APHASIOLOGY, 2009, 23 (3), 402–424

Psychology Press
Taylor & Francis Group

Effect of Verb Network Strengthening Treatment (VNeST) on lexical retrieval of content words in sentences in persons with aphasia

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Background: Verb Network Strengthening Treatment (VNeST) is a semantic treatment that aims to improve lexical retrieval of content words in sentence context by promoting systematic retrieval of verbs (e.g., *measure*) and their thematic roles—i.e., agent (doer of the action, e.g., *carpenter*, *chef*) and patient (receiver of the action, e.g., *lumber*, *sugar*). VNeST is influenced by Loverso and colleagues (e.g., Loverso, Selinger, & Prescott, 1979) who used "verb as core" treatment to improve sentence production with encouraging results, and McRae and colleagues who showed that verbs prime typical agents (e.g., pray–nun) and patients (arrest–criminal) (Ferretti, McRae, & Hatherell, 2001) and vice-versa (McRae, Hare, Elman, & Ferretti, 2005).

Aims: There are four specific questions in this study. Does training a set of verbs using VNeST generalise to the ability to produce (1) an agent (*carpenter*), trained verb (*measure*), and patient (*stairs*) in response to novel picture stimuli and (2) an agent (*nurse*), untrained semantically related verb (*weigh*), and patient (*baby*) in response to novel picture stimuli? (3) Are generalisation effects maintained? (4) Does VNeST generalise to the ability to retrieve nouns and verbs not directly related to treatment items in single word naming, picture description, and connected speech tasks?

Methods & Procedures: Four participants with aphasia participated. Participants received VNeST, which involves retrieval of agent–patient pairs (e.g., *chef/sugar*, *surveyor/land*) related to trained verbs (e.g., *measure*), twice per week. A single-participant, repeated probe, multiple baseline experimental design was used. Generalisation to sentence production for sentences containing trained verbs and untrained semantically related verbs was tested weekly.

Outcomes & Results: Results demonstrated generalisation to lexical retrieval of content words in sentences with trained and untrained verbs across participants. Additionally, pre- to post-treatment generalisation was observed on single verb and noun naming and

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The authors would first like to thank the four individuals who participated in this study. Additional thanks go Laura K. Allred for creating the artwork for developed stimuli, and Michela Palmieri and Adam Jacks for assistance with reliability.

http://www.psypress.com/aphasiology DOI: 10.1080/02687030802291339

lexical retrieval in sentences across a variety of tasks across participants. Generalisation to connected speech was observed for three of four participants.
Conclusions: Although preliminary, these results indicate that VNeST may be effective in promoting generalisation from single word naming to connected speech in persons with moderate aphasia. A number of clinical implications related to treatment efficiency are discussed.

Keywords: Aphasia; Semantic therapy; Verb, Generalisation; Connected speech; Thematic roles.

Many studies have now shown that speech-language therapy has a significant and in some cases quite large treatment effect in persons with aphasia. However, most of these studies involve some variation of "naming therapy" in which the person is taught to name a set of objects and the outcome measure is performance improvement on this set (Nickels, 2002). However, because there is usually no relationship between word meaning and word sound, naming treatments are intrinsically non-generalising. Knowledge gained tends to be limited to the words actually trained, and there is at best very modest improvement in naming performance with untrained words (Kiran & Thompson, 2003; McNeil, 1997). As is to be expected, persons with aphasia generally show minimal improvement in their ability to communicate in daily life. Achieving large-scale generalisation is essential if speech-language therapy is going to improve the daily communicative lives of people with aphasia.

Unlike naming therapy directed to lexical semantic deficits, therapy directed to semantic deficits might be expected to generalise intrinsically to the extent that trained items share features with untrained items (Plaut, 1996). Counter-intuitively, training on a spectrum of unusual exemplars of a category can be more effective in inducing generalisation than training on typical exemplars (Plaut, 1996). This is because unusual exemplars convey information about both the core regularities defining the category (which help to distinguish it from other categories) and the full range of regularities that are crucial in distinguishing all the different within-category exemplars from each other. Recent clinical work has confirmed this concept (Kiran & Thompson, 2003). Semantic treatments potentially have broad applicability to aphasia rehabilitation because most left hemisphere strokes either damage cortices supporting semantic representations or the interface between these cortices and perisylvian language cortex (Roth, Nadeau, Hollingsworth, Cimino-Knight, & Heilman, 2006). Furthermore, knowledge represented in association cortices in the right hemisphere may usefully contribute to aphasia recovery, but further training of right hemisphere semantic networks may be required for this to happen.

A variety of approaches to semantic therapy have been employed with some success (Raymer & Rothi, 2000). These have included: (1) word–picture matching tasks using semantically related foils; (2) answering yes–no questions about semantic features of pictured objects; (3) semantic sorting of objects; (4) variously cued matching of semantic associates as the number and relatedness of semantic foils are increased; (5) correction of naming errors by provision of additional semantic information that distinguishes the erroneous response from the correct response; and (6) systematic training in the semantic features of objects. Generally these approaches might be characterised as "item-centric" in that the focus is on enabling the participant to differentiate the item in question from near neighbours in its domain. Knowledge of particular semantic domains (e.g., animals) might usefully be fleshed out using item-centric techniques, but semantic knowledge that spans the breadth of daily life is difficult to achieve with this approach.

In a series of studies, Loverso and colleagues introduced a treatment conceptually similar to that of the current study (Loverso, Prescott, & Selinger, 1988; Loverso, Prescott, Selinger, Wheeler, & Smith, 1985; Loverso, Selinger, & Prescott, 1979). The treatment, originally known as "verb as core" (Loverso et al., 1979) and later known as cueing verbs treatment (CVT) (Loverso et al., 1988) was originally developed from theories in cognitive psychology and generative semantics that proposed that the verb is the predicate core of all simple sentences and specifies the relationships between concepts (e.g., Filmore, 1968). Participants moved through levels of the treatment, and the levels and tasks were refined over the series of studies. Tasks included generating, copying, writing, and repeating the agent and patient for the presented verbs and answering "wh" questions about them. Outcome measures showed pre- to post-treatment improvement in performance on the *Porch Index of Communicative Abilities* (PICA, Porch, 1973; Loverso et al., 1979, 1988) and improved ability to generate agents and patients for trained and untrained verbs (Prescott, Selinger, & Loverso, 1982).

The current treatment, Verb Network Strengthening Treatment (VNeST), focuses on what we will call the predicative components of the distributed semantic representation of concepts, which are expressed linguistically as verbs. Predicative components are features of noun concept representations that add meaning explicitly sustained dynamically over a period of time, in contrast to adjectival components, which are static and enduring. Thus, running, leaping, barking, and whining can be predicative components of a dog concept representation, whereas black, shaggy, large, or friendly can be adjectival components. Both adjectival and predicative components can be features of many noun concept representations. In addition, because verbs can have more than one thematic role (corresponding to arguments), a given predicative component can simultaneously be a feature of two or even three noun concept representations, and can link these representations to each other. Thus, measuring is something that can be done by carpenters, chefs, surveyors, and designers and to lumber [wood], sugar, and land (Figure 1) and therefore it constitutes a predicative component of each of these concept representations. Consistent with these theoretical principles, McRae and colleagues have shown bidirectional priming/co-activation of verbs and their thematic roles, so that a verb primes typical agents (e.g., *arresting/policeman*), patients (*arresting/criminal*), and instruments (e.g., *cutting/scissors*) (Ferretti et al., 2001) and vice versa (McRae et al., 2005), indicating that the meaning of a verb is not separate from its thematic roles but is dependent on them (Druks, 2002; Ferretti et al., 2001, Jackendoff, 1972). From the perspective of parallel distributed processing networks (Rumelhart, Smolensky, McClelland, & Hinton, 1986), the principle of content addressable memory posits that a predicative component can engage, at least to some degree, all the various concepts that can incorporate that component as a feature.

