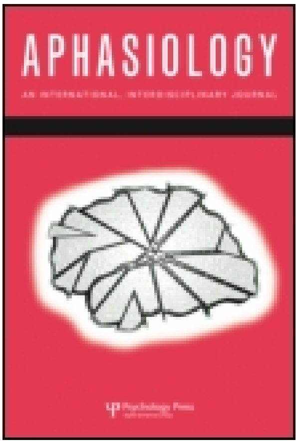

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Repetition priming of picture naming in semantic aphasia: The impact of intervening items

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Repetition priming of picture naming in semantic aphasia: The impact of intervening items

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Background: We present an experiment that explores the nature of repetition priming of picture naming in a group of semantic stroke aphasic patients. The study was designed to extend previous investigations of repetition priming effects among other stroke aphasic patients and patients with semantic dementia. This work builds on previous work with semantic aphasic patients that shows enhanced picture-naming performance due to correct phonemic cues.
Aims: To assess the extent to which semantic control deficits observed during semantic aphasic patients' picture naming are resolved by prior exposure to an identical stimulus, and to determine the optimal lag between prime and target to maximise naming success.
Methods & Procedures: The procedure was carried out with five stroke patients who had all failed verbal and picture versions of tests of semantic association, revealing difficulties with manipulation of semantic information, and their performance was compared to five age- and education-matched controls. A total of 180 pictures to be named were presented individually on a computer screen in two sessions at least a week apart, with half preceded by an identical item in session one and the other half preceded by an identical item in session two. Three lags (0, 1, and 7 items intervening) were embedded in the pseudo-random structure such that it was unpredictable whether the next trial would be a repeat or not.
Outcomes & Results: Considerable repetition priming was observed in this semantic aphasic patient group, bringing their performance up to control level at lag 0. Priming with a very short lag between prime and target (0–1 item) significantly reduced latency. Accuracy was significantly increased and semantic errors decreased with up to seven intervening items. Controls also benefited from repetition priming, but showed little variation in latency, accuracy or errors over this range of short lags.
Conclusions: For patients with problems manipulating semantic information, repetition priming was an effective way to boost naming performance, although increasing the number of intervening items had a progressively detrimental effect. The observed repetition priming effects are interpreted within a connectionist model of speech production.

Keywords: Repetition priming; Picture naming; Stroke aphasia; Semantic memory; Executive control; Speech production.

Behavioural facilitation by a previous encounter is one of the most powerful and widely studied effects in psycholinguistics (Francis, Corral, Jones, & Saenz, 2008; Stark & McClelland, 2000; Wheeldon & Monsell, 1992), and occurs across multiple

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tasks (Cumming, Graham, & Patterson, 2006; Howard, Patterson, Franklin, Orchard-Lisle, & Morton, 1985; Vitkovitch, Rutter, & Read, 2001). Repetition also forms the basis for much impairment-directed speech and language therapy for deficits such as anomia seen among aphasic patients (Fillingham, Sage, & Lambon Ralph, 2005; Helmick & Wipplinger, 1975; Hengst, Duff, & Dettmer, 2010; Nickels, 2002; Raymer & Ellsworth, 2002), although experimental investigations of repetition priming (RP) among patients have been relatively rare (e.g., Cumming et al., 2006; Howard, Hickin, Redmond, Clark, & Best, 2006; Martin & Laine, 2000).

Semantic aphasia (SA) is a multimodal semantic deficit characterised by a failure of control processes rather than damage to central semantic representations (Jefferies & Lambon Ralph, 2006; Jefferies Patterson, & Lambon Ralph, 2008; Noonan, Jefferies, Corbett, & Lambon Ralph, 2010; Soni et al., 2009). Anomia is a common feature of SA that can be alleviated by the provision of correct phonemic cues (Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009). Previous work showing substantial cueing effects in semantic aphasia suggests that this patient group should be particularly receptive to repetition priming in picture naming. Here we consider for the first time the extent and longevity of repetition priming effects in a small case-series of SA patients.

Work with SA patients in the verbal domain has highlighted the impact of both correct and misleading phonemic cues upon picture naming (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009); other studies have focused more on comprehension (Noonan et al., 2010) and the non-verbal domain (Corbett, Jefferies, & Lambon Ralph, 2009). Altogether, tests indicate a central amodal semantic impairment in SA resulting from poor semantic control, namely an impaired ability to harness semantic information appropriate to the task in hand. SA patients' performance provides a demonstration of the importance of semantic control in allowing effective use of intact semantic representations.

Cued naming experiments where pictures and single phonemes are presented simultaneously have helped to illustrate the semantic control difficulties of SA patients, and also to distinguish them from other groups with central semantic impairment such as semantic dementia (SD). Using cues that were either correct initial phonemes or initial phonemes from category co-ordinates or associates, it was found that correct cues significantly improved picture naming in SA patients (Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009), in contrast with SD patients in a similar experiment who gained no significant benefit from correct cueing (Jefferies et al., 2008). Phonemic cues were able to enhance activation of targets, showing that poor semantic control can be ameliorated, allowing SA patients to access semantic representations that still exist but are hard to reach, whereas correct cues were ineffective for SD patients whose core representations are degraded. Further work has shown that SA responses to miscue trials were significantly less accurate than with correct cues, with a stronger and more reliable effect from co-ordinate than associate miscues (Noonan et al., 2010; Soni et al., 2009; Soni, Lambon Ralph, & Woollams, 2011).

Given that a semantic control deficit leads to heightened sensitivity to cueing in SA patients, the question arises: How well would they prime from repeated stimuli? This can be seen as an extension of the correct cueing paradigm: instead of merely giving the initial phoneme, the entire name is elicited on the priming trial and then again on a subsequent trial. An important component of repetition priming in normal populations is that, as well as an effect on accuracy, there is a concomitant benefit to RT: primed items are produced significantly more quickly than unprimed (Lachman & Lachman, 1980; Mitchell & Brown, 1988; Wheeldon & Monsell, 1992). Although there can be methodological difficulties when measuring latency in patients, reaction time measures have been used to quantify repetition priming effects in other patient groups (Bird, Lambon Ralph, Patterson, & Hodges, 2000; Cumming et al., 2006), hence reaction times were measured in the present work in addition to accuracy and error types.

