**Title: Successful word retraining, maintenance and transference of practice to everyday activities: a single case experimental design in early onset alcohol-induced brain damage.**

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**Abstract**

Word retraining programs have been shown to improve naming ability post-stroke and in progressive aphasias. Here, we investigated benefits for a 22-year-old Danish man (DJ), whose difficulties followed brain damage from heavy alcohol misuse. Using a multiple baseline-across-behaviours design (target behaviour: retrieval of word list items), DJ completed a 4-week 'Look, Listen, Repeat' program on a computer. Ninety personally relevant target words were selected to create three matched lists. List 1 was trained for 10 sessions over 2 weeks, followed by 9 sessions for List 2 over 2 weeks, while the third list remained untrained. Naming performance was evaluated at baseline, during the intervention, and at 1 and 4 months post-training. Naming improved following each intervention block ($p < .001$), with only one data point overlapping between the baseline and treatment phases for trained items. Untrained words remained unchanged ($p=1.00$), with 50% of data points non-overlapping across baseline to treatment phases. Performance was maintained over time, and appeared to generalize, with DJ naming more trained objects in their natural setting (85%) than untrained items (64%). While more evidence is needed, brief (20-minute), intensive (5-day/week) word retraining programs may assist word retrieval for people with brain damage associated with alcohol misuse.

**Keywords:** naming therapy; word retrieval; generalization of learning; alcohol-related brain injury; cognitive rehabilitation

## INTRODUCTION

Alcohol related brain damage (ARBD) is a term used to describe a spectrum of neurocognitive impairments induced by chronic alcohol misuse (Jauhar & Smith, 2009; Kopelman et al., 2009; Wilson et al., 2012). This misuse is typically associated with periods of 10 years or more (Eckardt et al., 1998), thereby excluding alcohol use disorders of younger adults. In place of ARBD, the term early onset 'alcohol-induced brain impairment' has been used to describe these cases. Excessive alcohol use in younger adults, often involving heavy binge drinking, appears to result in similar cognitive impairments to chronic use in older adults (Hermens et al., 2013), despite the shorter period of misuse. This is thought to occur due to a developmental window of vulnerability (Bava & Tapert, 2010), driven by a lack of maturation of white matter and the prefrontal areas of the brain (Arain et al., 2013; Tamnes et al., 2010). The cognitive impacts include poor performances across a range of functions, primarily affecting memory and executive function (e.g. problem solving, mental flexibility, response inhibition, letter fluency, abstract reasoning) including control processing (e.g. motor speed, attention and working memory). Additional visuospatial deficits may also be found on tasks such as those involving figure copying (Jauhar et al., 2014; Saxton et al., 2000; Scheurich, 2005; Schmidt et al., 2005; Yücel et al., 2007). Notably some deficits may not be evident until later into adulthood (Gil-Hernandez et al., 2017).

Neuroanatomically, excessive alcohol use can result in both structural and functional brain changes. In adolescents, with either alcohol use disorders or binge drinking, abnormalities have been found within the prefrontal cortical volumes, through major white matter tracts, and within the hippocampus (De Bellis et al., 2005; McQueeny et al., 2009; Medina et al., 2008). Interestingly, functional imaging studies for adolescent males have shown increased blood oxygen level-dependent (BOLD) response within the frontal and parietal cortex during a spatial working memory task (Caldwell et al., 2005) and when encoding new verbal information (Schweinsburg et al., 2010), interpreted as a need to exert more effort in order to suppress irrelevant information. A systematic review of fMRI studies in adolescents suggests a broad pattern overall wherein task-relevant activation is lowered, but task-irrelevant activation is heightened (Feldstein Ewing et al., 2014).

A review by Hermens and colleagues (2013) examining the neuropsychological markers associated with alcohol misuse concluded that those in teenage years or early adulthood may be more susceptible to memory impairments associated with retrieval and poor attention, and that compared to older adults, may experience poorer language skills. For males in particular, heavy drinking patterns may be associated with poor sustained attention (Squeglia et al., 2009). There may be poor utilisation of semantic clustering when having to recall verbal information (Brown et al., 2000), and greater tendency toward perseverative errors (Sanhueza et al., 2011). The impact on language skills found in adolescents with alcohol use disorder, however, is unclear given the potential for these individuals to have pre-existing poorer language abilities (Moss et al., 1994).

With respect to prognosis, some spontaneous recovery in neuropsychological functions has been reported following periods of abstinence, together with recovery in white matter (see metanalysis by Monnig, Tonigan, Yeo, Thoma, & McCrady, 2013) and other brain tissue (Bartsch et al., 2007; Gazdzinski et al., 2010). In addition, benefits of engaging in cognitive rehabilitation have also been reported (Brown & Tapert, 2004; Carbia et al., 2017; Fals-Stewart & Lucente, 1994; Rupp et al., 2012; Svanberg & Evans, 2013), although most of the evidence has focused specifically on memory rehabilitation. Unfortunately, deficits in executive functions may persist (Lyvers, 2000; Petit et al.,

2017) and it is unclear the long-term impact on language abilities, as these are rarely assessed within these studies (Schulte et al., 2014). While less attention has been given to remediating executive function and executive-mediated language skills, these skills are of importance and their rehabilitation could positively impact a patient's ability to effectively engage in other rehabilitation processes (Bates et al., 2013).

Although not prominently reported in the ARBD literature, word finding difficulty is a commonly reported symptom in acquired brain impairment, including post-stroke (Engelhardt et al., 2011), in the context of neurodegenerative disease (Rohrer et al., 2008), or traumatic brain injury (King et al., 2006). Difficulties with word production may arise for a variety of reasons, including damage to motor-sequencing areas of speech (e.g. Broca's area), areas pivotal to semantic processing such as the anterior temporal lobes, as well as prefrontal cortex in strategic retrieval (Price, 2010). With respect to cognitive models, one way of conceptualising this identifies four types of word retrieval impairments: 1) Pure semantic anomia, wherein impairments arise due to the inability to recover a complete semantic description of a target item, resulting in semantic paraphasias; 2) Primary impairment in lemma retrieval, wherein consistent recovery of the correct lemma associated with the semantic description is impeded, producing circumlocutions and semantic paraphasias; 3) Primary impairment in phoneme retrieval, due to impaired ability to recover the phonological description which relates to the target lemma, resulting in phonemic paraphasias; and 4) Word retrieval deficits in nonfluent aphasia, where difficulties arise in syntax or lexical control processes, leading to semantic substitutions (Wilshire & Coslett, 2000).

