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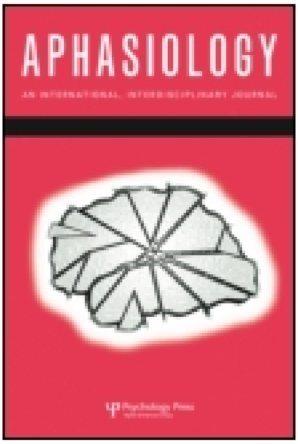

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Learning and maintaining new vocabulary in persons with aphasia: Two controlled case studies

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Learning and maintaining new vocabulary in persons with aphasia: Two controlled case studies

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Background: Novel word learning of persons with aphasia is little studied, even though a better understanding of learning processes would inform development of effective treatment strategies. Recent evidence suggests some remaining verbal learning capacity in persons with aphasia. Long-term maintenance of newly learned active vocabulary has not been reported previously in persons with aphasia.
Aims: To explore learning and long-term maintenance of novel words in persons with aphasia.
Methods & Procedures: Two English-speaking males with chronic anomic aphasia and two age-matched controls were taught novel names of 20 unfamiliar objects. Half of the words were taught with semantic information (definition) and half without. Participants were instructed to learn the names. The experiment included four training sessions, one post-training test and four follow-up tests administered 1 week, 4 weeks, 8 weeks, and 6 months post-training. We tested explicit learning of the new names through visual confrontation naming. In addition, incidental learning of semantic information was probed over the follow-up period.
Outcomes & Results: The two participants with aphasia learned 6–8 of the 20 novel names during the training. However, this new vocabulary dissipated during the 6-month follow-up. As expected, the controls showed better performance both in acquisition and in maintenance of the new vocabulary over the follow-up period. As regards the accuracy of semantic information, the aphasic participant with semantic impairment demonstrated worse incidental learning of semantic information than controls and the participant with intact lexical semantics.
Conclusions: Some new vocabulary can be acquired even in chronic aphasia but the ability to spontaneously retrieve the newly learned words gradually dissipates over the weeks following learning. Our results also indicate an interaction between the level

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of lexical-semantic processing skills and incidental learning of new lexical-semantic knowledge in aphasia.

Keywords: Aphasia; New word learning; Naming.

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To what extent is novel language learning possible in aphasia? This question may appear irrelevant or even paradoxical, as persons with aphasia must constantly struggle even with the language or languages that they had fully mastered premorbidly. This may partly explain the paucity of studies on this topic. However, there is no a priori reason to assume that an aphasic disturbance abolishes verbal learning ability. In fact, anecdotal clinical evidence indicates that even persons with aphasia can occasionally adopt newly introduced words such as "ringtone" or "tsunami" to the extent that they manage to actively use the words. The few studies on novel word learning in aphasia have also indicated some remaining verbal learning capacity in persons with aphasia, at least in the short term (e.g., Breitenstein, Kamping, Jansen, Schomacher, & Knecht, 2004; Kelly & Armstrong, 2008) but the available evidence is still very limited.

New word learning is a multifaceted process inherently linked to memory mechanisms and executive skills such as attentional control. The learner must encode the phonological and semantic characteristics of the novel word, consolidate the corresponding temporary memory traces, store the information in long-term memory, and retrieve it when the word is to be used. During word learning, retrieval processes are not necessarily identical to those used with familiar words. While the naming of familiar pictures is semantically mediated, it seems plausible that, when learning a new name for an unfamiliar object, direct links between the object representation and the phonological representation (excluding semantics) can also be established (Laine & Salmelin, 2010). Moreover, new word learning can take place consciously or incidentally. For example, Saffran, Newport, Aslin, Tunick, and Barrueco (1997) provided evidence for the ability of healthy adults and children to learn language incidentally even when occupied with another kind of task (drawing). A meta-analysis of studies on incidental word learning suggests that students learn approximately 15% of the unknown words they come across during reading (Swanborn & de Glopper, 1999).

Most studies on verbal learning in aphasia have investigated relearning or re-accessing premorbidly mastered vocabulary rather than acquisition of genuinely new words. Another popular approach in studying verbal learning in people with aphasia has concentrated on verbal short-term memory capacity and its effect on learning (Martin, 2009, p. 236). Several of these studies have utilised word list learning tasks with familiar words (see for example Martin & Saffran, 1999; Tikofsky, 1971).

Here we will review studies on word learning in aphasia summarised in Table 1. The word learning experiment by Marshall, Neuburger, and Phillips (1992) represents a study in which previously known phonological word forms are combined with new referents. In their investigation frequently occurring English word forms were paired with novel visual symbols. The aim was to compare the effects of various cueing and facilitation methods on word learning in participants with aphasia. In this study eight different learning conditions were used, part of which included oral production of the word forms. Learning was measured by accuracy of expressive recall. The results showed that while learning took place in all cueing and facilitation conditions, maintenance for 1 week was a great challenge for the participants with aphasia, except in a self-cue task. In the self-cue task participants were assisted in creating personalised cues to combine the visual symbol to the word form. The self-cues included, for

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TABLE 1
Summary of earlier studies on novel word learning in persons with aphasia

Study	*Participants*	*Learning targets*	*Learning method*	*Experiment length*	*Measures of learning*	*Follow-up assessments*	*Results*
Grossman & Carey (1987)	15 participants with aphasia (agrammatic vs fluent)	One infrequent colour name	No explicit teaching, "naturalistic exposures" during a drawing task (followed by a discussion during which participants were given examples of using the word)	Three exposures to the new word in one session	1. Grammatical judgements 2. Object classification 3. Naming and sentence production during follow-up	2 weeks post-exposure	Differential effects detected in patient groups according to language impairment During follow-up, 2 of 15 participants able to name the item
Marshall, Neuburger & Phillips (1992)	23 participants with aphasia (various diagnostic categories) 8 controls	12 frequent English words paired with novel, drawn symbols, one set for each experimental condition	Explicit teaching in eight experimental conditions (different facilitation and cueing methods, part of which included oral production of the targets)	Two training days with a 2–3 day interval between sessions	Accuracy of expressive recall	1 week post-training in each condition	Learning took place in all cueing and facilitation conditions but retaining the learning results to 1-week post-training test session was a great challenge to the participants with aphasia, except for a self-cue task
Freedman & Martin (2001)	Five participants with aphasia (two with semantic impairment)	1. 24 unfamiliar but real definitions for known words (novel semantics)	Auditorily presented paired associate learning task	Learning tasks completed in one session	Expressive recall of the pair of an item	"Long-term" refers to a test phase administered 5 seconds after the test trials	Learning profiles in line with the language processing deficit patterns of the participants: • More extensive phonological than semantic learning in participants with semantic impairment

(*Continued*)

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TABLE 1
(Continued)