As Figure 1 illustrates, a given verb can be a predicative component to an extraordinarily diverse array of concepts (whether as agent or patient). Furthermore, because VNeST requires the participant to generate agents and patients for verbs, it may plausibly encourage him/her to focus on the full spectrum of plausible predicative components for each agent and patient; in short, the full action milieu of a carpenter, chef, or surveyor. To the extent that the participant is successful in

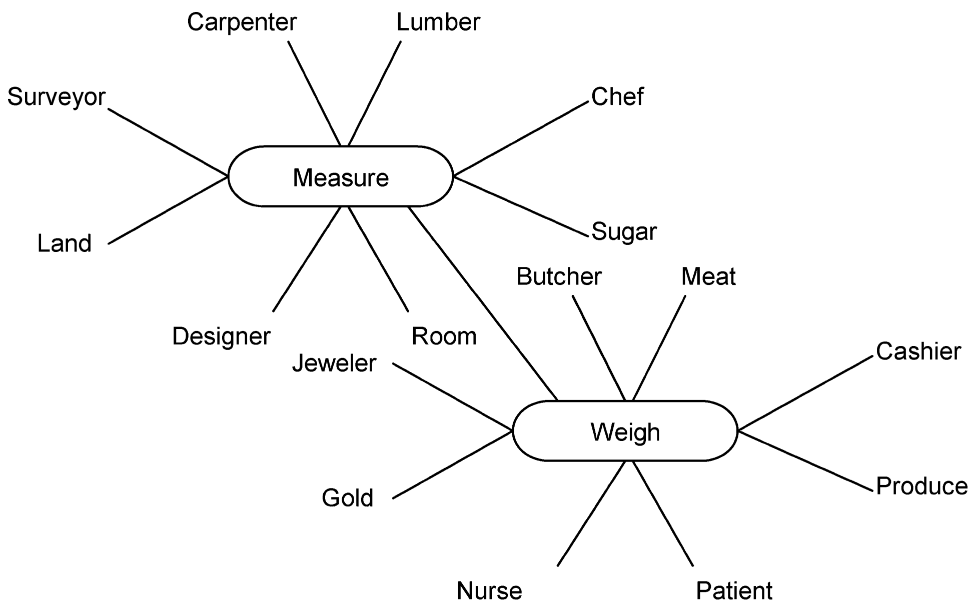

Figure 1. Schematic of the relationship between the verb–thematic network of *measure* and *weigh.* Treatment of agent–patient pairs in Verb Network Strengthening Treatment (VNeST) (e.g., *carpenter/lumber* and *chef/sugar*) in the context of the trained verb *measure* will strengthen the connections between the neural substrate for each agent–patient pair and the verb itself. In addition, the semantic representations of closely related verbs, such as *weigh*, will be strengthened, as will their connections to the neural substrates for their thematic pairs (e.g., *butcher/meat*), since they are thought to be engaged by the closely related verbs. Consequently, retrieval of both trained and untrained verbs and related thematics should be facilitated.

engaging these various concept representations, as reflected in success in retrieving them, there is an opportunity for Hebbian learning to occur within the neural networks supporting the concepts, thereby providing the basis for more successful retrieval in the future.

VNeST may take advantage of another potentially important mechanism. Engaging the semantic representation of a verb (which can become a feature of the multi-component distributed representation underlying a noun concept, as discussed) can partially engage the semantic representations of other verbs that share features with that verb (e.g., *weigh* and *measure* in Figure 1) but are predicative components of somewhat different sets of concepts. This mechanism could potentially expand the extent of the semantic field influenced by the therapy.

The basic task of VNeST is to generate agent and patient pairs to a target verb (e.g., chef/sugar, carpenter/lumber, surveyor/land for *measure*) with the intent of strengthening the connections between the verb and its thematic roles. The anticipation was of a broad semantic impact that would be reflected not only in improved ability to retrieve trained verbs and their thematic nouns but also untrained verbs and their thematic roles. The specific questions posed in this study were: Does training a set of verbs using VNeST generalise to the ability to produce (1) an agent (*carpenter*), trained verb (*measure*), and patient (*stairs*) in response to novel picture stimuli and (2) an agent (*nurse*), untrained semantically related verb (*weigh*), and patient (*baby*) in response to novel picture stimuli? (3) Are generalisation effects maintained? (4) Does VNeST generalise to the ability to retrieve nouns and verbs not directly related to treatment items in single word naming, picture description and connected speech tasks?

METHOD

Participants

Four participants with aphasia were recruited from Austin, TX, area hospitals and the University of Texas Speech and Hearing Clinic. Participants met several selection criteria: (1) aphasia due to single left hemisphere stroke 9+ months before participation, (2) monolingual English speaking, (3) impaired lexical access for nouns and verbs, (4) no other neurological or learning disorder, (5) right-handed prior to stroke, (6) adequate hearing, vision, and comprehension to engage fully in testing and treatment. (See Table 1 for demographic information.)

Participants who met inclusion criteria underwent several specific assessments to characterise aphasia type and severity and lexical retrieval impairments (see Table 2 for details). On the *Western Aphasia Battery* (*WAB*, Kertesz, 1982), Participants 1 and 2 (P1 and P2) exhibited moderate transcortical motor aphasia with no more than mild-moderate apraxia of speech (Dabul, 2001) whereas Participants 3 and 4 (P3 and P4) exhibited moderate conduction aphasia.

Materials

Single word lexical retrieval was evaluated with the *Boston Naming Test* (*BNT*, Goodglass, Kaplan, & Weintraub, 1983) and the *Northwestern Verb Production Battery* (*NVPB*, Thompson, 2002). The NVPB consists of 25 pictures that show people or animals engaging in a common action (e.g., *barking*, *climbing*, *putting*). Verbs identical to treatment verbs were omitted (e.g., *fry*, *write*). Participants exhibited a range of abilities on the *BNT* (Goodglass et al., 1983) with the participants with nonfluent aphasia performing better than those with fluent aphasia. The predominant error type on the BNT for P1 ($N = 17$ errors) was semantic (70.6%) followed by unrelated (17.6%) and No Response/I don't know (NR/IDK) (11.8%) errors. P2's predominant errors ($N = 11$ errors) were also

TABLE 1
Demographic information for participants

Participant	*M/F*	*Age*	*Education (years)*	*Occupation*	*Site of lesion*	*MPO*	*Type of aphasia*	*WAB AQ*
1	M	52	10	Body mechanic	Left MCA	10	TMA	76.4
2	F	63	16	Computer programmer	Left MCA	96	TMA	78.5
3	F	75	16	Retired school teacher	Left MCA	22	Conduction	73.8
4	F	56	14	Musician	Large Left MCA	21	Conduction	70.6

M = Male; F = Female; MCA = Middle Cerebral Artery; MPO = Months post onset; WAB AQ = *Western Aphasia Battery* Aphasia Quotient; TMA = Transcortical motor aphasia.

TABLE 2
Pre- and post-treatment scores for all administered tests/tasks

	Participant 1		*Participant 2*		*Participant 3*		*Participant 4*	
	pre-tx	*post-tx*	*pre-tx*	*post-tx*	*pre-tx*	*post-tx*	*pre-tx*	*post-tx*
Tests and tasks with inclusion criteria								
Western Aphasia Battery (AQ)	76.4	82.5	78.5	86.4	73.8	81.2	70.6	82.3
Information	7	9	8	9	9	9	8	9
Fluency	5	6	4	6	8	9	7	8
Comprehension	8.6	8.15	9.35	9.9	8.1	8.9	7.7	9.85
Repetition	9.4	9.8	9.6	9.5	3.9	6.2	4.9	6.4
Naming	8.2	8.3	8.3	8.8	7.9	7.5	7.7	7.9
Northwestern Verb Production Battery								
Sentence production without verb provided* ($N = 22$)	22 (54.5%)	19 (86.4%)	13 (59.1%)	18 (81.8%)	16 (72.7%)	19 (86.4%)	22 (31.8%)	22 (63.6%)
Tests and tasks to evaluate pre–post changes								
Boston Naming Test ($N = 60$)	43 (71.7%)	50 (83%)	49 (81.7%)	54 (90%)	27 (45%)	33 (55%)	27 (45%)	41 (68.3)
NVPB (Single verbs) ($N = 22$)	16 (72.7%)	19 (86.4%)	16 (72.7%)	16 (72.7%)	18 (81.8%)	20 (90.9)	11 (50.0%)	13 (59.1%)

Tx = treatment; * *The Northwestern Verb Production Battery* protocol requires showing and reading aloud the verbs for each sentence to be produced. However, the verbs were not seen or heard by the participants in this study during administration of the test in order to evaluate better noun and verb retrieval changes.

semantic (54.5%) followed by NR/IDK (36.4%) and phonemic (9.1%) errors. Error types were more varied for participants 3 and 4. P3's predominant error type ($N = 27$ errors) was phonemic (39.4%) followed by NR/IDK (33.3%), semantic (12.1%), neologisms (9.1%), and unrelated words (6.1%). P4's predominant error type ($N = 27$ errors) was NR/IDK (45.5%) followed by neologisms (24.2%), phonemic (21.2%), semantic (6.1%), and unrelated words (3.0%).