Although picture naming has been used as a priming task in studies with one or two patients in the contextual priming procedure, where several items are presented in an array (Laine & Martin, 1996; Martin & Laine, 2000; Renvall, Laine, Laakso, & Martin, 2003; Renvall, Laine, & Martin, 2007), repetition priming of single item picture naming has not been explored using a case-series approach, nor has it been explored with semantic aphasic patients. Furthermore, in the contextual priming procedure no feedback was given as to the correctness of the naming responses on priming trials, and the presence of multiple items may have obscured the link between picture and name for each individual item. Previous investigations of repetition priming among groups of aphasic patients have used either a lexical decision task throughout (Bird et al., 2000; Cumming et al., 2006) or WPM in the priming trials (Howard et al., 2006). In the current study the production task of single item picture naming with feedback was used for both the prime and target trials, as this procedure ensures both activation of an item's correct semantic representation and strengthening of the mapping from concept to phonological form, thus maximising the potential for repetition priming effects.

Previous considerations of RP effects among aphasic patients have suggested that the number of intervening items, or lag, is a crucial factor. In Cumming et al. (2006) a lexical decision task was used with SD patients, with variable lag between prime and target (0, 3, 9, or 23 items intervening). Knowledge of words was manipulated by using a word set previously tested on other SD patients and classified as "known" or "degraded". All types of words showed RP relative to nonwords (a lexicality effect), but the knowledge of words also interacted with lag: known words did show priming but degraded words showed "hyperpriming" (greater than expected RP relative to control performance) at the shorter lags (0 and 3 intervening items) but not longer (9 and 23). Hence it appears that the hyperpriming effect for degraded words decays relatively quickly to match the smaller priming effect shown for known words.

In addition to SD, stroke aphasic patients have also exhibited RP effects: both those with semantic impairments, for whom semantic errors are proportionally greatest in naming, and those with "post-semantic" impairments, whose primary error type is phonological (Howard et al., 2006). Howard et al. used the priming task of spoken word to picture matching (WPM), achieved by pointing at an item in an array on a computer screen. Patients did not produce the item name (although they did hear it in spoken WPM), nor did they receive feedback on the performance during the task. All patients showed some RP effects, but lag was again seen to have a differential effect: patients who were considered to have a semantic impairment only show RP at short lags (2–3 minutes) while those with a post-semantic impairment showed facilitation at both short and long lags (up to 25 minutes). However, the post-semantic group performed significantly better than the semantically impaired group on spoken, written, and concrete WPM, allowing the interpretation that poorer processing of primes accounted for the briefer priming effects in patients with greater semantic impairment. Furthermore, the patients never produced the name themselves but respond by pointing, minimising priming of meaning to form mappings. In this study we maximised the likelihood of such priming by ensuring all patients produced the correct picture name, whether spontaneously or via their good repetition skills.

Given that RP is observed in semantically impaired groups, and that lag has been shown to have a differential effect in semantically impaired groups, what lag would maximise priming effects for SA patients? Given their semantic control impairment, it seemed most likely that short lags would be most effective, with very few intervening items to disrupt or obscure the activation produced by the prime: thus lags of 0, 1, and 7 items were selected. The use of both lags 0 and 1 was to attempt to delineate between a true facilitation from RP (lag 1) and an effect which could be gained merely by residual phonological activation from the previous trial (lag 0); it could also reveal any possible refractory effects of having produced an item's name on the immediately preceding trial (lag 0).

METHOD

Participants

Five SA patients were recruited from stroke clubs or recommended by speech and language services in Greater Manchester, UK. They were a subset of those reported in other work on this patient group (Jefferies, Baker, Doran, & Lambon Ralph, 2007; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Soni et al., 2009). Patients were enrolled if they failed both word and picture versions of semantic association tests such as the Camel and Cactus Test (CCT; Bozeat, Lambon Ralph, Patterson, & Hodges, 2000) and/or the Pyramids and Palm Trees Test or (PPT; Howard & Patterson, 1992). Each patient had a chronic impairment from a CVA at least a year previous to the current study. Four were diagnosed with transcortical sensory aphasia (TSA) or anomic aphasia, with poor comprehension, fluent speech, and good repetition. Patient BB had less-fluent speech in addition to impaired comprehension. Table 1 includes biographical details, some details of lesion and aphasia type.

Background neuropsychology and semantic testing

Patients were tested on forward and backwards digit span (Wechsler, 1997), the Visual Object and Space Perception (VOSP) battery (Warrington & James, 1991), and the Coloured Progressive Matrices test of non-verbal reasoning (Raven, 1962). Executive skill and attention were tested with the Wisconsin Card Sorting test (Milner, 1963; Stuss et al., 2000), the Brixton Spatial Rule Attainment task (Burgess & Shallice, 1997), and Elevator Counting (with and without distraction) from the Test of

TABLE 1
SA patients' biographical details, lesion type, and patterns of co-occurrence

Patient	*Age*	*Sex*	*Education leaving age*	*Years since CVA*	*Frontal damage*	*Temporo parietal damage*	*Aphasia diagnosis*
HN	77	M	15	2	×	✓	Anomic/TSA
PG*	63	M	18	8	✓	w	TSA
SC	80	M	16	8	×	✓	Anomic/TSA
BB	59	F	16	6	✓	✓	Mixed transcortical
ME	40	F	16	9	×	✓	TSA

Patients are arranged in order of naming scores in the 64-item battery (Bozeat et al., 2000).
w = damage confined to white matter immediately underlying cortex.
* = no scan available. Description of lesion: L frontal & capsular.

TABLE 2
Background neuropsychological assessment of SA patients

Task/test	*Max*	*Normal cut-off*[α]	*HN*	*PG*	*SC*	*BB*	*ME*	*Mean*
VOSP dot counting	10	8	8	**5**	10	10	**3**	**7.2**
VOSP position discrimination	20	18	19	20	**17**	18	**15**	**17.8**
VOSP number location	10	7	9	9	10	8	**2**	**7.6**
VOSP cube analysis	10	6	**4**	10	9	**2**	**4**	**5.8**
Raven's coloured matrices (percentiles)	–	–	20	50	50	50	**<5**	35.0
WCST (number of categories)	6	1[γ]	6	**0**	6	1	**0**	2.6
Brixton spatial anticipation (correct)	54	28	28	**26**	**25**	**23**	**11**	**22.6**
TEA counting without distraction	7	6	7	**0**	7	**4**	7	**5.0**
TEA counting with distraction	10	3	9	3	**1**	**0**	9	4.4
Digit span forwards	–	5	6	6	6	5	6	5.8
Digit span backwards	–	2	2	2	2	**0**	3	**1.8**
PALPA word repetition	80	80	**69**	**73**	**78**	**77**	80	**75.4**
Picture PPT	52	48.4	**35**	**42**	50	**41**	**29**	**39.4**
Word PPT	52	48.9	**44**	**43**	51	**35**	**39**	**42.4**
Synonym judgement	96	90.1	**70**	**69**	**71**	**63**	**81**	**70.8**
Letter fluency	–	21.8	**19**	**2**	24	**0**	**14**	**9.56**
Category fluency	–	62.7	63	**4**	**17**	**13**	**25**	**24.4**
64 Item Picture Naming	64	59.1	**50**	**46**	**28**	**10**	**5**	**27.8**
64 Item Spoken Word–picture Matching	64	62.7	**50**	**58**	**59**	**54**	**50**	**54.4**
64 Item Picture CCT	64	52.7	54	**44**	**46**	**38**	**13**	**39.0**
64 Item Word CCT	64	56.6	**54**	**40**	**56**	**30**	**34**	**42.8**

