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Effects of visual-manual tracking under dual-task conditions on auditory language comprehension and story retelling in persons with aphasia

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Background: Two recent studies (McNeil et al., 2004, 2005) evaluated non-brain-injured (N-BI) elderly persons' dual-task performance on a story retell procedure (SRP) and a visual-manual line-tracking task. Results of both studies demonstrated a unidirectional cost whereby the difficulty of the language task had an effect on tracking performance; however, the difficulty of the tracking task had no effect on language comprehension as indexed by story retelling.
Aims: The specific aim of this investigation was to assess the effects of performing a concurrent visual-manual tracking task on the comprehension of stories in persons with aphasia (PWA).
Methods & Procedures: The current study evaluated the performance trading in these tasks in PWA using similar dual-task procedures as those employed in the McNeil et al (2004, 2005) studies. Specifically, two tracking difficulty levels were used to assess concurrent costs under a single difficulty level of the SRP.
Outcomes & Results: The results of this study replicate, in PWA, the null effect of tracking difficulty on story retell performance that was found in the two earlier studies in N-BI elderly persons. Contrary to predictions, there was no significant effect of tracking difficulty on story retell performance. There was also no significant difference between story comprehension or visual manual-tracking tasks performed alone or in the competing conditions.
Conclusions: The results of this study do not support the hypothesis that a deficit in allocating processing resources in PWA would result in a concurrent cost of tracking difficulty on story comprehension. The results are discussed relative to the limitations of the story retell procedure for indexing potential dual-task effects and relative to the possible structure of the shared cognitive architecture used in these specific dual-tasks.

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Attentional impairments secondary to brain damage have been proposed as part or all of the underlying mechanisms for the linguistic impairments that characterise aphasia (Clark & Robin, 1995; Granier, Robin, Shapiro, Peach, & Zimba, 2000; McNeil, Odell, & Tseng, 1991; Murray, Holland, & Beeson, 1997a, 1997b; Tseng, McNeil, & Milenkovic, 1993). Deficits in the control of attention have also motivated the development of a tool for quantifying the difficulty that non-brain-injured (N-BI) listeners have understanding the language production of persons with varying amounts of aphasia (McNeil, Doyle, Hula, Rubinsky, Fossett, & Matthews, 2004). In that study, McNeil and colleagues found a significant decrement in the visual-manual tracking accuracy of N-BI older individuals during concurrent listening to the connected language of a person with moderate, compared to mild, aphasia. Contrary to predictions, no performance costs were observed on the listening tasks across any of the three tracking difficulty levels. The authors reasoned that one possible explanation for the lack of performance cost on listening was that the tracking tasks were insufficiently challenging.

A replication of the McNeil et al. (2004) study using a more difficult tracking task paired with the same story difficulty levels that demonstrated an effect on tracking performance found the same unidirectional cost of listening difficulty on tracking accuracy. Given the volume and the consistency of evidence that persons with aphasia (PWA) have deficits with divided attention tasks that involve language processing, compared to N-BI elderly persons, we predicted that tracking task difficulty manipulation, which did not affect story comprehension and retell in N-BI elderly individuals in prior studies, would show an effect in this population. We hypothesised that the difficulty of a concurrent visual-manual tracking task would adversely affect story comprehension and retell in PWA, thereby affecting a reciprocal cost between these two tasks in this population.

METHOD

Participants

A total of 16 pre-morbidly right-handed individuals with aphasia participated in the study. Nine were male and seven were female. Their age ranged from 44 to 86 years, with mean of 57.3 and standard deviation of 12.2. All participants had sustained a single, left hemisphere lesion as confirmed by medical record documentation, and demonstrated language performance consistent with the definition of aphasia of McNeil and Pratt (2001). All participants met the following additional selection criteria: passing a pure tone hearing screening at 35 dB HL in at least one ear at 0.5, 1, and 3 KHz; word recognition scores of at least 51% accuracy at 50dB HL in at least one ear on the Picture Identification Task (Wilson & Antablin, 1980); 20/80 vision or better (with correction if necessary) measured with the reduced Snellen chart; performance > 5th percentile for left-hemisphere brain-damaged participants on the 55-item Revised Token Test (RTT) (Arvedson, McNeil, & West, 1986); performance > 20th percentile for individuals with left hemisphere damage on the Two-Item Shortened Porch Index of Communicative Ability (SPICA) (DiSimoni, Keith, & Darley, 1980); performance within 2 SD of normal older adults on the delayed/immediate recall ratio of the Story Retelling Test of the Arizona Battery for Communication Disorders in Dementia (ABCD) (Bayles & Tomoeda, 1993; see also Bayles, Boone, Tomoeda, Slauson, & Kaszniak, 1989); and a minimum of 12 years of education. Table 1 displays individual demographic information and language performance data for each participant.

