Temporal Characteristics of Semantic Perseverations Induced by Blocked-Cyclic Picture Naming

Esther Y. Hsiao[1], Myrna F. Schwartz[1], Tatiana T. Schnur[2], and Gary S. Dell[3]

[1] Moss Rehabilitation Research Institute, Albert Einstein Healthcare Network, Philadelphia PA

[2] Rice University, Houston TX

[3] University of Illinois at Urbana-Champaign, Champaign, IL

Running Head: Semantic perseverations

Corresponding Author:

Myrna F. Schwartz

Moss Rehabilitation Research Institute

MossRehab 4th fl. Sley

1200 West Tabor Road

Philadelphia, PA 19147

e-mail: mschwart@einstein.edu

Tel: 215.456.9210

Fax: 215.456.9613

Abstract

When unimpaired participants name pictures quickly, they produce many perseverations that bear a semantic relation to the target, especially when the pictures are blocked by category. Evidence suggests that the temporal properties of these “semantic perseverations” may differ from typical lexical perseverations in aphasia. To explore this, we studied semantic perseverations generated by participants with aphasia on a naming task with semantic blocking [*Schnur, T. T., Schwartz, M. F., Brecher, A., & Hodgson, C. (2006). Semantic interference during blocked-cyclic naming: Evidence from aphasia. Journal of Memory and Language, 54, 199-227*]. The properties of these perseverations were investigated by analyzing how often they occurred at each lag (distance from prior occurrence) and how time (response-stimulus interval) influenced the lag function. Chance data sets were created by reshuffling stimulus-response pairs in a manner that preserved unique features of the blocking design. We found that the semantic blocking manipulation did not eliminate the expected bias for short-lag perseverations (recency bias). However, immediate (lag 1) perseverations were not invariably the most frequent, which hints at a source of inconsistency within and across studies. Importantly, there was not a reliable difference between the lag functions for perseverations generated with a 5 s, compared to 1 s, response-stimulus interval. The combination of recency bias and insensitivity to elapsed time indicates that the perseveratory impetus in a named response does not passively decay with time but rather is diminished by interference from related trials. We offer an incremental learning account of these findings.

Keywords: Perseveration; semantic blocking; aphasia; naming; priming; incremental learning

Introduction

Studies of naming errors bring to light the interplay of cooperative and competitive mental representations that underpin lexical access. Errors known as recurrent lexical perseveration (Sandson & Albert, 1984), which repeat a response given earlier, reveal that processes from the past persist and have the potential to intrude on the present. To elucidate the nature of those persisting processes and their temporal dynamics, researchers typically derive a *lag function*, which reveals how perseveration probability is affected by the number of trials that intervene between the error and its source (Cohen & Dehaene, 1998; Gotts, della Rocchetta & Cipolotti, 2002). A few studies have also experimentally manipulated response-stimulus interval (RSI) for the purpose of exploring how the passage of time affects the perseveration lag function (Campbell & Clark, 1989; Gotts et al., 2002; Vitkovitch, Kirby & Tyrell, 1996).

The investigations of perseveration lag functions do not tell a consistent story, however. They have yielded one set of results when applied to the recurrent lexical perseverations produced by people with aphasia, and quite different results when applied to those produced by healthy individuals on naming tasks designed to promote perseveration. These perseveration-promoting manipulations frequently involve semantic blocking, i.e. arranging the trial sequence so that semantic competitors (typically exemplars of the same semantic category) appear on successive or nearby trials. In this situation, earlier named competitors, through priming, have a heightened probability of intruding as perseverations, specifically, *semantic perseverations*, since they are related to the names they replace.

The goal of the present study was to confront conflicting findings in these two literatures regarding the temporal characteristics of lexical perseverations. To achieve this goal, we reanalyzed data collected from 18 individuals with aphasia during performance of a task that involved semantic blocking and that elicited a large number of semantic perseverations (Schnur, Schwartz, Hodgson & Brecher, 2006, Experiment 2).

Perseverations Elicited by Semantic Blocked Naming

Neurologically healthy individuals do not make frequent errors when naming pictures of familiar objects. However, certain experimental manipulations can induce errors that are not unlike those seen in aphasia. One such manipulation is speeded naming, wherein participants name pictures to a fast deadline. This manipulation increases semantic errors, including semantic perseverations (Moses, Nickels, & Sheard, 2004). The manipulation works because picture naming is a semantically-driven task, and so there is natural competition among words that share semantic features (e.g., Dell, Schwartz, Martin, Saffran & Gagnon, 1997; Humphreys, Riddoch & Quinlan, 1988; Levelt, Roelofs & Meyer, 1991). It takes time for the target to accumulate enough input from semantics to emerge as the winner in the competition for selection, especially when a competing word experiences priming from having been named on an earlier trial (Wheeldon & Monsell, 1994). A fast deadline increases the probability that a semantic competitor, and particularly a primed semantic competitor, will be erroneously selected for output.

The probability of semantic perseveration in normal naming can be increased still further by combining speeded naming with a semantic blocking manipulation (Vitkovitch & Humphreys, 1991; Vitkovitch et al., 1996). Here, multiple semantic competitors, typically exemplars from the same superordinate category, are presented for naming on adjacent or nearby trials. As successive competitors are named, each is primed, and the presence of multiple primed competitors prolongs the time required for the target to win the competition (Brown, 1981; Howard, Nickels, Coltheart, & Cole-Virtue, 2006). With the requirement to respond quickly, it becomes more likely that one of the primed competitors will replace the target as the naming response, resulting in a semantic perseveration.

Entailed in the foregoing account is the idea that name priming persists across time and intervening trials. Vitkovitch and colleagues' seminal studies of blocking-induced semantic perseverations strongly support this. In Vitkovitch and Humphreys (1991), participants named pictures in two consecutive 20-item blocks, where each block contained multiple, non-identical exemplars from a small set of categories. The authors predicted that competitors primed by naming in block 1 would retain this priming advantage into block 2, whereupon they would exert interference in the naming of related block-2 targets. In support of this prediction, they observed an above-chance incidence of semantic perseverations in block 2 that duplicated a response produced back in block 1. An unexpected observation was that there were no instances of perseveration of an immediately preceding response.

Vitkovitch et al. (1996) performed a follow-up study that focused on the temporal characteristics of semantic perseverations induced by blocking. Two groups of healthy participants named pictures of 30 different 4-legged animals under speeded naming conditions (600 msec deadline). The groups experienced different response-stimulus intervals (RSI 7 s or 4 s). Semantic perseverations were analyzed for how far back the source occurred; an error whose source was on the preceding trial was coded as having lag 1. Estimates of chance were calculated at each lag to enable statistical testing of key findings from Vitkovitch and Humphreys (1991). The persistence of name priming was supported: peak perseveration frequency occurred at lag 11, which, in the longer RSI condition corresponded to about 90 s between source and error. The difference from chance was significant here and at neighboring lags, beyond which plotted observed and chance probabilities came together. The paucity of immediate perseverations was also supported. Zero lag 1 perseverations occurred, significantly below chance (see also Campbell & Clark, 1989); indeed, the plot for observed frequencies did not rise above the chance baseline until lag 4 or so. Another noteworthy finding was that in the comparison of effects at the two RSI values, none of the observed differences were statistically reliable, e.g., an ANOVA containing Lag and RSI as factors produced a non-significant interaction between them. The significance of this finding will be explained in the next section.

Perseverations in Aphasia

From an aphasia perspective, the Vitkovitch et al. (1996) study produced surprising findings. At least since Cohen and Dehaene's (1998) seminal study of the temporal characteristics of lexical perseverations in aphasia, it has been generally accepted that perseverations exhibit a strong *recency bias*, occurring with highest frequency at lag 1 and declining exponentially with increasing lag. Cohen and Dehaene (1998) collected perseveration data from three individuals with aphasia using naming tasks in which there was neither semantic blocking nor a fast deadline. They computed lag functions from actual data and from chance data created by randomly shuffling trials (i.e., stimulus-response pairs). Consistently, the plots of the observed vs. chance lag distributions revealed that short lags were over-represented in the actual data. Actual frequencies differed from chance frequencies at the shortest lags and declined to chance levels by lag 6 or so (depending on the individual and the analysis).

Cohen and Dehaene (1998, p. 1655) concluded from their analysis: "At any processing level, the probability that an error is a perseveration from a previous trial is a decreasing function of the lag between the two trials considered. This suggests that an exponentially decaying variable, such as an internal level of activation, is responsible for the recurrence of perseverations." As internal activation levels are generally held to decay spontaneously with time, this formulation invites the inference that the perseveration lag-function is time-sensitive.

Results from the Vitkovitch et al. (1996) study tell a different story. As the authors note, the under-representation of perseverations with very short lags indicates that these highly primed responses may have been suppressed either consciously or through automatic inhibition (Arbuthnott, 1996; Campbell & Clark, 1989; MacKay, 1986; Vitkovitch, Rutter & Read, 2001). Their second key finding, insensitivity to RSI, suggests that name priming may not dissipate passively as a function of time but instead might be actively interfered with by the occurrence of intervening trials (Cohen & Dehaene, 1998; Gotts et al., 2002).

How are we to understand the difference across studies? Is it because the perseverations that Vitkovitch and colleagues analyzed were generated by healthy participants, as opposed to individuals with aphasia? Or is it because the perseverations in their study were induced by semantic blocking? To address this question, the present study analyzed semantic perseverations generated by individuals with aphasia during performance of the semantic blocked naming task (Schnur et al., 2006, Experiment 2). The next section describes the methods used in that study and the findings that laid the groundwork for the present investigation.

Schnur, Schwartz, Hodgson and Brecher (2006)

The semantic blocked naming experiment that Schnur and colleagues conducted was inspired by similar experiments run with unimpaired speakers (e.g., Damian, Vigliocco, & Levelt, 2001; Kroll & Stewart, 1994) and individuals with aphasia (McCarthy & Kartsounis, 2000; Wilshire & McCarthy, 2002). Schnur et al.'s study was the first to demonstrate that participants with aphasia *as a group* experience reduced naming accuracy as a consequence of semantic blocking. For a complete description of participants and procedures, readers should consult Schnur et al. (2006). What follows is a summary of details relevant to the present follow-up study.

Participants were 18 individuals with post-stroke, chronic aphasia who had lesions to the left hemisphere and were right-handed native speakers of English (details in Table 1). They performed the blocked naming experiment on a computer programmed in Psyscope. The experiment consisted of multiple blocks, each comprising 24 consecutive naming trials. On each trial, a single target was presented for naming within a 5 s deadline, without feedback. In each block, 6 unique targets were named once (cycle 1), then again in a different random order (cycle 2), and so on for a total of 4 cycles (24 trials). Blocks were of two types: homogeneous and mixed. In a homogeneous block, targets were 6 exemplars from the same category (e.g., 6 animals or 6 vehicles); in a mixed block, targets were 6 exemplars from different categories (1 animal, 1 vehicle, etc.) There were 12 homogeneous blocks, each containing targets from a different category. (Categories and targets are shown in Appendix A.) There were also 12 mixed blocks, created by rearranging the targets of the homogeneous blocks. Phonological overlap within blocks was kept to a minimum. In each experimental run, all 24 blocks were named, with the homogeneous-mixed presentation order randomly varied. For example, one participant named 3 homogeneous blocks followed by 3 mixed blocks, whereas another participant named a homogeneous block followed by a mixed block then another mixed block, and so on. Between blocks, participants were given as much rest time as they required. Every participant completed two runs of the experiment. In one run, the interval programmed between the response and the following stimulus (response-stimulus interval, RSI) was only 1 s; in the other run-through, it was five times that (5 s). Order of RSI conditions varied across participants. In summary, over the entire experiment, each participant named all 24 sets twice (once with each RSI) for a total of 48 blocks, 1152 trials per subject. The number of sessions required to complete the experiment ranged from 2 to 7.

Across all 18 participants, significantly more errors were made in the homogeneous condition, compared to the mixed condition; and the homogeneous-mixed difference (indexing the blocking effect) increased across repetition cycles. This increase was subsequently shown to be associated with damage in the left inferior frontal gyrus (Schnur, Lee, Coslett, Schwartz, & Thompson-Schill, 2005; Schnur, Schwartz, Kimberg, Hirshorn, Coslett, & Thompson-Schill, submitted).

Schnur et al. (2006) also carried out separate analyses of the error types of interest. For present purposes, the most interesting errors are those that duplicate other items from the same set. These "within-set substitutions" occurred primarily in homogeneous blocks (e.g., DOG → ''horse''', where ''horse'' was one of the six items in the animal set featured in that block). A much smaller number occurred in mixed blocks (e.g., DOG → "toaster", where "toaster" was another member of the mixed set featured in that block). The vast majority of the within-set substitutions were perseverations of responses produced earlier in the block. These are the perseverations that we analyzed in the present study.

Schnur et al’s (2006) analysis demonstrated that the semantic blocking manipulation lowered accuracy in part by eliciting semantic within-set intrusions, which, as we said, were primarily of a perseveratory nature. Schnur et al. did not, however, analyze the temporal characteristics of these semantic perseverations. We took up that issue here, using analytic methods inspired by Cohen and Dehaene (1998) and Vitkovitch et al., (1996). First, we compared the semantic-perseveration lag functions to chance, looking for evidence of decay akin to what Cohen and Dehaene (1998) observed. Finding evidence for this, we then performed an ANOVA across subjects to determine whether RSI modulates the lag function and whether any such modulation differs for semantic perseverations versus the (semantically unrelated) perseverations produced in the mixed condition. We found that RSI did not modulate the lag function for either semantic or unrelated perseverations. In the Discussion, we consider what these findings reveal about the mechanisms that underpin semantic perseveration in competitor priming tasks and about perseveration production in normality and pathology.

Methods

[Insert Table 1 around here]

Participants

Table 1 reports background information on the 18 individuals with post-stroke aphasia who participated in the blocked naming experiment (Schnur et al., 2006) and whose perseverations we analyzed in the present study. The participants are heterogeneous with respect to aphasia subtype, aphasia severity (Aphasia Quotient) and picture naming accuracy (Philadelphia Naming Test). On the PNT, all produced occasional semantic errors and recurrent, whole-word perseverations. The rates of both error types were low (less than .15 of responses; see Table 1), except for BT, who, with .29 perseverations, was clearly an outlier. None of the participants exhibited verbal stereotypy or frequent runs of continuous perseveration (same response repeated on multiple consecutive trials).

Perseveration Analysis

Schnur et al. (2006) scored the first complete response on each trial of the experiment. The error taxonomy coded word errors by their relation to the target (semantic, phonological, or unrelated) and also contained codes for nonwords (neologisms), omissions, descriptions, and miscellaneous others. Secondary codes were used to designate within-set substitutions and other features of interest.