Verb naming accuracy on the *NVPB* was also variable across participants with no predictable pattern across aphasia type. With respect to verb naming errors, Participants 1 ($N = 6$ errors) and 3 ($N = 4$ errors) produced only semantic errors (100%). P4 ($N = 11$ errors) predominantly produced semantic errors as well (54.5%), followed by NR/IDK (36.4%) and unrelated words (9.1%). The predominant error for P2 ($N = 6$ errors) was NR/IDK (66.7%) followed by semantic (33.3%).

Lexical retrieval in a sentence context was also evaluated with the *NVPB* (Thompson, 2002). Picture stimuli elicit sentences with the same verbs used in the single word context (e.g., *The dog is barking.*, *The boy is climbing a tree.*, *The woman is putting the box on the shelf.*). This test's protocol typically involves showing and reading the verb to the participant. However, in order to evaluate the participants' abilities without verb assistance, the verb was not shown to or heard by the participants. Since lexical retrieval was of primary interest, participants were given credit for a sentence if all the required lexical items were present regardless of word order or inflection of the verb. Accuracy varied across participants with a range of 31.8 to 72.7%.

Connected speech samples

Connected speech samples were collected prior to the initiation of treatment to evaluate participants' lexical retrieval abilities in discourse. Two picture-description tasks, the *WAB* picnic picture (Kertesz, 1982) and cookie theft picture (*Boston Diagnostic Aphasia Examination*, Goodglass & Kaplan, 1983), and a Cinderella narrative were used. For picture description, participants were instructed to describe what was happening in the pictures and to use complete sentences. For the Cinderella task, participants reviewed the story by looking at the pictures in a book (without words), and then they told the story without the book. No prompts were provided except occasional encouragement. The responses for all three connected speech tasks were combined into one sample. They were transcribed by the first author and a trained Communication Sciences and Disorders undergraduate employing *Quantitative Production Analysis* (QPA, Saffran, Berndt, & Schwartz, 1989).

A standard measures analysis in *Systematic Analysis of Language Transcripts* (SALT) (Language Analysis Lab, 1984–2006) was conducted to determine total number of utterances and mean length of utterance (MLU). However, of primary interest was whether the participants showed changes in the proportion of utterances consisting of two elements: (1) lexical retrieval of an appropriate agent and verb (and patient when necessary) and (2) relevant meaning to a listener aware of the topic. These elements were examined because it was expected that the ability to retrieve the content words of a sentence would improve and that the words retrieved would contain more semantic specificity (i.e., relevance). Hereafter, utterances containing a relevant agent + verb + (object) will be referred to as *complete utterances.* Acceptable errors included grammatical, morphological, reference, and phonemic errors as well as circumlocutions, since these aspects of connected speech were not targeted in treatment. However, a complete utterance *could not* be an abandoned utterance or fragment, even if part of the utterance was correct. Likewise, a perfectly formed utterance not related to the stimuli was not considered a complete utterance.

The following are examples of utterances that represent all possible scoring combinations. The end of each utterance is marked with a + or – to indicate whether an utterance contained required content words (+/–SV) and relevant meaning (+/– RELEVANT):

1. The tree is open [+SV][–RELEVANT]. (Not *complete utterance* – irrelevant)
2. The son is flying is a kite [+SV][+RELEVANT]. (*complete utterance*)
3. To walk through the step [–SV][–RELEVANT]. (Not *complete utterance* – incomplete subject and verb combination and irrelevant)
4. A little guy with some sand on the shore with his hands the sand [–SV][+RELEVANT]. (not *complete utterance* – missing main verb)

After the utterances were coded, the number of *complete utterances* was divided by total number of utterances to determine the percentage of *complete utterances*. Before treatment, participants showed deficits in producing complete utterances (range = 50.4% to 62.5% of total utterances).

After initial scoring by the first author, a licensed speech-language pathologist familiar with speech output of persons with aphasia re-scored one complete randomly chosen transcript for each participant. Reliability (expressed as agreement between each scorer's count of complete utterances) was 93% for coding of complete utterances.

Stimuli development/validation

Sentence elicitation pictures. A total of 24 pictures were developed for baseline and treatment probes. All sentences elicited an agent, verb, and patient. The agents and patients portrayed had specific titles in most cases (e.g., *nurse*, *carpenter*) to promote specific language use instead of use of generic words (e.g., *lady*, *man*). Sentences were divided into two sets (verb set 1 and verb set 2) (see Table 3). Sets were created so that each verb in one set was semantically related to a verb in the other set (e.g., *measure/weigh*). As determined by Student's *t*-test, there was no significant difference in frequency (Coltheart, 1981) between the agents and patients for verb set 1, $t(24) = 0.35$, $p = 0.73$, or verb set 2, $t(23) = 0.57$, $p = 0.57$, or between the agents, $t(25) = 1.36$, $p = 0.19$, and patients, $t(22) = 0.48$, p = 0.63, in the two verb sets. All pictures designed for this study were hand-drawn by the same artist and were coloured with similar colour complexity. The drawings were approximately 4" × 6" and centred on 8½" × 11" white paper. A healthy younger group (10 females and 1 male; average age = 36.4 years; average education = 17.2 years) filled out a questionnaire that required them to rate verb pairs on a scale of 1 (not related) to 7 (highly related) for semantic relatedness. Only verb pairs with a rating of > 4.5 were selected for this study (average rating = 5.53, $SD = 0.94$) (see Table 3).

In addition to semantic relatedness, each verb pair shared at least one verb feature class—e.g., *measure* and *weigh* are both Measure verbs (major class) and Register verbs (subclass)—(Levin, 1993). Optional 2-place (e.g., *bake*), obligatory 2-place (e.g., *examine*), and optional 3-place (e.g., *deliver*) verbs were employed. Semantically "heavy" verbs with relatively specific semantic meanings (e.g., *bake*, *drive*) were used rather than "light" verbs (e.g., *make*, *go*). Verb sets were also matched for frequency, $t(11) = 0.17$, $p = 0.87$, imageability, $t(5) = 0.68$, $p = .53$, familiarity, $t(5) = 0.90$, $p = 0.40$, and number of syllables: range = 1–3 syllables, $t(11) = 0.32$, $p = .75$ (Colheart, 1981), although a number of words did not have imageability and frequency ratings. (See Table 3 for details.)

Control task. A single word adjective retrieval task was developed as a non-verb control task that would rule out the possibility that improvements occurring during treatment reflected a nonspecific effect on semantic knowledge underlying concept representations. Adjectives were chosen rather than verbs because a sufficient number of verbs that were unrelated to treatment verbs and balanced across retrieval variables (e.g., frequency) could not be generated. Participants were expected to complete a sentence by providing a synonym to the adjective provided in the sentence. For example, *Someone who is sick is also said to be* _____ (target is *ill*). The adjectives were matched to the 24 verbs included in the probe stimuli on frequency, $t(34) = 0.18$, $p = 0.86$, imageability, $t(24) = 0.71$, $p = 0.48$, and familiarity, ($t(22) = 1.22$, $p = 0.23$.