Patients are arranged in order of naming scores in the 64-item battery (Bozeat et al., 2000).
[α] For semantic tests, this represents the control mean – 2 *SD*.
[γ] Cut-off for 50–74-year-olds (regardless of educational level).
All impaired scores are shown in bold.
NT = Not taken.

Everyday Attention (Robertson, Ward, & Ridgeway, 1993). Semantic skills were tested using a number of assessments. For example, tests of semantic association included the Pyramids and Palm Trees Test (PPT; Howard & Patterson, 1992) and Camel and Cactus Test (CCT; Bozeat et al., 2000), where participants have to decide which of two (PPT) or four (CCT) items is most associated with a target, e.g. pyramid with a pine tree or a palm tree. Both PPT and CCT were assessed with word and picture versions. CCT forms part of a 64-item semantic battery that also tested spoken picture naming and spoken word to picture matching on the same items. Other semantic tests comprised synonym judgement (Jefferies, Patterson, Jones, & Lambon Ralph, 2009), category fluency (animals, birds, fruit, household items, tools, and vehicles) and letter fluency (letters F, A, and S). As is immediately apparent from Table 2, all patients showed significant impairments across a variety of tests tapping semantic knowledge.

Control participants

Five control participants were drawn from a pool of volunteers. Each one was individually matched with a patient on age and education leaving age. All controls had normal or corrected to normal vision and no history of neurological damage.

Stimuli

A total of 180 black and white line drawings of common natural and man-made objects were selected from standard picture sets (Snodgrass & Vanderwart, 1980; Szekely et al., 2003). The stimuli were then divided into three lists (one for each lag condition) matched on name agreement (mean = 0.98; *SD* = 0.03, from the International Picture Naming Project (IPNP): Szekely et al., 2003), reaction time (mean = 871 ms; *SD* = 114 ms, from IPNP: Szekely et al., 2003), number of syllables (mean = 1.53; *SD* = 0.72, from IPNP: Szekely et al., 2003), number of phonemes (mean = 4.03; *SD* = 1.50, from IPNP: Szekely et al., 2003), frequency (mean = 3.23; *SD* = 1.43, from CELEX lexical database: Baayen, Piepenbrock, & Gulikers, 1995), AoA (overall mean = 2.07; *SD* = 0.94, from the MacArthur Communicative Development Inventory (CDI): Fenson et al., 1994) and visual complexity (mean = 16304 kilobytes (KB); *SD* = 8027 KB, from IPNP: Szekely et al., 2003). Items and norms for each list plus matching statistics can be found in Appendices A to G. Each of the three lists was further divided into two sections (A and B) matched to each other on the same variables: this was to enable testing to take place over two sessions. If set A was repeated in session 1, then set B formed the "control" or unprimed items; this assignment was reversed on the second test occasion, hence all items were seen in each session but in different conditions.

Procedure

The experiment was presented using E-Prime (Schneider, Eschman, & Zuccolotto, 2002) on a laptop, with participants sitting around 80 cm from the screen. Testing occurred over two sessions at a minimum of 2 weeks apart and was carried out in the patients' homes. There were three lag conditions, lag 0 (no intervening trials), lag 1 (one trial intervening), and lag 7 (seven trials intervening). Each item was seen in only one lag condition by each participant, but separate versions of the test were constructed such that all items appeared in all lag conditions, counterbalanced across the group. A number of semantically unrelated filler items were also included in each test in order to fill the number of trials intervening between lags. Each test consisted of 270 items to name (primes, targets, and fillers); the lags were interleaved in a varied manner so that the possibility of a repeated item was unpredictable. The task instructions noted that the pictures would appear on the screen one at a time; some might be shown more than once, but the participant should just try to name the picture in each case. The tester marked responses on a printed scoresheet and also recorded test sessions on a Sony IC digital recorder for later use in measuring reaction times. Reaction times, accuracy and error rate and type were measured; RTs were measured using Wavepad Sound Editor software (NCH, Swiftsound: www.nch.com.au/wavepad).

At the onset of each picture an audio beep was played for 300 ms, to serve as a marker for RT measurement. The picture appeared on screen for a maximum of 5 seconds after which the screen went white; as soon as a correct response was given the tester initiated the next picture with a button press. If no response had been given the patient would be prompted for an answer; if no response was made or an error was produced, the tester would say the correct name and ask the participant to repeat it, ensuring that a correct production was obtained for all prime items.

RESULTS

Dependent variables were analysed using an ANOVA with the within-participants factors of priming (2 levels: repeated and unrelated prime) and lag (3 levels: 0, 1, and 7), and the between-participants factor group (2 levels: patients and controls). Initial analyses revealed minimal effects of session, therefore all analyses are reported with data collapsed across this variable. ANOVAs were also carried out separately for each group with the same within-participants factors of priming and lag. Initially the results for the overall comparison ANOVA will be reported in order to ascertain whether patients behaved significantly differently to controls. ANOVAs for each group will then be reported, followed by planned comparisons to elucidate the details of any interactions. All probabilities reported for *t*-tests are one-tailed due to prior prediction of a facilitative effect of repetition priming. Most *F*-values reported are with sphericity assumed; however, Huynh-Feldt values are reported as appropriate to correct for violations of sphericity. Errors were defined according to the following classification: semantic,[1] omission,[2] or other.[3]

Reaction times

Only reaction times for correct responses were analysed. For the group comparison ANOVA on RTs there was a significant three-way interaction between lag, priming, and group, $F(1, 8) = 11.819$; $p = .006$, showing that priming had the greatest effect on patients at the shortest lag, diminishing swiftly with longer lags, whereas controls' performance remained more stable throughout, as can be seen in Figure 1. There was also a significant two-way interaction between lag and group, $F(2, 13) = 5.069$; $p = .031$, showing that, collapsed across priming, patient performance slowed at longer lags compared to similar performance across all lags by controls; the two-way interaction between priming and group was also marginally significant, $F(1, 8) = 5.062$; $p = .055$,