For reasons that will be explained shortly, our analysis necessitated a recoding of their data. Using their trial-by-trial listing of targets and phonetically transcribed responses, we replaced any nonword that strongly approximated (at least 50% phoneme overlap) the name of an item in the current set with the actual name. We then identified the within-set substitutions (substituted words that named another target from the current set) and coded as perseverations those that matched a response produced earlier in the block. Note that perseverations of responses outside of the current set, e.g., matching a response produced in a prior block, were not counted as perseverations in this study. For each coded perseveration, we counted back to the most recent occurrence of the response to find the “lag” for that perseveration. Let us take as an example the following trial sequence from a mixed block:

DOG – dog

TOASTER - toaster

BUSH – bush

BED – ~~shoaster~~ toaster

The replacement of “shoaster” by “toaster” allowed us to capture the correspondence between that response and the earlier one; an automated matching procedure identified the BED→ toaster error as a within-set substitution, and a perseveration with lag of 2. The replacement rule had the desirable consequence of avoiding overestimation of long-lag perseverations. (Imagine another perseveration of “toaster” two trials later; with the replacement, lag = 3, without it, “shoaster” is passed over and lag = 5.) In any case, replacement affected only 2% of all responses, so the impact of this coding change was small.

For each participant, we tabulated the number of perseverations that occurred with lag 1 across blocks, then repeated this for perseverations with lag 2, lag 3, etc. up to lag 23 (recall that there are 24 items per block). Separate tabulations were performed for homogeneous and mixed blocks at each RSI. This yielded four summary lag distributions per participant (homogeneous RSI 1, 5; mixed RSI 1, 5)

(Insert Table 2 around here)

Chance. Chance data sets are typically generated by repeatedly re-pairing targets and responses, so as to determine whether observed target-error relationships (e.g., phonological relatedness) are real or due to chance. In Cohen and Dehaene’s (1998) study, the question was rather whether relationships observed *across trials* were real or due to chance, and so they generated the chance corpus by reshuffling whole trials (i.e., stimulus-response pairs). We used their method, but modified it so that the reshuffling was done within a block and in a manner that preserved the cyclic structure of the block. Table 2 illustrates the procedure: For a reshuffled trial list to be legal, each target in the current set had to be presented once before any was presented again, and so on for all four cycles. In other words, each target appeared exactly once within each cycle, together with its original response. Thirty reshuffled trial lists were generated per participant per each of the 48 blocks (12 homogeneous, 12 mixed at each of 2 RSI conditions). In each reshuffled list, we identified perseverations and determined their lags, calculated their frequency at each lag, and then averaged these across the 30 lists per block to derive the mean perseveration frequency at each lag that was due to chance.

When the lag calculated for a particular perseveration is *x*, this means not only that the response in question matched an earlier response at lag *x*, but that it did *not* match any responses at shorter lags. Thus, the comparison of perseveration frequencies in the observed and chance data sets at a particular lag must take into account the differing number of within-set substitutions that have yet to be matched to an earlier response. For example, in both the observed and chance data sets, a certain proportion of within-set substitutions will match the previous response (i.e., with lag 1). The number of perseverations with lag 1 is directly comparable between the two data sets because both began with the same number of within-set substitutions. However, the resulting numbers of *unmatched* within-set substitutions are now different, so that the number of perseverations at the following lag (here, lag 2) in the chance data set must be adjusted, so that the observed data set can be directly compared with it. The next section describes that adjustment.

(Insert Table 3 around here)

Adjusted chance frequency. For each individual's data, we adjusted the mean within-set perseveration frequencies derived from the reshuffled data sets using Cohen and Dehaene's (1998) procedure. Table 3 illustrates the procedure in relation to the data in Table 2. (Note that our terminology differs somewhat from what Cohen & Dehaene used in their text and their Table 1.) Consider the boxed example in Table 3: In the reshuffled list, the frequency of lag 3 perseveration was 2, and the adjustment was done by expressing this value as a proportion of the remaining errors in the reshuffled list (7) multiplied by the remaining errors in the observed data set (6). The resulting value (1.17) is the number of perseverations that would be generated by chance, given the actual number of remaining errors at this lag and the probability of generating perseverations by chance at that lag. We call this the *adjusted chance frequency.* For statistical analysis, we subtracted adjusted chance frequency from observed frequency to create the dependent variable, *chance-corrected frequency.*

The methods used to estimate chance, including the re-shuffling of stimulus-response *pairs,* ensured that the following properties of the original data set were preserved: 1) the number and nature of errors, 2) the response vocabulary (and therefore any given subject's bias towards producing one name over another), 3) the cyclic structure of stimulus presentation, and 4) opportunities to perseverate. There are more opportunities to perseverate at short lags than long ones for several reasons. Firstly, within each block of 24 trials, there are $24 - x$ trials in which it is possible to produce a perseveration with lag x. When x is high (lag is long), this value is small. Secondly, as noted earlier, in order for a response to be considered a perseveration with lag x, it must not only match the response produced x trials earlier, but must also *not* match any of the responses produced in the intervening trials. Since the probability of a response *not* matching any of the intervening responses is lower at longer lags, this, too, favors short-lag perseverations. This bias is further amplified by the cyclic presentation of stimuli, as the repetition of targets spaced on average six trials apart makes it even less likely that perseverations would occur at lags of more than six trials. Critically, given our method of estimating chance, all these factors should affect both the observed and chance lag frequency distributions in exactly the same manner. Any differences between them must therefore reflect a temporal bias that is present only in the actual data.

Results

(Insert Table 4 around here)

A total of 366 perseverations was produced (316 in the homogeneous condition, 50 in mixed). While contributions to this total from individual participants varied considerably (1 – 75; see Table 4), every participant made more perseverations in the homogeneous condition than in the mixed condition.

The remaining results are presented in three sections. In the first two sections we analyze observed and chance lag functions for just the homogeneous-condition perseverations (i.e., semantic perseverations), collapsed across RSI levels. In the third section, we expand the focus to include the mixed condition and the breakdown by RSI. Readers interested in comparing RSI-averaged lag effects in homogeneous and mixed conditions should consult Tables 5 and 6.

(Insert Tables 5 and 6 around here)

Lag Functions: Individual Participants Analysis

The four highest perseveration producers (last four in Table 4) account for more than half the total, with NQ alone accounting for 20%. Lag functions for these four individuals are shown in Figure 1. Looking first at the plots for adjusted chance, one sees that the frequencies are highest at short lags and decline to near zero by lag 9 or thereabouts. This confirms that our method of estimating chance did in fact preserve the differential opportunities at short versus long lags. The curves for the observed data are similarly shaped and, importantly, fall above the chance curves primarily at the shorter lags. In the case of immediate (lag 1) perseverations, individual differences are evident: For DAN and NQ, the observed lag function has its peak at lag 1; for the other two, the peak is at lag 2 and the lag 1 frequency is below chance. Examination of the data from other high perseveration producers revealed similar inconsistency at lag 1. Indeed, among the 9 participants who produced more than the median number of perseverations (and who accounted for 86% of all perseverations), the results are split; four had peak frequency at lag 1, whereas 5 had many fewer perseverations at lag 1 than at lag 2. In view of these marked individual differences, we omitted lag 1 data from the following statistical analysis of the recency bias.

The top four error producers had semantic perseveration counts high enough to warrant statistical analysis. For each of these, we correlated lag value against chance-corrected perseveration frequencies, excluding lag 1. Computed over lags 2-23, the correlation was strongly negative for all four participants (Pearson *r* between -.52 and -.72; $p < .05$ for all). It remained strong (*r* between -.49 and -.82) when computed over just lags 2-9 (i.e., excluding the long lags where chance was near zero). This demonstrates that at the level of individual participants, there was a significant trend toward higher chance-corrected frequency at short lags, i.e., a recency bias.

Insert Figure 1 around here

Lag Functions: Group Analysis

Figure 2 plots the observed and adjusted-chance lag functions averaged across all 18 participants. At lag 1, the observed and adjusted-chance values are about the same, reflecting the averaging of above- and below-chance trends in the individual data. Thereafter, the curves diverge, with observed frequencies exceeding chance at shorter lags. In the correlation analysis, mean chance-corrected frequencies were strongly correlated with lag value for lags in the range 2-23 ($r = -.62$, $p < .01$) and 2-9 ($r = -.81$, $p < .05$). Thus, in the grouped data, too, shorter lags were associated with a higher likelihood of perseveration.

[Insert Figure 2 around here]

Lag and RSI: Across Subjects Analysis of Variance

To assess the generality of the lag effect as well as the impact of RSI, we performed an ANOVA on the chance-corrected perseveration frequencies, using SAS (v. 9.1) mixed model. Subjects were treated as a random variable. Within-subjects factors of primary interest were Lag

(2-23) and RSI (1 s, 5 s). For completeness, we included a third within-subjects factor, Condition (homogeneous, mixed). Data from lag 1 were excluded from the analysis because we were primarily interested in effects on lag that were due to recency, and the inconsistent lag 1 dip had the potential to obscure such effects or complicate their interpretation.

The ANOVA produced the expected main effect for Lag (F(21, 1479) = 6.0, p < .0001), as well as a main effect for Condition (F(1, 1479) = 7.6, p = .006, and a significant Lag by Condition interaction (F(21, 1479) = 1.72, p = .022). No other main effects or interactions were significant (all Fs < 1); this includes the interactions of primary interest, involving RSI and Lag (RSI by Lag: F(21, 1479) = .11; RSI by Lag by Condition: F(21, 1479) = .38).[1] Figure 3 confirms that the lag plots at RSI 5 and RSI 1 were highly similar.

As mentioned, the ANOVA yielded a significant Lag by Condition interaction. We followed up with separate one-way ANOVAs testing for the Lag effect in each Condition; this revealed that Lag was significant in both (Homogeneous: F(21, 731) = 4.0, p < .0001; Mixed: F(2, 731) = 3.0; p < .0001). Due to the low perseveration counts (low power) in the mixed, we did not further analyze this interaction with post hoc tests. However, looking at Figure 3, and ignoring for the moment the data from lag 1, which were excluded from the ANOVAs, the likely interpretation of the Lag by Condition interaction is that chance-corrected frequencies are higher in the homogeneous condition at short lags (2-5) but not longer ones. In other words, the recency effect defined from lag 2 onwards was steeper in the homogeneous condition.

As far as lag 1 is concerned, Figure 3 indicates that the dip was present in both relatedness conditions but was more extreme in the homogeneous condition. Not surprisingly, given the variability at lag 1, effects here did not survive statistical analysis; when the lag 1 data

---

were averaged across RSI levels and submitted to separate one-sample t-tests, the mean chance-corrected frequency at lag 1 did not differ significantly from zero in either condition (Homogeneous: $t(17) = -0.89$; Mixed: $t(17) = 1.07$; both p's $< .05$).

To summarize the key findings: There was a significant main effect for Lag, which indicates that the recency bias – shown earlier by correlation analysis – generalizes across subjects. Furthermore, Lag and RSI did not interact, indicating that the recency bias was not modulated by time between responses.

Discussion

This study examined semantic perseverations elicited by semantic blocked naming as a means of clarifying the time course of such perseverations and the means by which they arise. Consistent with the seminal studies of Cohen and Dehaene (1998), who based their analyses on perseverations produced on standard naming tasks, we found that the lag function for semantic perseverations is biased in favor of short-lag perseverations. Consistent with the semantic blocking study that Vitkovitch et al., (1996) conducted with young, healthy adults, we found that the likelihood of perseveration is, within the limits of the RSI manipulation, insensitive to the passage of time. We also confirmed their finding that immediate perseverations are subject to other influences that exempt them from the recency effect. This hints at the basis for the across-study differences that were noted in the Introduction. Most important, the findings demonstrate that recency bias and insensitivity to time are reliable properties of semantic perseveration. After discussing the evidence more fully in the next two section, we move on to formulate an incremental learning account of these key properties of semantic perseverations.

Recency Bias

We analyzed the lag function for semantic perseverations generated in Schnur et al. (2006) to determine if it would exhibit recency bias such as was previously documented in people with aphasia on more standard naming tasks (Cohen & Dehaene, 1998). Examination of the lag function visually and with analysis of the correlation between lag and chance-corrected perseveration frequency revealed the expected trend toward higher chance-corrected frequency at short lags. We conclude that the recency bias is indeed a property of perseverations generated by the semantic blocking manipulation.

Semantic perseverations elicited from young, healthy adults rarely repeat the immediately preceding response (Campbell and Clark, 1989; Moses et al, 2004; Vitkovitch & Humphreys, 1991; Vitkovitch et al., 1996; Vitkovitch, et al., 2001; Wheeldon & Monsell, 1994). Vitkovitch et al. (1996) found that lag 1 perseverations were below chance, and the lag function did not peak and begin to decay until around lag 11. We wondered whether the hypothesized suppression of immediate perseverations applied uniquely to *nonaphasic* speech.

The answer to this question is “no” as judged by the lag 1 dip in a sizeable subset of the current’s study’s participants with aphasia. Moreover, the highest perseveration producers were as likely to show the dip as not, which argues against the possibility that the lag 1 dip goes along with low rates of perseveration. Such an association would be expected if inhibitory processes were needed to keep perseveration rates low, and the presence of the lag 1 dip were evidence of a well-functioning inhibitory system (Campbell & Clark, 1989; Vitkovitch et al., 1996; for more on inhibition-related accounts of perseveration; see Arbuthnott, 1996; Dell, 1986; MacKay, 1986; for a related account featuring synaptic depression, see Gotts & Plaut, 2002 and Gotts et al., 2002). Since this does not appear to be the case, it might be useful to look beyond automatic inhibition for an explanation of the lag 1 dip and the individual differences within and across studies.

One possibility relates to the special properties of tasks such as blocked picture naming that create a predisposition for semantic perseveration by the mechanism of competitor priming. Competitor priming paradigms are known to produce opposing facilitative and competitive (interference) effects on different time scales (Damian & Als, 2005; Wheeldon & Monsell, 1994). For example, Wheeldon and Monsell's (1994) seminal paper on competitor priming showed that naming was slowed on the second of two related items ("whale", following "shark") when multiple unrelated items intervened between them but *not* when they occupied adjacent positions in the list. Their explanation for the interference (slowing) effect was post-naming priming of a lemma-level competitor ("shark" competing with "whale"). The absence of competitor priming with adjacent pairs was attributed to an opposing effect – facilitative priming of WHALE by SHARK at the semantic-conceptual level – which, unlike competitor priming, persists for one trial only. Extending this argument to the present context, one could say that naming "horse" on trial *i* of a homogeneous block would, through semantic priming, facilitate the production of a different animal name on trial *j* (target or homogeneous setmate), thereby reducing the probability of repeating "horse" and making a lag 1 perseveration.[2] Note, however, that as adjacent items in the mixed condition would not be expected to benefit from semantic facilitation, this account has difficulty with the present evidence, which indicates that the lag-1 dip also occurred in the Mixed condition (see Figure 3).

