Language, Cognition and Neuroscience

Memory availability and referential access

Clinton L. Johns[a], Peter C. Gordon[c], Debra L. Long[b] & Tamara Y. Swaab[b]

[a] Haskins Laboratories, New Haven, CT, USA

[b] Department of Psychology and Center for Mind & Brain, University of California, Davis, CA, USA

[c] Department of Psychology, University of North Carolina, Chapel Hill, NC, USA
Published online: 01 Nov 2012.

PLEASE SCROLL DOWN FOR ARTICLE

Memory availability and referential access

Clinton L. Johns[a]*, Peter C. Gordon[c], Debra L. Long[b] and Tamara Y. Swaab[b]

[a]Haskins Laboratories, New Haven, CT, USA; [b]Department of Psychology and Center for Mind & Brain, University of California, Davis, CA, USA; [c]Department of Psychology, University of North Carolina, Chapel Hill, NC, USA

Most theories of coreference specify linguistic factors that modulate antecedent accessibility in memory; however, whether nonlinguistic factors also affect coreferential access is unknown. Here we examined the impact of a nonlinguistic generation task (letter-transposition) on the *repeated-name penalty*, a processing difficulty observed when coreferential repeated names refer to syntactically prominent (and thus more accessible) antecedents. In Experiment 1, generation improved online (event-related potentials) and offline (recognition memory) accessibility of names in word lists. In Experiment 2, we manipulated generation and syntactic prominence of antecedent names in sentences; both improved online and offline accessibility, but only syntactic prominence elicited a repeated-name penalty. Our results have three important implications: (1) the form of a referential expression interacts with an antecedent's status in the discourse model during coreference; (2) availability in memory and referential accessibility are separable; and (3) theories of coreference must better integrate known properties of the human memory system.

Keywords: coreference; event-related potentials; repeated-name penalty; generation effect

Maintaining a coherent discourse model requires that comprehenders represent objects and individuals as distinct entities in memory, and that they access and update their representations when they process new, incoming information. An important determinant of discourse coherence is coreferential processing, in which a referring expression (anaphor) is linked to an entity (antecedent) already present in the discourse model. Successful coreferential processing allows comprehenders to track who is doing what to whom. The ability to quickly and accurately access an anaphor's antecedent is central to coreferential processing (Clark & Sengul, 1979; van Dijk & Kintsch, 1983). Most theories of coreference attribute antecedent accessibility to language-specific factors. For example, entities are more easily accessed when they are mentioned first in a sentence or discourse (known as "the advantage of first mention"; Corbett & Chang, 1983; Gernsbacher & Hargreaves, 1988; Li & Thompson, 1981); when they are mentioned frequently (Givón, 1979) or in a recent clause (Bever & Townsend, 1979); or when they are positioned prominently in the syntactic structure of a sentence (Gordon, Grosz, & Gilliom, 1993; Gordon & Hendrick, 1998). However, it is not known whether referential access can be affected by nonlinguistic factors that influence memory. We addressed this issue by manipulating two factors—one that is specific to language processing, and one that is not—that are known to influence accessibility in memory, and examining subsequent coreferential processing.

A significant obstacle to an investigation such as this is that many of the linguistic factors that affect referential access have clear parallels in the memory literature. For example, the advantage of first mention may correspond to a primacy effect, and mention in a recent clause may correspond to a recency effect, leading to the possibility that these well-established, general principles of memory provide the basis for differential ease in referential access. In contrast, the highlighting of important information/relations by syntactic prominence can be dissociated from the list-like properties of a sentence or discourse through straightforward manipulations of syntactic organisation. The resulting effects on referential access are due to the centrality of the meanings and relations that are established in the comprehender's mental representation of the sentence or discourse. As such, the position of information in a syntactic structure is an unambiguously linguistic property that is encoded relatively automatically during sentence comprehension.

There is ample evidence that syntactically prominent information is more readily accessible in memory than nonprominent information (Birch, Albrecht, & Myers, 2000; Birch & Garnsey, 1995; Birch & Rayner, 2010; Sanford, Price, & Sanford, 2009; Sturt, Sanford, Stewart, & Dawydiak, 2004; Ward & Sturt, 2007).

---

*Corresponding author. Email: johns@haskins.yale.edu

Please note that this paper was previously published online in a different page layout.

However, while this increased accessibility facilitates pronoun processing (McKoon, Ward, Ratcliff, & Sproat, 1993; Sanford et al., 2009), its effect on the processing of repeated-name anaphors is less straightforward. When a repeated name refers to a syntactically prominent antecedent, coreferential processing appears to be impaired. To illustrate, consider the following example (from Gordon, Hendrick, Ledoux, & Yang, 1999):

1a. John went to the store so that John could buy some candy.
1b. John and Mary went to the store so that John could buy some candy.

When *John* is a singular subject (1a), a repeated-name anaphor in the second clause elicits processing difficulty relative to when *John* is part of a conjoined noun phrase (e.g., *John and Mary,* 1b). This difficulty, known as the repeated-name penalty, has been extensively documented in the anaphor processing literature, and has been observed using several experimental methods, including self-paced reading (Almor, 1999; Gordon et al., 1993), eye tracking (Garrod, Freudenthal & Boyle, 1994; Kennison & Gordon, 1997), functional magnetic resonance imaging (Almor, Smith, Bonilha, Fridriksson, & Rorden, 2007), and event-related potentials (ERPs; Camblin, Ledoux, Boudewyn, Gordon, & Swaab, 2007; Ditman, Nieuwland, & Kuperberg, 2009; Ledoux, Camblin, Swaab, & Gordon, 2006; Swaab, Camblin, & Gordon, 2004; see Ledoux & Camblin, 2008 and Ledoux, Gordon, Camblin, & Swaab, 2007, for reviews).

The finding that a repeated-name anaphor can induce a processing problem contradicts theories of coreference claiming that enhanced accessibility improves referential access (e.g., Gernsbacher, 1989, 1990; McKoon & Ratcliff, 1980; Stewart, Pickering, & Sanford, 2000). However, two theories of coreference specify mechanisms that accommodate the repeated-name penalty: Discourse Prominence Theory (DPT; Gordon & Hendrick, 1998) and the Informational Load Hypothesis (ILH; Almor, 1999, 2004, 2005; see Almor & Nair, 2007, for review). Both theories identify antecedent accessibility as a critical component of the anaphor resolution process. However, the theories differ according to how accessibility is achieved, and whether a nonlinguistic "boost" to antecedent accessibility should influence subsequent coreferential processing.

