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Research report

Bringing words back to mind – Improving word production in semantic dementia

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ABSTRACT

Patients with semantic dementia (SD) have significant impairments in naming and comprehension, but demonstrate relatively intact attention, everyday memory, and visuospatial skills. Given these preserved skills, attempts have been made to help re-build vocabulary in SD patients, with promising results. Such reports, however, are generally based upon only one or two cases and have employed variable retraining methods. It is thus unclear which elements of practice are crucial to success. Over two studies, we assessed four patients undergoing a word training program, who ranged in severity from mild to severe impairments to semantic knowledge. All four participants showed significant improvements in their ability to name trained items, with no changes in untrained items over the same time period. Improvements were evident within 3 weeks of practice, and could be established from a simple, repetitive practice of word-picture pairing, carried out at the participant's home. Strong effect sizes of the treatment were found in patients with severe deficits. Maintenance of learning was observed on some follow-up assessments, although continued practice is likely to be needed to sustain naming performance. Incorporating generation tasks into the practice may be assistive, but was not essential to success. These data support the utility of implementing simple home-practice programs even for patients with significant language deficits.

1. Introduction

Semantic dementia (SD) is a form of frontotemporal dementia characterized by marked anomia and word comprehension difficulties, arising from a slowly progressive degradation of conceptual knowledge (Hodges et al., 1992). This decline is associated with focal brain atrophy of the anterior–inferior temporal lobe, and in the vast majority of cases, an accumulation of an accumulation of TAR DNA-binding protein-43 (TDP-43) inclusions (Mion et al., 2010). The erosion of the semantic system leads to increasing communication difficulties that impacts significantly on the patient's psychological well-being (Thompson et al., 2003; Medina and Weintraub, 2007), and causes considerable caregiver distress and burden (Mioshi et al., in press, 2007). Other aspects of language processing, notably syntax, phonology and speech fluency remain relatively well preserved (Gorno-Tempini et al., 2004), as do other cognitive domains, such as attention, non-verbal aspects

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of executive function, everyday memory and visuospatial skills (Hodges et al., 1992, 1999; Hodges and Patterson, 2007).

The selectivity of the deficit in SD, coupled with the relative linguistic and neuropsychological strengths, provides a strong foundation for intervention. The presence of good phonological short-term memory has recently been shown to aid the acquisition of new phoneme sequences, with positive implications for verbal learning (Jefferies et al., 2011). Further, a small but growing body of evidence exists from single-case studies demonstrating that SD patients are able to relearn object labels after repeated exposure to the pictures or objects and the word form (Funnell, 1995; Graham et al., 2001; Jokel et al., 2002, 2006, 2010; Snowden and Neary, 2002; Henry et al., 2008; Heredia et al., 2009; Dressel et al., 2010; Senaha et al., 2010).

While positive, these studies have highlighted certain limitations regarding these improvements in naming; the best outcomes arise for items that are still well comprehended (Snowden and Neary, 2002; Jokel et al., 2006, 2010), the results may not generalize beyond the trained items, and improvements typically fade within a few months post-intervention (Croot et al., 2009). More detailed analysis of published results is difficult as few studies have used the same training method in more than one person, or reported a standard metric, such as an effect size, to allow comparison across individuals or studies. The key variables for success, and the intervention strategies most effective, are therefore yet to be identified.

To date, only one person with SD (participant “CUB”) has reportedly sustained her naming improvements over a 6-month period after ceasing practice (Heredia et al., 2009). The reasons for this successful maintenance are unclear. One contributing factor may relate to the frequency and length of time spent during relearning. As noted by the authors, CUB completed a daily practice of one word list for 4 weeks, in comparison to previous studies, where intervention periods have typically been restricted to 2 or 3 weeks per word list (Graham et al., 2001; Snowden and Neary, 2002; Jokel et al., 2006; Henry et al., 2008; Dressel et al., 2010), and/or required only a few sessions per week (Jokel et al., 2007; Bier et al., 2009). While improvements in naming often occur rapidly, CUB’s continued rehearsal of items over a longer period of time may have been a significant factor in extending the maintenance of her improvements. Certainly, principles relating to repetition and intensity of practice have been highlighted within animal models of successful learning and may be important for inducing experience-dependent plasticity in the brain (as outlined by Kleim and Jones, 2008). Despite this, no published studies have attempted to explore the effect of an intense practice over varying lengths of time in SD relearning.

In the past, therapist availability and expense have impeded the use of more intense forms of practice, but a growing trend exists toward interventions for aphasic patients which can be run on home computers (Jokel et al., 2006, 2010; Cherney et al., 2007; Katz, 2010; Mason et al., 2011). This approach has the additional benefit of providing training in a naturalistic setting, particularly in a condition where learning may be context dependent (Graham et al., 1999; Snowden and Neary, 2002). Successful intervention without the presence of a clinician requires a home program that maximizes effectiveness while minimizing complexity. Fortunately, the combination of elements thought to be assistive in word retrieval interventions is readily adaptable to computer programs, in delivering both phonologic and semantic inputs. Specifically, through simple computer based tasks (e.g., using Microsoft Powerpoint) pictures may be presented with both the spoken and written form of the word, and may be accompanied by a semantic description, so that the person sees, hears, and is encouraged to say the word aloud, all independent of a therapist’s presence. In so doing, a person could engage in a daily, multi-modal practice over an extended period of time without significant expense or therapist time.