Another possible explanation for the individual differences at lag 1 is strategic avoidance of repetition. In the Schnur et al. (2006) blocked naming experiment, the random ordering of trials resulted in immediate successive repetition of targets on only 2.2% of trials, so it would have been adaptive to avoid repeating a response that was produced one trial back. Participants could have differed in whether they chose to adopt this strategy and/or were capable of doing so. Similarly, in Vitkovitch et al. (1996), avoidance of repetition would have been adaptive, since the animal targets in that naming study did not repeat at all. Widespread deployment of an avoidance strategy by participants in that study would explain why none of the many perseverations recorded was of the immediate (lag 1) type and why perseveration frequency at lags 2 and 3 was low as well.

Clearly, future study is needed to elucidate why the recency trend in the perseveration lag function is sometimes violated at lag 1 and beyond. However, for present purposes, what is most important is not that the recency bias is sometimes violated at the shortest lags, but that this bias is present and must be explained in any theoretical account of semantic perseveration. We will expand on this after considering the evidence regarding RSI.

Effect of RSI

Cohen and Dehaene (1998) interpreted their analyzed lag functions as evidence that the recurrence of perseveration is due to an exponentially decaying variable; but they stopped short of concluding that the decay was sensitive to time. In their words, “a specific experiment would be needed to distinguish the effects of elapsed time versus elapsed number of trials on the decay of perseveration probability.” (Cohen & Dehaene, 1998, p. 1655). The manipulation of RSI in the current study constitutes the experiment that Cohen and Dehaene (1998) called for. If long-lag perseverations are less probable than short-lag perseverations on account of passive decay in activation that happens naturally with the passage of time, then spacing trials further apart by lengthening RSI should result in fewer perseverations overall, since that would add time for activation to decay and thereby render past items less competitive. Lengthening the RSI should also cause the lag function to fall to chance levels more quickly, yielding a steeper lag-decay function.

In partial support of these predictions, Santo Pietro and Rigrodsky (1986) obtained fewer perseverations in people with aphasia when RSI was long (RSI 10 s compared with 1 s), indicating that time is important. On the other hand, the RSI manipulation in Vitkovitch et al. (1996) (4 s vs. 7 s) did not produce a statistically reliable effect: perseveration rates did not differ in the two conditions, and the RSI by Lag interaction was not significant. Our findings agree with those of Vitkovitch et al. (1996).

The absence of RSI effects in our study is especially noteworthy because this null result coincides with a Cohen and Dehaene (1998) type lag-decay function. It points to the conclusion that the decay in perseveration probability across lags is not due to elapsed time but instead to the elapsed number of trials. This conclusion is reinforced by an investigation of perseverations that Gotts et al., (2002) carried out with EB, an individual with aphasia. EB performed several naming experiments that involved semantic blocking and a comparison of short (1 s) and long (10 s or 15 s) RSIs. She made numerous perseverations, which unlike the present study, did not tend to resemble the target semantically. When analyzed by lag, these unrelated perseverations showed the expected exponential decay; and the 10+-fold difference in RSI values did not affect the frequency of her perseverations or the shape of the lag function. The RSI difference in Gotts et al.'s (2002) study was twice as large as ours, making is less likely that our results would have been different had the long RSI been extended. On the other hand, it must be acknowledged that at RSI values of 1 s and 10 s, San Pietro and Rigrodsky (1986) did find significantly fewer lexical perseverations at the longer RSI. This early study did not include correction for chance or analysis of lag functions; and since RSI effects were not examined in relation to lag, it is unknown whether the perseveration drop at the longer RSI was due to drop-out of longer lag perseverations, as the time-sensitive decay account predicts. As it stands, the weight of evidence argues that the lag function is not altered by elapsed time, which points, albeit indirectly, to elapsed trials as the relevant factor. This means that the perseveratory impetus is stronger for recent responses not because the earlier responses are further removed in time but because those earlier responses have had more opportunity to be weakened by interference from intervening trials.

Activation Persistence in Competitor Priming

Repeatedly, we have tied the explanation for why semantic blocking encourages semantic perseveration to the mechanism of competitor priming, which rests on the notion that a word is primed by virtue of having been named. The apparent insensitivity of the perseveration lag function to time is relevant to how one conceives of such priming in connectionist or neural network terms. Specifically, such priming is unlikely to depend on a unit's being in a state of heightened activation, as activation levels are generally thought to decay quickly and spontaneously (e.g., Bock & Griffin, 2000). More likely, it depends on parameters of networks that encode long-term processing biases, for example, connection weights or activation thresholds (both of which would be neurally implemented through long-term synaptic changes). Connection weight changes, in particular, have been invoked to explain the persistence of competitor priming effects across time and trials (e.g., Damian & Als, 2005; Howard et al., 2006; Vitkovitch & Humphreys, 1991; Vitkovitch et al., 1996; Wheeldon & Monsell, 1994).

The study that Howard et al. (2006) conducted is instructive. Unimpaired speakers were given a sequence of 165 pictures to name. Items from the same semantic categories ("category coordinates") were interspersed throughout the list, with a predetermined spacing that the authors refer to as "lag"; for example, when successive category coordinate targets were separated by two different-category items, the lag was 2. Lags varied from 2-8. Items did not repeat. There were two critical findings: first, with each successive category coordinate named, mean naming times slowed by about 25 ms on average; second, the size of the effect was unrelated to the lag between one category coordinate and the previous one. The authors modeled the cumulative, linear interference effect with a simple connectionist network that updated its lexical-semantic knowledge after each naming trial by strengthening the connection between the named target's semantic representation and its name. Such updating of a network in response to experience is sometimes called "incremental learning" (see Damian and Als (2005) for related evidence of incremental learning, this time in the blocked naming paradigm).

An Error-based Incremental Learning Account

The weight-change model that Howard et al. (2006) proposed is consistent with the null effects for RSI that we and others have observed, since connection weights are typically not thought to decay passively with time. However, without some modification, that model can not handle the evidence for the recency bias in semantic perseverations, which, as we argued, indicates that the perseveratory impetus is unlearned or forgotten across intervening related trials. The desired result can be achieved by a model that incrementally adjusts its weights through *error-based* learning, e.g., using the delta-rule. Examples of such models can be found in Dell, Oppenheim and Kittredge (2008); Gordon and Dell (2003); Oppenheim, Dell and Schwartz (2007; submitted).

In these models, weights from distributed semantic features to words are tuned whenever a word is produced, such that there are increases in weights from the features to the target word *and* decreases in weights from the features to words that are erroneously activated. So, any under-activation of the target, or activation of a competitor word, stimulates the system to tweak the weights. The production of a word *i* therefore primes its representation in a manner that is undiminished by time (weight changes do not passively decay) and by subsequent unrelated trials (an unrelated item is not assumed to share features with the target). This comports with the evidence that competitor priming accumulates and is undiminished by intervening unrelated trials (Damian & Als, 2005; Howard et al., 2006). Critically, though, error-based learning ensures that a subsequent *related* trial (word *j)* will lessen the perseverative impetus of word *i* for replacing future related targets, because *i* will become activated when *j* is the target, stimulating weight changes that decrease *i*'s tendency to be active on future related trials. Thus, incremental error-based learning is consistent with the observed recency effect in semantic perseverations, as well as its insensitivity to time.

A prediction from the incremental, error-based learning account is that the recency bias should be weaker for perseverations produced in the mixed condition of semantic blocked naming, relative to the homogeneous condition. In the mixed condition, targets that follow word *i* share fewer of its features, so their production should stimulate less unlearning of *i,* hence less reduction in its perseverative impetus. The ANOVA on chance-corrected perseverations did yield a significant Condition by Lag interaction in the predicted direction; but further analysis was limited by the paucity of perseverations in the mixed condition. A definitive test of the prediction that the recency effect is weaker in the mixed condition will require experiments that generate more mixed-condition perseverations to analyze.

Conclusions and Future Directions

We found that the lag function for semantic perseverations resembles the negative exponential decay curve described by Cohen and Dehaene (1998) and that the 5-fold difference in RSI did not alter the shape of the lag function. These two findings constrain the explanation of how priming operates in semantic blocked naming to make the past competitive with the present. We maintain that responses are strengthened through a process of incremental learning, affecting connection strength, and that with the processing of successive trials, there is a degree of unlearning that accounts for the recency gradient.

It remains to be seen whether the evidence that motivates the incremental learning hypothesis of name priming – a perseveration lag function that decays and that is relatively insensitive to time – is also seen in naming tasks that do not include exotic manipulations like semantic blocking and short naming deadlines. Further research also is needed to determine whether the combination of recency bias and time-insensitivity is reliably seen in the data from individual participants with aphasia. Answering these questions will require a massive data gathering effort; with over 1000 trials per participant, the Schnur et al., (2006) study generated too few perseverations to afford adequately powered analysis of the mixed-condition perseverations or patterns of individual differences.

As Howard and colleagues demonstrated, priming by incremental learning is one of three legs on which a complete model of competitor priming rests (Howard et al., 2006). Also required is a mechanism for top-down activation sharing among related competitors (to explain relatedness effects), and a competitive selection mechanism that is slowed by the presence of primed competitors (to explain response time effects in competitor priming paradigms; see also Wheeldon & Monsell, 1994). What must one add to such a model to simulate the heightened frequency of perseverations in people with aphasia? According to one widely held view, what is needed is nothing more than to instantiate a retrieval deficit that lessens the advantage of the current target relative to primed past responses, particularly those that are also semantic competitors (e.g., Cohen & Dehaene, 1998; Dell, Burger & Svec, 1997; Moses et al., 2004; Martin & Dell, 2007; Martin, Roach, Brecher & Lowery, 1998; Schwartz, Saffran, Bloch, & Dell, 1994). In the incremental, error-based learning model of semantic blocking developed by Oppenheim and colleagues, such a retrieval deficit is simulated by adding noise to the activations of network units (Oppenheim et al., 2007; submitted). The result is a high rate of perseveration errors generated without altering the process by which the past is primed (error-based learning, which strengthens connections to the target and weakens connections to the competitors). Importantly, activation-based inhibitory processes, such as the explicit turning off of the recent past (e.g., Dell, 1986), play no role in generating the model's perseverations. It will be interesting to see whether a model constructed along these lines has adequate explanatory power to explain the totality of facts about lexical perseverations, including the yet to be explored individual differences.

References

Arbuthnott, K. D. (1996). To repeat or not to repeat: Repetition, facilitation and inhibition in sequential retrieval. Journal of Experimental Psychology: General, 125, 261-283.

Bock, K., & Griffin, Z. M. (2000). The persistence of structural priming: Transient activation or implicit learning? Journal of Experimental Psychology: General, 129, 177-192.

Brown, A. S. (1981). Inhibition in cued retrieval. Journal of Experimental Psychology: Human Learning and Memory, 7, 204-215.

Campbell, J. I. D., & Clark, J. M. (1989). Time course of error priming in number-fact retrieval: Evidence for excitatory and inhibitory mechanisms. Journal of Experimental Psychology: Learning, Memory & Cognition, 15, 920-929.

Cohen, L., & Dehaene, S. (1998). Competition between past and present - assessment and interpretation of verbal perseverations. Brain, 121, 1641-1659.

Damian, M. F., & Als, L. C. (2005). Long-lasting semantic context effects in the spoken production of object names. Journal of Experimental Psychology: Learning, Memory, and Cognition, 31, 1372-1384.

Damian, M. F., Vigliocco, G., & Levelt, W. J. M. (2001). Effects of semantic context in the naming of pictures and words. Cognition, 81, B77-B86.

Dell, G. S. (1986). A spreading-activation theory of retrieval in sentence production. Psychological Review, 93, 283-321.

Dell, G. S., Burger, L. K., & Svec, W. R. (1997a). Language production and serial order: A functional analysis and a model. Psychological Review, 104, 123-147.

Dell, G. S., Oppenheim, G. M., & Kittredge, A. K. (2008). Saying the right word at the right time: Syntagmatic and paradigmatic interference in sentence production. Language and Cognitive Processes, 23, 583-608.

Dell, G.S., Schwartz, M.F., Martin, N., Saffran, E.M., & Gagnon, D.A. (1997b). Lexical access in aphasic and nonaphasic speakers. Psychological Review, 104, 801-838.

Gordon, J. K., & Dell, G. S. (2003). Learning to divide the labor: An account of deficits in light and heavy verb production. Cognitive Science, 27, 1-40.

Gotts, S. J., della Rocchetta, A. I., & Cipolotti, L. (2002). Mechanisms underlying perseveration in aphasia: Evidence from a single case study. Neuropsychologia, 40, 1930-1947.

Gotts, S.J. & Plaut, D.C. (2002). The impact of synaptic depression following brain damage: A connectionist account of "access/refractory" and "degraded store" semantic impairments. Cognitive, Affective, & Behavioral Neuroscience, 2, 187-213.

Howard, D., Nickels, L., Coltheart, M., & Cole-Virtue, J. (2006). Cumulative semantic inhibition in picture naming: Experimental and computational studies. Cognition, 100, 464-482.

Howard, D., & Patterson, K. (1992). Pyramids and palm trees: A test of semantic access from pictures and words. Bury St. Edmunds, U.K.: Thames Valley Test Company.

Humphreys, G. W., Riddoch, J., & Quinlan, P. T. (1988). Cascade processes in picture identification. Cognitive Neuropsychology, 5, 67-103.

Kertesz, A. (1982). Western Aphasia Battery. New York: Grune & Stratton.

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. Journal of Memory and Language, 33, 149-174.

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. Behavioral and Brain Sciences, 22, 1-75.

MacKay, D. G. (1986). Self-inhibition and the disruptive effects of internal and external feedback in skilled behavior. In H. Heuer & C. Fromm (Eds.), Generation and modulation of action patterns (pp. 174-186). Berlin: Springer-Verlag.

Martin, N., & Dell, G. S. (2007). Common mechanisms underlying perseverative and non-perseverative sound and word substitutions. Aphasiology, 21, 1002-1017.

Martin, N., Roach, A., Brecher, A., & Lowery, J. (1998). Lexical retrieval mechanisms underlying whole-word perseveration errors in anomic aphasia. Aphasiology, 12, 319-333.

McCarthy, R. A., & Kartsounis, L. D. (2000). Wobbly words: Refractory anomia with preserved semantics. Neurocase, 6, 487-497.

Moses, M. S., Nickels, L. A., & Sheard, C. (2004). "I'm sitting here feeling aphasic!" - a study of recurrent perseverative errors elicited in unimpaired speakers. Brain and Language, 89, 157-173.