Study	*Participants*	*Learning targets*	*Learning method*	*Experiment length*	*Measures of learning*	*Follow-up assessments*	*Results*
		2. 24 common words paired with their Spanish translations (novel phonology)					• The participant with phonological processing abilities more compromised than semantics, showed the opposite pattern
Breitenstein, et al. (2004)	Two participants with aphasia RH and FR 38 controls (different study design)	Nonwords combined with pictures of everyday objects	Incidental associative learning method/ statistical learning, combined with massed practice	Partic. RH five training blocks (in a single session) Partic. FR additional session with 10 months' interval	Receptive task: judgements of accuracy of nonword–picture pairings presented during the actual training	Transfer session (immediately after the training) Partic. FR Maintenance from session 1 to session 2.	The learning method proved successful both for healthy speakers and two participants with aphasia while the role of feedback (provided only for the healthy participants) was not found essential for learning Aphasic participant FR retained his learning results between the sessions (10 months' interval)
Gupta et al. (2006)	12 participants with aphasia (various diagnostic categories) 10 controls	12 novel bisyllabic words associated with new pictures	Explicit teaching of pairings of pictures and auditorily presented word forms	Time course not reported	1. Confrontation naming task 2. Receptive matching task: auditorily presented word to picture	Not reported	Participants with aphasia showed lower learning results than controls in all three learning measures. In confrontation naming 6% improvement

(*Continued*)

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TABLE 1
(Continued)

Study	*Participants*	*Learning targets*	*Learning method*	*Experiment length*	*Measures of learning*	*Follow-up assessments*	*Results*
		(aliens from another planet)			3. Phonological learning in the context of nonword repetition		compared to the 27% of the controls
Kelly & Armstrong (2008)	12 participants with aphasia	20 novel words ("creatures") and semantic features, combined with new pictures	Explicit, errorless learning of pairings of pictures and auditorily as well as orthographically presented words/ semantic features	Four training sessions: once a day during four consecutive days, (introducing five new items during each session)	Composite scores of learning combining results of a variety of measures (spoken recall, written recall, lexical decision, syllable matching, word–picture matching, picture–syllable matching, categorisation, and reading aloud new names)	3–5 days post-training	Some phonological and semantic learning present in all 12 participants with variation of 15–99% learning results 10 participants able to maintain 49–83% of their learning scores to the follow-up session

example, semantically related words and mnemonics based on the visual appearance of the symbol. Marshall et al. (1992) suggested that the better maintenance of the items of the self-cue condition might have been connected to the greater depth of processing required during the training.

Freedman and Martin (2001) taught participants with aphasia two kinds of new verbal information using a paired associative learning method. The first task was designed to measure lexical-semantic learning: the participants were taught pairings of unfamiliar definitions and common, previously known words. The second task measured new lexical-phonological learning: the participants were instructed to pair common words with their Spanish translations (i.e., a foreign language in which the participants were not competent). The objectives of the experiment were to explore possible differential effects of semantic and phonological short-term memory capacity on verbal learning. Both learning tasks employed auditory stimuli and learning was measured by the production of the target words. Four out of the five participants with aphasia were able to learn some new verbal content. The learning profiles were in line with the language-processing deficit patterns of the participants, showing more extensive phonological than semantic learning in participants with semantic impairment. The participant with more compromised phonological than semantic processing abilities showed the opposite pattern, with semantic learning exceeding phonological acquisition. In this study maintenance of the learning results was not measured.

Breitenstein et al. (2004) used an incidental associative learning method based on statistical learning and massed practice to teach healthy speakers and two participants with aphasia new artificial names for everyday objects. In this study the participants' task was to judge the accuracy of pairings of shown pictures and heard nonwords. The correct pairs appeared 10 times more frequently than incorrect combinations. No explicit teaching took place and no feedback was provided for the participants with aphasia. Learning was measured by the number of correct matching responses during the actual training. No production of the nonwords was required during the learning task. The study design differed between the healthy and the two aphasic participants, and varied also between the aphasic participants. There were five training blocks during a single training session (aphasic participant FR also received an additional, similar training session with 10 months interval between sessions) and a transfer test immediately after the last training block. During the transfer test the nonwords were paired in a new way: instead of pairing them with pictures (as in the training sessions), they were now coupled with the written names of the pictured items (i.e., actual German names). The learning method proved successful both for healthy speakers and for the two participants with aphasia. The participants with aphasia reached an accuracy level of just over 70% during the training (vs 50% chance level as the task employed "yes" or "no" judgements). Of particular interest is aphasic participant FR who retained his learning result (66% accuracy) from the first training session to the second one 10 months later. Both participants with aphasia were able to transfer the learned connections from pictures to words.

The studies cited above have addressed word learning in aphasia by combining familiar and new elements in learning tasks. Acquisition of new referents coupled with novel or very infrequent phonological word forms has scarcely been studied. Grossman and Carey (1987) investigated agrammatic and fluent aphasic participants' capacity to learn features of a single novel word, and found differential effects in

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these patient groups. The target word was an infrequent colour name ("bice") that was exposed to the 15 participants with aphasia during a drawing task without explicit teaching. The initial learning results were measured with receptive tasks (metalinguistic judgement and object classification) only. The experiment continued with a discussion on the semantic and grammatical properties of the word "bice". Participants were given examples and the opportunity to form sentences including the new word. Two weeks post training the participants were re-tested and at that point encouraged to use the new word in a sentence as well as in a colour-naming task. The results showed that agrammatic participants demonstrated difficulty with grammatical features connected to the new word (i.e., judging the accuracy of sentences that included the new word either in the correct adjective slot or in an incorrect verb slot). In contrast, participants with fluent aphasia performed significantly worse than agrammatic participants on a task that engaged semantic processing (an identification task that required utilisation of the newly learned word). In other words, a double dissociation was found between agrammatic and fluent aphasic participants in relation to lexical-semantic and syntactic learning. Of the 15 participants with aphasia, 2 were able to retrieve the infrequent colour name in a naming task performed 2 weeks after the learning experiment.

Gupta, Martin, Abbs, Schwartz, and Lipinski (2006) taught 20 participants with aphasia pairings of novel names and novel drawings of "aliens from other planets" (for the material, see Gupta, 2003, and Gupta et al., 2004). They reported dissociations between learning outcomes in patients with semantically vs phonologically based language-processing impairments. New word learning was measured by visual confrontation naming of the taught items (expressive learning) as well as by a word-to-picture matching task (receptive recognition). They found that expressive recall remained virtually at floor (6% improvement in participants with aphasia compared to 27% improvement in control participants from baseline zero levels). Furthermore, participants with aphasia performed at a significantly lower level than controls in the recognition memory task. Impairment in semantic processing was found to be associated with impaired recognition memory. Finally, there was a strong positive correlation between phonological processing capacity and phonological learning. Maintenance of the learning was not measured in the study.