Another important factor for maintenance of words relates to their ongoing use – ideally through generalization of learning into everyday speech, as this mechanism allows for continued incidental practice after formal training ends. Although generalization to speech cannot fully explain CUB’s preserved learning, given some words were not part of everyday conversation (e.g., “dromedary”) and her conversation reportedly deteriorated significantly at the follow-up assessment, given relearning may be heavily dependent on short-term memory systems, some form of ongoing practice may be necessary to continually refresh memory of the words in order to sustain benefits (Graham et al., 1999). As yet, no studies in SD have described methods to bridge the gap between formal practice and a sustained, everyday use of words. Some attempt in stroke patients with aphasia has been described, including sessions where the patient is encouraged to use trained words in ways that simulate or approximate everyday use, while pictures and written cues are present (Hickin et al., 2007). Exercises ranged in complexity but included activities such as making shopping inventories, reminiscing or telling anecdotes about a chosen item, or engaging in conversation with the therapist regarding specific items; however, such an approach involves significant therapist input over multiple sessions. As sentence processing is often spared in SD, and related to the functional goal of carrying trained words into speech, one approach could be to include sentence generation into the formal practice. As a conversational task, this may be difficult, depending on the availability of others at home and the type of words selected for practice. A simple pencil and paper sentence generation task, however, may provide a stepping stone by encouraging participants to make use of the words beyond the learning context, in a format closer to everyday use. By also promoting a more active form of learning, recall of words may be further strengthened (as discussed in Wilson et al., 1994). Thus, in the same manner as providing a rich combination of inputs to the computer practice, the addition of a simple daily writing task, with the instruction to repeat the sentence aloud once complete, could further assist learning and maintenance of target words.

The purpose of the current study was to use a simple home-based method of word relearning to improve naming in a series of participants with SD. In particular, we sought to investigate some of the training variables which may affect maintenance of naming improvements, hypothesizing that:

(1) an intense daily practice would improve naming ability, with effect size potentially related to severity of semantic impairment;

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(2) while a 3-week period may improve naming of trained items, greater maintenance would be demonstrated for items which are trained over a longer interval of time;
(3) the combined practice of sentence generation and naming would result in stronger maintenance for these items at 4 weeks post-therapy.

2. Method

2.1. *Participants*

All participants were recruited from the specialist research clinic, FRONTIER (the Frontotemporal Dementia Research Group), at Neuroscience Research Australia, Sydney, and met clinical diagnostic criteria for SD (Neary et al., 1998). The diagnosis was made via a multi-disciplinary assessment, including clinical interview by an experienced behavioral neurologist (JRH), neuropsychological testing, and structural brain magnetic resonance (MR) imaging, where possible.

The study was approved by the Human Research Ethics Committees of South Eastern Sydney Illawarra Area Health Service and the University of New South Wales and all participants gave written informed consent either themselves or through their next of kin.

2.2. *Participant characteristics*

The average age of participants was 62 years (range 54–69). Participants were similar with respect to level of education, sex, and duration of symptoms. Two participants had pacemakers and were therefore unable to have MRI scans. The remaining participants showed the typical pattern of anterior temporal lobe atrophy, with left greater than right volume loss. On cognitive testing, participants showed the expected preservation of visuospatial skills, basic attention and executive function. Syntactic comprehension and word repetition remained generally intact, but each participant showed significant impairment on confrontational naming. Other measures of language revealed a range of performances on semantic tasks, from mild to severe impairments. A summary of participant characteristics and test results are provided in Table 1.

2.3. *Experimental design*

A single subject experimental design, using a 'multiple-baseline-across-behaviours' (three word lists) approach, was conducted. Naming was tested over a 3–4-week period to establish baseline (BL) performance. Following the BL period, participants were trained on their first word list for 3 weeks (T1–T3). Training was then extended to include a second list for 3 weeks (T4–T6), with both lists withdrawn from treatment at week 6 (T6). During the same period of time a separate control list remained untreated. During the training period, participants were re-assessed at the end of each therapy week. Follow-up assessments were undertaken 4 weeks later, with further follow-up assessments 7–8 weeks post-intervention for participants SD1 and SD3.

2.4. *Study 1 (SD1 and SD2) – rich practice (orthographic, phonological, and semantic input)*

A tailored program was developed for each participant, following an initial session with the researcher (SS) to select items and collect the materials.