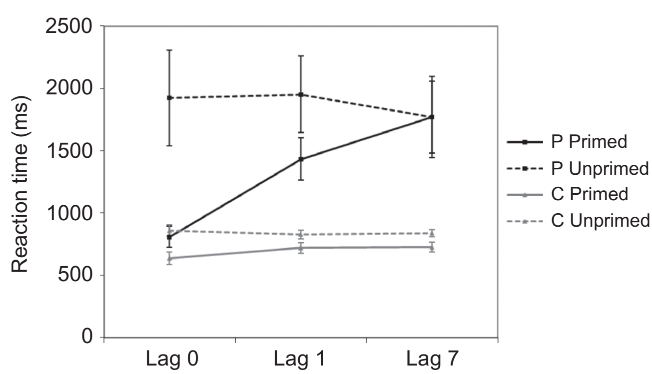

Figure 1. Reaction times for patients (P) and controls (C) according to priming and lag (error bars represent standard error).

[1] For example, co-ordinate, "kite" for BALLOON; associate, "cup" for SPOON; superordinate, "animal" for TIGER; or correct circumlocutions, "you light them" for CANDLE.

[2] No complete word answer, or "don't know".

[3] For example, incorrect circumlocutions, "you cook on them" for SINK; picture parts, "shirt" for MAN; phonological, "sky" for SKIS; visual "pen" for LIPSTICK; or unrelated/perseverative, "stairs" for PLATE.

indicating a trend towards greater priming for patients than controls when lag conditions were collapsed. The main effect of group was significant, $F(1, 8) = 11.261$; $p = .01$, showing that patients responded significantly more slowly than controls (1609 ms vs 767 ms respectively).

In the ANOVA for patients' RTs there were significant main effects of priming, $F(1, 4) = 9.670$; $p = .036$, and lag, $F(2, 8) = 6.026$; $p = .025$, and an interaction between priming and lag, $F(1,4) = 14.733$; $p = .018$, showing an effect of priming that decayed swiftly with increasing lag (see Figure 1). Planned comparisons revealed that for patients there were significant differences in RT at Lag 0, $t(4) = 3.552$), $p = .012$, and Lag 1, $t(4) = 3.396$; $p = .014$, but not at Lag 7. In the ANOVA for controls there were main effects of priming, $F(1, 4) = 47.905$; $p = .002$, and lag, $F(2, 8) = 6.765$; $p = .019$, and an interaction between priming and lag, $F(2,8) = 11.871$; $p = .004$, which appears to be driven by a larger priming effect at lag 0. Planned comparisons revealed that there were significant differences in controls' RT between primed and unprimed items (see Figure 1) at Lag 0, $t(4) = 5.470$; $p = .003$, Lag 1, $t(4) = 9.204$; $p = .001$, and Lag 7, $t(4) = 6.815$; $p = .001$, a continued effect of prior presentation throughout this range of lags.

Accuracy

The accuracy results revealed a three-way interaction between priming, lag, and group, $F(1, 11) = 4.654$; $p = .043$, showing that though patients' accuracy was raised to within the range shown by controls at lag 0, as can be seen in Figure 2, this priming advantage declined sharply with more intervening trials. There were also significant two-way interactions between priming and group, $F(1, 8) = 12.656$; $p = .007$, showing that the patients responded more to priming than controls regardless of lag, and lag and group, $F(2, 16) = 9.067$; $p = .002$, showing that when priming conditions were collapsed, longer lags reduced patients' but not controls' accuracy. The main effect of group was significant, showing that patients' responses were significantly less accurate than controls' (.662 vs .975, respectively).

In the group ANOVA for patients alone there were there were significant main effects of priming, $F(1, 4) = 16.973$; $p = .015$, and lag, $F(2, 8) = 9.107$; $p = .009$,

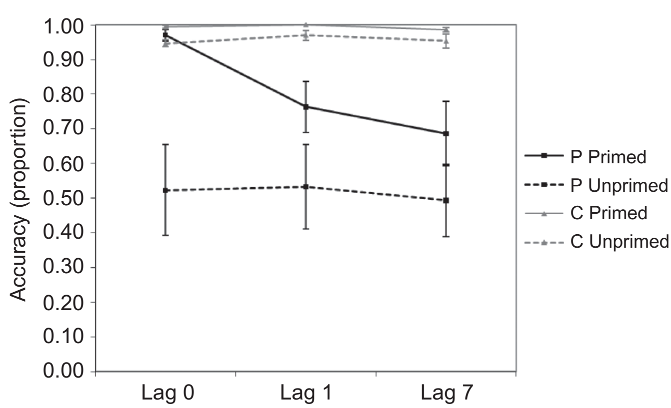

Figure 2. Accuracy for patients (P) and controls (C) according to priming and lag (error bars represent standard error).

and an interaction between lag and priming, $F(2, 8) = 5.617$; $p = .030$, driven by the larger priming effect at lag 0 (see Figure 2). Planned comparisons showed that there were significant benefits from priming at lag 0, $t(4) = 3.520$; $p = .012$, lag 1, $t(4) = 3.933$; $p = .009$, and lag 7, $t(4) = 4.302$; $p = .007$. In the ANOVA for controls there was a significant effect of priming, $F(1, 4) = 11.585$; $p = .027$, but not of lag, $F(2, 8) = 2.250$, and no interaction, $F(2, 8) = .344$. Although controls' accuracy was near ceiling throughout this range of lags (.95 or over in all conditions), planned comparisons showed a significant difference between primed and unprimed items (see Figure 5) at Lag 0, $t(4) = 4.176$; $p = .007$, Lag 1 was marginally significant, $t(4) = 2.107$; $p = .052$, and Lag 7 also approached significance, $t(4) = 1.533$; $p = .100$.

Semantic errors[4]

For semantic errors there was only a significant two-way interaction between priming and group, $F(1, 8) = 11.303$; $p = .01$, indicating that the priming effect was larger for patients than controls; see Figure 3 for performance of each group. The main effect of group was significant, $F(1, 8) = 9.729$; $p = .014$, showing that patients produced significantly more semantic errors than controls (.167 vs .018 respectively).