In this single case experimental study, we present the case of a young man (DJ) with alcohol-induced brain damage who undertook successful rehabilitation to address his significant word finding difficulties. As far as we know, no intervention has been published to-date to specifically address language impairment in this population.

## CASE REPORT

DJ was a 22-year-old right-handed, native Danish speaking man. He completed 10 years of formal education and was employed in a data entry job from the age of 15 to 18. He presented with a history of binge drinking since his late teens, including several hospital admissions due to falls, as well as episodes of loss of consciousness as consequence of excessive alcohol intake (which involved periods of up to 5 days in intensive care). He was assessed by a psychiatrist at this time and briefly treated for a presumed bipolar disorder (with Sertraline and Lithium), based on parental reports of fluctuations in his behaviour between low mood and excessive partying. This diagnosis was eventually ruled out. At the age of 20, he began reporting poor balance and memory problems and was examined in the Memory Clinic of Rigshospitalet, where a comprehensive cognitive assessment was conducted. Several diagnoses were considered (such as mitochondrial disease, dementia, Huntington disease and acanthocytosis) and eventually ruled out. His HIV test was negative and cerebrospinal fluid (CSF) analysis was within normal limits. The neurological examination revealed memory impairment, visuoperceptual deficits with nystagmus and discrete simultanagnosia, in the absence of optic ataxia, with no other neurological findings. The MRI brain scan revealed white matter parieto-occipital lesions, also encroaching frontal areas, although to a lesser degree, with marked atrophy of the corpus callosum. Consistent with this, FDG PET brain scan showed severe hypometabolism in parieto-occipital-temporal cortex. These neuroimaging findings were interpreted as consistent with brain damage due to anoxia from alcoholic intoxication, which was in keeping with the clinical history of excessive alcohol consumption.

After diagnosis, DJ attended outpatient rehabilitation at a brain injury rehabilitation centre. From age 22, he has lived in a residential Neurorehabilitation centre, given the extent of his cognitive difficulties. At the time of the study, DJ had been living at the centre for one year, during which time he had been abstinent from alcohol. He was receiving an adapted educational program to complete his higher certificate of secondary education (after originally leaving school in 10th grade) and training to move to independent living in the future. He was judged fully self-sufficient in his basic activities of daily living, and could independently complete some domestic tasks, such as doing laundry, and using public transport for areas known to him (but not for travelling to unfamiliar locations). Some support, however, was required when managing his asthma medication, tidying his room, cleaning his bathroom and cooking.

DJ completed a number of assessments within the residential centre to inform his rehabilitation. To evaluate his vision, DJ completed computerized perimetry using the EyesCream Eye Test Program (http://www.eyesage.org ). Here, DJ obtained 49 valid hits, but failed to correctly respond to 86 items. Responses were longer in the upper right quadrant and no responses were provided for stimuli presented in the lower right quadrant. Visual scanning was perceived by the examiner as unstructured and slow.

DJ's cognitive and communication skills were also fully evaluated. The neuropsychological assessment (Table 1) revealed good sustained attention and verbal attentional capacity, but impairments in executive functions (word generativity, abstract thinking), memory and visuospatial skills. Assessment by the speech and language therapist identified difficulties with word finding and an unusual use of language (clichés and low-frequency words). DJ was good at initiating conversation, and could adapt to topics and conversation partners, however, he was observed to make inappropriate word selections. On formal testing he showed impairments in picture naming, with some benefit from phonological cueing. His speech, while fluent and grammatical, was characterised by semantic paraphasias and perseverations, with limited use of vocabulary. On formal testing, auditory word recognition was also impaired.

Behavioural ratings using the Frontal Systems Behavior Scale (FrSBe - see Table 2) completed by both DJ and his mother showed a consistent pattern wherein apathy, disinhibition and executive dysfunction were rated numerically higher post-injury than before injury, however ratings were neither within the clinically significant range nor reflected a reliable level of change. DJ's ratings had a similar pattern to his mother's, although showing a slight tendency to rate these concerns with less severity, particularly pre-injury. Of the three subscales, difficulties with executive function were rated the highest and approached the clinically significant boundary (T score of 65).

On interview, DJ showed partial awareness of the scope and extent of his cognitive difficulties, identifying limitations with his vision and reading but not with his difficulties in cognition or behaviour (for example, he was unaware of the discord at times between his body language and verbal expression, such as smiling inappropriately while describing negative events).

**** insert Table 1 and 2****

DJ expressed a desire to increase his independence. In consultation with this occupational therapist, he wished to develop skills that would allow him to gain employment in a bike shop.

**Formulation of therapy approach**

Following the principles of the Declaration of Helsinki, DJ provided his written informed consent to take part in a word retraining program. The aims of the program were to assist his word retrieval difficulties and to prepare him for the vocabulary that would be required within the shop.

Based on his assessment results and evidence from his brain imaging investigations, DJ's difficulties with word production were hypothesised to reflect impairment within the lexical selection stage, akin to the second type described by Wilshire and Coslett (2000). This suggested compromised ability to select the most appropriate word, as opposed to difficulties in the phonological retrieval stage, where the word's sound form is retrieved. During this first stage of retrieval, according to the spreading activation approach (Dell, 1986), the activation of semantic feature units leads to activation of lexical units, with the word gathering the greatest number of relevant semantic features receiving the strongest activation (Wilshire, 2008). Given the reported damage to his white matter pathways, extending from temporal areas, we hypothesised that his impairments in word finding may be primarily a result of degraded activation patterns connecting semantic units to lexical units.

Word training approaches, which involve repetitive practice of associating a verbal and written label with an object, are commonly used to assist with word retrieval (Dressel et al., 2010; Heredia et al., 2009; Jokel & Anderson, 2012; Savage et al., 2015; Snowden &

Neary, 2002; Suárez-González et al., 2015). These require basic verbal attention capacity (in attending to an auditory stimulus, one at a time), word repetition ability (in correctly repeating the target word), visual perception (in attending to one picture at a time), and anterograde memory skills (in being able to learn and recall the associated words to pictures). Based on DJ's cognitive profile, his skills were deemed sufficient to engage with this approach.

Based on the hypothesis that his word finding difficulty was due to decreased activation between semantic and lexical units, DJ undertook a word retrieval practice designed to boost the strength of lexical-semantic connections.