Oppenheim, G.M., Dell, G.S., & Schwartz, M.F. (2007). Cumulative semantic interference as learning. Brain and Language, 103, 175-176. (Long abstract)

Oppenheim, G.M., Dell, G.S., & Schwartz, M.F. (submitted). The dark side of incremental learning: A model of cumulative semantic interference during lexical access in speech production.

Roach, A., Schwartz, M. F., Martin, N., Grewal, R. S., & Brecher, A. (1996). The Philadelphia Naming Test: Scoring and rationale. Clinical Aphasiology, 24, 121-133.

Saffran, E. M., Berndt, R. S., & Schwartz, M. F. (1989). The quantitative analysis of agrammatic production: Procedure and data. Brain and Language, *37*, 440-479.

Sandson, J., & Albert, M. L. (1984). Varieties of perseveration. Neuropsychologia, 22, 715-732.

Santo Pietro, M. J., & Rigrodsky, S. (1986). Patterns of oral-verbal perseveration in adult aphasics. Brain and Language, 29, 1-17.

Schnur, T. T., Lee, E., Coslett, H. B., Schwartz, M. F., & Thompson-Schill, S. L. (2005). When lexical selection gets tough, the LIFG gets going: a lesion analysis study of interference during word production. Brain and Language, 95, 12-13.

Schnur, T. T., Schwartz, M. F., Brecher, A., & Hodgson, C. (2006). Semantic interference during blocked-cyclic naming: Evidence from aphasia. Journal of Memory and Language, 54, 199-227.

Schnur, T. T., Schwartz, M. F., Kimberg, D. Y., Hirshorn, E., Coslett, H. B., & Thompson-Schill, S. L. Localizing interference during naming: Convergent neuroimaging and neuropsychological evidence for the function of Broca's area. Under review.

Schwartz, M. F., Saffran, E. M., Bloch, D. E., & Dell, G. S. (1994). Disordered speech production in aphasic and normal speakers. Brain and Language, 47, 52-88.

Vitkovitch, M., & Humphreys, G. W. (1991). Perseverant responding in speeded naming of pictures - its in the links. Journal of Experimental Psychology-Learning Memory and Cognition, 17, 664-680.

Vitkovitch, M., Kirby, A., & Tyrrell, L. (1996). Patterns of excitation and inhibition in picture naming. Visual Cognition, 3, 61-80.

Vitkovitch, M., Rutter, C., & Read, A. (2001). Inhibitory effects during object name retrieval: The effect of interval between prime and target on picture naming responses. British Journal of Psychology, 92, 483-506.

Wheeldon, L. R., & Monsell, S. (1994). Inhibition of spoken word production by priming a semantic competitor. Journal of Memory and Language, 33, 332-356.

Wilshire, C. E., & McCarthy, R. A. (2002). Evidence for a context-sensitive word retrieval disorder in a case of nonfluent aphasia. Cognitive Neuropsychology, 19, 165-186.

Appendix A

A list of the 12 categories and 72 targets used in Schnur et al. (2006)

Animals: bear, cat, dog, goat, horse, skunk

Appliances: fan, iron, radio, scale, toaster, vacuum

Body Parts: arm, chin, ear, nose, thumb, toe

Clothing: coat, dress, glove, hat, skirt, sock

Food: bread, cake, cheese, pie, shrimp, soup

Furniture: bed, chair, crib, sofa, stool, table

Nature: cloud, mountain, pond, sun, volcano, waterfall

Plants: bush, cactus, fern, flower, mushroom, tree

Roles: bride, clown, judge, nun, nurse, soldier

Shapes: arrow, circle, cone, cross, heart, star

Toys: ball, bat, blocks, doll, kite, top

Utensils: cup, fork, glass, knife, pitcher, spoon

Authors' Note

This research was funded by a grant from the National Institutes of Health's National Institute for Deafness and Other Communication Disorders: R01 DC000191-26 (M.F. Schwartz). Aspects of this study were reported in a poster presentation at the Psychonomics Society meeting, November 2005, in Toronto, Canada (Lee, E.Y., Schnur, T.T, & Schwartz, M.F., "Recency of production influences semantic substitutions in blocked-cyclic naming") and in a symposium paper at the Academy of Aphasia, October 2007, Washington DC (Lee, E.Y., Schnur, T.T., & Schwartz, M.F., "The temporal analysis of semantic perseverations in blocked-cyclic naming", delivered by TTS).
We gratefully acknowledge Adelyn Brecher's contribution to the analysis of errors.

Footnotes

1. The generality of these findings was confirmed in several follow-up analyses. The first showed that repeating the ANOVA with data from lag 1 *included* altered the findings only with respect to the Condition main effect. As noted in the text, with lag l excluded that effect is statistically significant; with lag 1 included, it is there at the level of a trend (F (1, 1547) = 3.0, p = .082). Next we determined that the results were not overly influenced by the data from NQ, who contributed 20% of total perseverations; repeating the original ANOVA with her data excluded did not change any of the results.

2. We wish to thank Marcus Damian for suggesting this account of the lag 1 dip for semantic perseverations.

Figure Legends

Figure 1. Individual lag plots for the four highest perseveration producers, representing observed and adjusted-chance frequencies of semantic perseverations (i.e., those from the homogeneous condition), averaged across RSI 1 s and 5 s.

Figure 2. Smoothed plots of the means across all 18 participants, representing observed and adjusted-chance frequencies of semantic perseverations (i.e., those from the homogeneous condition), averaged across RSI 1 s and 5 s.

Figure 3. Smoothed plot of chance-corrected perseveration frequencies, split by condition and RSI.

Temporal Characteristics of Semantic Perseverations Induced by Blocked-Cyclic Picture Naming

Esther Y. Hsiao[1], Myrna F. Schwartz[1], Tatiana T. Schnur[2], and Gary S. Dell[3]
[1] Moss Rehabilitation Research Institute, Albert Einstein Healthcare Network, Philadelphia PA
[2] Rice University, Houston TX
[3] University of Illinois at Urbana-Champaign, Champaign, IL

Running Head: Semantic perseverations

Corresponding Author:
Myrna F. Schwartz
Moss Rehabilitation Research Institute
MossRehab 4th fl. Sley
1200 West Tabor Road
Philadelphia, PA 19147
e-mail: mschwart@einstein.edu
Tel: 215.456.9210
Fax: 215.456.9613

Abstract

When unimpaired participants name pictures quickly, they produce many perseverations that bear a semantic relation to the target, especially when the pictures are blocked by category. Evidence suggests that the temporal properties of these "semantic perseverations" may differ from typical lexical perseverations in aphasia. To explore this, we studied semantic perseverations generated by participants with aphasia on a naming task with semantic blocking [*Schnur, T. T., Schwartz, M. F., Brecher, A., & Hodgson, C. (2006). Semantic interference during blocked-cyclic naming: Evidence from aphasia. Journal of Memory and Language, 54, 199-227*]. The properties of these perseverations were investigated by analyzing how often they occurred at each lag (distance from prior occurrence) and how time (response-stimulus interval) influenced the lag function. Chance data sets were created by reshuffling stimulus-response pairs in a manner that preserved unique features of the blocking design. We found that the semantic blocking manipulation did not eliminate the expected bias for short-lag perseverations (recency bias). However, immediate (lag 1) perseverations were not invariably the most frequent, which hints at a source of inconsistency within and across studies. Importantly, there was not a reliable difference between the lag functions for perseverations generated with a 5 s, compared to 1 s, response-stimulus interval. The combination of recency bias and insensitivity to elapsed time indicates that the perseveratory impetus in a named response does not passively decay with time but rather is diminished by interference from related trials. We offer an incremental learning account of these findings.

Keywords: Perseveration; semantic blocking; aphasia; naming; priming; incremental learning

Introduction

Studies of naming errors bring to light the interplay of cooperative and competitive mental representations that underpin lexical access. Errors known as recurrent lexical perseveration (Sandson & Albert, 1984), which repeat a response given earlier, reveal that processes from the past persist and have the potential to intrude on the present. To elucidate the nature of those persisting processes and their temporal dynamics, researchers typically derive a *lag function*, which reveals how perseveration probability is affected by the number of trials that intervene between the error and its source (Cohen & Dehaene, 1998; Gotts, della Rocchetta & Cipolotti, 2002). A few studies have also experimentally manipulated response-stimulus interval (RSI) for the purpose of exploring how the passage of time affects the perseveration lag function (Campbell & Clark, 1989; Gotts et al., 2002; Vitkovitch, Kirby & Tyrell, 1996).

The investigations of perseveration lag functions do not tell a consistent story, however. They have yielded one set of results when applied to the recurrent lexical perseverations produced by people with aphasia, and quite different results when applied to those produced by healthy individuals on naming tasks designed to promote perseveration. These perseveration-promoting manipulations frequently involve semantic blocking, i.e. arranging the trial sequence so that semantic competitors (typically exemplars of the same semantic category) appear on successive or nearby trials. In this situation, earlier named competitors, through priming, have a heightened probability of intruding as perseverations, specifically, *semantic perseverations*, since they are related to the names they replace.

The goal of the present study was to confront conflicting findings in these two literatures regarding the temporal characteristics of lexical perseverations. To achieve this goal, we reanalyzed data collected from 18 individuals with aphasia during performance of a task that involved semantic blocking and that elicited a large number of semantic perseverations (Schnur, Schwartz, Hodgson & Brecher, 2006, Experiment 2).

Perseverations Elicited by Semantic Blocked Naming

Neurologically healthy individuals do not make frequent errors when naming pictures of familiar objects. However, certain experimental manipulations can induce errors that are not unlike those seen in aphasia. One such manipulation is speeded naming, wherein participants name pictures to a fast deadline. This manipulation increases semantic errors, including semantic perseverations (Moses, Nickels, & Sheard, 2004). The manipulation works because picture naming is a semantically-driven task, and so there is natural competition among words that share semantic features (e.g., Dell, Schwartz, Martin, Saffran & Gagnon, 1997; Humphreys, Riddoch & Quinlan, 1988; Levelt, Roelofs & Meyer, 1991). It takes time for the target to accumulate enough input from semantics to emerge as the winner in the competition for selection, especially when a competing word experiences priming from having been named on an earlier trial (Wheeldon & Monsell, 1994). A fast deadline increases the probability that a semantic competitor, and particularly a primed semantic competitor, will be erroneously selected for output.

The probability of semantic perseveration in normal naming can be increased still further by combining speeded naming with a semantic blocking manipulation (Vitkovitch & Humphreys, 1991; Vitkovitch et al., 1996). Here, multiple semantic competitors, typically exemplars from the same superordinate category, are presented for naming on adjacent or nearby trials. As successive competitors are named, each is primed, and the presence of multiple primed competitors prolongs the time required for the target to win the competition (Brown, 1981; Howard, Nickels, Coltheart, & Cole-Virtue, 2006). With the requirement to respond quickly, it becomes more likely that one of the primed competitors will replace the target as the naming response, resulting in a semantic perseveration.

Entailed in the foregoing account is the idea that name priming persists across time and intervening trials. Vitkovitch and colleagues' seminal studies of blocking-induced semantic perseverations strongly support this. In Vitkovitch and Humphreys (1991), participants named pictures in two consecutive 20-item blocks, where each block contained multiple, non-identical exemplars from a small set of categories. The authors predicted that competitors primed by naming in block 1 would retain this priming advantage into block 2, whereupon they would exert interference in the naming of related block-2 targets. In support of this prediction, they observed an above-chance incidence of semantic perseverations in block 2 that duplicated a response produced back in block 1. An unexpected observation was that there were no instances of perseveration of an immediately preceding response.

Vitkovitch et al. (1996) performed a follow-up study that focused on the temporal characteristics of semantic perseverations induced by blocking. Two groups of healthy participants named pictures of 30 different 4-legged animals under speeded naming conditions (600 msec deadline). The groups experienced different response-stimulus intervals (RSI 7 s or 4 s). Semantic perseverations were analyzed for how far back the source occurred; an error whose source was on the preceding trial was coded as having lag 1. Estimates of chance were calculated at each lag to enable statistical testing of key findings from Vitkovitch and Humphreys (1991). The persistence of name priming was supported: peak perseveration frequency occurred at lag 11, which, in the longer RSI condition corresponded to about 90 s between source and error. The difference from chance was significant here and at neighboring lags, beyond which plotted observed and chance probabilities came together. The paucity of immediate perseverations was also supported. Zero lag 1 perseverations occurred, significantly below chance (see also Campbell & Clark, 1989); indeed, the plot for observed frequencies did not rise above the chance baseline until lag 4 or so. Another noteworthy finding was that in the comparison of effects at the two RSI values, none of the observed differences were statistically reliable, e.g., an ANOVA containing Lag and RSI as factors produced a non-significant interaction between them. The significance of this finding will be explained in the next section.

Perseverations in Aphasia

From an aphasia perspective, the Vitkovitch et al. (1996) study produced surprising findings. At least since Cohen and Dehaene's (1998) seminal study of the temporal characteristics of lexical perseverations in aphasia, it has been generally accepted that perseverations exhibit a strong *recency bias*, occurring with highest frequency at lag 1 and declining exponentially with increasing lag. Cohen and Dehaene (1998) collected perseveration data from three individuals with aphasia using naming tasks in which there was neither semantic blocking nor a fast deadline. They computed lag functions from actual data and from chance data created by randomly shuffling trials (i.e., stimulus-response pairs). Consistently, the plots of the observed vs. chance lag distributions revealed that short lags were over-represented in the actual data. Actual frequencies differed from chance frequencies at the shortest lags and declined to chance levels by lag 6 or so (depending on the individual and the analysis).

Cohen and Dehaene (1998, p. 1655) concluded from their analysis: "At any processing level, the probability that an error is a perseveration from a previous trial is a decreasing function of the lag between the two trials considered. This suggests that an exponentially decaying variable, such as an internal level of activation, is responsible for the recurrence of perseverations." As internal activation levels are generally held to decay spontaneously with time, this formulation invites the inference that the perseveration lag-function is time-sensitive.

Results from the Vitkovitch et al. (1996) study tell a different story. As the authors note, the under-representation of perseverations with very short lags indicates that these highly primed responses may have been suppressed either consciously or through automatic inhibition (Arbuthnott, 1996; Campbell & Clark, 1989; MacKay, 1986; Vitkovitch, Rutter & Read, 2001). Their second key finding, insensitivity to RSI, suggests that name priming **may** not dissipate passively as a function of time but instead might be actively interfered with by the occurrence of intervening trials (Cohen & Dehaene, 1998; Gotts et al., 2002).