In a recent study by Kelly and Armstrong (2008), 12 participants with aphasia were taught novel words and semantic information of 20 drawings of previously unknown "creatures" (see McGrane, 2006, for materials). The teaching took place over four training sessions, introducing five new items during each session. The researchers used composite scores of learning, combining results of a variety of assessments including results from spoken recall of the newly learned names and related semantic information, written recall, lexical decision, syllable matching, categorisation, word–picture matching, picture–syllable matching, and reading aloud the novel names. The experiment allowed individual learning time with an errorless learning method. Both immediate and delayed learning was measured, with a follow-up 3–5 days after the last training session. The results showed some phonological and semantic learning in all 12 participants, with a large inter-individual variation (15 to 99% success rate). Ten participants were able to maintain 49 to 83% of their immediate composite learning scores at the follow-up session.

To conclude, the literature review above indicates that at least some persons with aphasia partly retain the ability to learn new verbal material. Unsurprisingly, greater learning has been observed in receptive than in expressive language tasks. In several

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studies well-preserved semantic processing has been found to be crucial for new word learning. Further conclusions are difficult to make as the studies differ with respect to the type of phonological input (artificial words, foreign words, real words paired with unusual targets), semantic contents (verbal definitions, pictured novel or familiar items), the training methods used (associative learning, statistical learning, errorless learning, cueing, facilitation, or naturalistic exposure), the measures used in evaluating the learning effects (from expressive recall to recognition), and the length of follow-up (from no follow-up to up to 10 months post-training).

The fact that some new word learning is possible in aphasia is of both theoretical and clinical interest. This phenomenon may shed light on the neural mechanisms of both spontaneous and treatment-related improvement that are not well known (Basso, 2003, pp.76, 189; Howard, 1999). It also opens up the possibility that successful rehabilitation may not always be based on re-access to earlier available language representations but in fact encompasses the acquisition of new representations for previously known words. However, more research is needed to clarify the extent of word-learning ability in aphasia, also because this may have consequences for the choice of treatment methods.

In the present study we explored the ability of persons with aphasia to learn novel words with the so-called Ancient Farming Equipment (AFE) paradigm (Laine & Salmelin, 2010). The paradigm has been used earlier in several functional neuroimaging studies (for healthy speakers, see Cornelissen et al., 2004; Hultén, Laaksonen, Vihla, Laine, & Salmelin, 2010; Hultén, Vihla, Laine, & Salmelin, 2009). In a recent behavioural study by Grönholm-Nyman, Rinne, and Laine (2010), the AFE paradigm was applied to memory-impaired participants with early Alzheimer's disease or amnesic mild cognitive impairment.

In the AFE paradigm participants are presented with pictures of unfamiliar objects and their equally unfamiliar names, and learning takes place gradually over several days. This type of learning requires the formation of novel lexical representations and links to their equally novel object referents. The task thereby resembles a naturalistic situation where a new word in the native language is learned. Word-learning studies with the AFE paradigm have focused on phonological acquisition of new words as measured by oral naming. These studies have shown effective phonological acquisition in healthy adults after a few daily training sessions, while memory-impaired participants have exhibited deficient learning curves. The maintenance of the newly learned names has been followed up to 2 or even 10 months post-training. While the memory-impaired patients of Grönholm-Nyman et al. (2010) showed deficient learning curves, their forgetting patterns during a 2-month follow-up were found comparable with those of elderly controls. Based on their results, Grönholm-Nyman et al. (2010) suggest that the acquisition phase relies on the medial temporal episodic memory system (impaired in their patients), while the long-term maintenance of the new vocabulary (comparable in their patients and controls) is related to left-hemispheric cortical networks.

Our first aim was to explore the explicit acquisition of novel word forms in aphasia with the AFE paradigm where new words need to be associated with new pictures. Second, we examined the incidental learning of lexical-semantic attributes that were provided for half of the items. Third, we investigated the maintenance of the acquired lexical knowledge up to 6 months post-training. Finally we aimed to determine if the learning results were associated with the language processing and verbal short-term memory impairment profiles of the aphasic participants.

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METHOD

Materials

In order to obtain a comprehensive view of aphasic participants' cognitive-linguistic status, extensive background tests were administered (Table 2). The tests included the Temple Assessment of Language and Short-term Memory in Aphasia (TALSA; Martin, Kohen, & Kalinyak-Fliszar, 2010), the Western Aphasia Battery (Kertesz, 1982), the Philadelphia Naming Test (PNT; Roach, Schwartz, Martin, Grewal, & Brecher, 1996), the Pyramids and Palm Trees Test (Howard & Patterson, 1992), the Peabody Picture Vocabulary Test (PPVT, Dunn & Dunn, 1997), and the Comprehensive Trail Making Test (Reynolds, 2002). Two healthy control participants were tested with selected language and verbal span measures to ensure that no language-processing deficits were present. These measures included the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 2001), phonological and semantic fluency tasks, narration, as well as semantic and phonological probe span tests of the TALSA (Martin et al., 2010).

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Training stimuli

The training list included 20 items. They were pieces of archaic Finnish farming equipment presented in black-and-white line drawings (see Laine & Salmelin, 2010). Both the items and their names were unfamiliar to the participants. The names

TABLE 2
Details of the two aphasic participants' performances on the background language tests

Task	*QH*	*IU*
Aphasia quotient WAB	**84.90 (−13 *SD*)**	**82.00 (−16 *SD*)**
PNT 175 items (proportion correct)	0.91	**0.83 (−2 *SD*)**
Pyramids and Palm Trees (written word)	1.00	0.96
PPVT (standard score)	117	93
CTMT (composite index)	**37 (9)***	**30 (2)** *
Sentence comprehension	1.00	**0.74 (−3 *SD*)**
Synonym judgements#	1.00	**0.78 (−2 *SD*)**
Category judgements (words)	1.00	1.00
Rhyme judgements	0.98	**0.83 (−8 *SD*)**
Word repetition span ISO	5.00	**3.40 (−5 *SD*)**
Nonword repetition span ISO	4.00	2.00 **(−2 *SD*)**
Phonological probe	7.00	**2.98 (−3 *SD*)**
Semantic probe	5.93	**1.80 (−4 *SD*)**
Verbal word span ISO	4.20	4.40
Verbal digit span ISO	5.60	5.20

Performance below the normal range in bold; the number of standard deviations *(SD)* below the normal mean given in parentheses; for each TALSA task, performance at least two standard deviations (*SD*) below the mean of healthy controls ($N = 10$) in bold). WAB, Western Aphasia Battery, Kertesz, 1982; PNT, Philadelphia Naming Test, Roach et al., 1996; Pyramids and Palm Trees Test, Howard & Patterson, 1992; PPVT, Peabody Picture Vocabulary Test, Dunn & Dunn, 1997; CTMT, Comprehensive Trail Making Test, Reynolds, 2002; all other tasks are from the TALSA Temple Assessment of Language and Short-term Memory in Aphasia, Martin et al., 2010), *percentile value, #nouns and verbs varied for concreteness, ISO = in serial order.