According to DPT, entities that are syntactically prominent in the discourse model are more accessible than those that are not. Syntactically prominent entities occupy a relatively high position in a sentence's syntactic tree. An antecedent that is a singular senten-

tial subject (as in 1a) is more prominent, and more easily accessed, than one that is part of a conjoined noun phrase (as in 1b), which is more deeply embedded in the syntactic tree (see also Gordon et al., 1993; Gordon & Hendrick, 1997; Gordon & Scearce, 1995). DPT also states that pronouns and proper names elicit different processing operations during construction of a discourse representation: pronouns trigger an immediate search for a referent among entities already present in the representation, and proper names primarily serve to introduce new entities to the discourse representation. Consequently, repeated-name anaphors are initially interpreted as new entities, and must be reinterpreted in order to initiate a coreferential search. In both cases, the search for a referent considers the syntactic prominence of candidate antecedents in the discourse. However, the search operation also varies according to the form of the triggering anaphor: pronouns initiate a search that proceeds from the most prominent entity to the least, but repeated names begin with the least prominent candidate. Thus, the repeated-name penalty is the manifestation of a lengthier search for an antecedent, based both on the necessity of reinterpretation and on the antecedent's syntactic prominence. DPT is silent as to whether a penalty may also result from enhancing access to an antecedent memory representation by nonlinguistic means. However, DPT specifies expressly linguistic mechanisms (syntax, formal construction rules) that determine accessibility and give rise to the repeated-name penalty. Moreover, since lexical repetition in lists typically results in repetition priming, the repeated-name penalty has been interpreted as reflecting a reversal of this advantage, whereby syntactic processing overrides list-memory effects so that repetition yields a processing cost (e.g., Swaab et al., 2004). Thus, we may infer that enhancing access via a nonlinguistic device should not elicit a repeated-name penalty, because this does not alter syntactic structure (or, therefore, discourse prominence).

According to the ILH, the primary determinants of anaphor resolution are discourse function and processing cost. The discourse function of an anaphor is to identify its referent. In line with the maxim of quantity (Grice, 1975), processing is facilitated when an anaphor's semantic content is either less than or greater than that of its referent. For example, reduced referring expressions (e.g., pronouns) add no new information to the discourse, and best refer to salient, accessible entities; semantically explicit anaphors (e.g., repeated names) carry a heavier informational load, and are best used to introduce new information to a discourse (e.g., a new entity, or new information about an existing entity). Processing cost is indexed according to two factors: the overall activation of both anaphor and

referent, and the semantic overlap between the two. Activation is determined by both amount of semantic content and, critically, by a representation's salience in memory (Almor, 2004). Furthermore, the degree of semantic overlap between an anaphor and its antecedent can create costly interference, such that greater overlap results in higher processing costs during integration. Thus, the ILH suggests that the repeated-name penalty results when a salient, accessible antecedent is referenced by an explicit anaphor that, although semantically "loaded", adds no new information to the discourse. The ILH further suggests that increasing an antecedent representation's salience in memory enhances its activation and accessibility, and bears directly on processing costs (Almor, 2004; Almor & Nair, 2007); thus, a repeated name that refers to an antecedent that has been rendered more accessible (salient) by a nonlinguistic device should elicit a repeated-name penalty, regardless of syntactic position.

The divergent predictions of these theories of coreference demonstrate the importance of investigating potential effects of nonlinguistic factors on coreferential processing: essentially, the question is whether concepts like "prominence" and "salience" are determined by specialised linguistic processes, or whether they are by-products of memory operations engaged during language processing. Thus, in order to test these predictions, we manipulated antecedent accessibility in two ways. First, we manipulated the syntactic prominence of antecedent entities, and second, we capitalised on the *generation effect*, a well-established phenomenon in the study of memory. Generation instructions are typically used to study the influence of levels-of-processing in memory. Participants show improved memory performance for words that they generate themselves relative to those that they read normally. Generation effects have been found on both recall and recognition memory tests (see Mulligan & Lozito, 2004, and Yonelinas, 2002, for reviews). The generation task increases processing of item-specific features, enhancing the encoded memory trace by increasing the distinctiveness of the item (Gardiner & Hampton, 1988). According to some researchers (e.g., Hunt & McDaniel, 1993; Jacoby, 1978), generation may be a form of problem solving, in which multiple sources of information are used during generation and have subsequent effects on memory performance. Others suggest that it is the quantity of cognitive resources that is brought to bear during generation that drives the effect (Fiedler, Lachnit, Fay, & Krug, 1992; McFarland, Frey, & Rhodes, 1980)—although it has been shown that adding even a single letter to generate a word elicits the effect (Donaldson & Bass, 1980). Still others emphasise the importance of overlap of cognitive processes at study and test (e.g., Soraci et al., 1994).

A recent meta-analysis of 86 studies reporting the generation effects concludes that there is some merit to each of these positions (Bertsch, Pesta, Wiscott, & McDaniel, 2007).

We chose a letter-transposition paradigm as the generation task. In this paradigm, participants read stimuli that are presented either normally or with their two initial letters transposed (e.g., *Claire* vs. *lCaire*). Participants were instructed to 'unreverse' the letters in order to generate the correct name, presumably creating a more accessible memory representation. We chose the letter-transposition paradigm as our generation task because it is amenable to use with proper names, and is less likely to disrupt normal reading than other generation tasks (e.g., stem completion, fragment completion, antonym generation, anagram solving, etc.). In addition, aspects of the letter-transposition paradigm are ideally suited to investigating both DPT and the ILH. With regard to DPT, letter transposition does not alter the syntactic structure of sentences, and thus should not affect discourse prominence. With regard to the ILH, the letter-transposition paradigm permits a nuanced examination of the factors that contribute to the repeated-name penalty by holding constant both discourse function and one of the determinants of processing cost (the semantic overlap between anaphor and antecedent). Letter-transposition is based solely on visual information, so participants do not devote resources to semantic processing (Mulligan, 2006, 2011). Indeed, Kinoshita (1989) and Mulligan (2002a) have both noted that "letter-transposition enhances distinctiveness (and hence memory) along a nonsemantic dimension" (Mulligan, 2002a, p. 551). Consequently, letter-transposition only manipulates the ILH's second determinant of processing cost: the salience of the memory representation. Thus, any memory benefits that result when a name is generated from a transposed form are best described as nonlinguistic, and qualitatively distinct from language-specific processes such as syntactic analysis.