A group of older adults (eight females, two males; average age = 59.6 years; average education = 15.70 years) produced sentences for the sentence elicitation pictures and also completed the adjective control task. The sentence elicitation

TABLE 3
Trained and untrained verb sets compared on a number of variables

Verb Set 1				*Verb Set 2*				*Sem Rel*	*Target sentence**	
Item	*Freq*	*Image*	*Fam*	*Item*	*Freq*	*Image*	*Fam*	*(Avg./SD)*	*Verb set 1*	*Verb set 2*
Bake	12	495	549	Fry	2	n/a	n/a	5.54/0.52	The chef is baking a pie.	The cook is frying eggs.
Throw	42	477	548	Kick	16	551	563	5.18/0.75	The tennis player is throwing his racquet.	The soccer player is kicking the ball.
Sew	6	478	517	Knit	10	n/a	n/a	5.82/0.87	The tailor is sewing a jacket.	The mother is knitting a sweater.
Read	173	499	568	Write	106	548	560	5.54/1.13	The student is reading a book.	The policeman is writing a ticket.
Fly	33	582	537	Drive	105	n/a	n/a	5.0/0.77	The pilot is flying an airplane.	The chauffeur is driving a limousine.
Measure	91	379	555	Weigh	4	411	536	5.64/1.21	The carpenter is measuring the stairs.	The nurse is weighing a baby.
Scrub	9	n/a	n/a	Wash	37	522	632	7.0/0.0	The maid is scrubbing the floor.	The zoo keeper is washing an elephant.
Watch	81	525	576	Examine	33	341	549	5.0/1.41	The audience is watching the play.	The veterinarian is examining the dog.
tow	1	406	468	Push	37	341	549	4.64/1.80	The farmer is towing the (horse) trailer.	The gardener is pushing the lawnmower.
chop	3	575	487	Slice	13	507	540	6.0/0.89	The boy (scout) is chopping wood.	The father is slicing a ham.
Deliver	18	n/a	n/a	Send	74	n/a	n/a	4.7/1.27	The mailman is delivering the letter.	The woman is sending a package.
Mix	13	n/a	n/a	Shake	17	n/a	n/a	6.27/0.65	The bartender is mixing the drink.	The baby is shaking the rattle.
Avg	45.1	490.7	533.9	Avg	36.3	460.1	561.3	5.53/0.94		
SD	55.3	67.7	36.5	SD	38.7	93.8	32.7			

Freq = frequency (range 0–69971); image = imageability (range 100–700); fam = familiarity (range 100–700); n/a = not available; Sem Rel = Semantic relatedness ratings for verb pairs on 1–7 scale. *Present progressive form not required.

pictures chosen for use in this study were produced with the intended target with a minimum of 90% accuracy, and the adjective control items were completed with the correct target with a minimum of 85% accuracy.

Experimental design

A multiple baseline across behaviours and participants design (Connell & Thompson, 1986; McReynolds & Kearns, 1983) was used to evaluate the effects of VNeST. The design consisted of three phases: (1) baseline, (2) treatment of trained items with weekly administration of generalisation and control probes to monitor effects of treatment on untrained tasks/stimuli, (3) maintenance (1 month post-treatment when possible). Stable baselines (no greater than 20% variability across baseline probes) were established for generalisation and control probes (but please see comments about P4's control baselines in the results section) prior to treatment administration and weekly during the treatment phase.

To answer questions 1 and 2—Does training a set of verbs using VNeST generalise to the ability to produce (1) an agent (*carpenter*), trained verb (*measure*), and patient (*stairs*) in response to novel picture stimuli and (2) an agent (*nurse*), untrained semantically related verb (*weigh*), and patient (*baby*) in response to novel picture stimuli?—weekly probes of pictures depicting an agent (*carpenter*/*nurse*), action (*measure*/*weigh*), and patient (*stairs*/*baby*) were administered. To answer question 3 ("Are generalisation effects maintained following treatment?") generalisation and control probes were administered 1 month post-treatment. Finally, to answer question 4 ("Does VNeST treatment generalise to the ability to retrieve nouns and verbs not directly related to treatment items in single word naming, picture description and connected speech tasks?") pre- and post-treatment tests including the *BNT* (Goodglass et al., 1983), *NVPB* (Thompson, 2002) and various connected speech tasks were administered.

Generalisation was defined as 40 percentage points over the highest baseline (see Edmonds & Kiran, 2006; Kiran & Thompson, 2003; Thompson, Shapiro, Kiran, & Sobecks, 2003).

Baseline, treatment, and maintenance probe measures

During baseline, treatment, and maintenance probe sessions 20 pictures and the adjective control task were administered. During sentence production, pictures were pseudo-randomly presented so that verbs in the same semantic category (e.g., *bake* and *fry*) were not sequential. Participants were instructed to "Make a sentence and include him, the action, and this" (while pointing to the agent, verb, patient). Generally, no prompts were provided. However, if a participant produced a general word for the target (e.g., *cut* instead of *slice* or *man* instead of *carpenter*), the participant was prompted to use a more specific word. Additionally, if the participant produced a relevant target that was not the intended target (e.g., *The landscaper is* *<u>mowing</u>* *the grass* instead of *The landscaper is* *<u>pushing</u>* *the lawnmower*), the action or relevant item was pointed to for clarification. The first response produced after the prompt was recorded. These same prompts were given to the normal older group when the pictures were normed as well.

Responses to the pictures were scored as correct or incorrect based on success in lexical retrieval. A correct response included the agent, verb, and patient.

Grammatical and/or morphological errors were not considered since these were not targeted in treatment. A few alternative responses were considered correct based on responses from the normal older group (e.g., *pull* was accepted for *tow*). In the event of multiple attempts, the best sentence was scored.

For the adjective control task participants were expected to complete a sentence by providing a synonym to the adjective provided in the sentence. For example, *Someone who is sick is also said to be* _____ (target is *ill*). To be scored as correct a response had to be an adjective consistent with responses provided by the normal group. In the event of multiple attempts, the final adjective produced was scored. One phonological error (e.g., omission, addition) per lexical item was allowed for all tasks.

Treatment

Stimuli consisted of: (1) 10 cards containing the names of the 10 trained verbs (verb set 1) (e.g., *measure*); (2) 6–8 cards for each verb containing 3–4 agents and 3–4 patients that form 3–4 pairs related to each verb (e.g., *chef/sugar*, *carpenter/lumber*, *surveyor/land*, *designer/room*, for the verb *measure*) chosen to represent a range of possibilities to maximally expand the variety of scenarios related to each verb; (3) five cards containing the following words (*who*, *what*, *where*, *when*, *why*); and (4) 12 sentences used for semantic judgement (heard but not seen by participants). The 12 sentences contained the target verb broken into four categories: (a) correct (*The designer measures the room.*); (b) inappropriate agent (*The infant measures the lumber.*); (c) inappropriate patient (*The chef measures the television.*); (d) thematic reversal (*The room measures the designer*). (See step 4 of the training, Appendix A.)

VNeST was administered twice per week for 2-hour sessions. The first hour of the second session each week was dedicated to probes. Participants performed five treatment steps that aimed to strengthen the semantic meaning of the target verb and to promote stronger associations between the verb and related agents and patients. Essentially, the participants were asked to produce orally 3–4 thematic role pairs (e.g., carpenter and lumber) for a provided verb (e.g., measure). When they were unable to produce a word they were provided with written options on cards (some appropriate and some foils). They were encouraged to provide at least one personal pair, and the responses could change from week to week. After generating a list of items and reading them aloud, they chose a pair and answered wh-questions about it. See Appendix A for detailed treatment steps with examples, and Appendix B for an example of what was generated and seen by the participant for treatment steps 1–3.

Treatment was terminated when participants produced a minimum of 24 agent–patient pairs (80% accuracy) during treatment step #1 (e.g., for *measure*, acceptable pairs would include chef/sugar, surveyor/land, designer/room). Since there were 10 treatment items and 3 opportunities for agent/patient pairs, a total of 30 pairs in one week was possible. Thus, 24 correct pairs (80%) in 1 week met treatment termination criterion. All participants achieved the 80% accuracy criterion before the last administered probe, except for P2 who achieved criterion before the penultimate probe.

Treatment reliability

In order to ensure that the treatment protocol was conducted consistently within and across participants, a trained Communication Sciences and Disorders undergraduate observed 25% of the sessions live. The treatment protocol was followed with a reliability of 98% (determined by comparing the observed treatment steps to the written protocol). Reliability on scoring of the weekly probes was conducted by the same individual on 25% of the probes. Agreement in responses and scoring was 95%.