## METHOD

### Research Design

A multiple baseline-across-behaviours A-B experimental design with follow-up was implemented to investigate the effectiveness of naming therapy on DJ's word retrieval. The target behaviour was naming items from three word lists (two lists which were sequentially trained and one list left untrained). Both verbal and written retrieval were assessed throughout baseline, during intervention and at follow-up, with generalization of learning examined in reference to both expressive and receptive language. Each treatment (B) phase involved learning a list of 30 words (firstly focusing on List 1 for 2 weeks and then on List 2 for 2 weeks, while List 3 remained untrained throughout). Training involved completing a series of 20-minute computer-based sessions conducted 5 days per week, under the supervision of a clinician at the Rehabilitation Centre. While the clinician was not blinded, all therapeutic aspects of the intervention were delivered via the computer (while the clinician assisted with set-up and monitored sessions for compliance, no feedback or therapeutic input was offered by the clinician during sessions). Follow-up assessments were then conducted at both 1-month post-intervention and 4-months post-intervention.

**Item selection and lists of words**

Ninety items from three everyday living contexts that were important to DJ (bikeshop, kitchen, bathroom) were selected by his treating clinicians in conjunction with DJ. Words for the bikeshop were selected by asking the owners of the shop what words were needed. Kitchen and bathroom items were selected based on an informal test of naming, wherein DJ was shown each item and asked "Can you tell me what this is?". Items were selected if he was unable to produce the name. The 90 items were then divided to three sets, matched for Danish word frequency ($F(2,68) = .337, p=.715$) using the Ordnet database (https://ordnet.dk/korpusdk), semantic category and final baseline naming performance (see Table 3). Lists 1 and 2 were allocated for training, while List 3 was allocated as a control (untrained) list.

**** insert Table 3****

**Training materials**

E-Prime software was used to create the training slides (Version 2.0; Psychological Software Tools, Pittsburgh, PA). Photographs of target words were taken around the Brain Injury Centre (e.g. in DJ's kitchen and bathroom) and at the bike shop. Photographs were resized and edited to remove any labelling that featured the target words or to remove distracting background imagery. Two training slides were then created for each item on List 1 and 2 (items to be trained): the first comprising only the target picture (Figure 1 A); the second comprising the same target picture, together with the written label and audio presentation of the word (Figure 1 B). Only the first slide was created for the List 3, untrained items (i.e. picture only). A full list of the items are shown in the Appendix (Supplementary Table 1).

****insert Figure 1**

**Baseline assessment**

Naming performance was assessed in each study phase (A, B and follow-up), using the same photographs but in a different, random order each time, administered through a computer program at the Rehabilitation Centre. Prior to commencing training, DJ completed three full sessions of naming assessment, where he was presented with each of the 90 items, one at a time, and asked to provide the name of the object. The sessions were on separate days, but all within a one-week period, given DJ's desire to start the intervention as quickly as possible (and his low tolerance to undertake repeated baseline assessments over a protracted period of time).

Responses were primarily reviewed and scored by the same clinician (IS) who was assisted DJ with the selection of items, and who then went on to oversee the administration of the computer-based treatment. To confirm inter-rater reliability all items were also subsequently scored independently by a second clinician (IC), who was blind to phase.

**Training method and timeline**

A 'Look, Listen, Repeat' training approach was implemented and delivered via a desktop computer situated in the center of a small, private office within the Rehabilitation Centre. The supervising clinician was seated nearby within the room to observe and provide assistance with operating the program, if required. Each word list was trained intensively (5-days per week) over a 2-week period, with sessions lasting approximately 20 minutes (translating to approximately 3.5 hours of therapy per list).

Prior to commencing the training, the procedures of the therapy were explained by the clinician and also shown on the screen at the start of the program. DJ was instructed that he was going to be shown a series of pictures, for which he would first see the picture, and then see and hear the appropriate word label. He was asked to repeat the word out aloud before proceeding to the next item. After seeing all 30 pictures from the List, the computer program provided a second presentation of the same materials in a different, random order. To conclude the training session, the computer program then immediately tested DJ on his verbal and written retrieval of these trained words, presented in a random order (see example from Figure 1 C).

Procedural fidelity was confirmed through the detailed logging of responses available through the EPrime software, monitored by the treating clinician, who was able to ensure that the computer program ran correctly and that training and testing were consistently delivered as intended each session. Specifically, the supervising clinician ensured that DJ logged in and completed each session, attending to the computer screen and providing responses as required for all items (e.g. clicking to advance to the next screen, listening to audio files, saying words aloud and then typing the word said aloud when requested). Likewise, during the testing sessions, the clinician observed and confirmed that all items (both trained and untrained) were attended to and completed as directed. DJ's responses were then captured through the EPrime software, thereby establishing a record of his engagement as he completed the tasks. Inspection of this record confirmed that 100% of training and test items were delivered as intended.

Training of List 1 was conducted with the therapist over 10 sessions (Week 1: 5 consecutive weekdays; Week 2: 5 consecutive weekdays) and then withdrawn. Training then commenced on List 2, for 9 sessions over 2 consecutive weeks. The program was then removed, with follow-up assessments conducted 1-month and 4-months later. After this point, DJ was invited to participate in an interview with a clinician who was independent of the study, to reflect on his experience of the intervention.

**Follow-up assessments**

DJ undertook full reassessment of his naming ability at three follow-up intervals: once immediately following the end of training List 2, on four occasions at 1-month post-intervention and once at 4-months post-intervention. At each of these assessment points he was tested on all 90 items (i.e. both trained and control items were tested).

During each intervention (B) phase, testing was minimized as DJ expressed a dislike of the assessment procedures. To maintain rapport and his interest in the program, testing during this phase was focused upon the trained items and control list during the training of List 1, and then just the trained items during training of List 2, rather than re-testing all 3 item sets each assessment.

**Outcome measures**

*Treatment effect – naming performance ( % accuracy)*

Picture naming accuracy was evaluated in each assessment using a randomised order of items. Full assessments (when all three lists were tested) were always conducted at least one day after the final training session of that list. During each assessment, DJ was required to firstly say his answer out aloud, and then type the word into the program. Scoring was marked independently by the two native Danish authors (IC and IS) and was based on the written responses to each item. A response was considered correct if:

1) it matched the target word or was either a plural or singular form of that word;

2) the verbal pronunciation of the typed response matched the target word (i.e. spelling errors were permitted if the typed response was phonemically equivalent to the target word e.g. 'tricykkel' instead of correct 'tricykel' [triathlon/tri bike]);

3) DJ had said the correct word but his written response included a typing error (e.g. an odd letter appears within the word because it is the letter next to the intended letter on the keyboard e.g. 'hjrlm' instead of correct 'hjelm' [helmet]); or

4) DJ had produced a close synonym that would be clearly understood and often used by the general public to label the target object (e.g. 'kalkfjerner' instead of the target word 'badeværelsesafkalker' [limescale remover instead of bathroom descaling]).