We conducted two ERP experiments in this study. In Experiment 1, we used list-like stimuli in order to validate our generation manipulation and provide a set of baseline findings against which the results of our second experiment could be compared. Experiment 2 used sentence stimuli in order to compare the influence of linguistic and nonlinguistic manipulations on coreference; specifically, we manipulated antecedent encoding via syntactic and generation manipulations, and examined subsequent coreference with repeated-name anaphors. In each experiment, the ERP recording sessions were immediately followed by a surprise recognition test for names. The purpose of this test was to assess the memory effects of our encoding manipulations. We used a remember/know task to

obtain information about participants' retrieval experiences (Gardiner, 1988; Tulving, 1985). Participants were asked to make one of three memory judgments to test items. They responded 'remember' to those items that were accompanied by episodic details of the item's prior occurrence. They responded 'familiar' to those items that were recognised but were unaccompanied by episodic details. They responded 'new' to those items that they did not recognise. This task has shown robust sensitivity to encoding manipulations such as generation, with reliable effects emerging on recollection, as indexed by remember judgments, and smaller (but significant) effects on familiarity (see Yonelinas, 2002, for review).[1]

In examining the ERP data, we focused on the N400 effect, which is associated with semantic access/integration processes during language comprehension. It manifests as a negative shift in the ERP waveform that peaks approximately 400 ms poststimulus and is typically maximal over centro-parietal electrode sites (Kutas & Hillyard, 1980). Its amplitude is reduced to words that are easily retrieved or integrated in semantically congruent contexts (Chwilla, Brown, & Hagoort, 1995; Holcomb, 1993; Kutas & Federmeier, 2001; van Berkum, Hagoort, & Brown, 1999). N400 amplitudes are also reduced to repeated words that are presented in list formats (Holcomb, 1993; Nagy & Rugg, 1989). However, the reverse has been observed when repeated *names* in sentence contexts refer to syntactically prominent antecedents; that is, the N400 effect is a reliable index of the repeated-name penalty (Camblin et al., 2007; Ledoux et al., 2006, 2007; Swaab et al., 2004; cf. Ditman, et al., 2009). Because we were interested in the memory effects of the generation manipulation, we also included two ERP measures of recognition that are well established in the memory literature (for reviews, see Curran, Tepe, & Piatt, 2006; Luck, in press; Mecklinger, 2000; Rugg & Curran, 2007; Wilding & Sharpe, 2003). The first is a frontally distributed effect which manifests as a reduced negative shift to familiar items (i.e., the anterior old/new effect, Curran, 2000; Friedman & Johnson, 2000; Nessler, Mecklinger, & Penney, 2005; Rugg et al., 1998; Yu & Rugg, 2011). The second ERP measure of recognition memory is the posterior old/new effect, which manifests as a larger positive shift to "remembered" items (Curran, 2004; Düzel, Yonelinas, Mangun, Heinze, & Tulving, 1997; Smith, 1993; Woodruff, Hayama, & Rugg, 2006).

Experiment 1

Before examining how generation might affect coreferential processing, it was first necessary to demonstrate that the letter-transposition task could be used to enhance memory for proper names in the context of an ERP experiment. Previous behavioural experiments investigating the effect of letter-transposition on memory (e.g., Kinoshita, 1989; Mulligan, 2002a, 2002b, 2002c) differ in critical ways from the standard presentation paradigms used in ERP studies of sentence processing. Relative to ERP studies, presentation time in behavioural studies is typically quite long: for example, Mulligan (2002a, 2002b) presented words containing transposed letters for 8 seconds; Kinoshita (1989) and Mulligan (2002c) presented stimuli for 5 seconds. In contrast, visual presentation rate in ERP studies of online language processing is much faster, with words typically appearing for only 300 milliseconds. In addition, behavioural studies typically require some kind of explicit output showing that participants generated the transposed stimulus (such as stem or fragment completion tasks). However, our participants were asked to generate no explicit online responses to the transposed stimuli; rather, we indexed their online neural responses using ERPs, and their explicit responses were measured offline, in the surprise recognition test.

Participants in this experiment read a series of word lists. These lists were constructed by randomising sentence stimuli that were previously used to investigate the repeated-name penalty (Swaab et al., 2004). We randomised the positions of all words except the critical names, so that a name appearing early in the list either was or was not followed by a repetition of the name later in the list. In addition, the initial presentation either did or did not contain transposed letters (see Table 1 for examples). This approach—scrambling the words of sentence containing repeated-name anaphors—has been used successfully to examine other recognition memory phenomena related to coreference in previous research (see, e.g., Dopkins & Ngo, 2002).

N400 predictions for the repetition manipulation are straightforward: we should observe a reduced N400 effect to repeated names, reflecting facilitated processing. Predictions for the generation manipulation are less clear. The transposed names are orthographically different from the subsequent repeated names, and although there is evidence that letter-transposed common nouns do not impair subsequent priming effects (e.g., Gomez, Ratcliff, & Perea, 2008), there is also some evidence that the perceptual match between repeated instances of proper names is critical for priming to occur (Geva, Moscovitch, & Leach, 1997). Therefore, potential repetition priming effects at the critical name may be attenuated when the initial instance of the name is generated, resulting in a relative attenuation of the N400 effect to repetitions that follow generated names (or no N400 effect at all). However,

Table 1.   Examples of experimental items for Experiment 1.

Repeated name/read-only:
orchestra night **Claire** each because with *Claire* performing was drove downtown the symphony
Repeated name/generate:
orchestra night **lCaire** each because with *Claire* performing was drove downtown the symphony
No repetition/read-only:
orchestra night **Robert** each because with *Claire* performing was drove downtown the symphony
No repetition/generate:
orchestra night **oRbert** each because with *Claire* performing was drove downtown the symphony

---

Note: Initial names are boldfaced and critical names (repeated or not) are italicised, but were presented to participants without formatting. Generated names were presented in a different font, so that participants knew that the transposed letters were not typographical errors.

there is also evidence that generation effects may not affect an implicit measure (see Yonelinas, 2002) such as simply reading a word that has previously appeared in a list. Therefore, letter transposition may not affect online processing of the repeated names, leaving any N400 repetition effects intact. In addition, if the generation manipulation facilitates online recognition memory for the critical names, then this should manifest as a modulation of the anterior and/or posterior old–new ERP effects. Finally, generation should increase the distinctiveness of the studied items and, therefore, should improve recognition memory performance.

Method

Participants

Informed consent was obtained from 16 undergraduates at the University of California, Davis. The participants in this and the following experiment had normal or corrected-to-normal vision, were unmedicated, were neurologically unimpaired, were right-handed, native English speakers, and participated for course credit. (One note: in this experiment, two participants were excluded from the analysis of recognition memory data due to excessive false alarm rates. We reanalysed the ERP data excluding these two participants and found no changes in the patterns of significant and nonsignificant effects. However, we have elected to present the results of all 16 participants' ERP data, because of the greater power of the full data set.)

Materials

Word lists

Word list stimuli were adapted from the sentences used in the work of Swaab et al. (2004). The sentences in that study contained anaphors referring to an antecedent that was either a singular subject (e.g., *Claire*) or a member of a conjoined pair (e.g., *Claire and Robert*), and which occurred in the first clause. The anaphors were pronouns and repeated names that appeared in the

second clause; however, for this experiment all pronouns were replaced with repeated names. The words in the sentences were scrambled to create unstructured word lists. Names were kept in the same serial positions as those that they occupied in the original sentences. We created word lists without repetition by deleting antecedent names from previous conjoined pairs, leaving only nonantecedent names. Sequential repetitions of noncritical words were also eliminated; for example, in the event that the word 'and' was immediately followed by another 'and', the repetition was swapped with a neighbouring word. Participants received an initial block of practice trials (10 word lists) and then read a total of 240 word lists; 160 of these were experimental word lists and 80 were filler word lists. Filler word lists did not include repeated names. Half of the filler items contained a content word with its initial letters transposed (not a name). All word lists were followed by a simple forced-choice decision task about the lists' content (see below).