(see Appendix A) used for the items were derived from the actual Finnish names of the objects. They maintained the syllable number but were modified to follow the phonotactic constraints of the English language to ensure effortless pronunciation by the participants. Two sets of 10 items (*Name* = phonological condition and *NameDef* = phonological-semantic condition) were matched according to length in graphemes and syllables, phonotactic probability (Vitevitch & Luce, 2004), number of orthographic neighbours (as measured by Coltheart's *N*; see Medler & Binder, 2005), and visual complexity of the drawing (taken from Grönholm-Nyman et al., 2010). The semantic information coupled with the *NameDef* items was always a single sentence describing the actual use of the object. Two sample items are given in Figure 1.

Participants

Participants included two English-speaking persons with chronic anomic aphasia and two healthy control participants matched by age, gender, education, and ethnic background. Participant QH was a 59-year-old male who had suffered a sinus venous thrombosis and a left intracerebral haemorrhage with significant temporal bleed. He was 22 months post onset at the start of this experiment. QH's aphasia was classified as mild (aphasia quotient 84.9 in the Western Aphasia Battery; Kertesz, 1982). In lexical retrieval QH demonstrated difficulty in accessing the phonological forms of words. He produced a series of retrieval attempts with repeated approximations to the target and often reported tip-of-the-tongue state. An analysis of QH's responses in the PNT shows that the majority of his errors (counting the last response to each item) were semantically or both semantically and phonologically related to the target. There were no statistically significant effects of word length or word frequency on word retrieval in the PNT. QH's lexical-semantic abilities were spared: he performed well in synonym and category judgement tasks. His receptive vocabulary was accordant with the norms of the PPVT (Dunn & Dunn, 1997). QH excelled in verbal span tasks. Selected results of the background testing are shown in Table 2.

Participant IU was a 67-year-old male 32 months post-stroke at the start of the present experiment. He had multiple ischaemic left hemisphere lesions that had left him with mild aphasia (aphasia quotient 82.0 in the Western Aphasia Battery; Kertesz, 1982). IU had impaired semantic and phonological language processing (Table 2). As

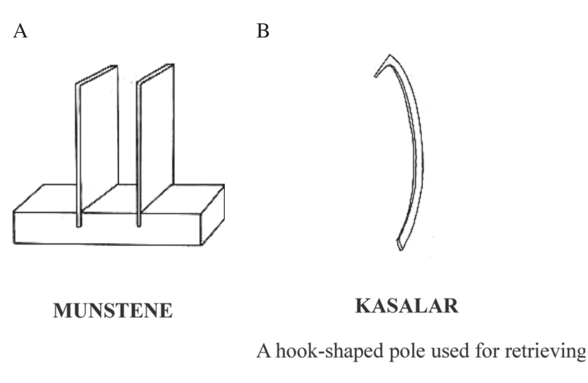

Figure 1. Sample items of the (A) *Name* and (B) *NameDef* conditions.

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regards lexical-semantic functioning he showed difficulties in synonym judgement (> 2 *SD* below the mean of healthy population) as well as in sentence comprehension (> 3 *SD* below). His semantic probe span was very low, 1.8 words (> 4 *SD* below). Similar to QH, IU also showed difficulty in accessing the phonological forms of words. His confrontation naming (> 2 *SD* below the mean of healthy population) and rhyme judgement (> 8 *SD* below) performances were impaired. In addition to phonological errors in lexical retrieval, he typically produced vague circumlocutions and semantic errors. An analysis of IU's responses in the PNT shows that majority of his errors (counting the last response to each item) were semantically or both semantically and phonologically related to the target. No statistically significant effects of word length or word frequency on word retrieval were found in the PNT. IU's word and nonword repetition spans were below the mean of healthy population (> 5 *SD* and > 2 *SD* below). Overall, participant IU demonstrated a more severe and extensive language processing impairment than participant QH. Also most of his verbal span measures were lower than those of QH.

The healthy participants were 59-year-old Control 1 and 71-year-old Control 2. They were interviewed as well as tested for their language processing skills (see the Materials section) prior to the study. They did not report a history of difficulties in language development, learning, or reading and writing. Both the aphasic participants and their controls were matched for education, as they all had a university degree. All participants were given information on the study in written and spoken form, and they signed a written informed consent form.

Experimental procedure

Each learning experiment consisted of nine sessions. These included four training sessions (one per day), one post-training test session, and four follow-up-test sessions that were administered 1 week, 4 weeks, 8 weeks, and 6 months post-training. Depending on practical arrangements (e.g., transportation), completing the series of four training sessions ranged from 9 to 13 days. The duration of each training and test session varied from 45 to 60 minutes.

The participants' task was to learn 20 novel names of objects that were not familiar to them. Half of the words were taught with semantic information (the *NameDef* condition) and half without (the *Name* condition). Training sessions consisted of a naming test including all of the 20 training targets, four rounds of training of the target names in a randomised order, and a pointing-and-naming task. During the training the items, their written names, and possible definitions were presented on a computer screen. In the *Name* condition the participant simultaneously listened to the name read aloud by the examiner and repeated the name aloud. In the *NameDef* condition the participant simultaneously listened to the name and semantic information read aloud by the examiner before repeating the name aloud. The participants were instructed to learn the names (but not the semantic information) of the items. If a participant made a phonological error in repetition, feedback was given, and a new repetition trial was administered to achieve accurate production. The stimuli were advanced manually, and each stimulus was shown for 12 seconds. During the pointing-and-naming task that was performed after going through all the items, the instructor pointed to the 20 items displayed on a sheet of paper one by one in random order, and the participant was asked to name each selected item. If the participant failed to name an item, its correct name was provided. This task thereby served as part of the training.

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The post-training test was administered on the day following the final training session to allow for an overnight consolidation effect (see Davis, Di Betta, Macdonald, & Gaskell, 2008), and four follow-up tests 1 week, 4 weeks, 8 weeks, and 6 months after the last training session. The participants did not have the opportunity to see the training material outside the training or test sessions. Each follow-up test started with an overall recognition memory test involving the 20 trained items as well as 20 similar new items not shown during the training period. The participants were asked to identify the trained ones. The second part of the post-training session was a naming test involving the trained items. If the participant was not able to recall the name, a phonological cue was provided. In addition to these two tests the participants' semantic knowledge of the items was probed with two tasks: they had to decide if an item had been coupled with semantic information (description of the use of the item), and if so, recall that piece of information.

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Data analysis

The data collected from the training and follow-up consisted of eight naming tests, four pointing-and-naming tasks, five overall recognition tests, and five semantic retrieval tests. Background data included language processing and verbal STM test results collected prior to the training period.