A response was considered incorrect if: there was no attempt made; if it was inexact or non-specific, such that important information regarding the object was missing (e.g. saying 'curtain' instead of 'shower curtain' or 'knife' instead of 'bread knife'); or if the wrong word was produced (e.g. 'ske' instead of correct 'paletkniv' [spoon instead of spatula]), including non-words or words not found in the Danish dictionary (e.g. 'varmebriks' instead of correct 'bordskåner' (trivet/coaster).

Scoring of responses was strict, with 1-point assigned per item for a correct response; all other responses were scored as 0. All responses were double-scored (by authors IS and IC), with high inter-rater reliability confirmed for all phases of the design (κ = 0.825 for baseline data; κ = .934 for treatment data; κ = .926 post-intervention), reflecting excellent agreement. The speech and language therapist (IC)'s data were used for analysis.

*Maintenance of naming performance ( % accuracy)*

To evaluate retention of any improvement in performance over time, therapy (List 1 and 2) and control items (List 3) were tested on four consecutive days 1 month after training of List 2 ceased, and on one further occasion 3 months later. Again, these assessments were conducted using a random order of items, displayed on the computer and scored according to the procedures described above.

*Generalization – video description task*

Generalization of word knowledge was assessed at baseline and post-intervention, using a video description task, as described in Savage, Piguet, & Hodges (2014). Four short video clips were created, depicting everyday scenes either in the kitchen of the Neurorehabilitation centre or at the bike shop where DJ wanted to start employment. These included scenes of cooking in the kitchen, doing the dishes; inspecting items in the bike shop or trying out items in the bike shop. DJ was instructed to watch each video and describe what he saw happening by explicitly referring to the objects and actions he could see. Video clips were designed to include items from both the trained and untrained lists (resulting in 22 target words from the trained lists and 14 target items from the untrained list). Responses were scored by tallying the number of target words retrieved (where a score of ‘1’ was given for each target object correctly named).

*Generalization – ecological test*

Lastly, an ecological test of DJ’s learning was conducted 2 months following the end of training, where DJ was once again asked to name target objects pointed out to him within the natural setting (either within the kitchen or in the bike shop), and to comprehend target words said aloud by locating the relevant objects within the setting. Again, the task was designed to include items from both trained and untrained lists. The final test involved 41 items (13 from List 1, 14 from List 2, 14 from List 3). Responses were scored by tallying the number of target words correctly retrieved and number of target items correctly identified within the environment (where a score of ‘1’ was given for each correct response).

*Post-intervention interview*

To capture DJ’s views on his rehabilitation program, a short interview was conducted at the end of the study by an independent clinician at the Neurorehabilitation centre. A copy of the interview guide is provided in Appendix B. The interview was audio recorded, transcribed and then translated into English.

**Data analysis**

Data were analysed using both structured visual analysis and statistical methods. Firstly, the level of naming accuracy (or mean accuracy) in each phase was calculated and the proportion of overlap in performance between phases was noted, to identify patterns within and across adjacent phases (baseline to treatment; treatment to post-intervention) in order to assess evidence of a functional relation between naming performance and treatment.

Statistical techniques were then used in addition to quantitatively measure any behavioural changes. Baseline stability of naming scores was examined using a combination of Cochran's Q Test and McNemar's test for related samples, applied to each list separately. The McNemar's test for related samples was then used as a quantitative method to evaluate treatment effectiveness, by comparing final baseline naming performance with immediate post-training performance for each of the three lists separately (using $p <.05/3$ as a threshold). To assess retention over time, McNemar's test was used to compare performance at immediate post-training for each list with the 4-month post-intervention assessment (using $p <.05/3$ as a threshold), and also to compare baseline performance with the 4-month post-intervention assessment (using $p <.05/3$ as a threshold). Likewise, pre- and post-intervention performances on the video generalization task were compared using McNemar's test for trained and untrained items (using $p<.05/2$ as a threshold).

Lastly, to provide a measure of the relative strength of the treatment, effect sizes were calculated following the approach advised by Beeson & Robey (2006) using Busk and Serlin's d: $d = \bar{x}_{A2} - \bar{x}_{A1} / S_{A1}$, where $\bar{x}A2$ is the mean of the data collected post-treatment (here, immediate post-treatment, 1 and 4-month follow ups), $\bar{x}A1$ is the mean of the data collected pre-treatment (here, the average of three baseline measurements for List 1 and four baselines measures for List 2) and SA1 is the standard deviation at pre-treatment (Busk & 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).

## RESULTS

DJ completed all 10 training sessions for List 1 and 9 of the 10 intended training sessions for List 2. There were no adverse events. Picture naming accuracy for each of the full assessments is depicted in Figure 2.

**** insert Figure 2 ****

*Baseline assessment – naming performance (% accuracy)*

At baseline, the naming accuracy for each list was 26% when averaged across the three assessments. For each list, the lowest accuracy was observed during the first baseline assessment, with scores significantly increasing between the first and second assessment, as DJ became more familiar with the testing procedure. Stability across all three baselines was statistically supported for List 2, but not for List 1 or 3 (List 1: Cochran's Q = 6.2, p=.045; List 2: Cochran's Q = 5.3, p =.069; List 3: Cochran's Q = 9.80, p = .007). Comparing performance between second and third assessments, however, indicated no significant differences (List 1: p = .125; List 2: p =1.0; List 3: p=1.0), suggesting some stability following the first assessment.

(see Figure 2).

*Treatment effect – naming performance (% accuracy)*

A clear improvement in the level of naming accuracy was observed in the trained lists when comparing performance during baseline (where mean accuracy was 26% for both List 1 and 2) to that shown during the treatment phase (where List 1 mean accuracy rose to 82% and List 2 rose to 83%). At the immediate post-tests, 87% and 90% accuracy was achieved for each list respectively. Over the same periods, minimal change in performance was observed on the untreated items, with average baseline accuracy of 26% rising to an average of 40% during treatment, and ending with 37% accuracy following the end of the List 2 intervention. All data points (100%) were non-overlapping between the baseline and treatment phases for List 2, with only the first measurement of the treatment phase overlapping for List 1. For List 3 (untrained), 50% of data points were non-overlapping when comparing across baseline and the List 1 intervention phase.