Four experimental lists were created. In the first list, 40 experimental word lists were pseudo-randomly assigned to each of four conditions: repetition/generate, repetition/read-only, nonrepetition/generate, nonrepetition/read-only. Each experimental word list rotated through the remaining conditions such that each appeared only once per list, in a different condition in each list. The experimental lists were then separately randomised. Each list contained 8 blocks of 30 word lists: 10 filler lists and 5 lists from each of the experimental conditions. Each block began with three "warm-up" filler word lists.

Recognition test

Participants received a surprise remember/familiar recognition test for all names. The recognition test consisted of the 160 names from the experimental word lists and 160 new names that did not appear in any of the lists. All names were randomised and presented normally (i.e., without transposed letters) in a single block, with each name appearing only once.

Procedure

EEG and behavioural sessions

Participants were tested individually in a dimly lit, electrically shielded, sound-attenuated room. They were seated approximately 100 cm from the computer screen. They were instructed to keep their eyes fixated on a cross that was presented in the centre of the screen, to refrain from blinking, and to limit their movements as much as possible during the presentation of the word lists. This was done to minimise participant-generated artifacts on the EEG signal. Participants were instructed that they were going to view a series of random word lists, and that they were to monitor them closely so that they could identify words that appeared in each list. In addition, they were told that some words would contain transposed letters, and they were instructed to "unreverse" the letters in these words to create real words.

Each trial began with a fixation cross, which was presented for 1,000 ms in the centre of the screen. This alerted participants to the beginning of a trial and indicated where they should fixate during word-list presentation. The fixation cross was replaced with words during the presentation of the lists. Word lists were presented using a rapid serial visual presentation (RSVP) procedure, with each word appearing in the centre of the screen for 300 ms and with an inter-stimulus interval of 200 ms, during which the screen was blank. In the read-only condition, words were presented in white, 24-point Tahoma font. In the generate condition, the antecedent names were presented in white, 24-point Courier New font, indicating that the letter-transposition was intentional (participants were advised that the font change was intended to keep them from attributing the transposed letters to typographical errors). The first letter of the names, which appeared in the second position in the transposed-letter condition, was capitalised. Each word list was followed by a blank screen for 1,000 ms, after which participants responded in a forced-choice decision task; participants had to identify which of two words had appeared in the list they had just read. For each forced-choice item, the word from the list was selected pseudo-randomly; in order to avoid strategic focus on proper names in the lists, only 10% of the forced-choice decision pairs contained names. The decision words appeared together, one on the left and one on the right side of the screen. Participants indicated which word had appeared in the list by pressing a button on a handheld keypad. Average accuracy on this task was 95.94%. After participants completed the memory task, the prompt "Press for next" appeared on the screen. Participants started the next trial by pressing any button.

Participants were given a short break between each of the eight experimental blocks. Following the final block, participants received instructions for the recognition test. The recognition test was administered in the same test room. Names appeared one at a time in the centre of the computer screen in white, 24-point Tahoma font. Throughout the recognition test, the words "Remember/Familiar/New" were displayed just above the names. Participants indicated their memory for each name by pressing one of three keys on the keypad, corresponding to remember, familiar, or new judgments. Names remained on the screen until a response was recorded. The response prompted the appearance of the next name in the list.

EEG recording

The electroencephalogram was recorded from 29 electrodes mounted in an elastic cap, referenced to the right mastoid. The EEG recording was re-referenced offline to an average of the left and right mastoids. Electrodes placed beneath the left eye and at the outer canthi monitored eye movements and blinks. Impedances were kept below 5 kΩ. All single-trial waveforms were screened for amplifier blocking, drift, muscle artifacts, eye movements, and blinks; trials containing artifacts were not included in the average ERPs or in the statistical analyses. Due to artifacts 11.4% of trials were rejected. The EEG signal was band-pass filtered between 0.01 and 30 Hz and sampled at 250 Hz.

Data analysis

Event-related potentials

ERPs were time-locked to the onset of the names appearing late in each of the word lists; that is, the names that either were or were not repetitions of the first-mentioned names. These data were analysed by using repeated-measures analyses of variance (ANOVAs) performed on the mean amplitude of the ERPs relative to a 100 ms pre-stimulus baseline. Significant interactions were tested with subsequent contrasts. The Greenhouse–Geisser correction was used to examine effects with more than one degree of freedom in the numerator (Greenhouse & Geisser, 1959). We examined three ERP effects; the N400 effect, the anterior old/new effect and the posterior old/new effect. For each of these ERP effects, analyses focused on regions and time windows in which these effects have been maximal in previous studies (see above). The N400 was analysed in the 300–500 ms epoch after onset of the critical word over 10 centro-parietal electrode sites (C3/4, CP5/6, CP1/2, P3/4, Cz, Pz); the anterior old/new effect was measured in a 350–600 ms epoch over 8 anterior electrode sites (FP1/2, F3/4, F7/8, AFz, Fz); and the

posterior old/new effect was measured in the 500–800 ms epoch over 6 posterior electrode sites (P3/4, O1/2, Pz, POz). Figure 1 depicts the electrode sites included in each of the analyses described here.

Recognition test

Recognition responses were analysed by using repeated-measures ANOVAs. The independence remember/know method (Yonelinas & Jacoby, 1995) was used to prepare the data for analysis. In the remember/know paradigm, participants are instructed to respond "remember" when an item is recognised with episodic detail, and "familiar" when an item is recognised without episodic detail. However, this results in an underestimation of the probability that an item is familiar; the independence remember/know method compensates for this under-

estimation by assuming that the probability that an item is familiar is equal to the probability that the item was rated "familiar" (F) and was also not recollected (R). Furthermore, remember judgments were corrected according to the false alarm rate for remember judgments. The formulas for remember and familiarity can be seen below (Equations 1 and 2).