How are we to understand the difference across studies? Is it because the perseverations that Vitkovitch and colleagues analyzed were generated by healthy participants, as opposed to individuals with aphasia? Or is it because the perseverations in their study were induced by semantic blocking? To address this question, the present study analyzed semantic perseverations generated by individuals with aphasia during performance of the semantic blocked naming task (Schnur et al., 2006, Experiment 2). The next section describes the methods used in that study and the findings that laid the groundwork for the present investigation.

Schnur, Schwartz, Hodgson and Brecher (2006)

The semantic blocked naming experiment that Schnur and colleagues conducted was inspired by similar experiments run with unimpaired speakers (e.g., Damian, Vigliocco, & Levelt, 2001; Kroll & Stewart, 1994) and individuals with aphasia (McCarthy & Kartsounis, 2000; Wilshire & McCarthy, 2002). Schnur et al.'s study was the first to demonstrate that participants with aphasia *as a group* experience reduced naming accuracy as a consequence of semantic blocking. For a complete description of participants and procedures, readers should consult Schnur et al. (2006). What follows is a summary of details relevant to the present follow-up study.

Participants were 18 individuals with post-stroke, chronic aphasia who had lesions to the left hemisphere and were right-handed native speakers of English (details in Table 1). They performed the blocked naming experiment on a computer programmed in Psyscope. The experiment consisted of multiple blocks, each comprising 24 consecutive naming trials. On each trial, a single target was presented for naming within a 5 s deadline, without feedback. In each block, 6 unique targets were named once (cycle 1), then again in a different random order (cycle 2), and so on for a total of 4 cycles (24 trials). Blocks were of two types: homogeneous and mixed. In a homogeneous block, targets were 6 exemplars from the same category (e.g., 6 animals or 6 vehicles); in a mixed block, targets were 6 exemplars from different categories (1 animal, 1 vehicle, etc.) There were 12 homogeneous blocks, each containing targets from a different category. (Categories and targets are shown in Appendix A.) There were also 12 mixed blocks, created by rearranging the targets of the homogeneous blocks. Phonological overlap within blocks was kept to a minimum. In each experimental run, all 24 blocks were named, with the homogeneous-mixed presentation order randomly varied. For example, one participant named 3 homogeneous blocks followed by 3 mixed blocks, whereas another participant named a homogeneous block followed by a mixed block then another mixed block, and so on. Between blocks, participants were given as much rest time as they required. Every participant completed two runs of the experiment. In one run, the interval programmed between the response and the following stimulus (response-stimulus interval, RSI) was only 1 s; in the other run-through, it was five times that (5 s). Order of RSI conditions varied across participants. In summary, over the entire experiment, each participant named all 24 sets twice (once with each RSI) for a total of 48 blocks, 1152 trials per subject. The number of sessions required to complete the experiment ranged from 2 to 7.

Across all 18 participants, significantly more errors were made in the homogeneous condition, compared to the mixed condition; and the homogeneous-mixed difference (indexing the blocking effect) increased across repetition cycles. This increase was subsequently shown to be associated with damage in the left inferior frontal gyrus (Schnur, Lee, Coslett, Schwartz, & Thompson-Schill, 2005; Schnur, Schwartz, Kimberg, Hirshorn, Coslett, & Thompson-Schill, submitted).

Schnur et al. (2006) also carried out separate analyses of the error types of interest. For present purposes, the most interesting errors are those that duplicate other items from the same set. These “within-set substitutions” occurred primarily in homogeneous blocks (e.g., DOG → ‘‘horse’”, where ‘‘horse’’ was one of the six items in the animal set featured in that block). A much smaller number occurred in mixed blocks (e.g., DOG → “toaster”, where “toaster” was another member of the mixed set featured in that block). The vast majority of the within-set substitutions were perseverations of responses produced earlier in the block. These are the perseverations that we analyzed in the present study.

Schnur et al's (2006) analysis demonstrated that the semantic blocking manipulation lowered accuracy in part by eliciting semantic within-set intrusions, which, as we said, were primarily of a perseveratory nature. Schnur et al. did not, however, analyze the temporal characteristics of these semantic perseverations. We took up that issue here, using analytic methods inspired by Cohen and Dehaene (1998) and Vitkovitch et al., (1996). First, we compared the semantic-perseveration lag functions to chance, looking for evidence of decay akin to what Cohen and Dehaene (1998) observed. Finding evidence for this, we then performed an ANOVA across subjects to determine whether RSI modulates the lag function and whether any such modulation differs for semantic perseverations versus the (semantically unrelated) perseverations produced in the mixed condition. We found that RSI did not modulate the lag function for either semantic or unrelated perseverations. In the Discussion, we consider what these findings reveal about the mechanisms that underpin semantic perseveration in competitor priming tasks and about perseveration production in normality and pathology.

Methods

[Insert Table 1 around here]

Participants

Table 1 reports background information on the 18 individuals with post-stroke aphasia who participated in the blocked naming experiment (Schnur et al., 2006) and whose perseverations we analyzed in the present study. The participants are heterogeneous with respect to aphasia subtype, aphasia severity (Aphasia Quotient) and picture naming accuracy (Philadelphia Naming Test). On the PNT, all produced occasional semantic errors and recurrent, whole-word perseverations. The rates of both error types were low (less than **.15** of responses; see Table 1), except for BT, who, with .29 perseverations, was clearly an outlier. None of the participants exhibited verbal stereotypy or frequent runs of continuous perseveration (same response repeated on multiple consecutive trials).

Perseveration Analysis

Schnur et al. (2006) scored the first complete response on each trial of the experiment. The error taxonomy coded word errors by their relation to the target (semantic, phonological, or unrelated) and also contained codes for nonwords (neologisms), omissions, descriptions, and miscellaneous others. Secondary codes were used to designate within-set substitutions and other features of interest.

For reasons that will be explained shortly, our analysis necessitated a recoding of their data. Using their trial-by-trial listing of targets and phonetically transcribed responses, we replaced any nonword that strongly approximated (at least 50% phoneme overlap) the name of an item in the current set with the actual name. We then identified the within-set substitutions (substituted words that named another target from the current set) and coded as perseverations those that matched a response produced earlier in the block. Note that perseverations of responses outside of the current set, e.g., matching a response produced in a prior block, were not counted as perseverations in this study. For each coded perseveration, we counted back to the most recent occurrence of the response to find the "lag" for that perseveration. Let us take as an example the following trial sequence from a mixed block:

DOG – dog
TOASTER - toaster
BUSH – bush
BED – ~~shoaster~~ toaster

The replacement of "shoaster" by "toaster" allowed us to capture the correspondence between that response and the earlier one; an automated matching procedure identified the BED→ toaster error as a within-set substitution, and a perseveration with lag of 2. The replacement rule had the desirable consequence of avoiding overestimation of long-lag perseverations. (Imagine another perseveration of "toaster" two trials later; with the replacement, lag = 3, without it, "shoaster" is passed over and lag = 5.) In any case, replacement affected only 2% of all responses, so the impact of this coding change was small.

For each participant, we tabulated the number of perseverations that occurred with lag 1 across blocks, then repeated this for perseverations with lag 2, lag 3, etc. up to lag 23 (recall that there are 24 items per block). Separate tabulations were performed for **homogeneous** and mixed blocks at each RSI. This yielded four summary lag distributions per participant (homogeneous RSI 1, 5; mixed RSI 1, 5)

(Insert Table 2 around here)

Chance. Chance data sets are typically generated by repeatedly **re-pairing** targets and responses, so as to determine whether observed target-error relationships (e.g., phonological relatedness) are real or due to chance. In Cohen and Dehaene's (1998) study, the question was rather whether relationships observed *across trials* were real or due to chance, and so they generated the chance corpus by reshuffling whole trials (i.e., stimulus-response pairs). We used their method, but modified it so that the reshuffling was done within a block and in a manner that preserved the cyclic structure of the block. Table 2 illustrates the procedure: For a reshuffled trial list to be legal, each target in the current set had to be presented once before any was presented again, and so on for all four cycles. In other words, each target appeared exactly once within each cycle, together with its original response. Thirty reshuffled trial lists were generated per participant per each of the 48 blocks (12 homogeneous, 12 mixed at each of 2 RSI conditions). In each reshuffled list, we identified perseverations and determined their lags, calculated their frequency at each lag, and then averaged these across the 30 lists per block to derive the mean perseveration frequency at each lag that was due to chance.

When the lag calculated for a particular perseveration is *x*, this means not only that the response in question matched an earlier response at lag *x*, but that it did *not* match any responses at shorter lags. Thus, the comparison of perseveration frequencies in the observed and chance data sets at a particular lag must take into account the differing number of within-set substitutions that have yet to be matched to an earlier response. For example, in both the observed and chance data sets, a certain proportion of within-set substitutions will match the previous response (i.e., with lag 1). The number of perseverations with lag 1 is directly comparable between the two data sets because both began with the same number of within-set substitutions. However, the resulting numbers of *unmatched* within-set substitutions are now different, so that the number of perseverations at the following lag (here, lag 2) in the chance data set must be adjusted, so that the observed data set can be directly compared with it. The next section describes that adjustment.

(Insert Table 3 around here)

Adjusted chance frequency. For each individual's data, we adjusted the mean within-set perseveration frequencies derived from the reshuffled data sets using Cohen and Dehaene's (1998) procedure. Table 3 illustrates the procedure in relation to the data in Table 2. (Note that our terminology differs somewhat from what Cohen & Dehaene used in their text and their Table 1.) Consider the boxed example in Table 3: In the reshuffled list, the frequency of lag 3 perseveration was 2, and the adjustment was done by expressing this value as a proportion of the remaining errors in the reshuffled list (7) multiplied by the remaining errors in the observed data set (6). The resulting value (1.17) is the number of perseverations that would be generated by chance, given the actual number of remaining errors at this lag and the probability of generating perseverations by chance at that lag. We call this the *adjusted chance frequency.* For statistical analysis, we subtracted adjusted chance frequency from observed frequency to create the dependent variable, *chance-corrected frequency.*

The methods used to estimate chance, including the re-shuffling of stimulus-response *pairs,* ensured that the following properties of the original data set were preserved: 1) the number and nature of errors, 2) the response vocabulary (and therefore any given subject's bias towards producing one name over another), 3) the cyclic structure of stimulus presentation, and 4) opportunities to perseverate. There are more opportunities to perseverate at short lags than long ones for several reasons. Firstly, within each block of 24 trials, there are $24 - x$ trials in which it is possible to produce a perseveration with lag x. When x is high (lag is long), this value is small. Secondly, as noted earlier, in order for a response to be considered a perseveration with lag x, it must not only match the response produced x trials earlier, but must also *not* match any of the responses produced in the intervening trials. Since the probability of a response *not* matching any of the intervening responses is lower at longer lags, this, too, favors short-lag perseverations. This bias is further amplified by the cyclic presentation of stimuli, as the repetition of targets spaced on average six trials apart makes it even less likely that perseverations would occur at lags of more than six trials. Critically, given our method of estimating chance, all these factors should affect both the observed and chance lag frequency distributions in exactly the same manner. Any differences between them must therefore reflect a temporal bias that is present only in the actual data.

Results

(Insert Table 4 around here)

A total of 366 perseverations was produced (316 in the homogeneous condition, 50 in mixed). While contributions to this total from individual participants varied considerably (1 – 75; see Table 4), every participant made more perseverations in the homogeneous condition than in the mixed condition.

The remaining results are presented in three sections. **In the first two sections we analyze observed and chance lag functions for just the homogeneous-condition perseverations (i.e., semantic perseverations), collapsed across RSI levels. In the third section, we expand the focus to include the mixed condition and the breakdown by RSI.** Readers interested in comparing RSI-averaged lag effects in homogeneous and mixed conditions should consult Tables 5 and 6.

(Insert Tables 5 and 6 around here)

Lag Functions: Individual Participants Analysis

The four highest perseveration producers (last four in Table 4) account for more than half the total, with NQ alone accounting for 20%. Lag functions for these four individuals are shown in Figure 1. Looking first at the plots for adjusted chance, one sees that the frequencies are highest at short lags and decline to near zero by lag 9 or thereabouts. This confirms that our method of estimating chance did in fact preserve the differential opportunities at short versus long lags. The curves for the observed data are similarly shaped and, importantly, fall above the chance curves primarily at the shorter lags. In the case of immediate (lag 1) perseverations, individual differences are evident: For DAN and NQ, the observed lag function has its peak at lag 1; for the other two, the peak is at lag 2 and the lag 1 frequency is below chance. Examination of the data from other high perseveration producers revealed similar inconsistency at lag 1. Indeed, among the 9 participants who produced more than the median number of perseverations (and who accounted for 86% of all perseverations), the results are split; four had peak frequency at lag 1, whereas 5 had many fewer perseverations at lag 1 than at lag 2. In view of these marked individual differences, we omitted lag 1 data from the following statistical analysis of the recency bias.

The top four error producers had semantic perseveration counts high enough to warrant statistical analysis. For each of these, we correlated lag value against chance-corrected perseveration frequencies, excluding lag 1. Computed over lags 2-23, the correlation was strongly negative for all four participants (Pearson *r* between -.52 and -.72; *p* < .05 for all). It remained strong (*r* between -.49 and -.82) when computed over just lags 2-9 (i.e., excluding the long lags where chance was near zero). This demonstrates that at the level of individual participants, there was a significant trend toward higher chance-corrected frequency at short lags, i.e., a recency bias.

Insert Figure 1 around here

Lag Functions: Group Analysis

Figure 2 plots the observed and adjusted-chance lag functions averaged across all 18 participants. At lag 1, the observed and adjusted-chance values are about the same, reflecting the averaging of above- and below-chance trends in the individual data. Thereafter, the curves diverge, with observed frequencies exceeding chance at shorter lags. In the correlation analysis, mean chance-corrected frequencies were strongly correlated with lag value for lags in the range 2-23 (*r* = -.62, *p* < .01) and 2-9 (*r* = -.81, *p* < .05). Thus, in the grouped data, too, shorter lags were associated with **a higher likelihood of perseveration**.

[Insert Figure 2 around here]

Lag and RSI: Across Subjects Analysis of Variance

To assess the generality of the lag effect as well as the impact of RSI, we performed an ANOVA on the chance-corrected **perseveration** frequencies, using SAS (v. 9.1) mixed model.

Subjects were treated **as a** random variable. Within-subjects factors of primary interest were Lag (2-23) and RSI (1 s, 5 s). For completeness, we included a third within-subjects factor, Condition (homogeneous, mixed). Data from lag 1 were excluded from the analysis because we were primarily interested in effects on lag that were due to recency, and the inconsistent lag 1 dip had the potential to obscure such effects or complicate their interpretation.