When evaluated statistically, these changes from baseline to immediate post-intervention were significant for the trained lists ($p < .001$ for both List 1 and List 2), but non-significant for the control list (Baseline vs Immediate post List 1: $p = .727$; Baseline vs Immediate post List 2: $p = 1.00$). The magnitude of change in performance for the trained lists, as measured by the overall effect size, was small to medium ($d = 6.92$).

*Maintenance of naming performance (% accuracy)*

Improvements in naming were well retained for the trained items over the 4-month follow-up period (Immediate post-intervention for List 2 vs 4-month follow up: $p = 1.0$ for both List 1 and List 2), with an average naming accuracy of 87% for List 1 and 89% for List 2. Naming performance for List 1 and List 2 were 100% overlapping with the treatment phase and 100% non-overlapping with the range observed within the baseline period. List 3 (untrained) data remained at a similar level to the treatment phase, with 83% of data overlapping and an average naming accuracy of 41%. Although List 3 performance was non-overlapping with the initial three-week baseline, values hovered just outside the baseline range. The statistical comparison of performance on untrained words suggested performance remained unchanged over this period ($p = .453$).

*Generalization – video description task*

When comparing over time, a minor increase in word retrieval was observed on the video description task. At baseline, DJ showed a comparable performance to his picture naming accuracy, in retrieving 14 of the 36 target words (39%) when describing the video scenes. After training, his word retrieval increased to 20 of the 36 target words (56%), however, this increase was non-significant ($p = .146$). When examining performance for untrained versus trained items, there was a slightly higher proportion of words retrieved from the trained lists than untrained, however, the result clearly fell short of the improvements observed on his post-intervention naming tests (Table 4).

**** insert Table 4****

*Generalization – ecological task*

DJ's ability to name target items in context (i.e. within their real-life environment) when assessed 2 months after training was withdrawn, was comparable to his naming accuracy on the formal tests at follow up for these same items (see Table 4). This suggests strong transference of knowledge into real-life settings.

*Patient experience - Post-training interview*

When interviewed 5 months after completing the intervention, DJ was generally positive about his experience of the program. Although he did not report noticing a dramatic change in his language skills *('I probably did better, I don't doubt it*'), this in part related to the fact that he did not believe he had a significant problem to begin with ('*Well I don't think I had any problems with my language before. Perhaps at the most a tendency to make the words sound more refined…so that people thought you said the wrong thing to make it misleading*'). He expressed some frustration in not being provided with all of the training words upfront ('*let me just learn them right now, right? So that I don't forget half when I learn the last ones… Instead of training along the way – I wanted to go "all in*"'), as he did not understand why he needed to work on the vocabulary in a stepped process ('*why couldn't I have all the words in one go, instead of training just a small bit at a time?... I just wanted a huge cocktail with words*').

Although he felt the process at times felt 'a bit trivial and monotonous', he reflected that although it may have felt '*a bit redundant …it probably was needed, as we did it'.* Overall he agreed that the program '*was good for me, I think. Even though I said that I didn't really, but I think that it was relevant and constructive'.*

The aspect he enjoyed the least was the time of day that he was completing the practice (‘*That you almost, at 6.30 in the morning had to be ready. … if Ida came all the way out here for it, then I had to be ready, and almost eat and make the training at the same time, right? That was not very well-phrased, but it was a bit, when you get up you want to wake up - you are not quite sharp in the mind. in my opinion*’).

Overall, however, he agreed that he would recommend others try the program (“*Yes. I would say, give it a shot. To try the training*”) and that he would certainly continue with training, were it available (‘*I would definitely do it even though I would think, because I'm very, I'll gladly accept, even though I will think, "oh no", but I would say yes*’).

When asked about areas to change or improve, his main suggestion revolved around increasing the amount of vocabulary to work on at a given time (‘*I think it should be like it is, but with a giant doses a intravenous injection of all the relevant things*’).

Following the end of the study, on DJ’s request, a training file was created for the untrained, List 3 words. This was provided to DJ on the same computer within the rehabilitation center for him to work on independently. Despite his expression of interest in continuing with training, no further sessions were completed. No treatment data were therefore collected for List 3.

## DISCUSSION

Consistent with the successful results of word training programs in patients with post-stroke (Beeson & Robey, 2006; Maher & Raymer, 2004) and progressive aphasia (Jokel et al., 2014), this study now provides evidence to suggest improvements in word retrieval in a case of alcohol misuse. Not only did these improvements appear to have been achieved quickly (within two weeks for each list), but they were also maintained and transferred into real-life contexts. This extends upon the previous literature in ARBD regarding the success of other forms of cognitive rehabilitation (Allen et al., 1997; Bates et al., 2013; Rupp et al., 2012; Svanberg & Evans, 2013).

Through engaging with a simple computer program, DJ showed a statistically significant improvement in the accuracy of his word retrieval. While the effect size was small to medium, according to benchmarks provided by Beeson and Robey (2006)'s meta-analysis in stroke, nonetheless it is consistent with other studies (Henry et al., 2008; Macoir et al., 2014). Notably, the intervention length was only 14 days per list (in comparison to other studies where lists may be studied for 3-4 weeks). Despite the short learning interval, DJ showed excellent retention over time.

*Proposed mechanisms of improvement*

Word training has typically been conducted to address word retrieval problems in people with a primary difficulty in language processing, however, in the current case, DJ's language skills were hypothesized to be driven by executive and attentional difficulties. His word finding difficulties and odd use of vocabulary in his speech suggest a disrupted pattern of activation. Given repetition has been used to successfully support other learning in patients with ARBD (Svanberg & Evans, 2013), we sought to determine whether a basic, repetitive word training practice may be assistive in re-strengthening or reinforcing retrieval links between semantic and lexical units. This appears to have been supported, and may reflect what has been hypothesized in other areas of aphasia research regarding optimum recovery through the restoration of original activation patterns (Heiss & Thiel, 2006).

*Generalization*

While DJ was able to draw upon his vocabulary in other contexts, his post-intervention performance on the video scene description task was poorer than expected given what he had achieved on the training stimuli. The less structured format of the task, however, may at least partly explain this poorer performance at post-intervention. Consistent with previous findings in the field, executive function problems are among the most pervasive cognitive symptoms in people with ARBD (Rupp et al., 2012). Persisting executive deficits may lead to difficulties structuring responses, as may be required when building the narrative around a video record. By requiring DJ to initiate and construct a narrative, rather than provide single responses to a picture presented one at a time, he may have neglected to draw upon known vocabulary. This is consistent with his performance on the story recall task in his neuropsychological assessment (where he generated only 5 out of the 18 details on immediate recall).