Stimuli and apparatus

The stimuli for the story retell procedure (SRP) consisted of 12 stories originally derived from the Discourse Comprehension Test (Brookshire & Nicholas, 1997) and recorded by a male speaker. Participants with aphasia listened to the stories and were then instructed to retell them as completely as possible. Participants' retells were audio recorded and the number of information units contained in each was determined offline by one of two scorers. The dependent variable used for this task was the %IUs retold. Both scorers had previously demonstrated>85% point-to-point reliability on scoring the SRP. The description of the story forms and the psychometric characteristics of the SRP have been described previously by McNeil, Doyle, Fossett, Park, and Goda (2001).

The stimuli for the visual-manual tracking task have also been previously described (McNeil et al., 2004). In each tracking condition, the computer monitor displayed an unpredictable varying line that scrolled across the screen from left to right. Participants were required to use a joystick with their non-dominant hand to keep a circle and crosshairs centred on the line. The dependent variable for tracking performance was root mean square (RMS) tracking error. There were two tracking

TABLE 1
Participant demographic and clinical characteristics

Subject	*Gender*	*Age*	*MPO*	*55-item RTT[1] %ile*	*SPICA[2] %ile*	*ABCD[3] story recall delayed/ immediate ratio*	*Lesion site (all left)*	*Lesion type[4]*
1	M	53	37	53	72	0.86	unspecified left	1
2	M	51	9	6	69	1.08	temporoparietal	2
3	M	86	27	90	75	0.93	unspecified left	3
4	M	73	141	10	44	1.00	frontoparietal	1
5	F	55	2	89	92	0.86	parieto-occipital	2
6	M	45	22	18	71	1.20	MCA	1
7	M	44	15	51	76	1.00	parietal	2
8	M	55	4	89	85	1.10	parietal	1
9	F	46	40	88	88	1.08	frontotemporal	1
10	F	50	55	85	90	1.06	frontotemporal, basal ganglia	2
11	F	70	4	70	93	1.16	unspecified left	3
12	F	77	69	89	84	1.20	temporoparietal	1
13	F	49	17	62	69	0.75	frontoparietal	2
14	M	54	5	46	90	0.90	inferior frontal	1
15	M	60	20	90	65	0.85	frontoparietal	2
16	F	48	55	86	87	1.15	frontoparietal	1
Mean		57.3	32.6	64	79	1.01		
SD		12.2	34.4	29	13	0.13		

[1]55-Item Revised Token Test (Arvedson et al., 1986).
[2]Shortened Porch Index of Communication Ability (DiSimoniet al., 1980).
[3]Arizona Battery for Communication Disorders of Dementia (Bayles & Tomoeda, 1993).
[4]1=thromboembolic, 2=haemorrhagic, 3=unknown.

conditions in the current study, labelled "easy" and "hard". In the "hard" condition, waveform direction changes were twice as frequent as in the "easy" condition. These two tracking conditions corresponded to the "moderate" and "difficult" tracking conditions, respectively, described in detail by McNeil et al. (2004).

The SRP and tracking tasks were administered, presented, and calculated (for the tracking task) by the Resource Allocation Paradigms of Pittsburgh dual-task software environment (Doyle & McNeil, 1998). The program was installed and operated on a Dell Latitude computer with a 366 MHz processor and 128 MB RAM. The joystick was a Saitek Cyborg.

Procedures

Following informed consent, screening instruments were administered in a single session of approximately 60 minutes in length. Experimental data were collected in a second 60–90 minute session held within 7 days of the first.

In order to minimise practice effects during experimental tasks, participants first performed six unanalysed 2-minute tracking-only trials at each of the two difficulty levels. Following practice, participants performed three 2-minute tracking trials at one difficulty level and one form (three stories) of the SRP under non-competitive conditions. Following completion of the dual-task procedure described below, subjects completed three additional single-task tracking trials at the remaining difficulty level and completed one additional form of the SRP in a single-task condition.

Following these procedures, participants listened to two forms of the SRP while simultaneously performing a tracking task. One form was presented with the easy tracking condition and one form was presented with the hard condition. Immediately following the presentation of each story, tracking ceased, and participants retold the story that they had just heard.

The order of presentation for the tracking difficulty conditions was counterbalanced across subjects. Story forms were randomly assigned to each participant from the four available forms and counterbalanced so that each story form was represented an equal number of times in the single- and dual-task conditions. The RAPP software automatically calculated the RMS tracking error and the %IUs were calculated off-line following the experimental procedures.