$$\text{Remember} = \text{R} - \text{FA(R)} \qquad (1)$$

$$\text{Familiarity} = \text{F}/(1 - \text{R}) \qquad (2)$$

Results and discussion

Grand average ERPs to the critical names are presented in Figures 2–4.
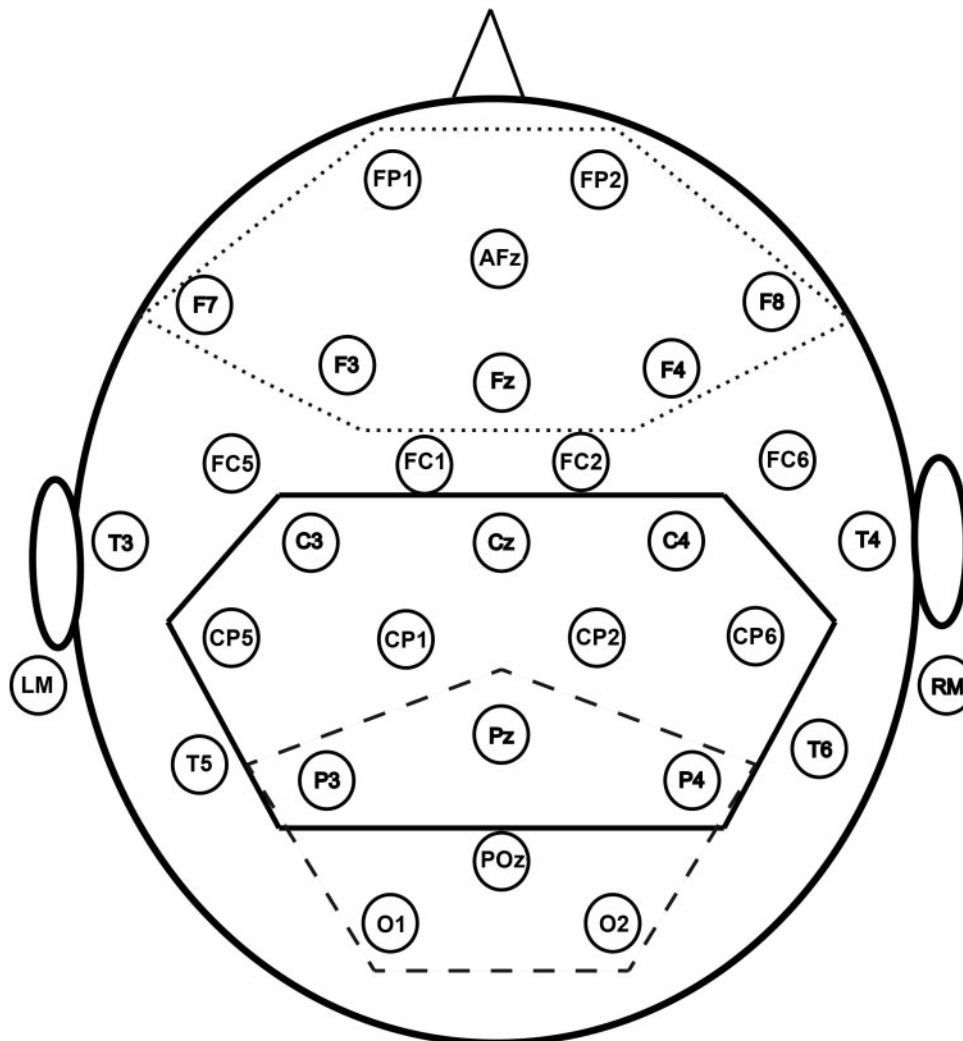

Figure 1.　Electrode map and definition of regions of interest (ROI) for the ERP effects in Experiments 1 and 2. The solid black lines identify the electrodes in the N400 effect ROI. The anterior dotted lines identify the electrodes in the anterior old/new effect ROI. The posterior dashed lines identify the posterior old/new effect ROI.

a   READ: orchestra night **Claire/Robert** each because with **Claire**....

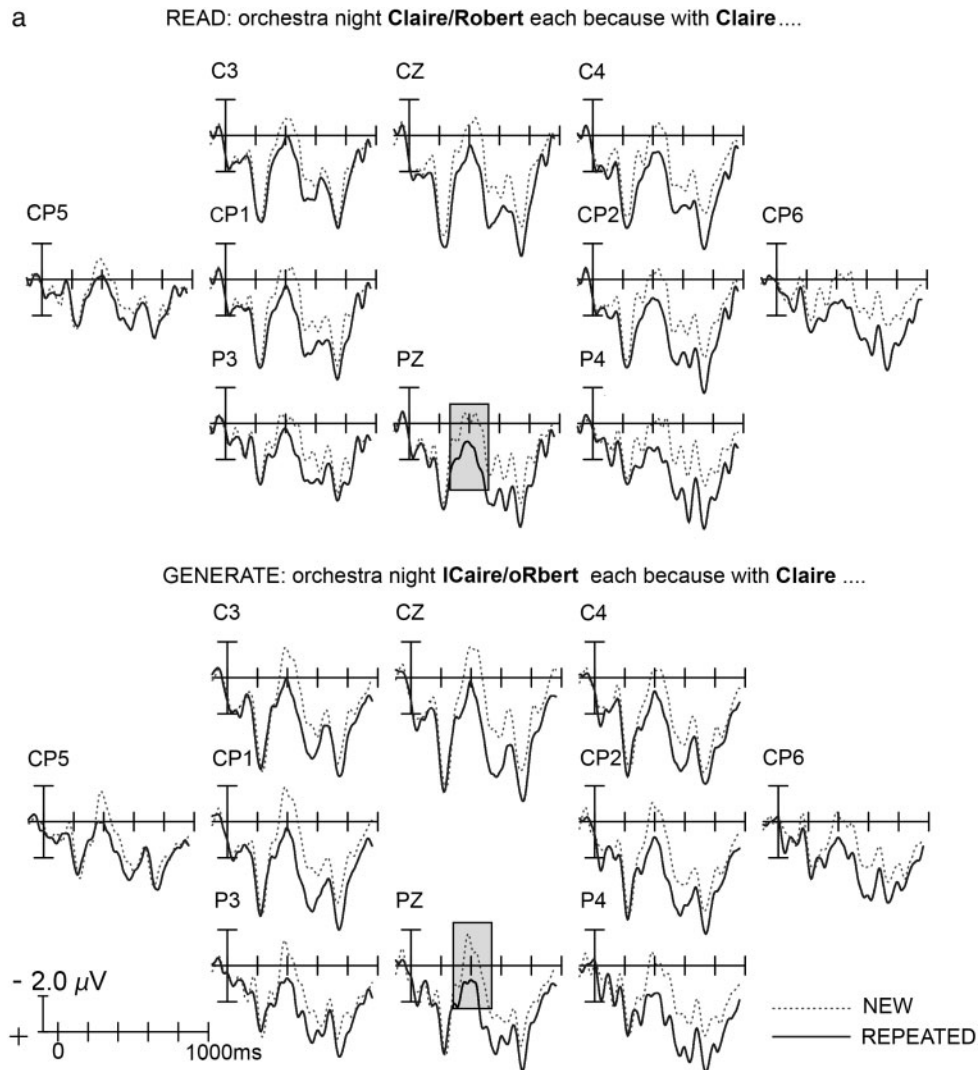GENERATE: orchestra night **lCaire/oRbert** each because with **Claire** ....