2.4.1. *Materials*

Digital photographs of household objects were taken at the participant's home and included: food, household appliances, kitchen utensils, outdoor tools and clothing. Items were included only if they were considered relevant by the family and participant, and if the participant could demonstrate semantic knowledge either by miming the use of the item or describing it. To measure item familiarity, the exposure or use of each item for each participant was rated on a frequency scale: daily, several times per week, once a week, once a fortnight, monthly, seasonally or less frequently.

Table 1 – Participant demographics and pre-therapy assessment results.

	SD1 (Study 1)	SD2 (Study 1)	SD3 (Study 2)	SD4 (Study 2)
Demographics				
Age/sex	61/M	69/M	65/M	54/M
Years education	11	11	9	11
Time since first symptoms (years)	4	5	5	4
Cognitive ability				
MMSE (/30)/ACE – R (/100)	26/65	20/46	27/68	23/56
Rey complex figure – copy (/36)	35	34	34	34
Rey complex figure – 3 min delay (/36)	12	16.5	2	30
Digit span (WAIS-III) – max fwds span, max bwds span	6, 5	7, 5	7, 5	8, 6
Language				
Naming (/30)	4*	3*	6*	5*
Category fluency – animals	5	2	12	8
Word-picture matching (/30)	15*	10*	22*	23*
Semantic association (/30)	15*	10*	21*	22*
Word repetition (/30)	29	26*	30	29
Test for reception grammar – 2 (/80)	66/80	56/80	76/80	76/80

WAIS-III = Wechsler Adult Intelligence Scale 3rd edition.
* Significant impairment compared with controls.

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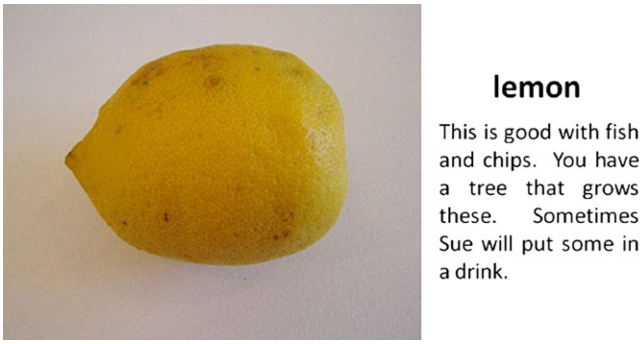

Fig. 1 – Example therapy slide for the item "lemon".

Items were then ranked in relation to this scale and assigned to one of three lists, so that lists were matched for frequency of exposure/use. Each of the two training lists comprised approximately 15–20 words, with a minimum of two items named correctly during BL testing, to provide the participant some sense of success when tested. The remaining items were assigned to the third list, as a control, such that all categories featured in the training lists also appeared within this list.

For each treated word, the participant provided a personally meaningful description, drawing on autobiographical memory, personal tastes or other associations. This was summarized into a short paragraph. An audio recording of the object name and this description was made by the researcher. Photographs and audio recordings were then incorporated into a computer program to produce a slideshow for use in therapy. An example slide is shown in Fig. 1. To prevent participants from rote learning the lists, the order of item presentation was varied each time, but items from the same category were blocked together to help stimulate semantic processing during training.

Approximately half of the items from the two training lists were then selected for the additional sentence generation exercise (SGE). Photographs of these items were arranged on paper handouts, with 4–5 images per page. Beside each photograph was the name of the item, an example sentence using the word, and blank lines for the participant to write their own sentence, incorporating the target word.

2.4.2. *Training procedures*

Based on the two sets of training materials (computer slideshow and paper handouts), two training procedures were developed. The first relied solely upon the more passive approach of "look, listen, repeat" (LLR) using the computer slideshow, repeated three times per item. The second, more effortful approach, incorporated the LLR strategy for two repetitions of the item, but used the SGE for the third exposure. Both procedures aimed for errorless learning (Fillingham et al., 2003) that was self-paced.

During the LLR practice, target items were presented one at a time on the screen, in five steps as shown in Table 2. For the SGE items, participants were asked to generate a sentence using the word by completing a daily worksheet. Participants were then instructed to read the sentence aloud. The completed activity sheets were returned to the researcher at the end of each week.

Participants were encouraged to practice once a day throughout the training period, initially for 30 min and then up to an hour once both lists were introduced. During the first 3 weeks of training, participants were provided with the slideshow and sentence worksheets for List 1. For weeks 4–6, the slideshow and worksheets were extended to include items from both List 1 and List 2. At the end of the 6-week period, all training materials were collected by the researcher so that no further structured practice could be carried out.

2.4.3. *Assessment measures*

The primary outcome measure was naming accuracy. At each assessment, participants were asked to provide the name of each item (treated and untreated), presented in a randomized slideshow, in the absence of the verbal label or description. Assessments were conducted by an independent researcher or through a computer program which recorded verbal responses for later scoring. Responses were given a score of 1 if the target word or a common synonym was provided, with all other responses, including minor phonemic errors, scored as incorrect (a score of 0).