In the patients' ANOVA for semantic errors there was a significant main effect of priming, $F(1, 4) = 15.366$; $p = .017$; planned comparisons revealed that patients produced significantly fewer semantic errors with primed than unprimed items (see Figure 3) at Lag 0, $t(4) = 3.089$; $p = .019$, Lag 1, $t(4) = 2.580$; $p = .032$, and Lag 7, $t(4) = 10.130$; $p = .001$. Being the reverse of the accuracy data, controls' semantic error rates were at floor in the primed condition and very low in the unprimed condition: nevertheless, there was a significant main effect of priming, $F(1, 4) = 11.497$; $p = .028$, and the main effect of lag approached significance, $F(2, 8) = 3.273$; $p = .092$. Planned comparisons showed that semantic error rates to primed targets were significantly lower than with unprimed items (see Figure 3) at Lag 0, $t(4) = 3.730$; $p = .010$,

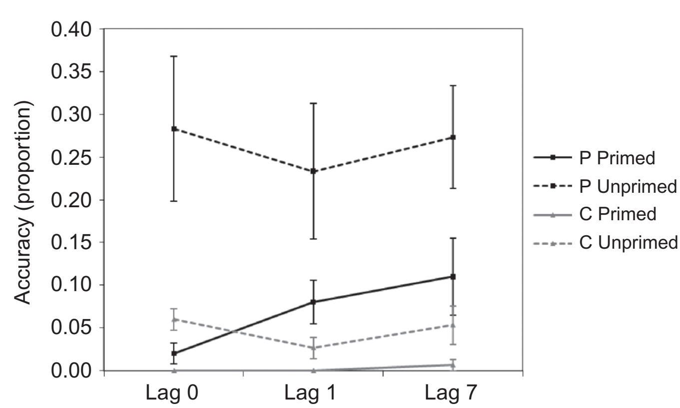

Figure 3. Semantic error rates as a proportion of all trials for patients (P) and controls (C) according to priming and lag (error bars represent standard error).

[4]There were no significant differences in omission rates or other errors, either in the overall comparison or in individual ANOVAs for each group.

and Lag 1, $t(4) = 2.161$; $p = .049$, but lag 7 did not quite show a significant difference, $t(4) = 1.484$; $p = .106$.

DISCUSSION

Patients' RTs with primed targets increased steeply with extra intervening items (lag 0 = 808 ms; lag 1 = 1433 ms; lag 7 = 1770 ms); although still showing a significant priming effect at lag 1, primed and unprimed latency were identical by lag 7. Patients' unprimed latencies remained relatively stable (lag 0 = 1924 ms; lag 1 = 1953 ms; lag 7 = 1770 ms), showing that the differences at each lag resulted from a progressive reduction in the effect of repetition priming (RP). Although significant main effects and an interaction were also seen for latency in control participants, the greater detail shown by planned comparisons demonstrated that controls maintained a latency benefit from priming across all lags in this range (primed vs unprimed latency: lag 0 = 637 vs 859 ms; lag 1 = 719 vs 827 ms; lag 7 = 724 vs 838 ms). These data show that compared with longer-lasting effects in controls, RP effects on latency in SA patients were quickly dissipated by additional intervening items. Although patients' accuracy retained a significant benefit from priming across all lags, this advantage declined with more intervening items (primed vs unprimed accuracy: lag 0 = 97% vs 52.3%; lag 1 = 76.3% vs 53.3%; lag 7 = 68.7% vs 49.3%), whereas controls' performance appeared to remain more stable for both primed and unprimed items (lag 0 = 99.3% vs 94.7%; lag 1 = 100% vs 97%; lag 7 = 98.7% vs 95.3%) across this range of lags. Patients also showed an increase in semantic error rates with increasing lag, although primed semantic error rates remained significantly lower than unprimed (lag 0 = 2% vs 28.3%; lag 1 = 8% vs 23.3%; lag 7 = 11% vs 27.3%). Concomitant with controls' high accuracy, semantic error rates were extremely low (primed vs unprimed semantic error rates: lag 0 = 0% vs 6%; lag 1 = 0% vs 2.7%; lag 7 = 0.7% vs 5.3%): unlike the patient group there is little reduction in RP with increasing lag.

As can be seen from this summary the detrimental effect of increasing lag is mirrored in all variables for this group of SA patients. We hypothesise that the prime guides the semantic control system during subsequent target selection, but impaired semantic control allows the initial benefits of RP to be dissipated by the presentation of intervening items. It is likely that, with longer lags, the raised activations of other more recent though irrelevant intervening items are harder to inhibit when semantic control is impaired, leading to less-efficient name selection and reduced priming. This is particularly clear in the arguably more sensitive latency measure, where the benefit of prior presentation is entirely absent for patients by lag 7. Continuing raised activation of the primed items can be detected in the significantly higher accuracy and lower semantic error rates even at lag 7, but the enhanced speed of processing induced by priming is more vulnerable when semantic control is impaired. In the control participants, who have intact semantic control, the effects of RP remain relatively stable across this series of short lags, although as with the patients, lag 0 produces the fastest, most accurate responses. The difference between impaired and control performance is most clear when comparing across longer lags: intervening items clearly cause far greater disturbance to RP in the patients' than the controls.

Other studies have shown that RP effects diminish over time in those with a semantic impairment, although these semantic deficits may originate from different functional and anatomical causes. Semantic dementia patients, who are known to have a semantic impairment resulting from degradation of core semantic representations due to anterior temporal lobe atrophy (Bozeat et al., 2000, 2003; Jefferies & Lambon Ralph, 2006; Jefferies, Patterson, & Lambon Ralph, 2006; Rogers et al., 2004), have also been found to show greater RP in a lexical decision task at short than long lags (Cumming et al., 2006), but only on "degraded" words: known words showed an improvement at both short and long lags. In Howard et al. (1985) stroke patients with various aphasia diagnoses showed an effect of RP on naming accuracy that declined to the level of unprimed performance after 30 items. In Howard et al. (2006) stroke aphasic patients with semantic impairment showed an effect of priming on naming accuracy at short but not long lags, compared with stroke aphasic patients without semantic impairment who benefited from priming at both short and long lags. Although the integrity of semantic control processes and the precise anatomical location of damage for the stroke patients in these studies are unknown, we would suggest that the reduction in RP effects over time observed in the present cohort of SA patients occurs due to their impaired semantic control resulting from frontal and temporo-parietal lesions (Soni et al., 2011).

Support for the interpretation of the reduction of the RP effect at increasing lags observed here in terms of semantic control deficits is given by reports of refractory effects among the same group, where patients show poorer accuracy when required to name semantically related relative to unrelated sets of items, particularly in rapid succession (Jefferies et al., 2007). Similar deficits are observed in the comprehension performance of other patients described as having refractory access disorders (Crutch & Warrington, 2003, 2005; Warrington & Cipolotti, 1996; Warrington & Crutch, 2004). Although these studies observed increased inhibition due to semantic relatedness, whereas we observed a reduction in facilitation from repetition here, both effects can be attributed to increased susceptibility to competition from the semantic activation of intervening items as a result of impaired semantic control. Essentially, semantic control impairments mean that these patients are more vulnerable to the build-up of competition over time, either from the requirement to name semantically related items repeatedly in the case of refractory effects or from the presence of more intervening items in the present work.