The ANOVA produced the expected main effect for Lag (F(21, 1479) = 6.0, p < .0001), as well as a main effect for Condition (F(1, 1479) = 7.6, p = .006, and a significant Lag by Condition interaction (F(21, 1479) = 1.72, p = .022). No other main effects or interactions were significant (all Fs < 1); this includes the interactions of primary interest, involving RSI and Lag (RSI by Lag: F(21, 1479) = .11; RSI by Lag by Condition: F(21, 1479) = .38).[1] Figure 3 confirms that the lag plots at RSI 5 and RSI 1 were highly similar.

As mentioned, the ANOVA yielded a significant Lag by Condition interaction. We followed up with separate one-way ANOVAs testing for the Lag effect in each Condition; this revealed that Lag was significant in both (Homogeneous: F(21, 731) = 4.0, p < .0001; Mixed: F(2, 731) = 3.0; p < .0001). Due to the low perseveration counts (low power) in the mixed, we did not further analyze this interaction with post hoc tests. However, looking at Figure 3, and ignoring for the moment the data from lag 1, which were excluded from the ANOVAs, the likely interpretation of the Lag by Condition interaction is that chance-corrected frequencies are higher in the homogeneous condition at short lags (2-5) but not longer ones. In other words, the recency effect defined from lag 2 onwards was steeper in the homogeneous condition.

As far as lag 1 is concerned, Figure 3 indicates that the dip was present in both relatedness conditions but was more extreme in the homogeneous condition. Not surprisingly,

---

given the variability at lag 1, effects here did not survive statistical analysis; when the lag 1 data were averaged across RSI levels and submitted to separate one-sample t-tests, the mean chance-corrected frequency at lag 1 did not **differ significantly from** zero in either condition (Homogeneous: t(17) = -0.89; Mixed: t(17) = 1.07; both p's < .05).

To summarize the key findings: There was a significant main effect for Lag, which indicates that the recency bias – shown earlier by correlation analysis – generalizes across subjects. Furthermore, Lag and RSI did not interact, indicating that the recency bias was not modulated by **time between responses**.

Discussion

This study examined semantic perseverations elicited by semantic blocked naming as a means of clarifying the time course of such perseverations and the means by which they arise. Consistent with the seminal studies of Cohen and Dehaene (1998), who based their analyses on perseverations produced on standard naming tasks, we found that the lag function for semantic perseverations is biased in favor of short-lag perseverations. Consistent with the semantic blocking study that Vitkovitch et al., (1996) conducted with young, healthy adults, we found that the **likelihood of perseveration** is, within the limits of the RSI manipulation, insensitive to the passage of time. We also confirmed their finding that immediate perseverations are subject to other influences that exempt them from the recency effect. This hints at the basis for the across-study differences that were noted in the Introduction. Most important, the findings demonstrate that recency bias and insensitivity to time are reliable properties of semantic perseveration. After discussing the evidence more fully in the next two section, we move on to formulate an incremental learning account of these key properties of semantic perseverations.

Recency Bias

We analyzed the lag function for semantic perseverations generated in Schnur et al. (2006) to determine if it would exhibit recency bias such as was previously documented in people with aphasia on more standard naming tasks (Cohen & Dehaene, 1998). Examination of the lag function visually and with analysis of the correlation between lag and chance-corrected perseveration frequency revealed the expected trend toward higher chance-corrected frequency at short lags. We conclude that the recency bias is **indeed a property of perseverations** generated by the semantic blocking manipulation.

Semantic perseverations elicited from young, healthy adults rarely repeat the immediately preceding response (Campbell and Clark, 1989; Moses et al, 2004; Vitkovitch & Humphreys, 1991; Vitkovitch et al., 1996; Vitkovitch, et al., 2001; Wheeldon & Monsell, 1994). Vitkovitch et al. (1996) found that lag 1 perseverations were below chance, and the lag function did not peak and begin to decay until around lag 11. We wondered whether the hypothesized suppression of immediate perseverations applied uniquely to *nonaphasic* speech.

The answer to this question is “no” as judged by the lag 1 dip in a sizeable subset of the current’s study’s participants with aphasia. Moreover, the highest perseveration producers were as likely to show the dip as not, which argues against the possibility that the lag 1 dip goes along with low rates of perseveration. Such an association would be expected if inhibitory processes were needed to keep perseveration rates low, and the presence of the lag 1 dip were evidence of a well-functioning inhibitory system (Campbell & Clark, 1989; Vitkovitch et al., 1996; for more on inhibition-related accounts of perseveration; see Arbuthnott, 1996; Dell, 1986; MacKay, 1986; for a related account featuring synaptic depression, see Gotts & Plaut, 2002 and Gotts et al., 2002). Since this does not appear to be the case, it might be useful to look beyond automatic inhibition for an explanation of the lag 1 dip and the individual differences within and across studies.

One possibility relates to the special properties of tasks such as blocked picture naming that create a predisposition for semantic perseveration by the mechanism of competitor priming. Competitor priming paradigms are known to produce opposing facilitative and competitive (interference) effects on different time scales (Damian & Als, 2005; Wheeldon & Monsell, 1994). For example, Wheeldon and Monsell's (1994) seminal paper on competitor priming showed that naming was slowed on the second of two related items ("whale", following "shark") when multiple unrelated items intervened between them but *not* when they occupied adjacent positions in the list. Their explanation for the interference (slowing) effect was post-naming priming of a lemma-level competitor ("shark" competing with "whale"). The absence of competitor priming with adjacent pairs was attributed to an opposing effect – facilitative priming of WHALE by SHARK at the semantic-conceptual level – which, unlike competitor priming, persists for one trial only. Extending this argument to the present context, one could say that naming "horse" on trial i of a homogeneous block would, through semantic priming, facilitate the production of a different animal name on trial j (target or homogeneous setmate), thereby reducing the probability of repeating "horse" and making a lag 1 perseveration.[2] Note, however, that as adjacent items in the mixed condition would not be expected to benefit from semantic facilitation, this account has difficulty with the present evidence, which indicates that the lag-1 dip also occurred in the Mixed condition (see Figure 3).

Another possible explanation for the individual differences at lag 1 is strategic avoidance of repetition. In the Schnur et al. (2006) blocked naming experiment, **the random ordering of trials resulted in immediate successive repetition of targets on only 2.2% of trials**, so it would have been adaptive to avoid repeating a response that was produced one trial back. Participants could have differed in whether they chose to adopt this strategy and/or were capable of doing so. Similarly, in Vitkovitch et al. (1996), avoidance of repetition would have been adaptive, since the animal targets in that naming study did not repeat at all. Widespread deployment of an avoidance strategy by participants in that study would explain why none of the many perseverations recorded was of the immediate (lag 1) type and why perseveration frequency at lags 2 and 3 was low as well.

Clearly, future study is needed to elucidate why the recency trend in the perseveration lag function is sometimes violated at lag 1 and beyond. However, for present purposes, what is most important is not that the recency bias is sometimes violated at the shortest lags, but that this bias is present and must be explained in any theoretical account of semantic perseveration. We will expand on this after considering the evidence regarding RSI.

Effect of RSI

Cohen and Dehaene (1998) interpreted their analyzed lag functions as evidence that the recurrence of perseveration is due to an exponentially decaying variable; but they stopped short of concluding that the decay was sensitive to time. In their words, “a specific experiment would be needed to distinguish the effects of elapsed time versus elapsed number of trials on the decay of perseveration probability." (Cohen & Dehaene, 1998, p. 1655). The manipulation of RSI in the current study constitutes the experiment that Cohen and Dehaene (1998) called for. If long-lag perseverations are less probable than short-lag perseverations on account of passive decay in activation that happens naturally with the passage of time, then spacing trials further apart by lengthening RSI should result in fewer perseverations overall, since that would add time for activation to decay and thereby render past items less competitive. Lengthening the RSI should also cause the lag function to fall to chance levels more quickly, yielding a steeper lag-decay function.

In partial support of these predictions, Santo Pietro and Rigrodsky (1986) obtained fewer perseverations in people with aphasia when RSI was long (RSI 10 s compared with 1 s), indicating that time is important. On the other hand, the RSI manipulation in Vitkovitch et al. (1996) (4 s vs. 7 s) did not produce a statistically reliable effect: perseveration rates did not differ in the two conditions, and the RSI by Lag interaction was not significant. Our findings agree with those of Vitkovitch et al. (1996).

The absence of RSI effects in our study is especially noteworthy because this null result coincides with a Cohen and Dehaene (1998) type lag-decay function. It points to the conclusion that the decay in perseveration probability across lags is not due to elapsed time but instead to the elapsed number of trials. This conclusion is reinforced by an investigation of perseverations that Gotts et al., (2002) carried out with EB, an individual with aphasia. EB performed several naming experiments that involved semantic blocking and a comparison of short (1 s) and long (10 s or 15 s) RSIs. She made numerous perseverations, which unlike the present study, did not tend to resemble the target semantically. When analyzed by lag, these unrelated perseverations showed the expected exponential decay; and the 10+-fold difference in RSI values did not affect the frequency of her perseverations or the shape of the lag function. The RSI difference in Gotts et al.'s (2002) study was twice as large as ours, making is less likely that our results would have been different had the long RSI been extended. On the other hand, it must be acknowledged that at RSI values of 1 s and 10 s, San Pietro and Rigrodsky (1986) did find significantly fewer lexical perseverations at the longer RSI. This early study did not include correction for chance or analysis of lag functions; and since RSI effects were not examined in relation to lag, it is unknown whether the perseveration drop at the longer RSI was due to drop-out of longer lag perseverations, as the time-sensitive decay account predicts. As it stands, the weight of evidence argues that the lag function is not altered by elapsed time, which points, albeit indirectly, to elapsed trials as the relevant factor. This means that the perseveratory impetus is stronger for recent responses not because the earlier responses are further removed in time but because those earlier responses have had more opportunity to be weakened by interference from intervening trials.

Activation Persistence in Competitor Priming

Repeatedly, we have tied the explanation for why semantic blocking encourages semantic perseveration to the mechanism of competitor priming, which rests on the notion that a word is primed by virtue of having been named. The apparent insensitivity of the perseveration lag function to time is relevant to how one conceives of such priming in connectionist or neural network terms. Specifically, such priming is unlikely to depend on a unit's being in a state of heightened activation, as activation levels are generally thought to decay quickly and spontaneously (e.g., Bock & Griffin, 2000). More likely, it depends on parameters of networks that encode long-term processing biases, for example, connection weights or activation thresholds (both of which would be neurally implemented through long-term synaptic changes). Connection weight changes, in particular, have been invoked to explain the persistence of competitor priming effects across time and trials (e.g., Damian & Als, 2005; Howard et al., 2006; Vitkovitch & Humphreys, 1991; Vitkovitch et al., 1996; Wheeldon & Monsell, 1994).

The study that **Howard et al.** (2006) conducted is instructive. Unimpaired speakers were given a sequence of 165 pictures to name. Items from the same semantic categories ("category coordinates") were interspersed throughout the list, with a predetermined spacing that the authors refer to as "lag"; for example, when successive category coordinate targets were separated by two different-category items, the lag was 2. Lags varied from 2-8. Items did not repeat. There were two critical findings: first, with each successive category coordinate named, mean naming times slowed by about 25 ms on average; second, the size of the effect was unrelated to the lag between one category coordinate and the previous one. The authors modeled the cumulative, linear interference effect with a simple connectionist network that updated its lexical-semantic knowledge after each naming trial by strengthening the connection between the named target's semantic representation and its name. Such updating of a network in response to experience is sometimes called "incremental learning" (see Damian and Als (2005) for related evidence of incremental learning, this time in the blocked naming **paradigm).**

An Error-based Incremental Learning Account

The weight-change model that Howard et al. (2006) proposed is consistent with the null effects for RSI that we and others have observed, since connection weights are typically not thought to decay passively with time. However, without some modification, that model can not handle the evidence for the recency bias in semantic perseverations, which, as we argued, indicates that the perseveratory impetus is unlearned or forgotten across intervening related trials. The desired result can be achieved by a model that incrementally adjusts its weights through *error-based* learning, e.g., using the delta-rule. Examples of such models can be found in Dell, Oppenheim and Kittredge (2008); Gordon and Dell (2003); Oppenheim, Dell and Schwartz (2007; submitted).

In these models, weights from distributed semantic features to words are tuned whenever a word is produced, such that there are increases in weights from the features to the target word *and* decreases in weights from the features to words that are erroneously activated. So, any under-activation of the target, or activation of a competitor word, stimulates the system to tweak the weights. The production of a word *i* therefore primes its representation in a manner that is undiminished by time (weight changes do not passively decay) and by subsequent unrelated trials (an unrelated item is not assumed to share features with the target). This comports with the evidence that competitor priming accumulates and is undiminished by intervening unrelated trials (Damian & Als, 2005; Howard et al., 2006). Critically, though, error-based learning ensures that a subsequent *related* trial (word *j)* will lessen the perseverative impetus of word *i* for replacing future related targets, because *i* will become activated when *j* is the target, stimulating weight changes that decrease *i*'s tendency to be active on future related trials. Thus, incremental error-based learning is consistent with the observed recency effect in semantic perseverations, as well as its insensitivity to time.

A prediction from the incremental, error-based learning account is that the recency bias should be weaker for perseverations produced in the mixed condition of semantic blocked naming, relative to the homogeneous condition. In the mixed condition, targets that follow word *i* share fewer of its features, so their production should stimulate less unlearning of *i,* hence less reduction in its perseverative impetus. The ANOVA on chance-corrected perseverations did yield a significant Condition by Lag interaction in the predicted direction; but further analysis was limited by the paucity of perseverations in the mixed condition. A definitive test of the prediction that the recency effect is weaker in the mixed condition will require experiments that generate more mixed-condition perseverations to analyze.

Conclusions and Future Directions

We found that the lag function for semantic perseverations resembles the negative exponential decay curve described by Cohen and Dehaene (1998) and that the 5-fold difference in RSI did not alter the shape of the lag function. These two findings constrain the explanation of how priming operates in semantic blocked naming to make the past competitive with the present. We maintain that responses are strengthened through a process of incremental learning, **affecting connection strength**, and that with the processing of successive trials, there is a degree of unlearning that accounts for the recency gradient.

It remains to be seen whether the evidence that motivates the incremental learning hypothesis of name priming – a perseveration lag function that decays and that is relatively insensitive to time – is also seen in naming tasks that do not include exotic manipulations like semantic blocking and short naming deadlines. Further research also is needed to determine whether the combination of recency bias and time-insensitivity is reliably seen in the data from individual participants with aphasia. Answering these questions will require a massive data gathering effort; with over 1000 trials per participant, the Schnur et al., (2006) study generated too few perseverations to afford adequately powered analysis of the mixed-condition perseverations or patterns of individual differences.