2.5. *Statistical analysis*

BL stability of naming scores was established using Cochran's Q Test. To examine the effectiveness of therapy length (List 1 for 6 weeks or List 2 for 3 weeks) and for each therapy approach (LLR only or LLR + SGE), pre-treatment and post-treatment results were compared using McNemar's Test for related samples. Similarly, to evaluate maintenance, follow-up results were compared with the immediate post-treatment results using McNemar's Test.

Table 2 – LLR self-paced procedure.

Step	Display	Response
1	A photograph of a training item appears	The participant is asked to recall the name if possible, but not to guess. When ready, the participant clicks a button
2	The word form appears beside the photograph at the same time as the voice recording of the word plays	The participant is instructed to repeat the word out aloud then click a button when ready to proceed
3	The written form and audio recording of the item description provided by the participant appear	The participant listens and when ready, clicks a button to continue
4	The word form beside the photograph disappears	The participant is encouraged to concentrate on the word and when ready, click a button
5	The word form is re-displayed beside the photograph and the voice recording of the object name is re-played	The participant is instructed to repeat the word out aloud. When ready, the participant clicks a button and the next item is shown

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To compare treatment results between participants and provide a measure of the relative strength of the treatment, effect sizes were calculated following the approach advised by Beeson and Robey (2006) using Busk and Serlin's *d*:

$$d = \frac{\overline{x}_{A2} - \overline{x}_{A1}}{S_{A1}}$$

where *A2* refers to post-treatment (here, immediate post-treatment and 1 month follow-up), *A1* to pre-treatment (here, the average of three BL measurements), $\overline{x}\,A$ is the mean of the data collected at each time point, and *SA* is the corresponding standard deviation (Busk and Serlin, 1992). Separate effect size calculations were made for each treatment list and then averaged to represent the overall treatment effect for each participant. The results were then compared with benchmarks provided by Beeson and Robey (2006), based on a meta-analysis of 12 studies in lexical retrieval studies (small $d = 4.0$; medium $d = 7.0$, large $d = 10.1$).

3. Study 1 results

3.1. *Overall training effect*

A clear improvement in naming scores was observed in the trained lists, with no change in performance on the untreated items over the same period (Figs. 2 and 3). This was confirmed in both patients statistically, with significant increases after both 3 and 6 weeks of training for List 1 compared with BL performance (all McNemar Tests $p \le .004$), and at the end of the training period for List 2 (McNemar Tests – final BL assessment *vs* T6: $p \le .001$), as expected from the treatment schedule. No significant differences were found for the untreated list (all $p > .55$), nor in the pre-treatment BL period for any item lists (Cochran's Q, exact probability two-tailed, $p > .05$, for all comparisons). The magnitude of change in performance, as measured by the overall effect size, was large for both participants (SD1 = 10.9; SD2 = 11.6), regardless of their level of semantic impairment.

3.2. *Length of training effect*

The length of training (6 weeks *vs* 3 weeks) had equivalent benefit during the treatment phase, with equally high levels of attainment despite fewer sessions for List 2 (see Figs. 2 and 3). The maintenance of this improvement, however, appeared less robust for the shorter-trained list. Comparisons of naming performance at treatment end (T6) with follow-up showed a significant drop for the shorter-trained List 2 for SD1 at both 4 weeks ($p = .022$) and 7 weeks ($p = .031$) post-treatment, and at the follow-up assessment for SD2 ($p = .031$). While some declines were also observed for the longer-trained List 1, these were not significant for either SD1 or SD2, supporting the hypothesis that better maintenance may be achieved with longer training.

3.3. *Type of training effect*

With regard to the two training procedures, both forms of practice delivered strongly significant increases from BL to