Although we propose impaired semantic control to account for RP effects in our data, other potential explanations exist. In the current experiment pictures were named in both prime and target tasks, sometimes with no intervening trials. Howard et al. (1985) suggest that when target immediately follows prime, a kind of phonological "prompting" may be taking place, perhaps due to the information remaining in working memory. Wheeldon and Monsell (1992) further suggest that there could be an episodic memory trace, especially where priming and target tasks are identical. It could also be argued that, at lag 0, due to our protocol of eliciting a correct production before proceeding to the next trial, a correct response is in fact merely repetition of the previous response rather than naming via word retrieval. However, due to the pseudorandom trial order, the nature of an individual trial was not predictable: any trial could have been primed 0, 1, or 7 trials previously, or indeed could be unprimed. Thus a strategy of repeating the previous response would seldom be successful, and would have resulted in a high level of perseverative errors, which did not in fact occur. We therefore argue that, even at lag 0, responses represent naming via word retrieval triggered by viewing a picture, not repetition. Effects such as retention of information by working memory or an episodic memory trace cannot be ruled out by our data, indeed the heightened priming at lag 0 seen in both patient and control groups could indicate some retention in working memory, but we argue that continued effects on

RT at lag 1 and on accuracy and error rates at lags 1 and 7 show true facilitation by priming in this patient group.

There are of course multiple potential loci for these RP effects within the picture-naming process: object recognition/identification, linking initial visual processing to a semantic representation; mapping between semantics and phonology, linking a concept to a phonological form; and production of that phonological form (Francis et al., 2008; Glaser, 1992; Humphreys, Riddoch, & Quinlan, 1988; Morrison, Ellis, & Quinlan, 1992; Wheeldon & Monsell, 1992). In our task the pictured items were always overtly named in the priming trials (with or without assistance from the tester), which necessarily primes all stages from object recognition to name production, as was our intent in order to maximise priming.

Different studies have offered various hypotheses on the locus of RP. In Howard et al. (1985) several priming tasks were used with stroke aphasic patients: auditory and written word to picture matching and a semantic judgement task consisting of answering a yes/no question about the characteristics of an item (e.g., "Does a cow eat grass?"). None of these tasks involved production of the item's name by the patients, and the semantic judgement task made no connection between an item's picture and its name, requiring only an internal access to the meaning. Both auditory WPM and the semantic judgement task produced a facilitatory effect on naming up to 41 items later (around 20 minutes). The authors concluded that, because no overt production was required, these priming tasks improved subsequent naming performance by boosting target activations at the semantic level. Support for a semantic locus of RP effects in the SA patients we consider here is given by the refractory effects seen in picture naming in a similar group of patients (Jefferies et al., 2007). Both the reduced RP effects at longer lags observed in the current experiment and the increased difficulties of SA patients when naming blocks of semantically related items could be accounted for by increased competition at the semantic level.

In their study of RP using spoken word to picture-naming priming trials with stroke aphasic patients with and without semantic deficits, Howard et al. (2006) suggest that RP can also occur later in the word production process, for example during meaning to form mapping. They concluded that, for those with semantic deficits, lemma access is primed over short lags; for those who can access lemmas well they cite a longer-lasting boost in meaning to form mapping. Wheeldon and Monsell (1992) used both word reading and naming to definition as their priming tasks with normal participants, and found a consistent and long-lasting priming effect on naming. The lack of facilitation when the priming trial elicited a homophone of the target ruled out boosting phonological activation alone; priming of object identification alone was also ruled out, as their cross-modal priming tasks did not include pictures. Wheeldon and Monsell concluded that because all priming trials involve overt production of an item's name, their results could support an effect based on boosting semantic representations and/or meaning to form mapping.

Other evidence indicating a semantic component to RP is provided by observations that the effect declines more quickly in patients with more severe semantic impairment (Howard et al., 2006) or on items that are more semantically degraded (Cumming et al., 2006). In the current experiment it is clear that the SA patients can still reap benefits in terms of accuracy after seven intervening items, although the benefit accruing to latency has diminished by this point. We suggest that in connectionist models of learning and speech production (de Zubicaray, McMahon, Eastburn, Pringle, & Lorenz, 2006; Foygel & Dell, 2000; Hinton & Shallice, 1991; McClelland & Rumelhart, 1987; Seidenberg & McClelland, 1989; Stark & McClelland, 2000), RP causes change in the connection weights between semantic units, or between semantic and phonological units, raising the activation of the target. When that item is presented again soon afterwards, residual activation makes name selection more efficient.

The current study was exploratory in nature and was not designed to determine the precise locus of RP effects. Although we favour an account of RP in SA patients in terms of facilitation at the semantic level or strengthened mapping between concept and form, it is possible that there may also be a boost to phonological representations or retention of information in working memory, particularly at lag 0. Future research could use different tasks for prime and target trials to determine more precisely the locus of the RP effect observed here among patients with SA, and could explore the possibility that RP could provide more long-lasting benefits to word retrieval.

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APPENDIX A

List 1 items and associated stimulus properties

Item	*Set*	*Name agreement*	*Reaction time*	*Syllables*	*Phonemes*	*Frequency*	*AoA*	*Visual complexity*
anchor	A	1	951	2	4	1.946	3	14010
baby	B	0.94	729	2	4	5.557	1	18598
barrel	A	0.98	882	2	4	3.091	3	18478
beard	A	0.96	1033	1	4	3.258	3	30362
bed	A	1	706	1	3	5.136	1	13761
book	A	1	656	1	3	6.075	1	8619
boot	B	0.9	869	1	3	3.689	1	8857
bra	B	1	917	1	3	1.946	3	11410
broom	A	1	821	1	4	2.197	1	11261
button	B	1	917	2	4	3.296	1	5726
cannon	A	1	1159	2	5	1.946	3	17678
castle	B	1	893	2	4	3.332	3	22746
chair	A	1	732	1	2	4.92	1	11238
church	B	0.96	988	1	3	5.215	1	34595
comb	A	1	717	1	3	1.792	1	28324
cow	A	0.94	1079	1	2	3.714	1	17300
dinosaur	A	0.98	1012	3	6	1.792	3	12393
door	B	1	719	1	2	5.958	1	12638

(*Continued*)

APPENDIX A
(Continued)