RESULTS

Weekly probes

Results of weekly probes for all participants are presented in Figures 2 to 5 in multiple baseline format. These results address research questions 1 and 2, which were: Does training a set of verbs using VNeST generalise to the ability to produce (1) an agent (*carpenter*), trained verb (*measure*), and patient (*stairs*) in response to novel picture stimuli and (2) an agent (*nurse*), untrained semantically related verb (*weigh*), and patient (*baby*) in response to novel picture stimuli? For the top two graphs of each figure, credit was given only if participants produced all content words (agent, verb, *and* patient).

Participant 1. Correct production of agent, verb, and patient in description of pictures depicting trained actions increased from a baseline maximum of 0% to a high of 80%. For pictures depicting untrained actions, correct production of agent, verb, and patient increased from a baseline maximum of 10% to 90%. Maintenance probes were 30% and 50% greater than the highest baseline value for sentences with trained and untrained verbs, respectively. There was no evidence of improvement on the adjective control task.

Participant 2. Correct production of agent, verb, and patient in description of pictures depicting trained actions increased linearly from a baseline maximum of 40% to a high of 80%. For pictures depicting untrained actions, correct production of agent, verb, and patient increased from a baseline maximum of 40% to 90%. Maintenance probes were 20% and 30% over the highest baseline for sentences with trained and untrained verbs, respectively. There was no evidence of improvement on the adjective control task.

Participant 3. Correct production of agent, verb, and patient in description of pictures depicting trained actions increased linearly from a baseline maximum of 30% to a high of 60%. For pictures depicting untrained actions, correct production of agent, verb, and patient increased from a baseline maximum of 30% to 90%. Maintenance probes were 50% and 60% over the highest baseline for sentences with trained and untrained verbs, respectively. There was no evidence of improvement on the adjective control task during the treatment phase. Improvement on the control task during the baseline phase reflects a growing understanding of the task by the participant (which she expressed). However, there was no improvement from the baseline phase to the treatment phase, so experimental control was maintained. See Peach and Wong (2004) for a similar observation.

Participant 4. Correct production of agent, verb, and patient in description of pictures depicting trained actions increased linearly from a baseline maximum of 0% to a high of 40%. For pictures depicting untrained actions, correct production of agent, verb, and patient increased from a baseline maximum of 0% to 50%.

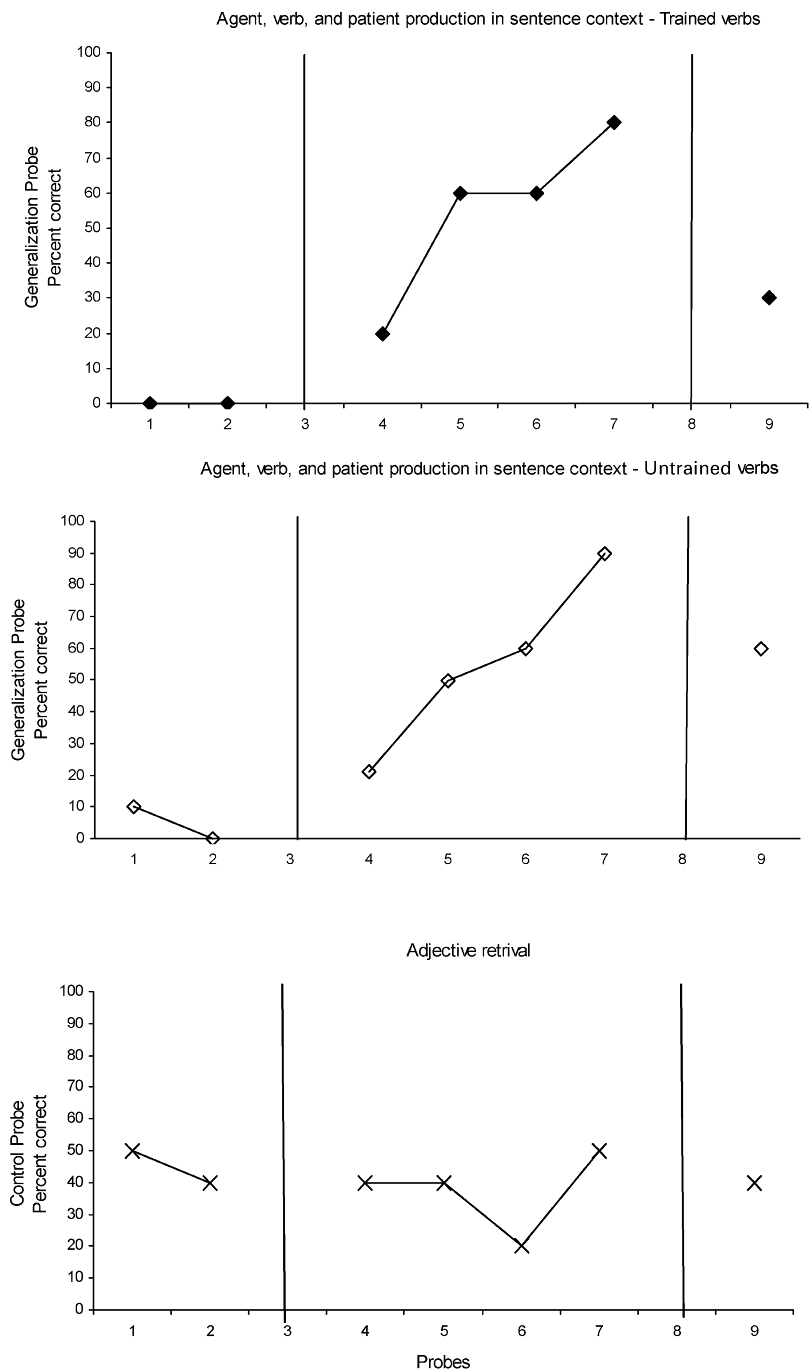

Figure 2. Participant 1 weekly generalisation and control tasks. The first and second graphs indicate a correct production of all three content words—the agent, verb, and patient—for picture description probes.