Figure 2. (a) N400 effect: Repetition effects on critical words in the random word lists in Experiment 1. ERPs are shown for the electrodes included in the statistical analyses of the N400 effect, which was performed in the 300–500 ms epoch. ERPs were time-locked to the names in the second half of the word lists that either were or were not repeated from earlier in the list. The boxed area highlights the N400 effect at electrode Pz in both normally read (top) and generation (bottom) conditions.

N400 effect

There was greater negativity in the N400 time window for new names as compared to repeated names (Figure 2a); this effect of repetition was significant, $F(1, 15) = 17.24$, $p < .0001$. Neither the effect of generation nor the interaction of repetition and generation reached significance (Figure 2b; all Fs < 1). These results are consistent with previous ERP research showing the effects of lexical repetition in word lists (Paller & Kutas, 1992; Rugg, 1985), viz. decreased N400 amplitude for repeated words.

Anterior old/new effect

We observed a significant main effect of generation; when the first iteration of a name was generated, the subsequent repeated name elicited a more positive-going waveform than when the first instance of the name was read normally, $F(1, 15) = 4.62$, $p = .048$ (Figure 3a). The appearance of a slight anterior effect of repetition in the generation condition (Figure 3b) was not significant; and there was no interaction between repetition and generation (Fs < 1)

Posterior old/new effect

We found a significant main effect of repetition, $F(1, 15) = 33.17$, $p < .0001$, depicted in Figure 4a; and no effect of, or interaction with, generation, Fs < 1 (Figure 4b). Thus, repeated names elicited a positive shift in the waveforms relative to names that were not repeated, regardless of whether the first iteration of the name was generated or not. Notably, this pattern of
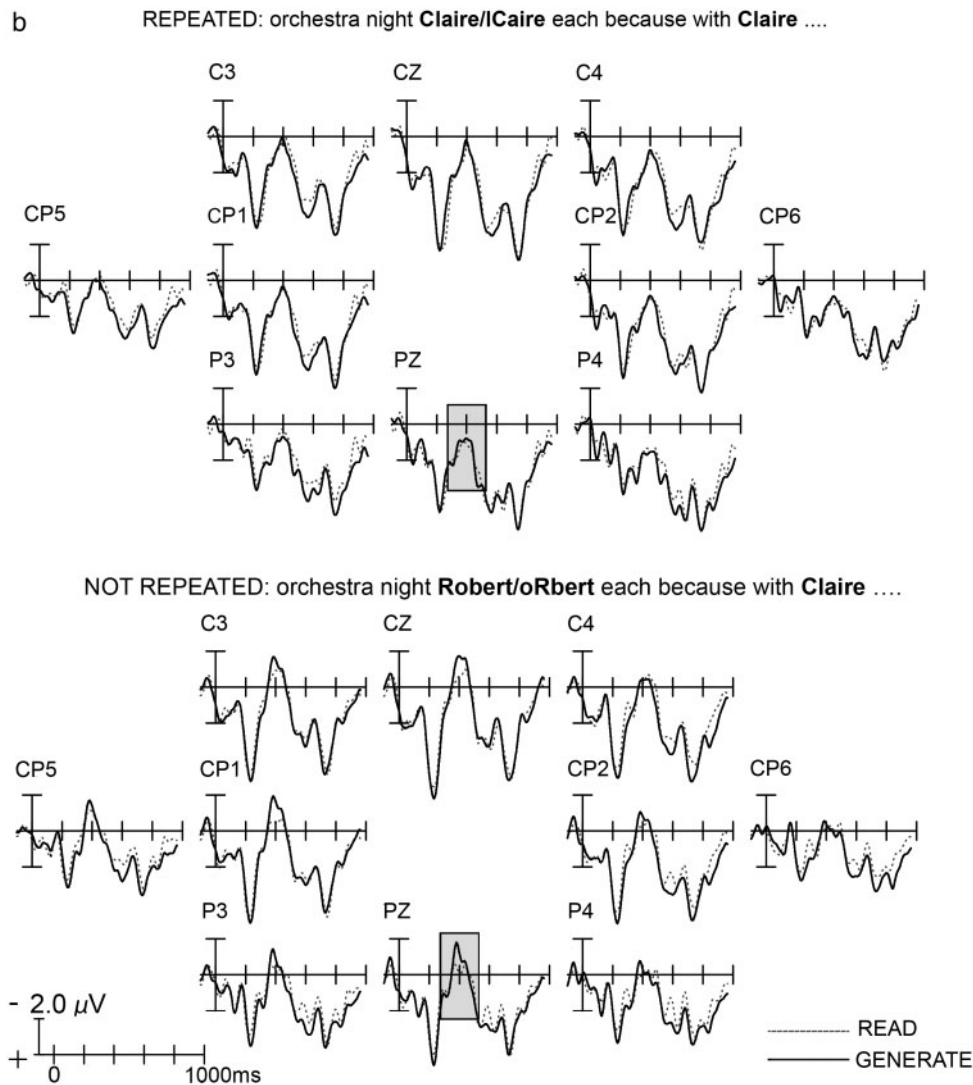
Figure 2. (b) N400 effect: There was no effect of generation on critical words in the random word lists in Experiment 1 in the N400 effect region of interest. ERPs are shown for the electrodes included in the statistical analyses of the N400 effect, which was performed in the 300–500 ms epoch. ERPs were time-locked to the names in the second half of the word lists that either were or were not generated earlier in the list. The boxed area highlights the N400 time window at electrode Pz in both repeated (top) and unrepeated (bottom) conditions.

anterior and posterior old/new effects perfectly corresponds with the results of the behavioural recognition test (see below).

Recognition test

The results of the recognition test are shown in Table 2. For familiarity judgments, there was no main effect of either repetition, $F < 1$, or generation, $F(1, 13) = 1.795$, $p = .203$. However, we found a significant interaction between repetition and generation in our analysis of familiarity judgments, $F(1, 13) = 6.599$, $p = .023$. Contrasts showed that familiarity judgments increased to repeated names that followed a generated form, $t(13) = 2.424$, $p = .031$, but not a form that was presented normally, $t(13) = -.218$, $p = .831$. With re-

spect to remember judgments, the ANOVA revealed a significant main effect of repetition $F(1, 13) = 20.25$, $p = .001$, but not of generation, $F(1, 13) = 2.973$, $p = .108$, and no interaction, $F < 1$. Thus, repeated names were more likely to be remembered than unrepeated names regardless of initial presentation.