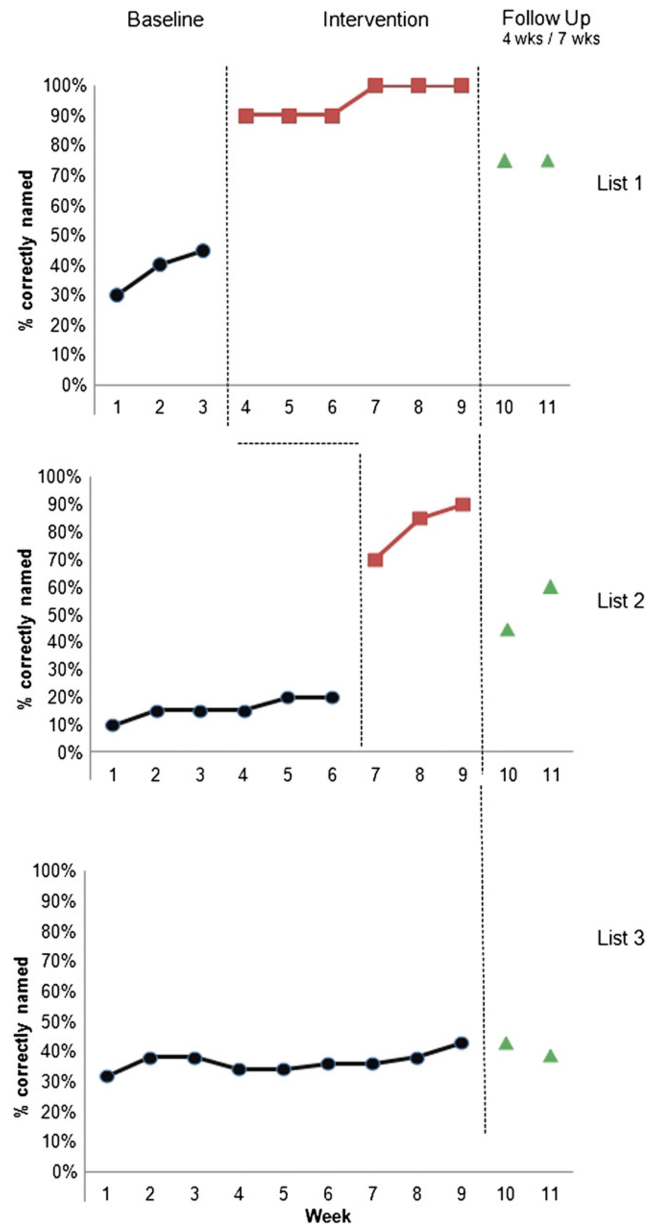

Fig. 2 – Case SD1 – dotted lines mark the three phases of the study. Follow-up period is for 4 weeks and 7 weeks.

post-treatment (all McNemar's Tests: $p \le .002$). A higher final level of attainment was consistently observed however for items engaged in the combined LLR + SGE practice (up to 100% for both SD1 and SD2, compared to 90% and 88% respectively on the LLR only items, Table 3). This difference was also reflected in larger effect sizes for LLR + SGE items than LLR only items (SD1: $d = 11.8$ *vs* 7.5; SD2: $d = 8.6$ *vs* 8.1, respectively). Evaluating the longer term benefits, however, did not reveal a consistent pattern of advantage for words trained under the combined LLR + SGE approach. The expected result was found for SD2, with only the words in the combined approach being successfully maintained at follow-up 4 weeks later (McNemar's Tests – LLR only: $p = .016$; LLR + SGE: $p = .375$). For SD1, results were variable across the two follow-up periods; while at 4 weeks post-intervention LLR only items appeared better

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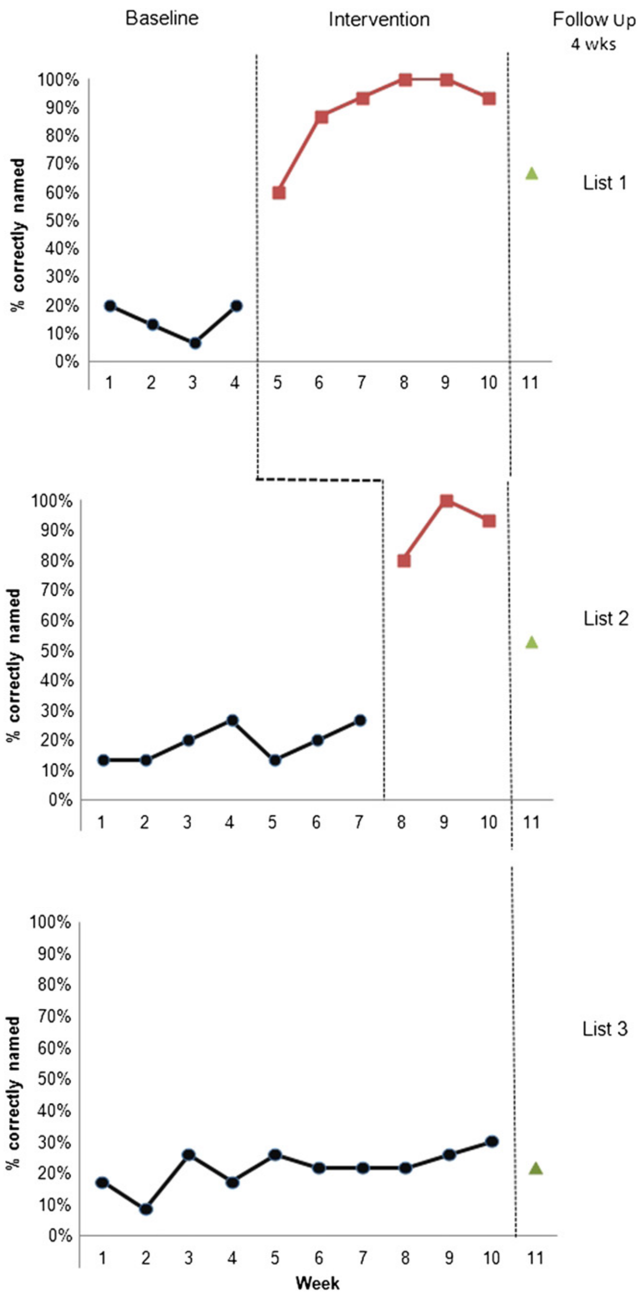

Fig. 3 – Case SD2 – dotted lines mark the three phases of the study. Follow-up period is at 4 weeks.

maintained compared with results immediately following the end of intervention (LLR only: $p = .11$; LLR + SGE: $p = .008$), the reverse was observed at 7 weeks post (LLR only: $p = .008$; LLR + SGE: $p = .25$).