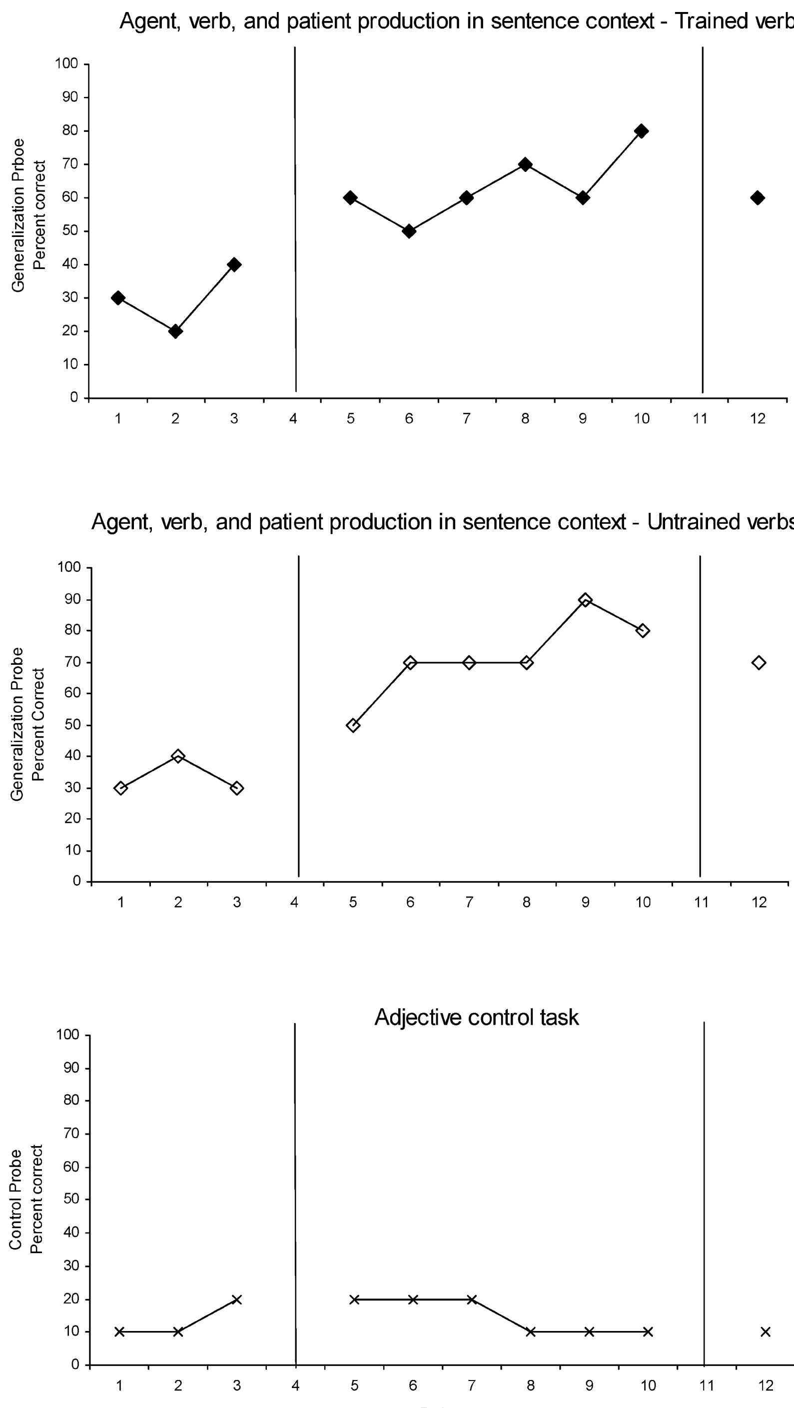

Figure 3. Participant 2 weekly generalisation and control tasks. The first and second graphs indicate a correct production of all three content words—the agent, verb, and patient—for picture description probes.

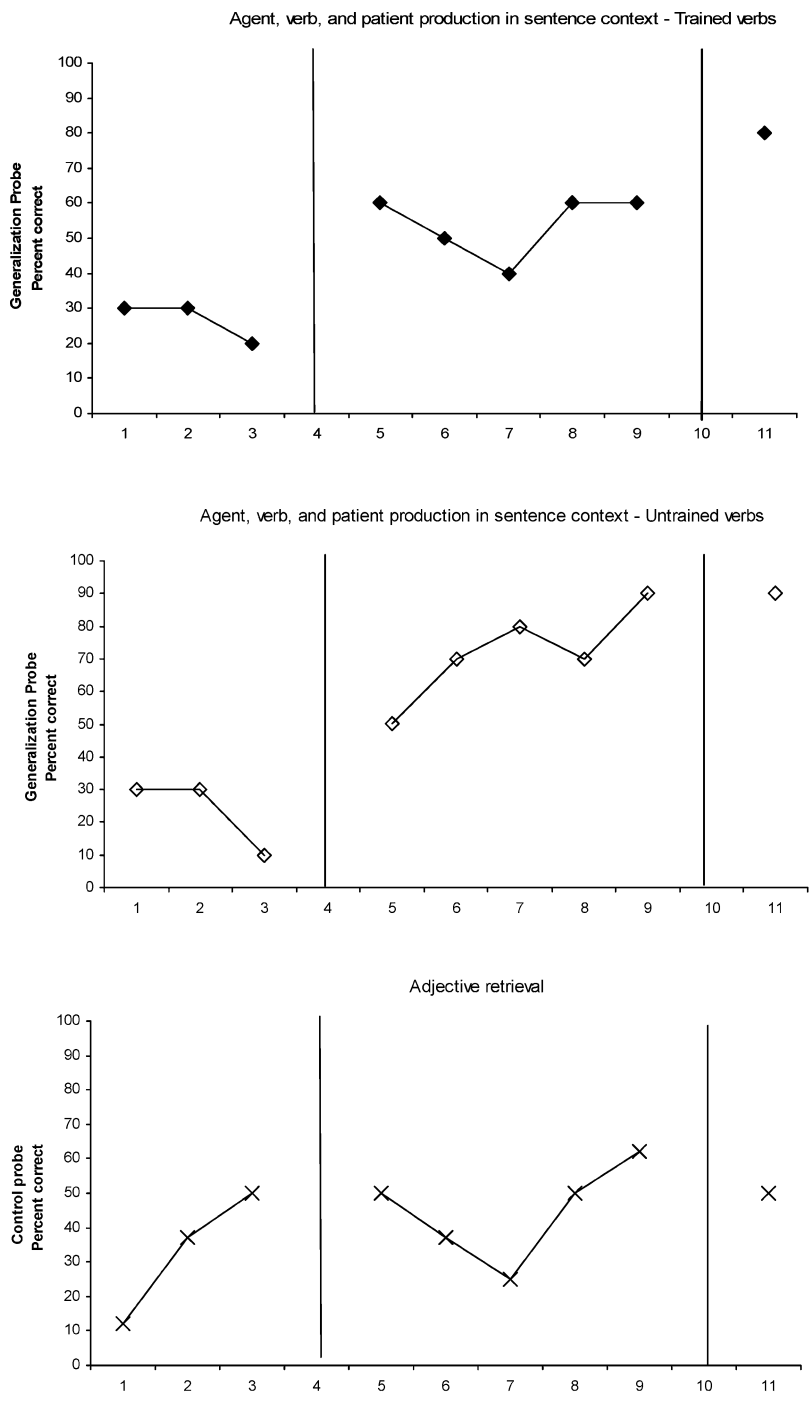

Figure 4. Participant 3 weekly generalisation and control tasks. The first and second graphs indicate a correct production of all three content words—the agent, verb, and patient—for picture description probes.

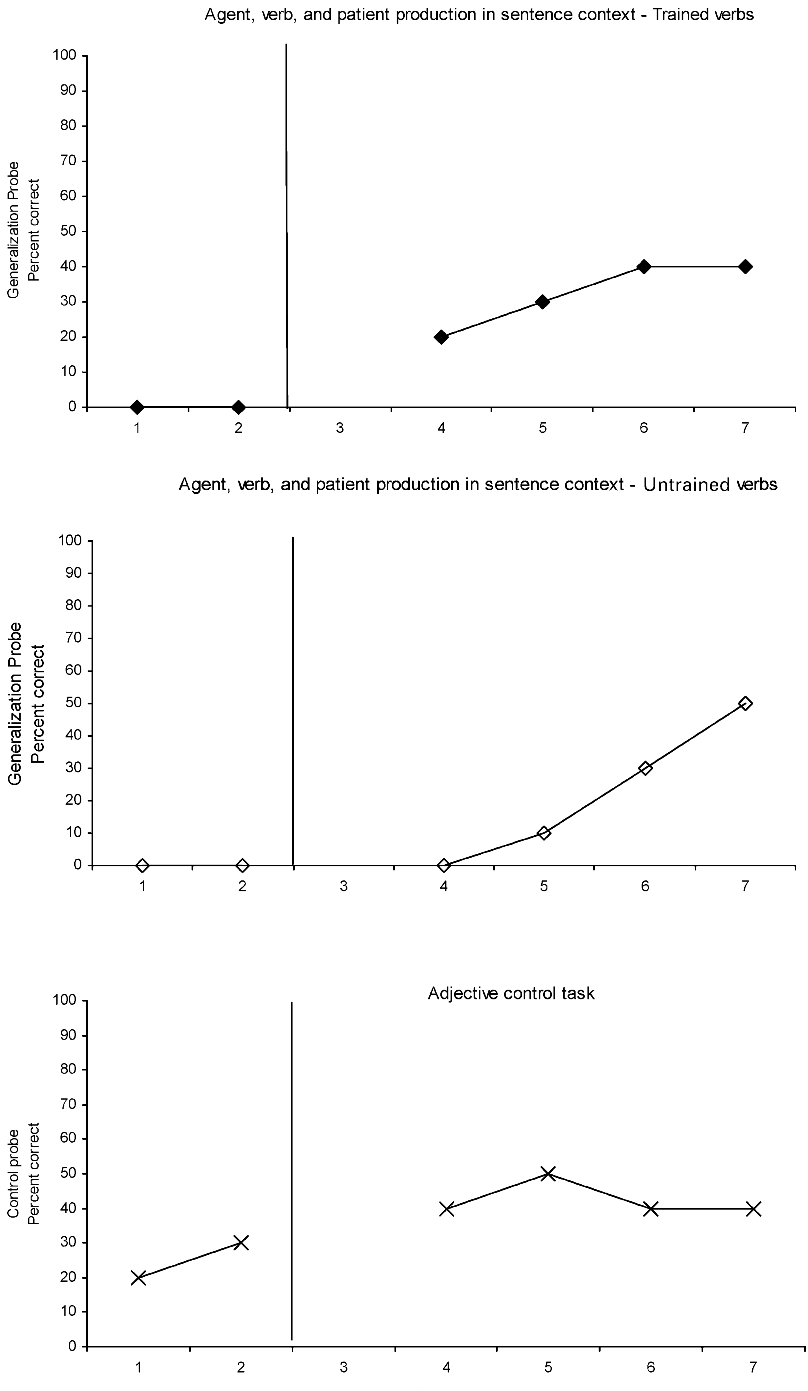

Figure 5. Participant 4 weekly generalisation and control tasks. The first and second graphs indicate a correct production of all three content words—the agent, verb, and patient—for picture description probes.