As Howard and colleagues demonstrated, priming by incremental learning is one of three legs on which a complete model of competitor priming rests (Howard et al., 2006). Also required is a mechanism for top-down activation sharing among related competitors (to explain relatedness effects), and a competitive selection mechanism that is slowed by the presence of primed competitors (to explain response time effects in competitor priming paradigms; see also Wheeldon & Monsell, 1994). What must one add to such a model to simulate the heightened frequency of perseverations in people with aphasia? According to one widely held view, what is needed is nothing more than to instantiate a retrieval deficit that lessens the advantage of the current target relative to primed past responses, particularly those that are also semantic competitors (e.g., Cohen & Dehaene, 1998; Dell, Burger & Svec, 1997; Moses et al., 2004; Martin & Dell, 2007; Martin, Roach, Brecher & Lowery, 1998; Schwartz, Saffran, Bloch, & Dell, 1994). In the incremental, error-based learning model of semantic blocking developed by Oppenheim and colleagues, such a retrieval deficit is simulated by adding noise to the activations of network units (Oppenheim et al., 2007; submitted). The result is a high rate of perseveration errors **generated without altering the process by which the past is primed (error-based learning, which strengthens connections to the target and weakens connections to the competitors). Importantly, activation-based inhibitory processes, such as the explicit turning off of the recent past (e.g., Dell, 1986), play no role in generating the model's perseverations.** It will be interesting to see whether a model constructed along these lines has adequate explanatory power to explain the totality of facts about lexical perseverations, including the yet to be explored individual differences.

References

Arbuthnott, K. D. (1996). To repeat or not to repeat: Repetition, facilitation and inhibition in sequential retrieval. Journal of Experimental Psychology: General, 125, 261-283.

Bock, K., & Griffin, Z. M. (2000). The persistence of structural priming: Transient activation or implicit learning? Journal of Experimental Psychology: General, 129, 177-192.

Brown, A. S. (1981). Inhibition in cued retrieval. Journal of Experimental Psychology: Human Learning and Memory, 7, 204-215.

Campbell, J. I. D., & Clark, J. M. (1989). Time course of error priming in number-fact retrieval: Evidence for excitatory and inhibitory mechanisms. Journal of Experimental Psychology: Learning, Memory & Cognition, 15, 920-929.

Cohen, L., & Dehaene, S. (1998). Competition between past and present - assessment and interpretation of verbal perseverations. Brain, 121, 1641-1659.

Damian, M. F., & Als, L. C. (2005). Long-lasting semantic context effects in the spoken production of object names. Journal of Experimental Psychology: Learning, Memory, and Cognition, 31, 1372-1384.

Damian, M. F., Vigliocco, G., & Levelt, W. J. M. (2001). Effects of semantic context in the naming of pictures and words. Cognition, 81, B77-B86.

Dell, G. S. (1986). A spreading-activation theory of retrieval in sentence production. Psychological Review, 93, 283-321.

Dell, G. S., Burger, L. K., & Svec, W. R. (1997a). Language production and serial order: A functional analysis and a model. Psychological Review, 104, 123-147.

Dell, G. S., Oppenheim, G. M., & Kittredge, A. K. (2008). Saying the right word at the right time: Syntagmatic and paradigmatic interference in sentence production. Language and Cognitive Processes, 23, 583-608.

Dell, G.S., Schwartz, M.F., Martin, N., Saffran, E.M., & Gagnon, D.A. (1997b). Lexical access in aphasic and nonaphasic speakers. Psychological Review, 104, 801-838.

Gordon, J. K., & Dell, G. S. (2003). Learning to divide the labor: An account of deficits in light and heavy verb production. Cognitive Science, 27, 1-40.

Gotts, S. J., della Rocchetta, A. I., & Cipolotti, L. (2002). Mechanisms underlying perseveration in aphasia: Evidence from a single case study. Neuropsychologia, 40, 1930-1947.

Gotts, S.J. & Plaut, D.C. (2002). The impact of synaptic depression following brain damage: A connectionist account of “access/refractory” and “degraded store” semantic impairments. Cognitive, Affective, & Behavioral Neuroscience, 2, 187-213.

Howard, D., Nickels, L., Coltheart, M., & Cole-Virtue, J. (2006). Cumulative semantic inhibition in picture naming: Experimental and computational studies. Cognition, 100, 464-482.

Howard, D., & Patterson, K. (1992). Pyramids and palm trees: A test of semantic access from pictures and words. Bury St. Edmunds, U.K.: Thames Valley Test Company.

Humphreys, G. W., Riddoch, J., & Quinlan, P. T. (1988). Cascade processes in picture identification. Cognitive Neuropsychology, 5, 67-103.

Kertesz, A. (1982). Western Aphasia Battery. New York: Grune & Stratton.

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. Journal of Memory and Language, 33, 149-174.

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. Behavioral and Brain Sciences, 22, 1-75.

MacKay, D. G. (1986). Self-inhibition and the disruptive effects of internal and external feedback in skilled behavior. In H. Heuer & C. Fromm (Eds.), Generation and modulation of action patterns (pp. 174-186). Berlin: Springer-Verlag.

Martin, N., & Dell, G. S. (2007). Common mechanisms underlying perseverative and non-perseverative sound and word substitutions. Aphasiology, 21, 1002-1017.

Martin, N., Roach, A., Brecher, A., & Lowery, J. (1998). Lexical retrieval mechanisms underlying whole-word perseveration errors in anomic aphasia. Aphasiology, 12, 319-333.

McCarthy, R. A., & Kartsounis, L. D. (2000). Wobbly words: Refractory anomia with preserved semantics. Neurocase, 6, 487-497.

Moses, M. S., Nickels, L. A., & Sheard, C. (2004). "I'm sitting here feeling aphasic!" - a study of recurrent perseverative errors elicited in unimpaired speakers. Brain and Language, 89, 157-173.

Oppenheim, G.M., Dell, G.S., & Schwartz, M.F. (2007). Cumulative semantic interference as learning. Brain and Language, 103, 175-176. (Long abstract)

Oppenheim, G.M., Dell, G.S., & Schwartz, M.F. (submitted). The dark side of incremental learning: A model of cumulative semantic interference during lexical access in speech production.

Roach, A., Schwartz, M. F., Martin, N., Grewal, R. S., & Brecher, A. (1996). The Philadelphia Naming Test: Scoring and rationale. Clinical Aphasiology, 24, 121-133.

Saffran, E. M., Berndt, R. S., & Schwartz, M. F. (1989). The quantitative analysis of agrammatic production: Procedure and data. Brain and Language, *37*, 440-479.

Sandson, J., & Albert, M. L. (1984). Varieties of perseveration. Neuropsychologia, 22, 715-732.

Santo Pietro, M. J., & Rigrodsky, S. (1986). Patterns of oral-verbal perseveration in adult aphasics. Brain and Language, 29, 1-17.

Schnur, T. T., Lee, E., Coslett, H. B., Schwartz, M. F., & Thompson-Schill, S. L. (2005). When lexical selection gets tough, the LIFG gets going: a lesion analysis study of interference during word production. Brain and Language, 95, 12-13.

Schnur, T. T., Schwartz, M. F., Brecher, A., & Hodgson, C. (2006). Semantic interference during blocked-cyclic naming: Evidence from aphasia. Journal of Memory and Language, 54, 199-227.

Schnur, T. T., Schwartz, M. F., Kimberg, D. Y., Hirshorn, E., Coslett, H. B., & Thompson-Schill, S. L. Localizing interference during naming: Convergent neuroimaging and neuropsychological evidence for the function of Broca's area. Under review.

Schwartz, M. F., Saffran, E. M., Bloch, D. E., & Dell, G. S. (1994). Disordered speech production in aphasic and normal speakers. Brain and Language, 47, 52-88.

Vitkovitch, M., & Humphreys, G. W. (1991). Perseverant responding in speeded naming of pictures - its in the links. Journal of Experimental Psychology-Learning Memory and Cognition, 17, 664-680.

Vitkovitch, M., Kirby, A., & Tyrrell, L. (1996). Patterns of excitation and inhibition in picture naming. Visual Cognition, 3, 61-80.

Vitkovitch, M., Rutter, C., & Read, A. (2001). Inhibitory effects during object name retrieval: The effect of interval between prime and target on picture naming responses. British Journal of Psychology, 92, 483-506.

Wheeldon, L. R., & Monsell, S. (1994). Inhibition of spoken word production by priming a semantic competitor. Journal of Memory and Language, 33, 332-356.

Wilshire, C. E., & McCarthy, R. A. (2002). Evidence for a context-sensitive word retrieval disorder in a case of nonfluent aphasia. Cognitive Neuropsychology, 19, 165-186.

Appendix A

A list of the 12 categories and 72 targets used in Schnur et al. (2006)

Animals: bear, cat, dog, goat, horse, skunk

Appliances: fan, iron, radio, scale, toaster, vacuum

Body Parts: arm, chin, ear, nose, thumb, toe

Clothing: coat, dress, glove, hat, skirt, sock

Food: bread, cake, cheese, pie, shrimp, soup

Furniture: bed, chair, crib, sofa, stool, table

Nature: cloud, mountain, pond, sun, volcano, waterfall

Plants: bush, cactus, fern, flower, mushroom, tree

Roles: bride, clown, judge, nun, nurse, soldier

Shapes: arrow, circle, cone, cross, heart, star

Toys: ball, bat, blocks, doll, kite, top

Utensils: cup, fork, glass, knife, pitcher, spoon

Authors' Note

This research was funded by a grant from the National Institutes of Health's National Institute for Deafness and Other Communication Disorders: R01 DC000191-26 (M.F. Schwartz). Aspects of this study were reported in a poster presentation at the Psychonomics Society meeting, November 2005, in Toronto, Canada (Lee, E.Y., Schnur, T.T, & Schwartz, M.F., "Recency of production influences semantic substitutions in blocked-cyclic naming") and in a symposium paper at the Academy of Aphasia, October 2007, Washington DC (Lee, E.Y., Schnur, T.T., & Schwartz, M.F., "The temporal analysis of semantic perseverations in blocked-cyclic naming", delivered by TTS).
We gratefully acknowledge Adelyn Brecher's contribution to the analysis of errors.

Footnotes

1. The generality of these findings was confirmed in several follow-up analyses. The first showed that repeating the ANOVA with data from lag 1 *included* altered the findings only with respect to the Condition main effect. As noted in the text, with lag l excluded that effect is statistically significant; with lag 1 included, it is there at the level of a trend (F (1, 1547) = 3.0, p = .082). Next we determined that the results were not overly influenced by the data from NQ, who contributed 20% of total perseverations; repeating the original ANOVA with her data excluded did not change any of the results.

2. We wish to thank Marcus Damian for suggesting this account of the lag 1 dip for semantic perseverations.

Figure Legends

Figure 1. Individual lag plots for the four highest perseveration producers, representing observed and adjusted-chance frequencies of semantic perseverations (i.e., those from the homogeneous condition), averaged across RSI 1 s and 5 s.

Figure 2. Smoothed plots of the means across all 18 participants, representing observed and adjusted-chance frequencies of semantic perseverations (i.e., those from the homogeneous condition), averaged across RSI 1 s and 5 s.

Figure 3. Smoothed plot of chance-corrected perseveration frequencies, split by condition and RSI.

Table 1. Clinical profiles are characterized by the *Western Aphasia Battery* (Kertesz, 1992) and *Philadelphia Naming Test* (PNT; Roach, Schwartz, Martin, Grewal & Brecher, 1996) . B (Broca), A (Anomic), W (Wernicke), C (Conduction). Low values of the Aphasia Quotient indicate greater severity. PNT data are proportional to total responses; "persev" are whole word perseverations unrelated or related (semantically or phonologically) to the target.

					Western Aphasia Battery		Philadelphia Naming Test		
Participant	Sex	Age	Education	Mos. Post Onset	Subtype	Aphasia Quotient	Correct	Semantic Err	Persev
BAC	M	57	19	118	A	86.6	0.93	0.03	0.01
TB	F	35	12	10	A	75.1	0.79	0.10	0.02
MD	M	54	12	96	A	81.6	0.89	0.02	0.03
KAC	M	61	11	16	C	72.9	0.38	0.02	0.01
OE	M	60	11	29	A	93.6	0.82	0.03	0.02
MX	F	39	12	49	B	67.2	0.74	0.06	0.01
TG	F	68	12	20	A	91.2	0.71	0.07	0.05
CT	F	41	10	22	B	69.7	0.80	0.06	0.02
MO	M	60	13	135	B	70	0.77	0.04	0.00
SL	M	50	12	36	A	92.7	0.87	0.07	0.01
EC	F	56	17	175	B	68.2	0.62	0.05	0.05
EAC	F	50	17	52	A	84.4	0.79	0.04	0.04
DD	M	56	16	28	B	53.1	0.39	0.11	0.06
ED	F	80	16	15	W	39.3	0.07	0.09	0.12
LF	M	53	20	25	W	66.1	0.64	0.05	0.01
BT	M	68	14	82	B	68.8	0.69	0.13	0.29
DAN	F	75	11	19	C	66.7	0.26	0.03	0.06
NQ	F	62	12	62	B	63.6	0.62	0.06	0.03

Table 2. Example of a legal reshufled list for a given block of trials. Numbers after targets denote their successive occurrences. The reshuffling preserves the target-response pairings from the original list (e.g., cat3 -> HORSE) as well as the cyclic order of targets (all five targets presented in each cycle). In the Response columns, within-set substitutions are highlighted, perseverations with rectangles, nonperseverations with circles. For each perseveration, in each list, the corresponding lag is shown.

	Original list			Reshuffled list		
	Target	Response	Lag	Target	Response	Lag
Cycle 1	dog1	DOG		bear3	BEAR	
	horse1	HORSE		cat4	DOG	non persev
	cat1	DOG	2	skunk3	SKUNK	
	bear1	BEAR		dog4	DOG	
	skunk1	SKUNK		goat3	BEAR	4
	goat1	GOAT		horse3	HORSE	
Cycle 2	horse2	CAT	non persev	cat1	DOG	3
	dog2	DOG		bear2	BEAR	
	bear2	BEAR		skunk4	SKUNK	
	goat2	GOAT		horse4	BEAR	2
	cat2	DOG	3	dog2	DOG	
	skunk2	DOG	1	goat4	GOAT	
Cycle 3	horse3	HORSE		horse2	CAT	non persev
	bear3	BEAR		cat2	DOG	3
	cat3	HORSE	2	goat2	GOAT	
	dog3	DOG		dog1	DOG	
	skunk3	SKUNK		skunk1	SKUNK	
	goat3	BEAR	4	bear4	SKUNK	1
Cycle 4	skunk4	SKUNK		cat3	HORSE	13
	dog4	DOG		goat1	GOAT	
	horse4	BEAR	3	horse1	HORSE	
	bear4	SKUNK	3	bear1	BEAR	
	cat4	DOG	3	skunk2	DOG	7
	goat4	GOAT		dog3	DOG	
	Total within-set substitutions, 9			*Total within-set substitutions, 9*		
	No. perseverations, 8			*No. perseverations, 7*		
	No. non perseverations, 1			*No. non perseverations, 2*		

Table 3. Using the data from Table 2, this table illustrates the procedure used to create Adjusted Chance values, as explained in the text. The procedure is taken from Cohen and Dehaene (1998), and the table is based on their Table 1. The last column in the table shows the Chance-Corrected perseveration frequencies, computed by the formula (Original No. Persev – Adjusted Chance No. Persev).