4. Study 2 – exploring key variables of practice

To begin exploring the minimal requirements for effective practice, two further participants (SD3 and SD4) were recruited. In particular, this series examines: (a) whether the inclusion of a semantic description of the item is a key component of retraining; and (b) whether a simple LLR training approach, without semantic descriptors or the SGE, is sufficient (given results of Study 1 did not demonstrate as clear an effect of training type on maintenance as expected).

4.1. *Case SD3 – LLR with picture and word only (no semantic description) + SGE*

Materials and measures for case SD3 were assembled using the same approach as in Study 1, with the exception that no semantic descriptions were obtained for training. All other aspects of the design and intervention approach remained identical, with half of the trained words including the SGE, and the other half using LLR only. Follow-up was conducted at 1 month and 2 months post-intervention.

Once again, clear improvements in naming scores were observed in the trained lists as compared to the untreated list (see Fig. 4). For List 1, BL stability was confirmed (Cochran's Q, $p = .311$), and a significant improvement in naming was found at the end of the third week of training (T3, McNemar's Test, $p = .002$) and at the immediate post-treatment assessment (T6, McNemar's Test, $p = .002$), with 100% of the words correctly named throughout the training period. Improvements were well maintained at 1 and 2 months post-treatment. For List 2, SD3 was pre-exposed to some items prior to training commencement at week 4, which affected BL stability (Cochran's Q, $p = .007$ over the 6 week BL period), such that while an improvement was found, it was not significant at the immediate post-treatment assessment (McNemar's Test, $p = .125$). Items in the control list remained unchanged throughout the study period (McNemar's, $p > .500$). List 2 items were well maintained over the 1 and 2-month follow-up periods ($p = 1.00$ for both follow-up periods). The weighted effect size was small to medium ($d = 4.9$).

No additional benefits were found for items trained under the combined LLR + SGE training approach, with both procedures resulting in similar improvements in naming accuracy by the end of week 6 (Table 4), and maintenance at 1 and 2-month follow-up assessments (all McNemar Tests $p \geq .500$).

Thus the results of SD3 support the hypothesis that the semantic description is not a necessary component to the success of improved naming, or maintenance.

4.2. *Case SD4 – LLR with picture and word only (no semantic description). No SGE*

Materials and measures for case SD4 were identical to those used for SD1 in Study 1, with the exception that no semantic descriptions were obtained for training, and all items were practiced using the LLR approach only. As SD4 was living interstate, the training procedure and schedule was modified slightly. Data were collected once at BL, three times at the conclusion of the treatment, and finally at a 3-week follow-up.

Once again, clear improvements in naming accuracy were observed for both trained lists (McNemar's Test, BL *vs* T6: $p \leq .002$), but not for the untreated items ($p = 1.00$, see Table 5). Only List 1, practiced over the 6-week period, was maintained at follow-up (no significant difference between T6 and Fl-U, $p = .375$), while performance on List 2, practiced for only 3 weeks, fell back to BL levels ($p = .004$).

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Table 3 – Naming performance by type of practice versus untrained words.

	Naming performance over time (% correct)			
	BL	T6	Fl-U1	Fl-U2
SD1				
LLR ($n = 20$)	30%	90%	60%	50%
LLR + SGE ($n = 20$)	30%	100%	60%	85%
Untrained ($n = 56$)	38%	43%	43%	39%[a]
SD2				
LLR ($n = 17$)	24%	88%	59%	–
LLR + SGE ($n = 13$)	15%	100%	62%	–
Untrained ($n = 23$)	22%	26%	22%	–

BL: final BL assessment; T6: assessment at the end of treatment week 6; Fl-U: assessment at follow-up, after treatment withdrawn.
a The items within the control list reduced to 36 as a result of the introduction of practice on a third training list for TM between the two follow-up periods.

5. Summary and discussion

Improvements in word production were observed in a range of patients with SD, using simple methods of practice conducted at home over a 3–6-week period. All participants improved significantly, regardless of level of semantic impairment, consistent with prior case reports where significant improvements have been demonstrated in patients even with severe semantic losses (Snowden and Neary, 2002; Frattali, 2004; Jokel et al., 2010). In these studies, however, the effectiveness of learning varied according to patients' comprehension for the items being trained. Our study focused exclusively on items at least partially still meaningful to participants, thereby providing the greatest utility and maximizing the likely effect.