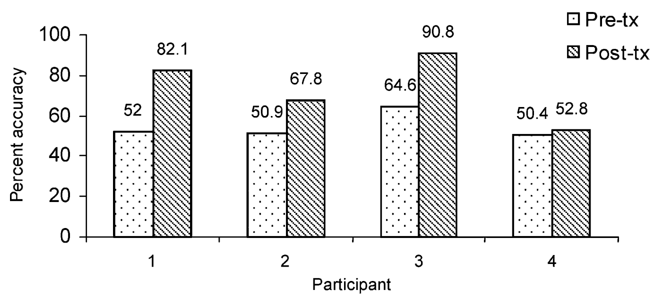

Figure 6. Percentage of pre- and post-treatment "complete utterances" in connected speech for all participants.

Maintenance probes were not administered for P4 due to her unavailability. There was no evidence of improvement on the adjective control task.

Pre- and post-treatment language measures

The results for tests administered pre- and post-treatment are presented in Table 2. These results address research question 3, "Does VNeST generalise to nouns and verbs not directly related to treatment items in single word naming, picture description and connected speech tasks?"

Noun retrieval improved an average of 13.2 percentage points (range = 8.3–23.3) on the *Boston Naming Test* (Goodglass et al., 1983), and verb retrieval improved an average of 8.0 percentage points (range = 0–13.7%) on the *NVPB* (Thompson, 2002). Noun and verb retrieval in sentence production on the *NVPB* improved on average 25 percentage points (range = 13.7–31.9). All participants improved at least 5 points, (range = 6.1–12. 8 points) on the *Western Aphasia Battery* (*WAB*, Kertesz, 1982), an indication of clinically significant improvement (Katz & Wertz, 1997). However, improvement on naming was not observed for any participant, as would be expected. Rather, the nonfluent participants showed improvement on spontaneous speech (information and fluency) while the fluent participants improved in comprehension and repetition. These improvements reflect improvements in the relative weaknesses of the aphasia types and are consistent with various tasks involved in the VNeST protocol (e.g., comprehension of wh-questions and sentence judgement) and other pre- to post-treatment improvements (connected speech tasks). See Table 2.

Participants 1, 2, and 3 improved 16.9% to 30.1% on connected speech samples as measured by their production of complete utterances (defined by presence of an appropriate agent, verb, and patient, and relevance to the topic). Participant 4 (P4) showed no improvement (see Figure 6). All participants produced more utterances (P1: 25 pre-treatment to 29 post-treatment; P2: 53 to 59; P3: 48 to 65; P4: 121 to 159). Change in mean length of utterance (MLU) was variable (P1: 4.79 to 6.29; P2: 5.48 to 5.98; P3: 8.62 to 8.71; P4: 6.99 to 6.90). See Appendix C for an example of P3's pre- and post-treatment cookie theft picture description.

DISCUSSION

The purpose of this study was to investigate the effects of Verb Network Strengthening Treatment (VNeST), a novel treatment inspired by the work of

Loverso and colleagues (Loverso et al., 1979, 1985, 1988) and McRae and colleagues (Ferretti et al., 2001; McRae et al., 2005), on the lexical retrieval of nouns and verbs in sentences containing trained and untrained verbs as well as in other tasks ranging from single word naming to connected speech.

Research questions 1 and 2 asked whether VNeST would result in generalisation of lexical retrieval of agent, verb, and patient in a picture description task with stimuli that included trained and semantically related untrained verbs. For sentences containing trained verbs, three of the four participants met the generalisation criterion, with Participant 3 missing criterion by 10%. All participants achieved generalisation criterion for sentences containing untrained verbs. Overall, these generalisation patterns are encouraging since the picture stimuli were never seen in treatment, and the particular agent-verb-patient combinations tested in probes were never trained. Further, many errors during the treatment and maintenance phases were either semantic errors (e.g., *fly* → *drive*) or consisted of good sentences (e.g., *The policeman is writing a ticket.* → *The policeman gave a ticket to the owner of the car.*), representing highly communicative responses that did not pass our strict scoring criteria.

Research question 3 asked whether generalisation measured during the treatment phase would be maintained one month post-treatment. The results overall were encouraging, with Participants 1 and 3 showing a maintenance of 30 to 60 percentage points above the maximum baseline value and Participant 2 with 20 to 30 percentage points above maximum baseline value. Interestingly, P3 showed improvement in sentences with trained verbs in the maintenance probe relative to her performance at conclusion of treatment. This improvement was due to a resolution of semantic errors observed during the treatment phase.

Research question 4 asked whether noun and verb retrieval would improve in single word production and sentence production with stimuli that did not explicitly include trained or semantically unrelated verbs. All participants showed gains in single noun retrieval, and three of four participants improved on single word verb retrieval. All participants improved on agent-verb-(patient) retrieval in sentence production as evidenced by improved sentence production on the *NVPB* (Thompson, 2002) stimuli. Widespread generalisation was hypothesised because Verb Network Strengthening Treatment (VNeST) focuses on increasing semantic knowledge underlying noun and verb representations and the connections between their neural substrates. It takes advantage of the fact that many verbs allow a very broad range of possibilities for both agent and patient, thereby providing an opportunity for highly diverse modifications of the neural networks underlying cerebral representations of potential agents and patients. In this way, the therapy (in which six to eight nouns are retrieved per verb) vastly expands the spectrum of semantic features that are incorporated in the training. Further, the therapy exploits the semantic representation of verbs as a contributor to the semantic representations of agents and patients.

Question 4 also asked whether lexical retrieval of nouns and verbs improved in constrained connected speech tasks. Three of the participants showed improvement in the ability to produce utterances containing a relevant subject, verb, and object with an increase in number of utterances overall. Participant 4 did not show improvements in connected speech on any measure. In fact she became less efficient, producing more total utterances with no increase in *complete utterances*. A post hoc examination of participant 4's sentence production revealed difficulty constructing a sentence frame and substantial paragrammatism not observed in P3, the other fluent participant. Thus, the increased ability in lexical retrieval observed in single words and constrained sentence production did not translate to less constrained speech tasks, perhaps due to her overall difficulty in sentence construction.

The breadth of generalisation observed in this study has not generally been reported in studies of semantic treatment of aphasia (see Raymer & Rothi, 2000). However, in studies targeting verb retrieval there has been evidence of generalisation to semantically related verbs and their potential thematic roles in sentences (Prescott et al., 1982; Raymer & Ellsworth, 2002) and connected speech (Edwards, Tucker, & McCann, 2004). VNeST is likely more conducive to widespread generalisation because of the extensive networks of concepts that are engaged in treatment. Specifically, the primary task of VNeST is systematic retrieval of nouns that vary in semantic category, animacy, frequency, and typicality and that represent plausible agents and recipients of target verbs. Because verbs can be predicative components of noun concept representations (whether agent or recipient), verbs prime potential thematic roles and vice versa (Ferretti et al., 2001; McRae et al., 2005). This priming occurs through the capacity for content addressable memory that is intrinsic to neural networks supporting parallel distributed processing, as in the brain. Verbs should also, in principle, prime the representations of other verbs with which they share features. Thus, centring a semantic therapy on verbs provides the basis for engaging large expanses of semantic networks during treatment and through Hebbian learning, strengthening the neural basis for a large variety of concept representations, and increasing the probability that those representations can elicit corresponding word production. The initial success with VNeST provides tentative evidence in support of this hypothesis.