Original List			Reshuffled list (Chance)			Adjusted Chance			Chance-Corrected	
Lag	No. Persev	No. Err Remaining	Lag	No. Persev	No. Err Remaining	Lag	No. Persev		Lag	No. Persev
1	1	8	1	1	8	1	1.00		1	0.00
2	2	6	2	1	7	2	1.00		2	1.00
3	4	2	3	2	5	3	1.71	(2/7) * 6 = 1.71	3	2.29
4	1	1	4	1	4	4	.40		4	0.60
5	0	1	5	0	4	5	0		5	0.00
6	0	1	6	0	4	6	0		6	0.00
7	0	1	7	1	3	7	.25		7	-0.25
8	0	1	8	0	3	8	0		8	0.00
9	0	1	9	0	3	9	0		9	0.00
10	0	1	10	0	3	10	0		10	0.00
11	0	1	11	0	3	11	0		11	0.00
12	0	1	12	0	3	12	0		12	0.00
13	0	1	13	1	2	13	.33		13	-0.33
14	0	1	14	0	2	14	0		14	0.00
15	0	1	15	0	2	15	0		15	0.00
						[Table continues on next page]				

[Table 3 Continued]

Original List			Reshuffled list (Chance)			Adjusted Chance			Chance-Corrected	
Lag	No. Persev	No. Err Remaining	Lag	No. Persev	No. Err Remaining	Lag	No. Persev		Lag	No. Persev
16	0	1	16	0	2	16	0		16	0.00
17	0	1	17	0	2	17	0		17	0.00
18	0	1	17	0	2	17	0		17	0.00
19	0	1	19	0	2	19	0		19	0.00
20	0	1	20	0	2	20	0		20	0.00
21	0	1	21	0	2	21	0		21	0.00
22	0	1	22	0	2	22	0		22	0.00
23	0	1	23	0	2	23	0		23	0.00
24	0	1	24	0	2	24	0		24	0.00

Table 4. Number and percentage of perseverations contributed by each participant to the current analysis.

	Number			Percentage
Participant	Homogeneous	Mixed	Total	Total
BAC	1	0	1	0.1%
TB	2	0	2	0.2%
MD	2	0	2	0.2%
KAC	5	0	5	0.4%
OE	6	0	6	0.5%
MX	4	2	6	0.5%
TG	8	1	9	0.8%
CT	7	3	10	0.9%
MO	10	1	11	1.0%
SL	9	5	14	1.2%
EC	21	0	21	1.8%
EAC	20	4	24	2.1%
DD	21	3	24	2.1%
ED	23	6	29	2.5%
LF	34	7	41	3.6%
BT	39	2	41	3.6%
DAN	37	8	45	3.9%
NQ	67	8	75	6.5%

Table 5. Means and standard deviations for the Homogeneous condition.

		Observed		Chance		Adjusted Chance		Chance Corrected	
LAG	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	36	1.64	3.07	1.84	2.23	1.84	2.23	-0.20	1.47
2	36	2.25	2.60	1.65	1.72	1.67	1.62	0.58	1.42
3	36	1.36	1.53	1.31	1.33	1.20	1.15	0.16	0.77
4	36	1.36	1.57	1.03	0.99	0.93	0.85	0.43	1.02
5	36	0.94	1.24	0.72	0.65	0.58	0.52	0.36	0.92
6	36	0.39	0.60	0.53	0.50	0.36	0.39	0.03	0.48
7	36	0.19	0.47	0.38	0.33	0.26	0.27	-0.06	0.38
8	36	0.22	0.54	0.24	0.20	0.18	0.19	0.04	0.50
9	36	0.11	0.32	0.16	0.18	0.12	0.13	-0.01	0.30
10	36	0.06	0.23	0.11	0.10	0.08	0.10	-0.02	0.22
11	36	0.06	0.23	0.05	0.07	0.04	0.07	0.02	0.23
12	36	0.11	0.40	0.06	0.07	0.04	0.07	0.07	0.36
13	36	0.03	0.17	0.03	0.05	0.02	0.03	0.01	0.17
14	36	0.00	0.00	0.02	0.02	0.01	0.03	-0.01	0.03
15	36	0.00	0.00	0.01	0.03	0.01	0.03	-0.01	0.03
16	36	0.00	0.00	0.01	0.02	0.01	0.02	-0.01	0.02
17	36	0.03	0.17	0.01	0.02	0.01	0.02	0.02	0.17
18	36	0.03	0.17	0.01	0.02	0.00	0.01	0.02	0.17
19	36	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01
20	36	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01
21	36	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
22	36	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01
23	36	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00

Table 6. Means and standard deviations for the Mixed condition.

		Observed		Chance		Adjusted Chance		Chance Corrected	
LAG	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	36	0.36	0.72	0.27	0.38	0.27	0.38	0.09	0.57
2	36	0.42	0.73	0.22	0.33	0.20	0.35	0.22	0.55
3	36	0.17	0.45	0.18	0.26	0.12	0.24	0.05	0.36
4	36	0.22	0.49	0.14	0.20	0.09	0.19	0.13	0.40
5	36	0.11	0.40	0.12	0.15	0.05	0.11	0.06	0.32
6	36	0.00	0.00	0.08	0.11	0.03	0.09	-0.03	0.09
7	36	0.03	0.17	0.06	0.10	0.02	0.08	0.00	0.11
8	36	0.00	0.00	0.04	0.06	0.02	0.04	-0.02	0.04
9	36	0.03	0.17	0.03	0.04	0.01	0.03	0.02	0.14
10	36	0.00	0.00	0.02	0.03	0.01	0.02	-0.01	0.02
11	36	0.00	0.00	0.01	0.04	0.00	0.02	0.00	0.02
12	36	0.03	0.17	0.00	0.01	0.00	0.01	0.03	0.17
13	36	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
14	36	0.03	0.17	0.00	0.02	0.00	0.01	0.03	0.16
15	36	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
16	36	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
17	36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 1

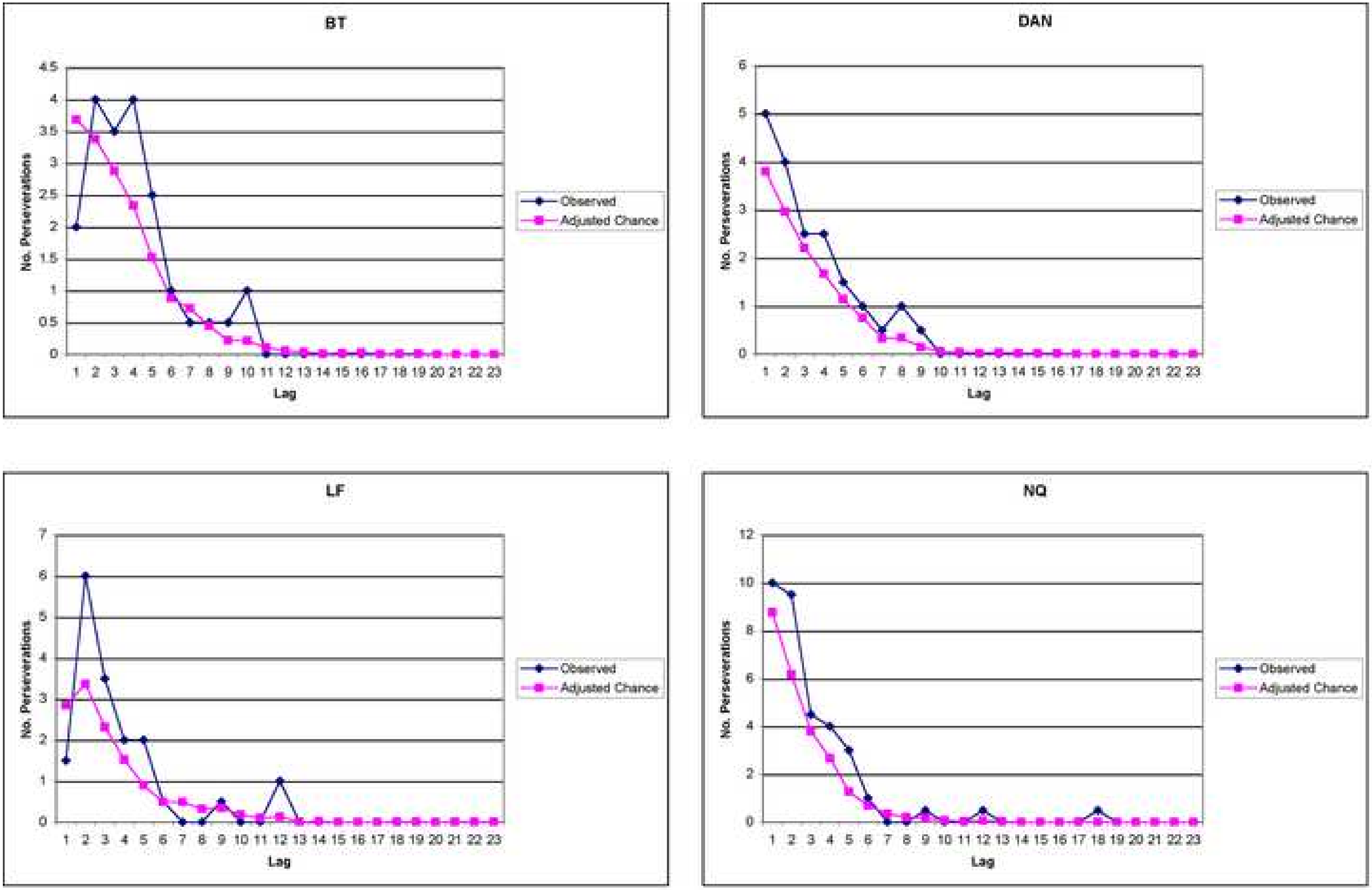
BT
No. Perseverations
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Lag
Observed
Adjusted Chance
DAN
No. Perseverations
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Lag
Observed
Adjusted Chance
LF
No. Perseverations
7
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Lag
Observed
Adjusted Chance
NQ
No. Perseverations
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Lag
Observed
Adjusted Chance

Figure 2

Click here to download high resolution image

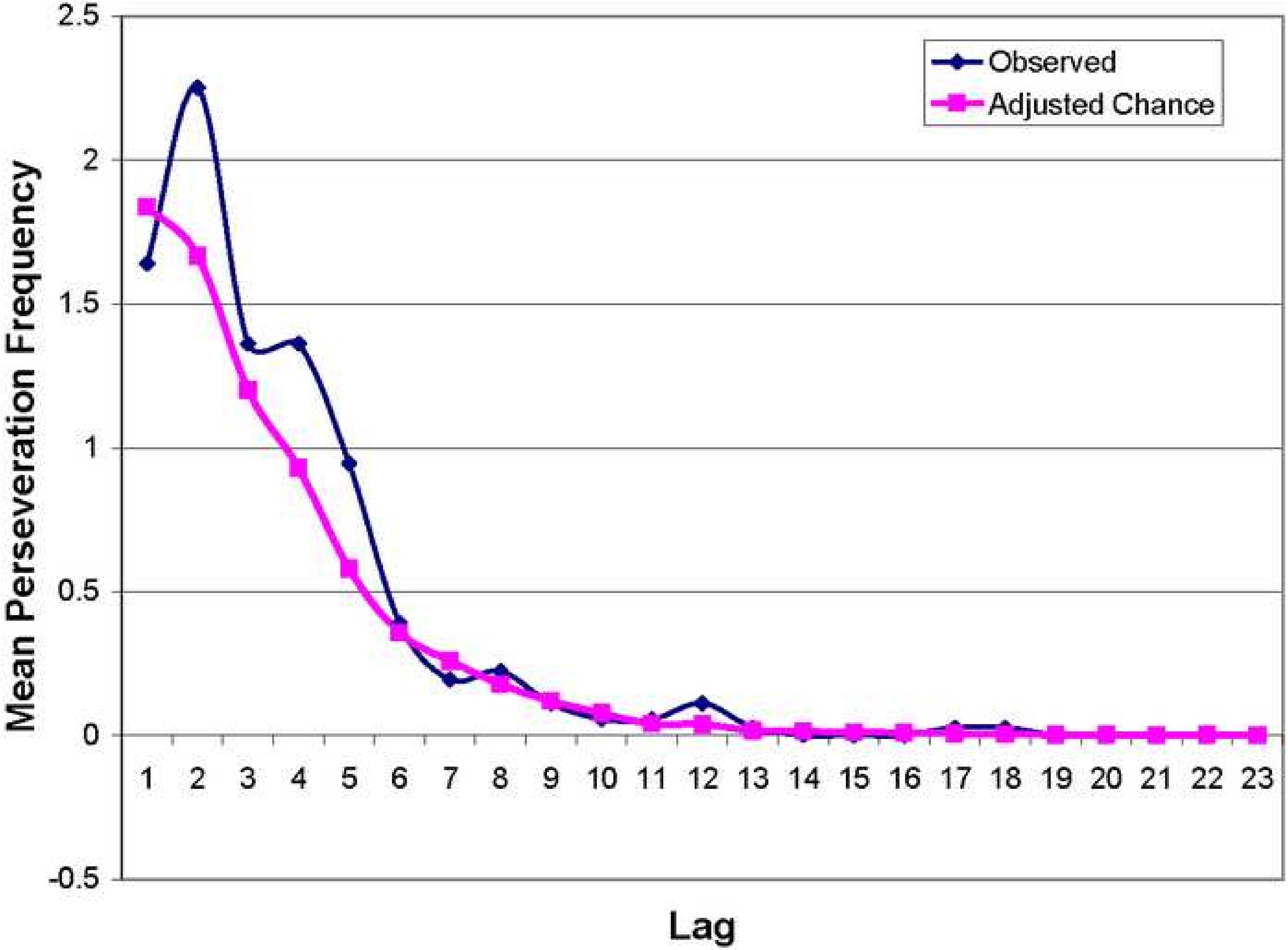

Figure 3

Click here to download high resolution image