Surprising at first glance, was that severely impaired participants showed the greatest level of change over time. While the only other study to have quoted an effect size in a fluent, progressive aphasic patient (PA2, Henry et al., 2008) found a very small effect on the treated list ($d = 2.00$), the current study demonstrated large effect sizes for participants SD1 and SD2, and a small to medium effect for the milder participant, SD3. This difference in effectiveness can readily be explained by the differing levels of opportunity for improvement. While all participants demonstrated equally high levels of achievement - between 80% and 100% correct by the end of training – higher performance at BL provided SD3 with fewer words from which to improve. Patients with a wide range of semantic impairments benefit from such practice, most likely reflecting the similar level of preservation in other cognitive skills necessary to engage meaningfully in the practice, such as everyday memory and attention. Importantly, this finding has implications for treatment planning, and suggests that patients with severe semantic impairments should not be overlooked when considering word relearning programs.

Rapid improvement was observed consistently across participants, with high levels of achievement produced within a 3-week period. The majority of previous studies have likewise demonstrated significant improvements following a 1–2-week practice period per list (Graham et al., 2001; Snowden and Neary, 2002; Jokel et al., 2006; Henry et al., 2008; Dressel et al., 2010). While Heredia and colleagues' participant CUB was reported to improve quickly, practice continued for a further 2-week period after having learned the full list. Whether this additional practice beyond simply attaining the words contributed to the successful maintenance over time has not previously been explored. The results of our study

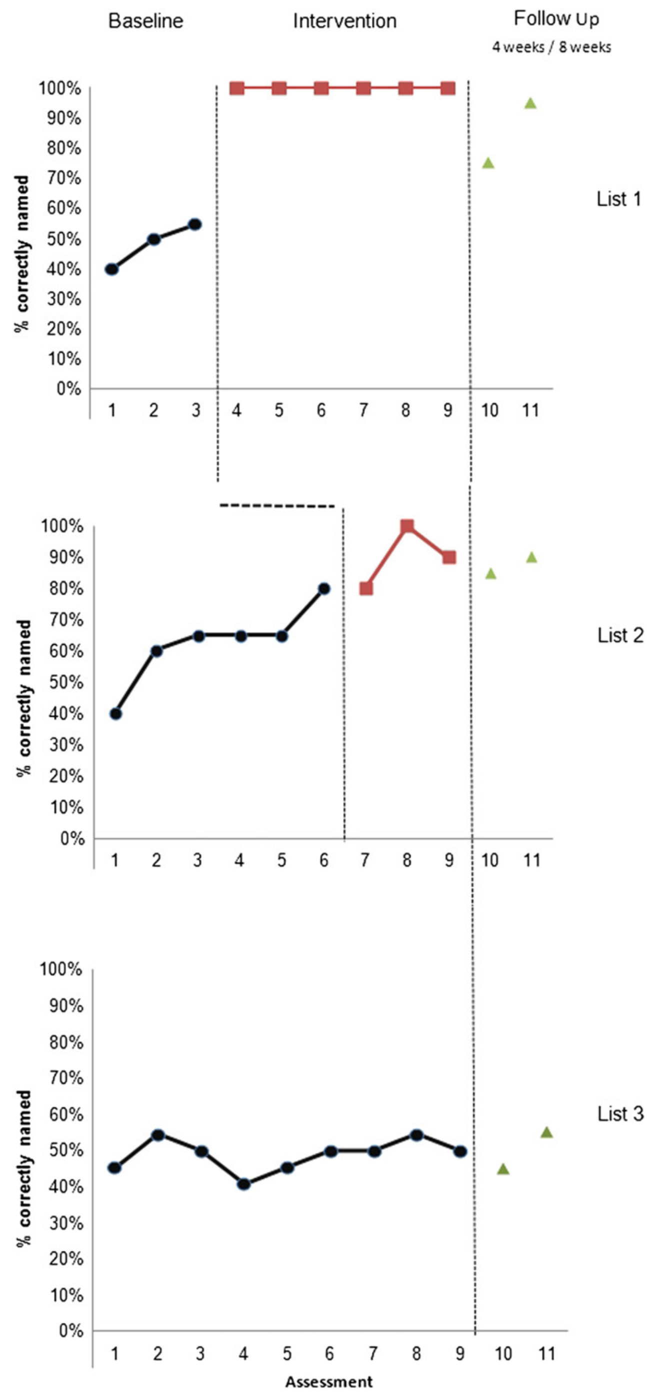

Fig. 4 – SD3 – dotted lines mark the three phases of the study. Follow-up period is at 1 month and 2 months.

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Table 4 – SD3 – naming performance by type of practice compared to untrained words (% correct).

	Naming performance over time			
	B3	T6	Fl-U1	Fl-U2
LLR ($n = 20$)	50%	90%	80%	95%
LLR + SGE ($n = 20$)	65%	100%	80%	90%
Untrained ($n = 22$)	50%	50%	45%	55%

B3: BL assessment; T6: assessment at the end of treatment week 6; Fl-U1: assessment at 1 month after treatment withdrawn; Fl-U2: assessment at 2 months after treatment withdrawn.

suggest this is the case: SD1, SD2 and SD4 all showed better maintenance for words practiced over 6 weeks, with losses in learning experienced for words practiced over a 3-week interval. While not significant for SD3, fewer words were learned and retained from the list practiced for 3 weeks only.

