. Generally, correlational and ratio data (see Tables 4 and 5, respectively) indicated that both groups demonstrated a negative relationship between their accuracy and perceptions of task difficulty; that is, the accuracy of most subjects decreased as their perceptions of task difficulty increased. However, aphasic and control groups showed some differences in the relationship between these two variables. First, the statistical findings for accuracy and perceived task difficulty data differed in terms of group effects: (a) for perceived task difficulty, there were no group differences, regardless of condition or distractor type; and (b) for accuracy, there were no group differences during isolation conditions, but during competing task conditions the control group responded more accurately than the aphasic group (see Table 3). Second, there was a tendency for the magnitude of the aphasic group's ratios (change in accuracy to change in perceived task difficulty) to be larger than that of the control group. Although only one of the ratio comparisons (control ratio = −0·423, aphasic ratio = −0·776) reached significance (i.e. the control group's 95% confidence interval fell below that of the aphasic group), it was also noted that 30% of the aphasic subjects' ratios (24/80) exceeded a magnitude of /1/ compared to 5% of the control subjects' ratios (2/40). Therefore, larger changes in accuracy corresponded to smaller changes in perceived task difficulty for the aphasic group in comparison to the control group.

Discussion

The purpose of this study was to explore two hypotheses about the nature of resource allocation impairments in aphasia. Specifically, we examined whether failure to monitor accuracy, difficulty in evaluating task demands, or both, were related to the resource allocation deficits of individuals with aphasia. The results indicated that these aphasic individuals were as skilled as the control subjects at monitoring the accuracy of their lexical decisions for a variety of listening conditions and distractor types. That is, aphasic and control groups demonstrated a positive relationship between accuracy and perceived accuracy ratings. These findings contrast with those of LaPointe and Erickson (1991), who found that their aphasic subjects had difficulty in accurately assessing their performance. These conflicting results may be associated with methodological differences. For example, LaPointe and Erickson reported that subjects were interviewed following performance of experimental tasks, but provided few details regarding how these interviews were conducted. In contrast, we required subjects to mark a visual analogue scale which may have encouraged more objective, specific, or reliable ratings of self-accuracy than an open-ended question/answer format.

Like Clark and Robin (1995), we found that aphasic individuals showed an inconsistent relationship between perceived task difficulty, reaction time, and task complexity. Furthermore, we found differences between aphasic and control groups in terms of the relationship between perceived task difficulty, accuracy, and task complexity. Given that the aphasic group completed the lexical decision task less accurately and more slowly than the control group during complex conditions (i.e. focused and divided attention conditions), one might hypothesize that the aphasic group's perceptions of task difficulty would exceed those of the control group. However, the perceived task difficulty ratings of the aphasic and control groups failed to differ significantly. Correlational and ratio data also indicated some group differences in the relationship between perceived task difficulty and achieved performance (i.e. accuracy and reaction time). If perception of task difficulty reflects the amount of resources invested in task completion (Derrick 1988, Yeh and Wickens 1988), then these present findings suggest that aphasic individuals' poor performances during complex conditions were associated, at least in part, with failure to appreciate and, consequently, to satisfy task demands.

The findings of Tseng and colleagues (1993) also support the contention that resource allocation deficits in aphasia are associated with poor evaluation of task demands. Tseng *et al.* examined the ability of aphasic and normal individuals to make use of target occurrence probability information during a target-detection dual task (i.e. concurrent phoneme monitoring and semantic judgement). For example, improved semantic judgement performance was expected for conditions in which semantic targets occurred more frequently than phonemic targets; that is, in order to optimize accuracy, greater effort or more resources should be dedicated to the semantic as opposed to the phonemic task. Whereas normal individuals displayed this predicted performance pattern, the aphasic individuals failed to show a probability effect. Therefore, the aphasic group failed to utilize the probability information that was indicative of task demands.

The results of the present study indicate that the resource allocation deficits of aphasic individuals may be reflective of inadequate evaluation of task or resource demands rather than inadequate monitoring of one's own accuracy. However, these findings must be regarded as preliminary due to the following caveats. First, given the small size of our groups, the lack of group differences in terms of perceived task difficulty may reflect insufficient statistical power as opposed to aphasic individuals' difficulty in evaluating task demands. For example, the power estimate of our ability to detect a large effect size (i.e. one standard deviation between the means for the aphasic and control groups) is only approximately 0·68 for $\alpha = 0{\cdot}05$; this power estimate drops to an even more unacceptable level of less than 0·35 if we had wanted to detect a medium effect size of one-half of a standard deviation (Goodwin 1983). Thus, although our findings support those of Clark and Robin (1995), a replication of this study with larger subject groups is necessary to validate our results and conclusions.

Second, workload research with neurologically intact individuals has identified several sources of dissociation between performance and subjective measures of task difficulty (Derrick 1988, Vidulich and Wickens 1986). For example, when non-brain-damaged individuals perceive a large discrepancy between their actual performance and the objective criterion (e.g. 100% accuracy), they may become discouraged, invest fewer resources, and consequently report decreased sense of effort (Yeh and Wickens 1988). Therefore, the dissociation between our aphasic subjects' reaction times and perceptions of task difficulty may be a manifestation of some unspecified motivational factor rather than inadequate evaluation of the demands of a particular task. Future studies should incorporate a variety of subjective experience scales (e.g. task difficulty, stress level, incentive/motivation), physiological correlates of sense of effort (e.g. P300, heart rate), and rating paradigms (e.g. rate perceived task difficulty before and after task completion; require aphasic individuals to rate their own perceptions of task difficulty as well as predict non-brain-damaged individuals' perceptions of task difficulty). These experimental manipulations would not only improve the reliability and validity of measurement techniques, but would also characterize further factors associated with resource allocation deficits in aphasia.

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