Responses given during the naming tests were first transcribed from sound files and then analysed for their phonological proximity to the target word. We selected the last response if there were several, and gave one credit for each phoneme correctly produced in the correct place and half a credit when a correct phoneme was produced in a wrong position. The credits were added together and the sum was divided by the number of target phonemes in each word. If a response consisted of more syllables than the target word, the exceeding syllables from the end were excluded from the analysis. In the statistical analysis of the learning results a cutoff of $\geq$ 80% phonological proximity was used as the criterion for successful naming. This value corresponds to a maximum of one phoneme distortion, as all the target words were at least five phonemes long. As regards phonological cueing effects during the follow-up naming tests, the same cutoff was used.

In order to measure possible learning effects and their maintenance, naming performance during the post-training test session and follow-up test sessions was compared to the initial state of no knowledge of the names using the McNemar test (Siegel & Castellan, 1988) or the exact binomial test (Siegel & Castellan, 1988). The binomial test was applied in cases of small expected frequencies as suggested by Siegel and Castellan (1988, p. 78). Due to the low number of *Name* and *NameDef* items (10 each), we collapsed them for the spontaneous and cued naming analyses. The inclusion of stimuli with semantic information enabled us to probe recognition memory for the presence of semantic information for the individual items, as well as incidental memory for the contents of the semantic information itself. Within-participant χ^2 tests were run to examine possible word length effects (number of phonemes) in new word learning.

Overall recognition memory of the trained items was assessed by calculating the percentage of correctly recognised items in each follow-up test. The semantic tests administered during the follow-ups were first scored for the accuracy of recall of an item having vs not having been taught with semantic information (i.e., the *NameDef* vs the *Name* items). The recognition accuracy for the presence of a definition (answering "yes" or "no") was calculated for each follow-up test using d-prime measures (http://memory.psych.mun.ca/models/dprime/) that remove the effects of response biases.[1] The minimum proportion for hit and false alarm rates was set for .05 ($1/N$ where N corresponds to the number of trials). Respectively, the maximum proportion was set for .95 ($(N–1)/N$). Next, the semantic information recalled by the participants was transcribed and given credit for each correctly produced essential content word of the target definition (only the word "tool" was not counted as it was less informative due to its frequent appearance in the definitions). Close synonyms to the target definition words were accepted. The credits were summed and the total sum divided by the number of essential content words in the recalled definitions to obtain a percentage of semantic information accuracy. This percentage was drawn from each test session and the percentages across measurements were compared between participants by Mann-Whitney tests to reveal possible differences in recall accuracy.

RESULTS

An analysis of the aphasic participants' picture-naming performances collapsed over the two stimulus categories indicates that both participants were able to acquire some novel items in their vocabulary (Figure 2). The binomial test shows significant improvement in spontaneous naming at the post-training session compared to the start of the training—QH: binomial test, one-tailed $P(1, N = 20)$, $p = .004$; IU: binomial test, one-tailed $P(1, N = 20)$, $p = .016$. QH was also able to maintain the statistically significant learning effect in a follow-up test conducted 1 week post-training, whereas IU's result was significantly better than zero only with phonological cueing—QH: binomial test, one-tailed $P(1, N = 20)$, $p = .008$; IU: binomial test, one-tailed $P(1, N = 20)$, $p = .016$. Furthermore, at 4 weeks post-training QH reached a statistically

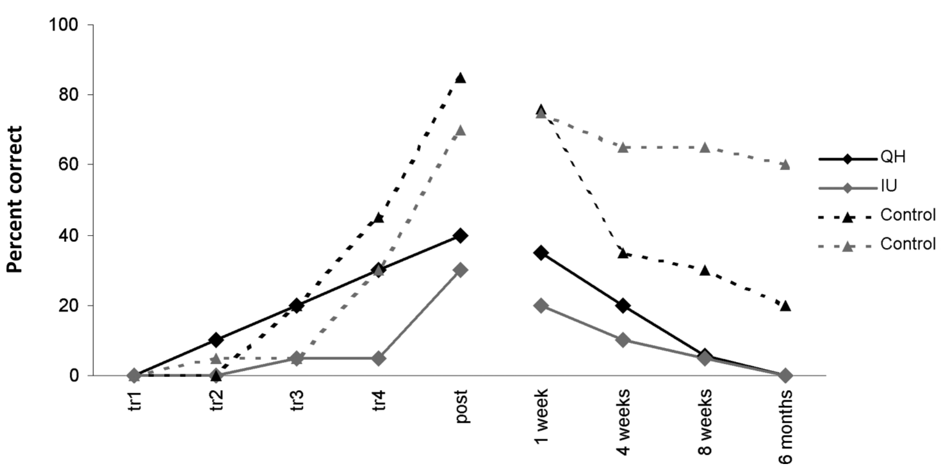

Figure 2. Spontaneous naming results of all trained targets during the four training and the five post-training measurements.

[1]D-prime scores were not calculated for the overall recognition test due to the participants' high performances on this test.

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significant level of maintenance when cued phonologically—binomial test, one-tailed $P(1, N = 20)$, $p = .016$. The controls showed more successful spontaneous naming, and the deviation of their learning effect from zero level was statistically significant 8 weeks post-training—Control 1: binomial test, one-tailed $P(1, N = 20)$, $p = .016$; Control 2: McNemar test, Yates' corrected $\chi^2(1, N = 20) = 15.08$, $p < .001$. At this time point Control 1 showed substantial decline in his naming performance compared to the level immediately post-training. At 6 months Control 2 maintained his learning while for Control 1 maintenance of learning results deviated significantly from the initial zero-performance level only with phonological cueing—Control 1: binomial test, one-tailed $P(1, N = 20)$, $p = .002$; Control 2: McNemar test, Yates' corrected $\chi^2(1, N = 20) = 14.08$, $p < .001$.

The aphasic participants, but not the controls, exhibited a statistically significant word length effect in learning to name, with longer words being more difficult than shorter ones (items grouped into three groups of 5, 6, and 7–8 phonemes; all naming responses of the training and follow-up period summed up); QH: $\chi^2(2, N = 160) = 14.56$, p .001; IU: $\chi^2(2, N = 160) = 9.05$, $p < .05$.