In contrast, when completing the ecological task wherein he was directly asked items one at a time, DJ slowed excellent transfer of his naming skills, correctly identifying 85% of trained items in their real-life setting (a performance level consistent with the accuracy achieved on the direct naming tests).

*Implementation issues and future directions*

DJ was given List 3 to practice at the conclusion of the study, but no longer had a clinician by his side to prompt him to complete the program. Despite his desire to work in the bike shop and learn these words, he did not complete any sessions over the proceeding weeks. Again, while this may be explained by executive difficulties with self-motivation and regulation, it highlights the need for clinician involvement to ensure patients sufficiently engage with available treatment options.

Adherence can be challenging when using computer therapy, even when patients are confident in their use of computers. Personal factors, such as mood and motivation, can be key factors influencing the likelihood that people with aphasia continue engaging in treatment (Harrison et al., 2020; Taylor-Rubin et al., 2019). Without inherent rewards built within the treatment approach, people like DJ may particularly struggle, as a consequence of the damage to brain structures vital to regulating motivation and executive function. To improve motivation and engagement it may be beneficial to gamify elements of the practice (e.g., introduce badges, trophies or points which can be earned when achieving goals or completing levels in the word list learning). There is evidence that using these types of personal informatics, together with iterative feedback and motivational narratives can improve adherence in various forms of rehabilitation (Tuah et al., 2021). However, as these studies do not specifically focus on patients who have behavioural symptoms subsequent to acquired brain injury, any adaption to the treatment approach should be co-designed with people living with these conditions, to ensure the most suitable techniques are embedded.

Determining the amount of time the therapist is present to support the practice is also an important factor for motivation when using computer-based methods (Harrison et al., 2020). For DJ, the social element of shared experience when completing his exercises with another person appeared to increase his enjoyment, as he liked to comment and share stories about items as he worked through the program. The presence of his clinician also promoted a sense that someone cared whether he did the practice, together with a sense of accountability to do the sessions to which he had agreed. When configuring a computer-based treatment for a patient, it may be advisable to examine social needs and determine to what degree the patient will be able to adhere to computer practice independently and at what intervals direct human support is required to maintain motivation and engagement. For some, it may be necessary for frequent contact between the therapist and patient, in other instances it may be as minimal as prompts or remote assistance. Altering delivery in recognition of these patient needs ultimately provides a more person-centred approach likely to yield greater therapeutic benefits.

DJ viewed the program favorably and indicated that he would recommend it to others, although he indicated a preference for one long list rather than build up vocabulary over time. Future programs (e.g. delivered via apps) could offer this flexibility to individuals, allowing them to construct lists of the desired length. This should be developed under guidance of a clinician to ensure the program constructed is appropriate to the person's skill level. The important role of the clinician in initiating and monitoring such programs is also highlighted in this case report, given DJ's unawareness of his difficulties and inability to self-direct.

*Limitations*

Despite our attempt to select a rigorous design type to measure the treatment effects of DJ's word retrieval, the current study was limited by practical constraints regarding DJ's level of tolerance for frequent, full assessments of naming accuracy. This limited the ability to fully monitor performance across all lists during the training phases in order to meet current standards and methodological recommendations for single subject designs. As a result, we acknowledge that our ability to make strong statements regarding treatment efficacy is somewhat weakened. The delicate balance of maintaining rapport and motivation can be particularly challenging when working with patients with executive difficulties. Using shorter, probe assessments which only test a sample of words from each list each time may be a more acceptable approach for such individuals.

The current study included only a relatively short follow-up period of 4 months. Future studies would benefit from an extended follow-up period to see how long benefits are maintained, and the benefit of introducing any booster sessions over time. In addition, strategies to help these patients build up a more articulate narrative through the use of simple verbal scripts, may improve generalization of gains beyond naming to real-life settings.

Despite these limitations regarding study design, an evaluation of the methodological quality of this study using the Risk of Bias in N-of-1 Trials (RoBiNT) scale (Tate et al., 2013), suggested moderate methodological rigor was upheld, according to the algorithm (Perdices et al., 2019). On this measure, internal validity (7/14) was limited by the lack of randomization of the onset of treatment in the multiple-baseline design, the collection of three rather than five measures per phase, the inability to blind DJ, and the lack of independent assessors. External validity and interpretation however scored highly, limited only by the lack of additional participants to replicate the findings and by not having measures of generalization across all phases of the design.

*Conclusion*

Word training may provide an effective and inexpensive treatment option for word retrieval difficulties in various types of acquired brain injury, including alcohol-induced brain damage.

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## Appendix A

## Supplementary Table 1

| List allocation | Danish Word | English translation | Category | Word Frequency |
|---|---|---|---|---|
| 1 | Bruseforhæng | shower curtain | Bathroom item | 0.07 |
| 1 | dankort-terminal | credit-card payment machine | bike shop | 0.04 |
| 1 | butikken | shop | bike shop | 23.27 |
| 1 | lager | storage | bike shop | 11.07 |
| 3 | fælg | rim | bike shop | 0.13 |
| 1 | hjul | wheel | bike shop | 15.9 |
| 1 | arrow cykelhandsker | bike gloves | bike shop | |
| 1 | dæk med kanttråd | tyre with a thread | bike shop | |
| 1 | frempind | stick to adjust the handlebars | bike shop | 0.02 |
| 1 | saddelpind | saddle stick | bike shop | 0.02 |
| 1 | cykelbukser | bike pants | bike shop | 0.18 |
| 1 | mountainbike | mountain bike | bike shop | 1.13 |
| 1 | Kona | brand of bike | bike shop | |

| | | | | |
|---|---|---|---|---|
| 1 | WC-rens | toilet-cleaner | cleaning | 0.05 |
| 1 | badeværelses afkalkning | to take calcium away from shower/sink | cleaning | |
| 1 | peber | pepper | Condiments | 38.05 |
| 1 | olivenolie | olive oil | Condiments | 11.27 |
| 1 | flåede tomater | canned tomatoes | food | |
| 1 | torskerogn | cod roe | food | |
| 1 | urtepotte | flower pot | household item | 0.5 |
| 1 | opslagstavle | notice board | household item | 1.18 |
| 1 | skuresvamp | scourer | Kitchen item | 0.05 |
| 1 | brødkniv | bread knife | Kitchen item | 0.77 |
| 1 | dørslag | colander | Kitchen item | 0.3 |
| 1 | grydelapper | pot holders | Kitchen item | 0.2 |
| 1 | opvasketabs | dishwashing tablets | Kitchen item | |
| 1 | sølvpapir | tin foil | Kitchen item | 0.66 |
| 1 | plastikposer | plastic bags | Kitchen item | 0.57 |
| 1 | Viskestykke | tea towel | Kitchen item | 3.19 |
| 1 | Startnummer | Marathon starting number | sports item | 0.66 |