These findings validate the letter-transposition paradigm as a nonlinguistic tool that increases the accessibility of encoded memory traces. These results demonstrate that the generation manipulation does not result in idiosyncratic lexical processing based on a perceptual mismatch between a generated item and a subsequent repetition. The N400 effect to repeated names was very similar, regardless of whether the initial instance of a name contained transposed letters, and despite evidence suggesting that names that were
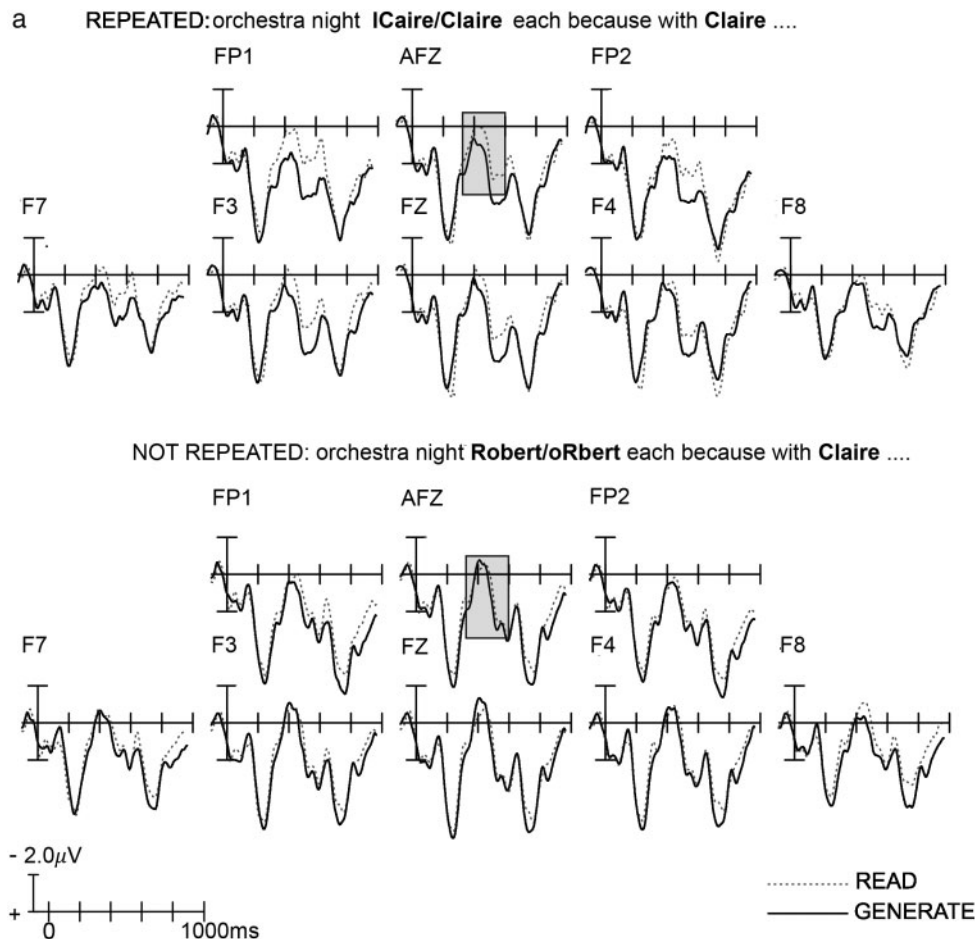
Figure 3.   (a) Anterior old/new effect: Generation effects on critical words in the random word lists in Experiment 1. ERPs are shown for the electrodes included in the statistical analyses of the anterior old/new effect, which was performed in the 350–600 ms epoch. ERPs were time-locked to the names in the second half of the word lists that either were or were not generated earlier in the list. The boxed area highlights the anterior old/new effect at electrode AFz, and shows an effect of generation when words were repeated (top) but not when they are unrepeated (bottom).

generated were more available in memory both during online processing (the anterior old/new effect) and offline retrieval (increased familiarity ratings).

In addition, these results also represent an important incremental extension of the lexical-priming literature. Although it is intuitive to suggest that proper name repetition in lists should elicit the same online priming effects as repetition of common nouns in lists, no previous ERP studies have addressed this assumption. There is behavioural evidence of proper-name priming (Geva et al., 1997; Hollis & Valentine, 2001; Valentine, Hollis, & Moore, 1998), but name-priming patterns are known to differ from those of common nouns (Hollis & Valentine, 2001; Valentine et al., 1998). Furthermore, there is behavioural and electrophysiological evidence that proper names and common nouns differ on a number of dimensions (e.g., uniqueness, meaningfulness, referential specificity; see Hollis & Valentine, 2001) and are, at least initially, processed differently (Müller & Kutas, 1996; Yasuda,

Nakamura, & Beckman, 2000). Although repetition priming for famous names (e.g., Bill Clinton) has been shown in immediate, masked priming paradigms, in which no other words intervene between the prime and the target (Pickering & Schweinberger, 2003), our demonstration of online proper name priming in lists of clearly visible words is a new finding. Finally, by showing that repeated proper names elicit online lexical priming effects (i.e., reduced N400 amplitude) in a list format, we support a key assumption in the reasoning behind the Swaab et al. (2004) characterisation of the repeated-name penalty: that the penalty results because syntactic prominence overrides and reverses typical lexical priming effects.

Experiment 2

The results of the first experiment show that the letter-transposition task is suitable to test whether referential
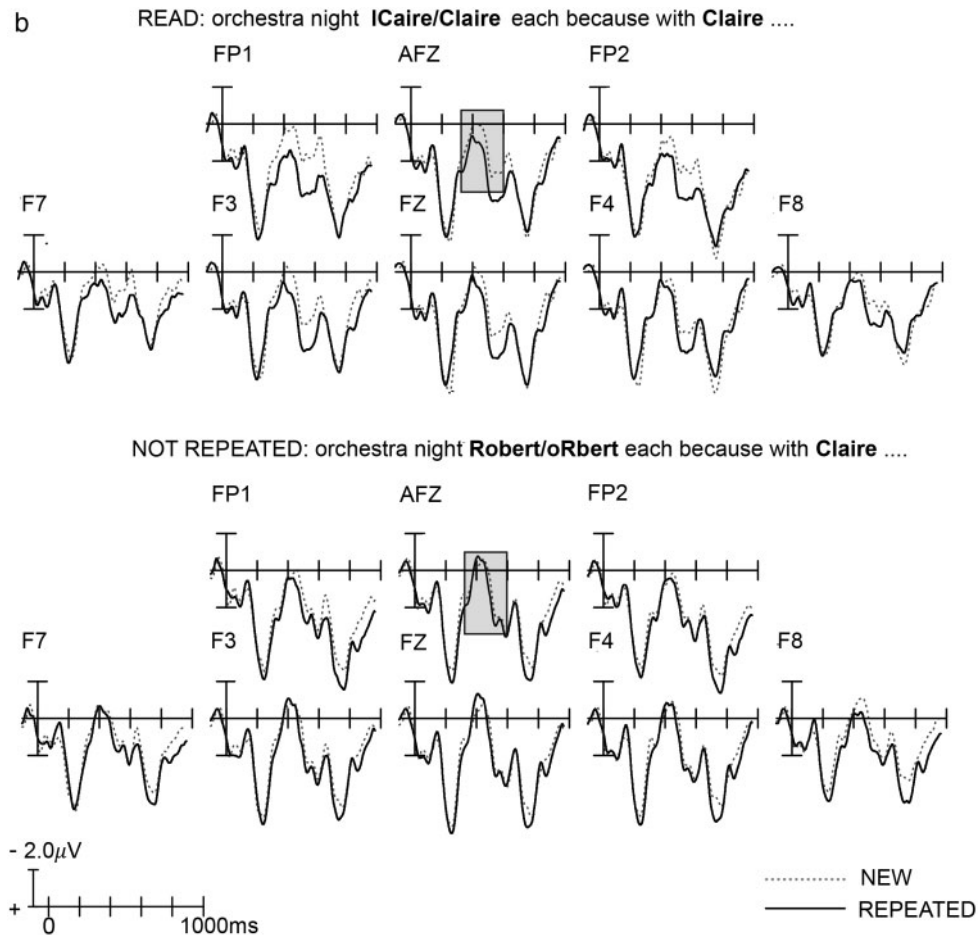
Figure 3. (b) Anterior old/new effect: There was no effect of repetition on critical words in the random word lists in Experiment 1 in the anterior old/new effect region of interest. ERPs are shown for the electrodes included in the statistical analyses of the anterior old/new effect, which was performed in the 350–600 ms epoch. ERPs were time-locked to the names in the second half of the word lists that either were or were not repeated earlier in the list. The boxed area highlights the anterior old/new time window at electrode AFz, in both the read-only (top) and generation (bottom) conditions.