Both participants with aphasia were to some extent responsive to phonological cueing. Figure 3 shows the number of accurate spontaneous and cued naming responses during follow-up tests across the aphasic participants and the healthy controls. For

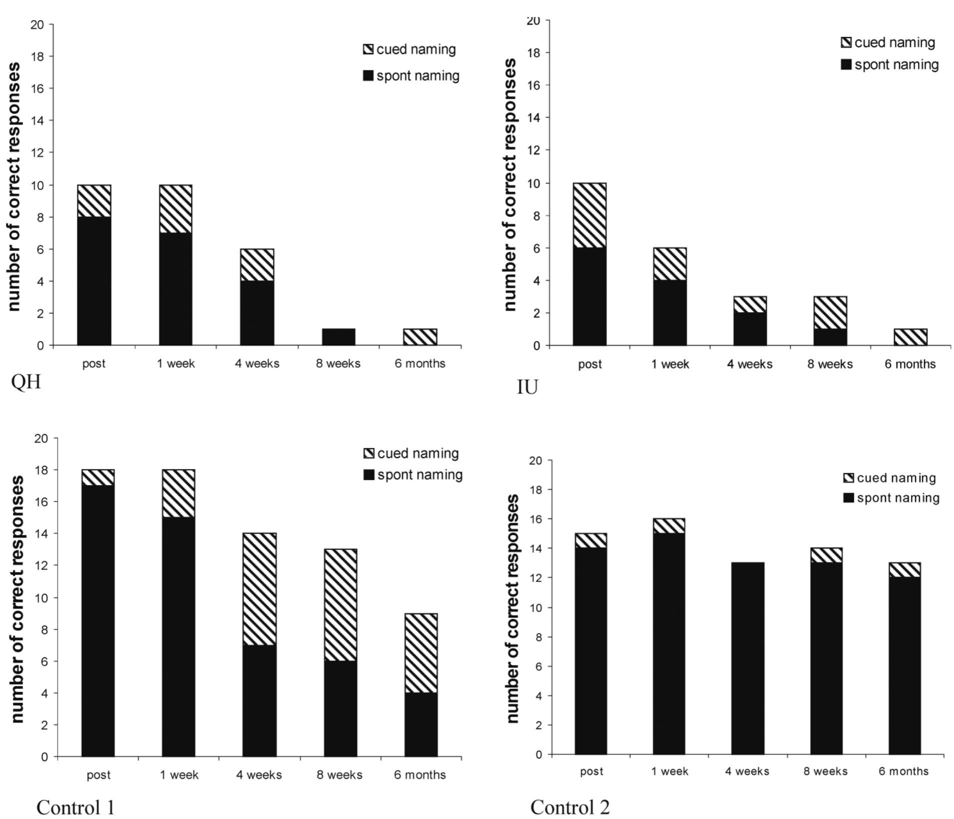

Figure 3. Naming of the novel items spontaneously and after phonological cueing during follow-up. The criterion for a correct response (both spontaneous and cued) is at least 80% phonological proximity to target word, corresponding to a maximum of one phoneme deviance.

the aphasic participant QH the effect of cueing was lost at 8 weeks post-training but emerged again for one item at 6 months post-training. Aphasic participant IU named spontaneously fewer items than QH but maintained some effect of cueing across the follow-up period. For the healthy controls cueing was only occasionally required during the post-test and the 1-week follow-up as the spontaneous naming performance stayed at a high level. After that the first control participant's spontaneous naming accuracy declined but he retained his naming with the help of phonological cueing. The second control participant maintained his level of spontaneous naming more successfully from 1 week post-training to as long as 6 months post-training and never required much cueing. Raw data of naming responses produced during the learning and maintenance period by all participants are provided in Appendix B.

All participants performed flawlessly in the overall recognition memory test (i.e., identification of the trained items) in the post-test and 1-week follow-up tests. In subsequent tests they remained at or close to ceiling levels. Aphasic participant QH produced 1–2 errors and Control 1 produced a single error. At 6 months QH's result was back to 100%. IU was 100% accurate except at 6 months (2 errors) while Control 2 always performed flawlessly.

During the training period participants were instructed only to learn the names of the items, and were not instructed to learn the semantic information provided for half of the items. This enabled testing of incidental learning of the semantic information during the follow-up. Figure 4 depicts the accuracy of judgements concerning the presence of semantic information for a given item. Accuracy is shown as d-prime values for each participant across the follow-up period. The d-prime values are high overall (with the only exception of participant IU's follow-up measure at 6 months post-training), indicating that the participants gained knowledge of the presence of semantic information incidentally and maintained that knowledge.

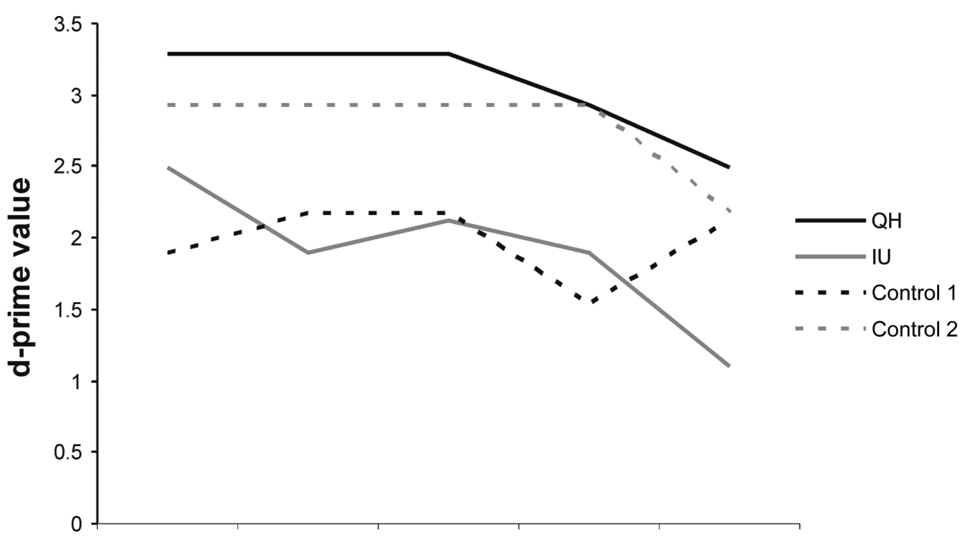

Figure 4. The d-prime values for judgements of the presence of semantic information for a given trained item. The minimum proportion for hit and false alarm rates was set for 0.05 ($1/N$ where N corresponds to the number of trials). Respectively, the maximum proportion was set for 0.95 ($(N\text{-}1)/N$). With these adjustments the highest possible d-prime value equals 3.29.

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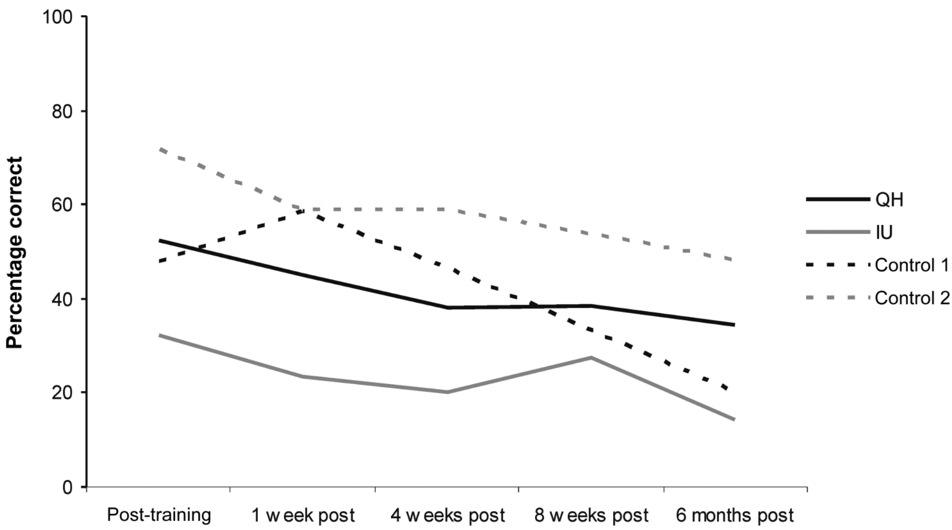

Figure 5. Percentage of accurately recalled content words of the items for which a semantic definition was provided.