Improved results following a longer period of practice makes sense, as it allows for greater reinforcement of the material learned. It is also consistent with connectionist semantic memory models of SD wherein patients experience a weakened consolidation memory system, and longer term links within the neocortex may be difficult to form (Murre et al., 2001). While a longer period assisted in strengthening or establishing stronger links within the memory system, participants in the current study still experienced some losses over time. This finding suggests that simply increasing the length of consolidation is insufficient to maintain benefit. The first study to investigate brain-related changes arising from word relearning in SD reported an increased brain activity of the right superior temporal gyrus and right pre- and post-central gyrus immediately post-treatment. This change, however, was no longer significant 2 months later, in parallel with declining behavioral performance (Dressel et al., 2010). This finding provides further evidence that without some ongoing practice, benefits will fade over time. The nature and level of practice required once words have been sufficiently re-attained, however, remains unclear. Studies in aphasia following stroke suggest that improvements could be observed simply through repeated attempts to name, even without feedback (Nickels, 2002). Whether some form of repeated self-assessment following the treatment period may assist SD patients to sustain benefits remains to be shown. Future studies in this area will assist in understanding what practices over what time course allow for these increased activations to persist.

The current study illustrates that methods to improve naming can be simply constructed, by the pairing of a picture of an object with the word form, presented both visually and aurally. While more elaborate materials, including semantic descriptions may support learning, such additional elements are not necessary. This result was demonstrated by the improvements shown by participants SD3 and SD4, whose practice did not involve this component at any stage. Evidence from related studies in aphasic stroke patients also support the finding that pairing of the object and word form is perhaps the crucial element of training, with reduced learning demonstrated for interventions which focus on semantic associations without reference to the phonological presentation of the word (Crofts et al., 2004). No doubt enriched practice that combines all elements are assistive, and may be more important where the training goal is to relearn concepts rather than the labels. For the purposes of a simple, home program where the goal is to restore words associated with at least partially known concepts, however, this simple approach appears sufficient.

Maintenance of words relearned was demonstrated using both the LLR method alone, as well as when practiced in conjunction with the sentence generation task. For SD1, SD2 and SD3, 100% of the words were learned using the LLR + SGE technique by week 6, but after 1 month the level of retention was not consistently above words practiced on the computer alone. Further, patient SD4 was able to relearn words in the absence of this form of practice. While the results therefore do not support a clear benefit to maintenance, consideration of methods to promote transference of learning into everyday life remains important.

While previous research has highlighted the vulnerable nature of naming improvements in SD once practice ceases, investigation into the factors affecting maintenance has been lacking, and it is difficult to compare results across individuals and studies. The present study sought to address factors contributing to maintenance, and by calculating effect sizes, allow for easy comparison across individuals and methods. Key components of training were explored in the second study to identify the minimum requirements for practice. Despite these strengths, this study has important limitations, which may be addressed in the future. Firstly, the current study only assessed the impact of the practice on naming ability, however how this learning translates into everyday life is an important clinical goal. The sentence generation task was an attempt to begin bridging an artificial form of practice with use in everyday life. Additional measures, however, will be required to illustrate how participants are able to capitalize on their practice.

The degree to which patients are able to use trained words in everyday conversation is an area of interest that requires future investigation. The integration of practiced words into everyday conversation is likely to have an important role in maintaining the benefits of word retraining, although naturalistic methods alone are unlikely to be sufficient, given that

Table 5 – SD4 – pre- versus post-treatment naming of treated and control lists.

	Naming performance over time			McNemar's Test	
	BL	Final immediate post (T6)	Follow-up 3 weeks post (FL-U)	BL versus T6	Fl-U versus T6
List 1 ($n = 20$) 6 weeks	30%	80%	65%	$p = .002$	$p = .375$
List 2 ($n = 20$) 3 weeks	35%	80%	35%	$p = .004$	$p = .004$
Control list ($n = 51$)	29%	29%	37%	$p = 1.00$	$p = 454$

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not all words which are important for a patient to understand and use necessarily form part of everyday conversations. Thus, longitudinal work is also needed to understand whether simple revision practices may maintain benefits into the longer term. The current study was limited in only being able to follow-up participants for up to 2 months. Lastly, if some form of ongoing practice of words is required, a further question is whether a maximum number of items can be maintained over time. In the study reporting the longest periods of intervention, the best results appeared to arise from the patient with the fewest words to learn (Senaha et al., 2010). Understanding what limits may apply when using these methods will also be important to the development of future retraining programs.

Despite these limitations, our results are encouraging and provide evidence for the effectiveness of basic strategies to reinstate or refresh vocabulary in SD patients. Relearning may be achieved quickly and viably through home practice that involves simple, imitative naming of salient vocabulary, which can easily be set up on patients' home computers or potentially developed for the smartphone or other mobile technologies.

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