RESULTS

Tracking performance was examined in a two-way ANOVA with condition (single vs dual-task) and tracking level (easy vs difficult) as repeated factors with RMS tracking error as the dependent variable. This analysis revealed a significant main effect of tracking difficulty level on tracking performance, F (1, 15) = 293.41, $p < .001$, partial $\eta^2 = .87$, corrected for an approximately 0.65 correlation between repeated measures), but no significant difference between tracking performance in the single versus dual-task conditions, F (1, 15) = 0.011, $p = .920$, partial $\eta^2 < .001$ and no interaction, F (1, 15) = 0.425, $p = .525$, partial $\eta^2 = .01$. Of the 16 participants, 9 produced more tracking error (RMS) under the single-easy tracking task condition than in the dual-easy tracking condition, and 9 of the 16 participants produced more tracking error (RMS) in the single-hard tracking task condition than in the dual-hard tracking condition. Six of the nine participants were the same individuals showing the increased tracking error in both tracking difficulty conditions. Mean tracking performance for each condition is displayed in Figure 1.

Story retell performance was examined in a one-way ANOVA with condition (single task, dual-task easy, dual-task hard) as a repeated factor. This analysis revealed no significant differences between any of the conditions for %IUs, $F(2, 30) = 2.054$, $p = .146$, and a small estimated effect size (partial $\eta^2 = .015$, corrected for 0.89 correlation between repeated measures). Of the 16 participants, 11 produced fewer %IUs under the dual-easy tracking condition than in the single-task condition, and 12 of the 16 participants produced fewer %IUs in dual-hard tracking condition than in the single-task condition. Eight of those participants whose performance was poorer under dual-task conditions performed more poorly in both the easy and the hard tracking conditions. Mean story retell performance for each condition is displayed in Figure 2.

With a sample size of $n = 16$, this investigation was appropriately powered (0.80) to detect an effect of small-to-moderate size ($\eta^2 = .04$). This is equivalent to differences of approximately three %IUs between the two dual-task conditions and six %IUs between the single-task and dual-task-hard conditions, given the observed within-cell variance. Post-hoc analysis revealed power$\approx\sim$0.40 to detect the effect size estimated from the current data.

DISCUSSION

The lack of a significant difference in the number of information units retold under concurrent easy versus hard tracking conditions in PWA replicates the results obtained in the two previous studies using N-BI elderly participants (McNeil et al., 2004; McNeil, Matthews, Hula, Doyle, Rubinsky, & Fossett, 2005). That is, while manipulation of tracking difficulty affected visual-manual tracking performance, it had no effect on concurrent SRP performance. This replication does not support the

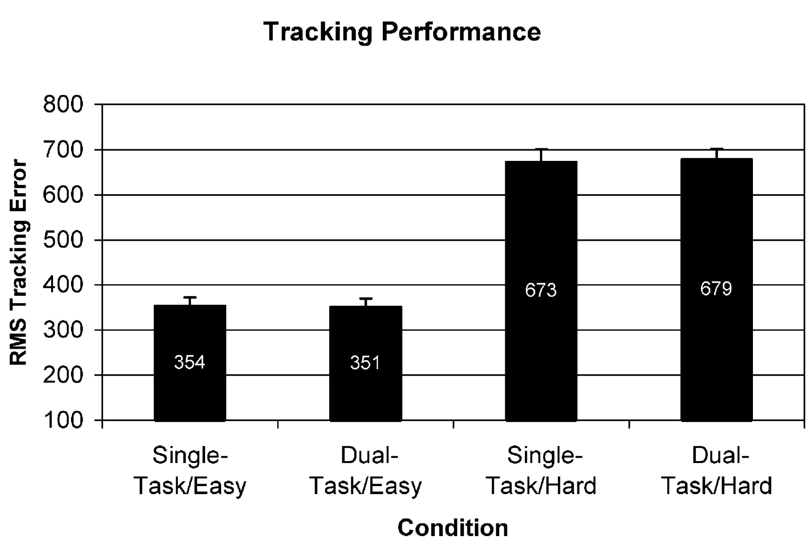

Figure 1. Visual-manual tracking performance in single and dual-task conditions. Error bars indicate one standard error.

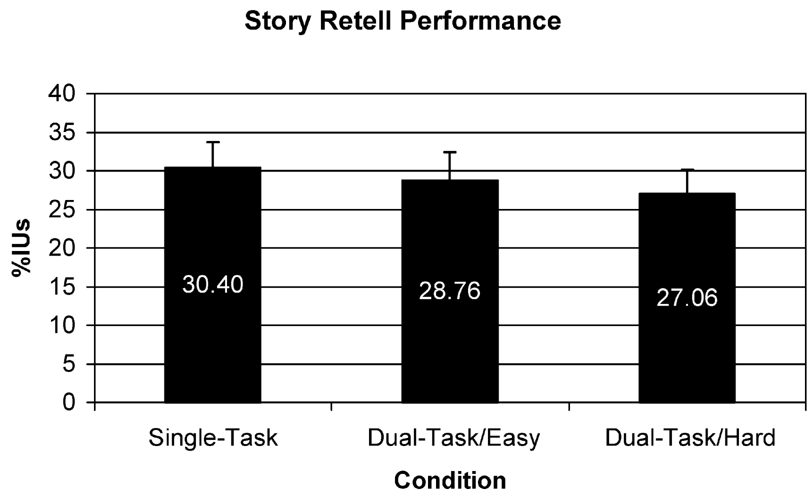

Figure 2. Story retell performance in single and dual-task conditions. Error bars indicate one standard error.