| | | | | |
|---|---|---|---|---|
| 2 | barberskum | shaving cream | Bathroom item | 0.43 |
| 2 | vandhane | faucet | Bathroom item | 1.1 |
| 2 | værkstedet | repair-shop | bike shop | 9.27 |
| 2 | behandlingsrum | treatment room | bike shop | 0.04 |
| 2 | outlet | outlet | bike shop | |
| 2 | racerstyr | handlebar for racing bike | bike shop | |
| 2 | cykelslange | bicycle tube | bike shop | 0.13 |
| 2 | cykelhjelm | helmet | bike shop | 0.8 |
| 2 | kranksæt | crank set | bike shop | 0.07 |
| 2 | kasette | bike chain | bike shop | 0.07 |
| 2 | stel | frame | bike shop | |
| 2 | tri-cykel | triathlon bike | bike shop | |
| 2 | Team cykeltrøje | team bike shirt | bike shop | |
| 2 | folde-dæk | folding tyre | bike shop | |
| 2 | Gulvvask | soap for the floor | cleaning | 0.21 |
| 2 | sukker | sugar | Condiments | 40.23 |
| 2 | guacamole | guacamole | food | 0.21 |

| | | | | |
|---|---|---|---|---|
| 2 | makrel i tomat | mackerel in tomato sauce | food | |
| 2 | æg | egg | food | 48.36 |
| 2 | magneter | magnets | household item | 2.14 |
| 2 | dørmåtte | doormat | household item | 0.23 |
| 2 | Opvaskebørste | dish brush | Kitchen item | 0.11 |
| 2 | termokande | thermos | Kitchen item | 0.84 |
| 2 | plastikbøtte | plastic tub | Kitchen item | 0.02 |
| 2 | grydelåg | casserole lid | Kitchen item | 0.2 |
| 2 | grydeske | casserole spoon | Kitchen item | 0.34 |
| 2 | bordskåner | trivet | Kitchen item | 0.04 |
| 2 | køkkenrulle | paper towel | Kitchen item | 4.64 |
| 2 | bagepapir | baking paper | Kitchen item | 2.98 |
| 2 | microovn | microwave | Kitchen item | 0.05 |
| 3 | Mappe | binder | household item | 3.79 |
| 3 | sko-blok | Shoe holder | household item | |
| 3 | Vaskemiddel | detergent | cleaning | 1.68 |
| 3 | håndsæbe | hand soap | Bathroom item | 0.5 |

| | | | | |
|---|---|---|---|---|
| 3 | bruser | shower head | Bathroom item | 2.6 |
| 3 | Karklud | dish cloth | Kitchen item | 1.07 |
| 3 | saks | scissors | Kitchen item | 4.5 |
| 3 | spækbræt | cutting board | Kitchen item | 0.14 |
| 3 | urtekniv | vegetable knife | Kitchen item | 0.11 |
| 3 | piskeris | whisk | Kitchen item | 0.38 |
| 3 | paletkniv | spatula | Kitchen item | 0.48 |
| 3 | skål | bowl | Kitchen item | 21.5 |
| 3 | bageplade | baking tray | Kitchen item | 1.43 |
| 3 | salt | salt | Condiments | 60.1 |
| 3 | plastikfilm | plastic wrap | Kitchen item | 0.02 |
| 3 | profile-design reolen | profile design shelves | bike shop | |
| 3 | Kyota | brand of bike | bike shop | |
| 3 | human speed cykeltrøje | brand of bike-shirt | bike shop | |
| 3 | Lounge | lounge | bike shop | 0.5 |
| 3 | styrbånd | tape for the handlebars | bike shop | 0.02 |

| | | | | |
|---|---|---|---|---|
| | | handlebar for | | |
| 3 | tri-styr | triathlon bike | bike shop | |
| 3 | flaskeholder | flask holder | bike shop | 0.02 |
| 3 | racercykel | racing bike | bike shop | 0.66 |
| 3 | saddel | saddle | bike shop | 0.29 |
| 3 | cykelsko | bike shoe | bike shop | 0.16 |
| 3 | løse ærmer | sleeves | bike shop | |
| 3 | outlet | outlet | bike shop | 0.11 |
| 3 | Boller | buns | food | 7.41 |
| 3 | tomatsauce | tomato sauce | Condiments | 0.71 |
| 3 | tortilla pandekager | tortilla pancakes | food | |

## Appendix B

### <u>Interview Guide – Post List 1 and 2 (Guided training)</u>

1. **Thinking about when you speak to other people, has your confidence in communicating changed now, as compared to how you felt before doing the word training?**

   (If **no**, confirm that he feels there has been no change;

   if **yes**, explore if he feels less or more confident and see if he can give an example or explain)

2. **Has there been any change in your ability to think of these trained words in real-life situations?**

   (if **yes**, please ask for examples)

3. **Thinking about the training sessions themselves – were you satisfied with the length of time you spent completing the sessions? (that is, was the length of sessions long enough to give you the opportunity to practice, but not so much time that you would become tired or bored or disinterested ?)**

   (If **no**, ask – what do you think the ideal length of time would be per session e.g. to allow enough practice but not get bored/ tired/ uninterested?)

4. **Did you like doing the training?** (if **yes**, explore what they liked best)

5. **What did you like least about doing the training?**

6. **How did you feel when you were completing the sessions (e.g. happy, calm, stressed, frustrated?)** (explore which emotions and why)

7. **Do you think the training was helpful to you?** (if **yes**, clarify in what way)

8. **Would you recommend this training to someone else who had problems with words?**

9. **Thinking about the future, if it was available to you, do you think you would want to do more training**?