Item	*Set*	*Name agreement*	*Reaction time*	*Syllables*	*Phonemes*	*Frequency*	*AoA*	*Visual complexity*
egg	A	0.98	874	1	2	4.466	1	10440
fan	B	0.98	865	1	3	2.89	3	35152
finger	B	0.98	775	2	5	4.82	1	5370
flag	B	1	847	1	4	3.296	2	9461
fork	A	1	723	1	3	2.773	1	8818
genie	A	0.98	1214	2	4	0.693	3	18559
glasses	B	0.96	758	2	6	3.497	1	11525
goat	B	0.96	972	1	3	3.367	3	15302
grapes	A	0.9	849	1	5	0	2	23841
hammer	B	1	724	2	4	2.485	1	9533
hat	A	0.98	684	1	3	4.234	1	8732
hook	B	1	919	1	3	3.638	3	10144
house	A	0.98	745	1	3	6.409	1	18069
jar	B	0.9	979	1	2	2.996	2	7664
kangaroo	A	1	856	3	7	1.386	3	14555
kite	B	1	796	1	3	1.792	3	17880
lion	A	1	812	2	4	3.258	1	32267
mirror	B	1	873	2	4	3.912	3	11938
mushroom	A	1	746	2	6	2.639	3	8337
owl	B	1	837	1	2	2.079	1	15316
pencil	A	1	702	2	5	2.996	2	7899
pig	B	1	855	1	3	3.784	1	10411
piggybank	A	0.94	965	3	8	0	3	24489
pizza	A	1	973	2	4	1.099	1	40526
plate	A	0.94	1013	1	4	4.025	1	21533
queen	B	1	931	1	4	3.989	3	11277
road	A	0.92	925	1	3	5.521	3	26797
ruler	B	1	779	2	4	2.944	3	10785
screwdriver	B	1	1179	3	9	1.386	3	9051
shoe	A	1	737	1	2	4.382	1	14105
skis	A	0.95	1039	1	4	0	3	20764
sock	B	1	712	1	3	2.944	1	8316
strawberry	B	1	1052	3	8	1.946	2	16771
sword	B	0.92	1084	1	3	2.89	3	10243
telescope	B	0.98	1011	3	8	2.197	3	21547
tie	B	0.98	758	1	2	3.555	3	19103
tomato	A	0.98	962	3	6	2.708	3	8388
tree	B	1	796	1	3	5.257	1	26074
umbrella	A	1	738	3	7	2.708	3	15140
watch	B	1	780	1	3	3.714	1	14511
wheel	A	1	913	1	4	3.807	3	22753
window	B	1	822	2	5	5.303	1	26944
MEAN	–	**0.9812**	**872.57**	**1.550**	**4.017**	**3.211**	**1.983**	**16305.4**

APPENDIX B

Means for Sets A and B of List 2 with associated *t*-tests

Variable	*Set A*	*Set B*	*t =*	*p =*
Name agreement	0.9803	0.9820	.382	.745
RT	873.93	871.20	.100	.921
Syllables	1.6	1.5	.711	.483
Phonemes	4.13	3.90	.814	.422
Frequency	2.97	3.46	1.539	.135
AoA	2.00	1.96	.186	.854
Visual complexity	17647.9	14962.9	1.789	.084

APPENDIX C

List 2 items and associated stimulus properties

Items	*Set*	*Name agreement*	*Reaction time*	*Syllables*	*Phonemes*	*Frequency*	*AoA*	*Visual complexity*
apple	A	1	810	2	3	3.434	1	8241
balloon	B	1	702	2	5	1.946	1	8015
basket	A	0.98	832	2	5	3.219	2	23651
bat	B	1	764	1	3	2.708	2	16687
bone	A	1	872	1	3	4.248	3	14370
bottle	B	0.9	956	2	4	4.762	1	6551
bowl	A	0.98	831	1	3	3.526	1	9408
bus	B	1	771	1	3	4.382	1	23164
cake	A	1	789	1	3	3.555	1	16237
candle	B	1	831	2	5	2.833	3	8385
car	A	1	751	1	2	5.872	1	9255
cat	B	0.96	766	1	3	4.22	1	9894
chain	A	1	943	1	3	3.892	3	12912
cheese	B	1	843	1	3	3.466	1	12988
cigarette	A	0.94	1016	3	7	4.277	3	7988
dog	A	1	702	1	3	4.754	1	12012
dragon	A	1	891	2	5	2.303	3	19272
ear	B	1	681	1	2	4.489	1	9033
feather	A	0.98	977	2	4	3.091	3	21626
fish	B	1	777	1	3	5.1	1	12019
flower	A	1	754	2	4	4.543	1	15082
foot	B	0.98	758	1	3	5.79	1	7638
frog	A	1	751	1	4	2.303	1	14773
ghost	B	1	849	1	4	3.466	3	23538
girl	A	0.92	861	1	3	6.084	1	15540
guitar	B	0.98	870	2	4	2.079	3	12032
hair	A	0.98	999	1	2	5.298	1	41463
harp	B	0.96	914	1	3	1.386	3	14170
horse	A	1	809	1	3	4.89	1	18397
iron	B	1	856	2	3	4.277	3	16843

(*Continued*)

APPENDIX C

(Continued)

Items	*Set*	*Name agreement*	*Reaction time*	*Syllables*	*Phonemes*	*Frequency*	*AoA*	*Visual complexity*
ironing board	B	0.9	1105	4	8	0	3	12848
jacket	B	0.92	881	2	5	3.761	1	30351
key	A	1	738	1	2	4.466	1	7493
king	B	1	898	1	3	4.605	3	31165
lemon	A	0.96	911	2	5	2.773	3	8524
match	B	1	910	1	3	4.06	3	13078
mouse	A	0.92	961	1	3	2.944	1	13250
nail	B	1	1086	1	4	3.258	2	9585
orange	A	0.96	1098	2	5	3.045	1	10314
pear	B	1	949	1	2	1.946	3	18960
pen	A	1	753	1	3	3.296	1	9078
pineapple	B	0.98	871	3	6	1.386	3	20721
pumpkin	A	1	909	2	7	1.099	2	18960
pyramid	B	0.98	987	3	7	2.079	3	19838
rake	A	0.98	828	1	3	1.099	3	5156
rocket	A	0.9	854	2	5	2.708	3	18164
rope	A	1	810	1	3	3.761	3	34568
shark	B	0.96	1014	1	3	3.045	3	14311
sink	A	0.96	984	1	4	2.773	1	26560
skeleton	B	1	817	3	8	2.565	3	10724
skunk	A	0.98	1044	1	5	0	3	16683
spoon	B	1	777	1	4	2.773	1	7344
tiger	B	0.91	1072	2	4	2.565	1	45476
toaster		0.96	860	2	5	0.693	3	13290
toilet	A	1	825	2	5	3.367	3	22049
train	B	1	838	1	4	4.407	1	18361
unicorn	A	1	928	3	7	0.693	3	12749
well	B	0.96	991	1	3	1.792	3	12965
whistle	A	1	790	2	4	2.303	3	10521
witch	B	1	879	1	3	3.497	3	27723
MEAN	–	**0.9798**	**871.57**	**1.533**	**3.967**	**3.216**	**2.033**	**16033.2**