The mechanism for improvement on tests involving words not directly related to treatment items (BNT, NVPB) is not clear, particularly because the failure to improve on the adjective control task suggests that the treatment did not have a nonspecific effect on semantic knowledge underlying concept representations. It is possible that there was such a nonspecific effect but that the adjective task represented a poor control because it was more difficult than the tasks we used involving verbs. However, this seems unlikely because, with the possible exception of participant 2, there was no evidence of a potential floor effect in adjective task performance. It is conceivable that improvements in performance on completely unrelated words reflected the effect of other generalisation mechanisms than semantic generalisation (Nadeau & Kendall, 2006). The data collected in this study do not enable us to draw further conclusions, but future studies will examine this issue.

Because this is a phase 1 treatment study involving a limited number of participants, the current results must be interpreted conservatively and further studies are needed. In particular, longer baseline phases, treatment phases, and more maintenance data points are needed to establish baseline stability and to better evaluate treatment results. Our results also need to be replicated in participants with a greater spectrum of aphasia types. However, the results are compelling given that the improvement on all dependent variables was evident across all four participants. Additionally, this treatment offers a more expansive yet systematic approach to semantic treatment than more traditional approaches that focus on single items. Finally, because this treatment allows participants to draw exemplars from daily life, it enhances participant interest and increases the likelihood that therapeutic gains will be personally relevant and potentially directly applicable to daily communicative life. Ecologically valid outcome measures examining functional changes are needed in future studies to evaluate treatment effects on participation and communicative success in functional situations.

Manuscript received 3 March 2008
Manuscript accepted 20 June 2008
First published online 21 October 2008

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APPENDIX A

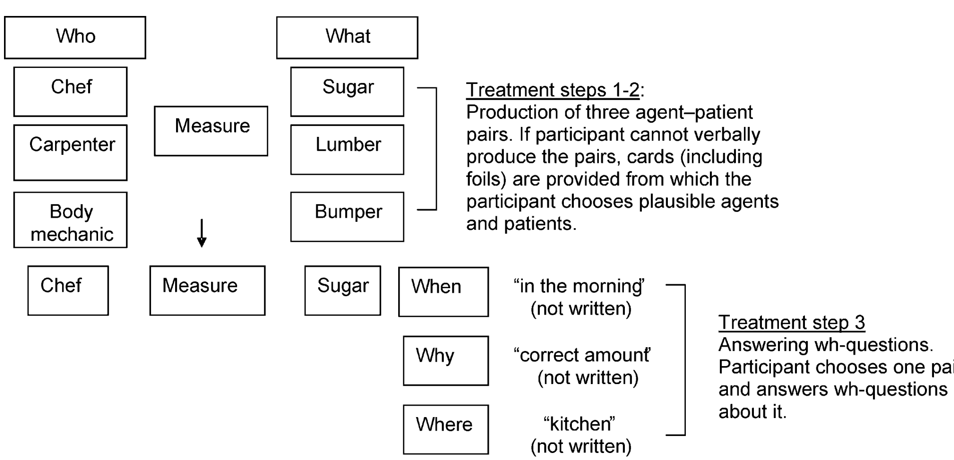
Step	*Objective*	*Therapy step*	*Examples*
1	Generation of three agents or patients for verb.	Clinician says to pt: Tell me *who* (or *what*, to be alternated throughout a session) can verb (be verbed). Clinician puts down card with the word *who* or *what* written on it as well as a card with the verb written on it. For each word generated, a card with the word written on it is put under the word who or what. (See Appendix B for examples.). Participants are encouraged to provide personal responses. A minimum of three words are required before moving to next step. If pt cannot produce three words, the pt receives cards with appropriate responses and three foils written on them and chooses those that go with the verb and rejects those that do not.	Agents for verb *measure*: Chef Carpenter Body mechanic (personal example)
2	Generation of corresponding agent or patient to complete agent–patient pairs	Clinician asks pt to generate another three words that correspond to the agents or patients generated in step 1. For each word generated, a card with the word written on it is put under the word who or what, as appropriate. (See Appendix B.) As in step 1, if pt cannot produce three words, the pt receives words with appropriate responses along with three foils and chooses those that are appropriate and rejects those that are not. All word pairs are read aloud by pt.	Patients to match agents: (Chef)/sugar (Carpenter)/lumber (Body mechanic)/bumper

APPENDIX A (CONTINUED)

Step	*Objective*	*Therapy step*	*Examples*
3	Answer wh-questions about agent–patient pair	The pt chooses one agent–patient pair that he/she wants to discuss in more detail (different pair each week). That pair of words is moved out of the lists of agents and patients to focus attention. (See Appendix B.) The clinician then asks the pt to answer *wh*-questions (where, when, and why) about that pair. Complete sentences were not required for their responses.	When does a chef measure sugar? "in the morning" Why… "correct amount" Where… "kitchen"
4	Semantic judgement of sentences	All cards are removed from the table. Clinician reads 12 sentences containing the target verb (4 correct, 4 with inappropriate agent, 4 with inappropriate patient, 4 with agent and patient switched). The pt indicates whether the sentences make sense or not.	Inappropriate agent: *The dentist measures the door.* (It's possible but not the job of a dentist.)
5	Generation of three agent–patient pairs (repeat steps 1–2)	a) The clinician asks the same question asked in step 1. Clinician says to pt: Tell me *who* (or *what*) can verb (be verbed). Pt encouraged to produce up to three items. b) Clinician asks for words that correspond to those produced in step 5a. No cards are used during this step. General feedback was provided ("Good work," etc.)	a) Who measures things? "Chef" "Mechanic" b) What does a chef (then mechanic) measure? "sugar" "I don't know."

pt = participant.

APPENDIX B



APPENDIX C

PRE- AND POST-TREATMENT COOKIE THEFT PICTURE DESCRIPTION FOR P3

Utt	*Pre-treatment*	*Post-treatment*
1	A mother is working in the kitchen.	Mother and two of her children were in the kitchen.
2	While she has her back to them her two children (xxx).	The children were not looking at mother.
3	The boy is standing on the top (of a xxx).	They were trying to find some cookies.
4	(But) he's standing up.	The girl was standing on the floor.
5	It's tilting.	She was reaching with one hand to reach a cookie.
6	He's almost starting to fall.	Her brother was handing her a cookie.
7	He's the top of the cookie (car car) jar (xxx).	The boy was standing on a stool.
8	He has a cookie xxx.	It was beginning to fall.
9	Looking for a cookie while his sister is reaching (xxx).	(As) he hit with two hands.
10	His last cookie.	One hand was leaning over.
11	While they're doing that the mother is drying a plate.	He was beginning to fall.
12	He's not paying attention to the water that's coming.	With his other hand he was reaching for the cookie jar.
13	The sink and pouring over the sink.	He had the cupboard.
14	And he has a (xx xx) for get that.	He had it opened.
15	The mother is standing with curtains folded on each side.	(So) the top part was beside it.
16	(So) she can look through the window.	He was picking up a cookie with the other hand.
17	To walk through the step.	He had one door that he had opened of the cabinet.
18	There's some plants near there.	While he was on that, mother was standing on the kitchen where the sink was.
19	Back in the kitchen again he's standing with two cups and a plate over there.	Evident she was not looking.
20	n/a	Water was pouring from the sink and pouring over all the way to the floor.
21	n/a	The mother was drying a (a) plate.
22	n/a	And he had one pool in front.
23	n/a	He was wearing an apron.
24	n/a	He possibly was looking toward the window.
25	n/a	It looked like the bottom window was open.
26	n/a	The other side you could see the window and part of a house and some plants beside that.
27	n/a	He had curtains on the side of the window.
28	n/a	Beside the kitchen was two cups.
29	n/a	There was one glass.

Utt = Utterance; n/a = not applicable.