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Incidental learning and maintenance of the contents of the semantic definitions given for the *NameDef* items are depicted in Figure 5 as percentages of accurately recalled words. The accuracy of the recalled information declined during the follow-up period in all participants but in somewhat different ways. A significant difference emerged between QH's and IU's accuracy of recalled information across the follow-up period (Mann-Whitney test; $U = .000$, $p < .001$). QH's performance did not differ from the performance of Control 1 (the control participant performing at a lower level) while the difference between IU and Control 1 almost reached statistical significance (Mann-Whitney test; $U = 3.5$, $p = .059$).

DISCUSSION

The results of the present study support the previous findings indicating that people with chronic aphasia are able to learn new verbal material, even when word learning is probed with the particularly demanding task of visual confrontation naming. This general finding of some spared learning capacity is in line with the results of Kelly and Armstrong (2008). However, these two studies are not comparable as they differ in many respects. First, they measured word acquisition with a composite score drawn from a variety of learning measures. Second, in the present study an identical training procedure and fixed training time were used for all participants while Kelly and Armstrong (2008) included independent rehearsal and consolidation time. Third, all training targets were introduced from the very beginning of the experiment. In Kelly and Armstrong's study items were divided into sets that were assigned to different training sessions. Fourth, we used only verbal production of the newly learned names as the measure of phonological learning while Kelly and Armstrong (2008) had a variety of measures. In addition we measured both active and passive (incidental) aspects of learning.

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Our two aphasic participants differed in their language-processing deficits but nonetheless showed significant short-term learning of novel phonological word forms. The ability to learn new phonological word forms has been related to nonword repetition accuracy as well as verbal short-term memory capacity as measured in the immediate serial recall paradigm (e.g., Baddeley, Gathercole, & Papagno, 1998; Gathercole, 2006; Gupta, 2003). The present participants showed some immediate serial recall capacity, and were both capable of repeating a minimum of two nonwords in a row. However, participant QH's nonword repetition skills were markedly superior to those of participant IU. This could at least partially account for the better learning results of QH.

Participant QH not only showed better nonword repetition skills but also exhibited intact lexical semantic abilities, whereas participant IU also had a lexical-semantic impairment. Recent studies of learning in aphasia note the intimate connection of language processing abilities, verbal short-term memory, and learning. For example, Martin and Saffran (1999; using word lists) as well as Freedman and Martin (2001; using paired associate paradigm) have provided evidence for the differential effects of phonologically and semantically based word processing deficits and verbal short-term memory impairment on word learning. Lexical-semantic impairment has been found to impede verbal learning in general as compared to phonological processing impairment with intact lexical-semantic skills (see also Papagno, Valentine, & Baddeley, 1991; Trojano & Grossi, 1995; Trojano, Stanzione, & Grossi, 1992). Additionally, recent evidence suggests that the integrity of lexical-semantic processing is positively related to achieving and maintaining improvements in response to aphasia treatment (e.g., Martin, Fink, Renvall, & Laine, 2006). The findings of the present study thus support the earlier views of the role of lexical-semantic skills in verbal learning. The present results also suggest that the level of semantic processing skills is related to incidental learning of new lexical-semantic knowledge. Aphasic participant IU of the present study with impaired lexical-semantic skills showed a poor recall of semantic information during the follow-up period.

Even though some new word learning took place in our participants with aphasia, the long-term maintenance of the limited new active vocabulary proved to be exceedingly difficult. Between the 1 and 4 weeks post-training assessments the significant learning effect in naming vanished in both cases. Also the healthy control participants showed decline during the follow-up period with a substantial variation between the two control participants. The present investigation highlights the importance of follow-up of language learning beyond the first days and weeks following training. In earlier studies on word learning in aphasia the follow-up periods have been 2 weeks or less, with the exception of one participant (FR in Breitenstein et al., 2004). With regard to acquisition of new names for new objects, earlier follow-up data have been even more limited (3–5 days post-training).

As noted earlier, we measured phonological learning by a particularly challenging task, namely visual confrontation naming. It is quite possible that our participants could have shown evidence for phonological learning in receptive tasks even when naming was too difficult. Adding a receptive task such as picture-to-word matching to the learning tests could thus give a more comprehensive picture of what has been learned and maintained. However, additional exposures to the new word forms during receptive tasks would probably have an effect on the naming performance during the long follow-up period.

One should note that, although the learning effect disappeared during the long-term follow-up, it remains to be seen whether additional exposures to the trained

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stimuli could provide more successful maintenance and retrieval. Due to the nature of the new vocabulary our participants did not have an opportunity to start using the learned words in everyday communication. This is an unavoidable side effect of choosing genuinely new vocabulary to an experiment; the learned items lack everyday relevance for the participants. Friedman, Lacey, and Nitzberg Lott (2003) have provided evidence that, in order to achieve successful maintenance in people with aphasia, the new lexical representations need to be accessed on a regular basis. The vocabulary chosen for treatment has to be relevant to the person with aphasia in order to implement the regular access to the corresponding lexical representations. The careful selection of the treatment targets is also motivated by the often modest generalisation effects of naming treatment (Nickels, 2002). The severe problems that aphasic participants face in long-term maintenance of acquired words stand in contrast with findings from healthy controls. Hultén et al. (2010) employed the AFE paradigm and showed that healthy young adults can retain new vocabulary long-term up to 10 months post-training without actually using the words.

One should also note that part of the differences in our aphasic participants' naming performances may be related to their response strategies. Participant IU tended to produce long series of self-corrections, and many of his answers were longer than three syllables even though in the training sets there were no items exceeding three syllables. IU's own view on his success in naming was, in general, excessively positive. In contrast, participant QH tried to avoid incorrect answers and might have given "I don't remember" answers even when actually being able to partly retrieve the target word. This happened despite constant encouragement to produce anything he could remember of the target.