APPENDIX D

Means for Sets A and B of List 2 with associated *t*-tests

Variable	*Set A*	*Set B*	$t =$	$p =$
Name agreement	0.9813	0.9783	.582	.565
RT	867.4	875.8	.455	.653
Syllables	1.5	1.6	.580	.566
Phonemes	3.93	4.00	.258	.798
Frequency	3.32	3.11	.797	.432
AoA	1.93	2.13	1.117	.273
Visual complexity	15809.9	16256.6	.304	.763

APPENDIX E
List 3 items and associated stimulus properties

Items	*Set*	*Name agreement*	*Reaction time*	*Syllables*	*Phonemes*	*Frequency*	*AoA*	*Visual complexity*
arrow	A	0.98	785	2	3	2.773	3	5990
ball	B	1	886	1	3	4.718	1	13345
banana	A	1	808	3	6	2.197	1	8767
belt	B	1	812	1	4	3.296	2	18762
bench	A	0.94	896	1	4	3.178	2	25379
box	B	1	753	1	4	4.635	1	18074
bread	A	0.98	773	1	4	4.317	1	10161
bridge	B	0.98	862	1	4	4.205	3	27543
camel	A	1	892	2	4	3.258	3	26026
camera	B	1	725	3	5	3.611	2	16408
carrot	A	1	806	2	5	2.197	1	13201
clock	B	0.98	772	1	4	3.689	1	25639
cross	A	1	793	1	4	3.135	3	9790
crown	B	0.94	945	1	4	3.219	3	23655
desk	A	1	975	1	4	4.522	3	17761
dolphin	B	0.98	894	2	6	1.386	3	9949
drawer	A	1	994	2	3	3.219	1	16141
dress	B	1	840	1	4	4.477	1	23619
elephant	A	0.98	837	3	7	3.219	1	24585
eye	B	0.98	700	1	1	6.261	1	9104
fence	A	0.98	819	1	4	3.434	3	17349
fly	B	0.9	1080	1	3	3.611	3	11935
globe	B	0.98	883.00	1	4	2.485	3	24454
glove	A	1	848	1	4	2.996	3	11509
hand	B	0.98	723	1	4	6.586	1	13345
helicopter	A	1	793	4	9	2.833	2	18241
hose	B	0.96	983	1	3	1.609	2	26130
igloo	B	1	963	2	4	0.693	3	9673
knife	B	1	816	1	3	3.807	2	8773
ladder	A	1	988	2	4	2.833	2	25701
lamp	A	0.92	835	1	4	3.584	1	13522
leaf	A	1	848	1	3	4.407	3	26600
lightbulb	A	0.92	737	2	7	0	3	10034
lipstick	A	1	803	2	7	2.079	3	6029
man	A	0.94	978	1	3	7.396	1	15791
map	A	1	847	1	3	3.714	3	41029
mask	B	0.98	852	1	4	3.045	3	13646
monkey	A	1	794	2	5	2.944	1	18988
moon	B	1	804	1	3	4.094	1	3730
mop	A	0.94	933	1	3	1.386	2	14393
mountain	B	0.94	921	2	6	4.443	3	13588
nose	A	1	721	1	3	4.407	1	4703
nurse	B	0.96	1039	1	3	3.912	2	19385
onion	A	0.94	1100	2	5	2.833	3	11645
piano	B	1	798	3	5	3.332	3	19570
pipe	A	0.98	866	1	3	3.466	3	7235
razor	B	0.94	1089	2	4	2.303	3	14404
ring	B	1	785	1	3	1.386	3	7652
robot	B	0.98	793	2	5	2.079	3	9502

(*Continued*)

APPENDIX E

(Continued)

Items	*Set*	*Name agreement*	*Reaction time*	*Syllables*	*Phonemes*	*Frequency*	*AoA*	*Visual complexity*
roof	A	0.94	1094	1	3	4.043	2	13178
saddle	A	1	1019	2	4	2.398	3	10307
saw	A	1	863	1	2	0.693	3	11302
slide	B	1	1003	1	4	2.565	1	20613
snake	B	1	775	1	4	3.178	3	23761
sun	A	1	762	1	3	5.03	1	18102
table	B	0.98	852	2	4	5.464	1	12010
typewriter	B	1	778	3	7	2.485	3	28850
whale	B	0.96	1050	1	4	2.485	3	15429
wig	A	0.94	933	1	3	2.639	3	22371
zebra	B	1	864	2	5	1.099	2	36034
MEAN	–	**0.9800**	**869.67**	**1.500**	**4.117**	**3.255**	**2.183**	**16573.5**

APPENDIX F

Means for Sets A and B of List 3 with associated *t*-tests

Variable	*Set A*	*Set B*	*t* =	*p* =
Name agreement	0.9793	0.9807	.256	.800
RT	871.3	868.0	.182	.857
Syllables	1.57	1.43	.944	.353
Phonemes	4.2	4.1	.576	.569
Frequency	3.17	3.34	.680	.502
AoA	2.17	2.2	.200	.843
Visual complexity	15861.0	17286.1	.980	.335

APPENDIX G

Means for Lists 1–3 with associated *t*-tests

Variable	*List 1 mean*	*List 2 mean*	*List 3 mean*	*1–2 t*	*1–2 p*	*2–3 t*	*2–3 p*	*1–3 t*	*1–3 p*
Name agreement	0.9812	0.9798	0.98	.367	.715	.043	.966	.313	.755
RT	872.57	871.57	869.67	.058	.954	.141	.888	.168	.867
Syllables	1.550	1.533	1.500	.182	.856	.357	.723	.536	.594
Phonemes	4.017	3.967	4.117	.231	.818	.791	.432	.468	.642
Frequency	3.211	3.216	3.255	.027	.978	.217	.829	.229	.820
AoA	1.983	2.033	2.183	.399	.692	1.191	.239	1.602	.114
Visual complexity	16305	16033	16574	.262	.794	.504	.616	.258	.797