hypothesis that PWA would show a greater performance cost on story comprehension as tracking became more difficult, because they bring to the task an impaired ability to divide their attention when language tasks are engaged. Indeed, these results stand in sharp contrast to a number of studies that have shown that PWA demonstrate greater costs to language performance than their normal control participants in a variety of linguistic-to-linguistic dual-task conditions (Arvedson & McNeil, 1987; Murray et al., 1997b; Tseng et al., 1993) and linguistic-to-nonlinguistic dual-tasks (Erickson, Goldinger & LaPointe, 1996; Murray et al., 1997a).

McNeil and colleagues (2005) increased difficulty on the tracking task by increasing the number of directional changes per unit of time and by decreasing the horizontal tracking window to 10% of the screen compared to the effects shown in the McNeil et al. (2004) study. In order to modulate the overall difficulty of the tracking task for PWA, only the increased number of directional changes per unit of time was employed in this study. In spite of this procedural difference, the findings of this study provide additional support for the hypothesis that a unidirectional cost is likely due to the insensitivity of the language task for indexing any concurrent costs under dual-task tracking. Supporting this interpretation is the fact that 11 (easy tracking) and 12 (hard tracking) of the 16 participants actually did perform more poorly under dual-task conditions than under single-task conditions, although the magnitude of this effect was too small to reach statistical significance. Indeed, it was previously speculated that either the off-line nature of the story-retelling procedure used to measure story comprehension, or the coarse/macro-structural and perhaps insensitive nature of the information unit metric, are likely sources for the lack of changes in the story comprehension as a result of the difficulty manipulations in the visual-manual tracking task. It does seem reasonable to point to the measurement of the competing story rather than the possibility that the story comprehension simply does not share processing resources with the tracking task, because the story difficulty manipulation did in fact have a significant effect on tracking performance. However, as speculated by McNeil et al. (2005), there remains the possibility that the resources dedicated to the visual-manual tracking are only partially overlapping with the language processing task (Backs, 1997; Isreal, Chesney, Wickens & Donchin, 1980; Navon & Gopher, 1980). Additional research will be required to explore this possibility.

While McNeil et al. (2005) found that single-task performance was poorer than dual-task performance; the current study found no statistical difference among single- and dual-task conditions for either the tracking or the story comprehension tasks. Two explanations were offered: either subjects perceived greater task demands under the dual-task conditions and ramped up their flexibly allocated processing resources to meet the demands of the task; or tasks performed in isolation and under dual-task conditions are psychologically and neurophysiologically different. The latter explanation finds support from the neuroimaging literature where it has been found that performance during dual tasks recruits areas of brain activation that neither of the component tasks utilise (Schubert, & Szameitat, 2003; Szameitat, Schubert, Muller, & Von Cramon, 2002). That is, neural computations or processes may be employed during dual tasks that are not used during performance of either of the single tasks and this common form of indexing concurrent costs, whether viewed as a processing resource (Navon & Miller, 2002) or a time-shared bottleneck (Pashler, 1998), must be interpreted with great caution. In the current study, either the participants' success at meeting the demands of the task, and/or the incomparability of single to dual tasks remain viable explanations for the lack of significant differences between single and dual tracking and story comprehension tasks. Perhaps the PWA underestimated the demands of the single tasks as requiring fewer processing resources compared to their N-BI elderly counterparts in the McNeil et al. (2005) study, but still had sufficient resources available to perform the dual tasks at a level comparable to their single-task level; but not with as much fidelity as the N-BI elderly participants.

The finding of a null effect of tracking difficulty on SRP performance in PWA in this appropriately powered study provides additional and substantial support to the conclusion that the story comprehension task is inadequate to index a reciprocal processing cost, if one does indeed exist between these two tasks. It seems apparent that the off-line nature of the retelling, with the built-in opportunity to develop strategies for the retelling and/or the insensitivity of the information unit as an appropriate index for any possible concurrent language-processing disruptions caused by the tracking difficulty manipulations needs to be reconsidered. Additional studies using the tracking tasks described here and newly developed concurrent language tasks are in progress.

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