   (if **yes**, explore in what way or how much or for what period of time)

   (if no**,** explore reasons why)

**Table 1: Background neuropsychological test results**

| | Raw score | Percentile/ ASS /z-score |
|---|---|---|
| **Attention and concentration** | | |
| WAIS-IV Digit span - maximum forward | 7 | 61st %ile |
| WAIS-IV Digit span - maximum backward | 5 | 36th %ile |
| WAIS-IV Symbol Search | 6 | 1 |
| BIT star-cancellation - errors | 0, 0, 1, 0, 0, 0 | WNL |
| BIT line-crossing - errors | 0 | WNL |
| BIT Letter cancellation - errors | 3, 1, 2, 0 | WNL |
| BIT Line-parting | 3, 3, 3 | WNL |
| **Episodic Memory** | | |
| Free and Cued Selective Reminding Test (/10) | | |
| Learning trial errors (10 trials) | 4,5,5,5,5,5,3,6,3,3 | |
| Free recall (10 minute delay) | 2 | |
| Category cued immediate recall (/64) | 17 | * |
| Short story - The Shipwreck (/18) | | |
| immediate | 5 | Z = -2.0 |

| | | |
|---|---|---|
| delayed | 3 | Z = -2.0 |
| Recognition Memory Test – Words (/50) | 41 | |
| **Semantic memory** | | |
| Camel and Cactus test (/32) | 27 | |
| Pyramids and Palm Trees Test (/26) | 22 | |
| **Language** | | |
| Boston naming test (/30) | 15 | * |
| Expressive One Word Picture Vocabulary Test | 69 | 2%ile |
| Western Aphasia Battery - naming (/60) | 52 | * |
| Western Aphasia Battery - Auditory word recognition (/60) | 57 | |
| WAIS-IV Vocabulary | 15 | 5 |
| WAIS-IV Information | 6 | 5 |
| PALPA (subtest 47) Matching spoken word/picture (/20) | 19 | |
| **Visuoconstruction and visual perception** | | |
| WAIS-IV Block Design | 24 | 5 |
| WAIS-IV Visual Puzzles | 5 | 2 |
| Clock test (/11) | 10 | |
| Poppelreuter figure (/14) | 10 | |
| Street (/20) | 8 | * |

| | | |
|---|---|---|
| **Executive function** | | |
| TEA Elevator task – accuracy score (/10) | 7 | |
| WAIS-IV Similarities | 15 | 5 |
| WAIS IV Matrices | 9 | 4 |
| Verbal fluency (animals) | 15 | 2-5%ile |
| Verbal fluency ‘s’ | 17 | Z= 0.5 |
| Ordkenskabs test of concepts (/22) | 15 | 10%ile |
| Iowa gambling task – 100 trials; net total | 48 | 90 |

ASS = age scaled score; BIT = Behavioural inattention test; PALPA= Psycholinguistic Assessment of Language Processing in Aphasia; WAIS = Weschler Adult Intelligence Scale. Ordenskabs test of concepts involves identifying the underlying common concept of 2 words at a time

* percentile not available, but interpreted as significantly impaired

**Table 2: Ratings on the Frontal Systems behavioural Scale**

| | Before injury | | After Injury | |
|---|---|---|---|---|
| **Family rating (mother)** | **Raw score** | **T-score** | **Raw score** | **T-score** |
| Apathy | 22 | 39 | 24 | 43 |
| Disinhibition | 30 | 49 | 34 | 55 |
| Executive dysfunction | 42 | 56 | 46 | 61 |
| Total | 94 | 50 | 104 | 56 |
| **Self-rating (DJ)** | **Raw score** | **T-score** | **Raw score** | **T-score** |
| Apathy | 16 | 23 | 23 | 38 |
| Disinhibition | 26 | 42 | 34 | 55 |
| Executive dysfunction | 37 | 55 | 42 | 64 |
| Total | 79 | 37 | 84 | 42 |

**Table 3: Training List properties**

| List | n | Word Frequency per million (M; SD) | Semantic categories | Final baseline accuracy |
|---|---|---|---|---|
| 1 | 30 | 6.11 (12.89) | Household items (n = 18): Bathroom, Cleaning, kitchen, condiments, food | |
| | | | Bike shop items (n=12) | 23% |
| 2 | 30 | 3.30 (8.58) | Household items (n = 18): Bathroom, Cleaning, kitchen, condiments, food | |
| | | | Bike shop items (n=12) | 30% |
| 3 | 30 | 4.88 (13.19) | Household items (n = 18): Bathroom, Cleaning, kitchen, condiments, food | |
| | | | Bike shop items (n=12) | 33% |

**Table 4**: Generalization performance over time for the video description task and ecological task

| **List** | | | **McNemar's Test** |
|---|---|---|---|
| ***Video description task*** | **Baseline** | **Post-intervention** | **Baseline vs Post** |
| Trained (List 1+ List 2) | 9 / 22 (41%) | 13 / 22 (59%) | p = .289 |
| Untrained (List 3) | 5 / 14 (36%) | 7 / 14 (50%) | p =.625 |
| ***Ecological task*** | **Named** | **Located** | **Follow up vs Postecol naming** |
| Trained (List 1+ List 2) | 23 / 27 (85%) | 26 / 27 (96%) | p = .375 |
| Untrained (List 3) | 9 / 14 (64%) | 10 / 14 (71%) | p =.125 |

**Figure captions**

Figure 1: Example materials A) Target picture only; B) Target picture with written label and audio presentation; C) Testing screen – (English translation: "Say the name of the object out aloud")

Figure 1 Alt-Text: An example of the computer screen set up for training and testing is shown. During training, firstly there is a screen showing the target picture only, positioned towards the left of the screen. The next screen shows the target picture again, but now with the written label to the right of the image. The final panel shows an example of the test screen, wherein the target picture is shown, with a written request to say the name of the picture out aloud.

Figure 2. Naming accuracy. Dotted lines mark the phases of the study. List 1 is trained in the first intervention period, List 2 is trained in the second intervention period; and grey squares represent List 3 (untrained throughout the study). BL denotes baseline phase; T indicates training sessions; ImmPL1 denotes immediate post measurement after training List 1; ImmPL2 demotes immediate post measurement after training List 2; F1 to F4 represents four follow up assessments conducted 1 month after the end of training List 2; 4MF denotes the final assessment conducted 4 months after the end of training List 2

Figure 2 Alt-Text:

A stacked chart comprising three line graphs to show the percentage of pictures correctly named for each of the word lists over the same time course. Baseline, intervention and maintenance phases of List 1 and List 2 are marked to show the performance during each phase. During baseline (before training), accuracy for all 3 lists was no higher than 50%. Following training, Lists 1 and 2 significantly improved (close to 100%) while the accuracy of the untrained list remained below 50%.