Aphasic participant QH's performance at the initial phase of the training period is quite interesting. Despite his aphasia he learned two whole new words earlier than either one of the healthy controls, maintaining the effect to the next sessions. QH's accurate insight into the nature of his language-processing impairment, perhaps leading to more effective compensation (for reviews of compensating for cognitive deficits see Bäckman & Dixon, 1992; Wilson, 2000), as well as his high motivation, might have helped him in the learning process. It is possible that he directed his effort to learning only part of the material initially, thus matching his available resources with the high task demands (Bäckman & Dixon, 1992). The two words he learned before the others ("piara" and "kahar") belonged to the shortest ones in the training. These two items were the easiest and the fifth easiest in the general ranking (i.e., number of all correct naming responses produced during any of the tests and by any participant, aphasic or control). However, QH lost these early learned new words during the long-term follow-up and was not able to recall them even with phonological cue at the 8-week follow-up.

The learning strategies utilised by the participants were not measured in this study, but they repeatedly and spontaneously commented on creating mnemonic strategies to promote memory for the new words. All participants except the aphasic participant IU described their learning during the training sessions as actively creating associations between the new items and for example familiar items having a name phonologically close to the target. To take a concrete example, participant QH memorised the item "siapor" as an oriental-style object coming from "Singapore". This process included visualising the item in a novel way in order to build up an association between the keyword "Singapore" and the target word "siapor" (for the cognitive processes employed in using the keyword method, see Shapiro & Waters, 2005). For the aphasic participants these associations, which proved successful during training, may have been difficult to maintain during the long follow-up period. For example, at 8 weeks post-training QH tried unsuccessfully to access the target word "lisket" through the associative word "cracker" while his original, successful association was "biscuit". Similarly, he still recalled creating an association for the target word "siapor" but could no more retrieve the name of "the country somewhere in Asia", i.e., the associative word "Singapore". The lack of spontaneously reported strategies by IU does not necessarily imply that they were not utilised. His ability to describe abstract thinking may have been compromised due to his more severe language-processing deficit. Another possible explanation for IU's lack of reported strategies is an executive function deficit that might have impacted his ability to initiate the use of mnemonic strategies. IU's performance in the CTMT (Comprehensive Trail Making Test; Reynolds, 2002) was moderately impaired while QH performed on a higher level (although still below the average of healthy population).

As regards the training techniques used in the previous studies on lexical learning in aphasia, approaches differ in their allowance of errors and provision of corrective feedback during learning. The techniques used by Breitenstein et al. (2004), Grossman and Carey (1987) and Marshall et al. (1992) could be classified as errorful learning methods that use feedback in at least part of the study (for discussion on errorful and errorless learning see, for example, Fillingham, Hodgson, Sage, & Lambon Ralph, 2003; Fillingham, Sage, & Lambon Ralph, 2005). Fillingham et al. (2003) note that learning is a process affected by many factors such as the executive and memory functions and attention control, as well as the quality and quantity of feedback given during training. They propose that errorless learning may prove more useful when cognitive functions are more compromised. The studies by Freedman and Martin (2001), Gupta et al. (2006), Kelly and Armstrong (2008), and the present investigation represent relatively errorless methods. However, any task that employs oral repetition of novel word forms in participants with speech production impairment (such as in Gupta et al., 2006, with no corrective feedback, and the present study where feedback followed incorrect repetitions) has the potential for reinforcing error patterns.

When considering further research it is clear that the foundation and potential of verbal learning in aphasia is still insufficiently understood. More language-learning studies are needed to better understand the limits and possibilities of new learning in a damaged and language-impaired brain. Besides re-access to previously functional operations and language representations, recovery from aphasia (spontaneous or induced by treatment) may also involve new learning where novel connections and memory traces are formed. Further aphasia case studies of individuals with different functional profiles and lesion loci should help in determining neurocognitive factors that contribute to acquisition and maintenance of new vocabulary.

CONCLUSION

The present results indicate that persons with chronic aphasia can learn some new vocabulary, even when probed by naming that is particularly challenging for persons with anomic aphasia. Our follow-up results revealed that the limited new active vocabulary dissipates after 1 week post training. Finally the present results also suggest an interaction between lexical learning and language performance patterns in aphasia so

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that the level of lexical-semantic processing skills is related to incidental learning of new lexical-semantic knowledge.

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APPENDIX A

Stimulus words

Name condition
kiridge
lempit
munstene
yuntip
lohotin
kerotige
latarp
haparel

varkin
lirtege

NameDef condition
piara
siapor
kahar
vedin
lamuska
taskoine
lisket
kasalar
lungkero
kamsterp

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APPENDIX B

Raw data of naming responses (as number of occurrences) in the word-learning task produced during the learning and maintenance period by all participants. A cutoff of ≥ 80% phonological proximity was used as the criterion for successful naming (both spontaneously and after a cue). Partial responses share between 50 and 79% phonology with the target. In addition, we counted omissions. All remaining responses were registered under "other" responses. Cueing was provided only from post-training session.

QH						
	Correct (crit. ≥ 80%)	*Partial (crit. 50–79%)*	*Omission*	*Other*	*Total*	*Correct post-cued (crit. ≥ 80%)*
Training 2	2	0	13	5	20	
Training 3	4	1	10	5	20	
Training 4	6	2	5	7	20	
Post-training	8	1	4	7	20	2
1 week post	7	1	9	3	20	3
4 weeks post	4	1	11	4	20	2
8 weeks post	1	0	15	4	20	0
6 months post	0	1	11	8	20	1

IU						
	Correct (crit. ≥ 80%)	*Partial (crit. 50–79%)*	*Omission*	*Other*	*Total*	*Correct post-cued (crit. ≥ 80%)*
Training 2	0	1	13	6	20	
Training 3	1	2	2	15	20	
Training 4	1	5	2	12	20	
Post-training	6	3	0	11	20	4
1 week post	4	3	2	11	20	2
4 weeks post	2	2	10	6	20	1
8 weeks post	1	2	4	13	20	2
6 months post	0	0	6	14	20	1

Control 1

	Correct (crit. ≥ 80%)	*Partial (crit. 50–79%)*	*Omission*	*Other*	*Total*	*Correct post-cued (crit. ≥ 80%)*
Training 2	0	1	12	7	20	
Training 3	4	5	3	8	20	
Training 4	10	5	0	5	20	
Post-training	17	1	1	1	20	1
1 week post	15	2	1	2	20	3
4 weeks post	7	4	6	3	20	7
8 weeks post	6	1	9	4	20	7
6 months post	4	2	5	9	20	5

Control 2

	Correct (crit. ≥ 80%)	*Partial (crit. 50–79%)*	*Omission*	*Other*	*Total*	*Correct post-cued (crit. ≥ 80%)*
Training 2	1	0	16	3	20	
Training 3	1	2	13	4	20	
Training 4	6	1	8	5	20	
Post-training	14	0	3	3	20	1
1 week post	15	0	4	1	20	1
4 weeks post	13	1	5	1	20	0
8 weeks post	13	0	5	2	20	1
6 months post	12	1	5	2	20	1

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