access can be affected by nonlinguistic factors that influence memory. In Experiment 2, we used names in sentence contexts to determine whether antecedents that are more accessible due to generation affect referential access and coreferential processing in the same way as syntactically prominent antecedents do. That is, will a repeated name that initiates a coreferential search for a generated, accessible antecedent that is *not* prominent in a sentence's syntactic structure elicit a repeated-name penalty?

Participants in this experiment read a series of two-clause sentences that included repeated-name anaphors. The first clause introduced either a single character or two characters in a conjoined noun phrase, and the second clause contained the repeated-name anaphor. Syntactic prominence was determined by the syntactic position of the antecedent. Antecedents were either single names, shallowly embedded in the sentence's syntactic tree (prominent, accessible), or were part of a conjunctive pair of names, more deeply embedded in the syntactic structure (nonprominent, less accessible). Letter-transposition was used to manipulate accessibility of antecedents according to nonlinguistic, nonsemantic memory principles: that is, antecedents were either presented normally (the read-only condition) or with their initial letters transposed (the generate condition). Examples of the stimuli may be seen in Table 3.

This experiment tests the predictions of both DPT and the ILH. DPT and the ILH make the same prediction for the comparison of repeated names referring to syntactically prominent vs. syntactically nonprominent antecedents: a repeated-name penalty, manifesting as increased amplitude of the N400 effect. However, the theories make divergent predictions for the
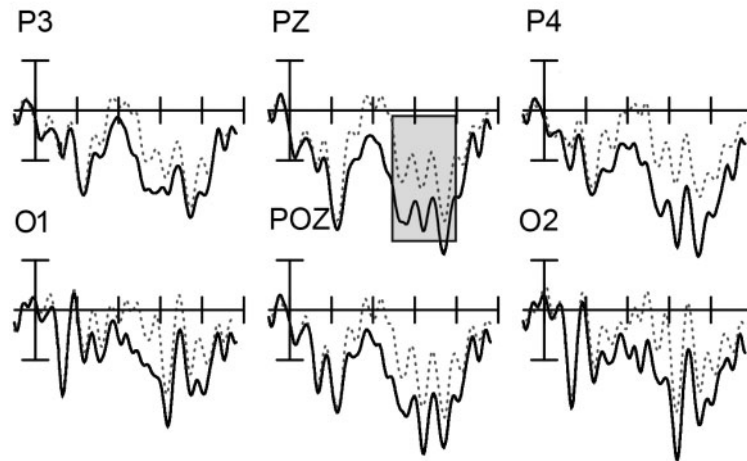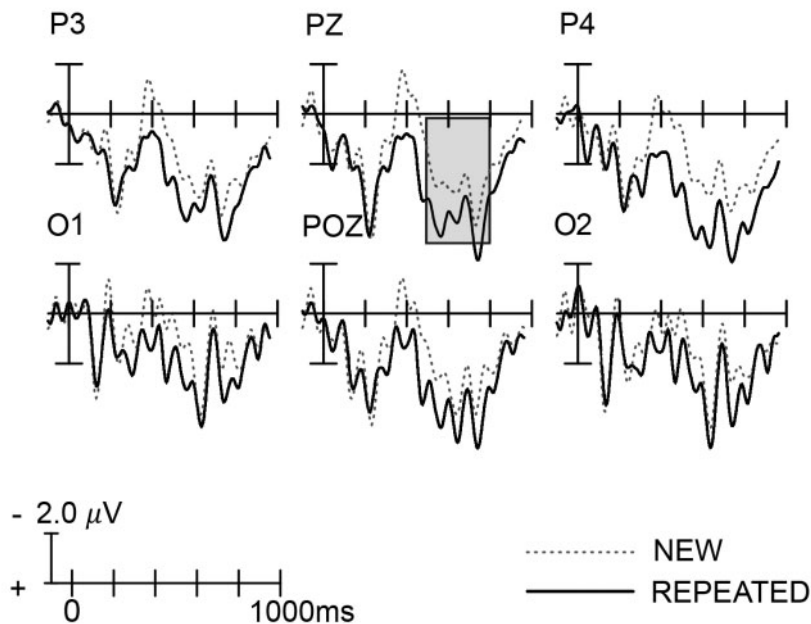
a READ: orchestra **Claire/Robert** each because with **Claire** ....

GENERATE; orchestra night **ICaire/oRbert** each because with **Claire** ....

Figure 4.   (a) Posterior old/new effect: Repetition effects on critical words in the random word lists in Experiment 1. ERPs are shown for the electrodes included in the statistical analyses of the posterior old/new effect, which was performed in the 500–800 ms epoch. ERPs were time-locked to the names in the second half of the word lists that either were or were not repeated from earlier in the list. The boxed area highlights the posterior old/new effect at electrode Pz, and shows an effect of repetition when words were read normally (top) and when they were generated (bottom).

effects of generation. According to DPT, generating an antecedent name does not affect its position in a sentence's syntactic structure; thus, although it may be more accessible in memory, it will not be prominent in the discourse representation. Therefore, repeated reference to a generated but syntactically nonprominent antecedent should not result in a processing problem,

and no repeated-name penalty should be evident. In contrast, the ILH suggests that an explicit repeated name that refers to a highly accessible (i.e., salient) but semantically identical antecedent will result in a processing problem; thus, the ILH suggests that a penalty will result when the repeated name refers to a generated but syntactically nonprominent antecedent, relative to a
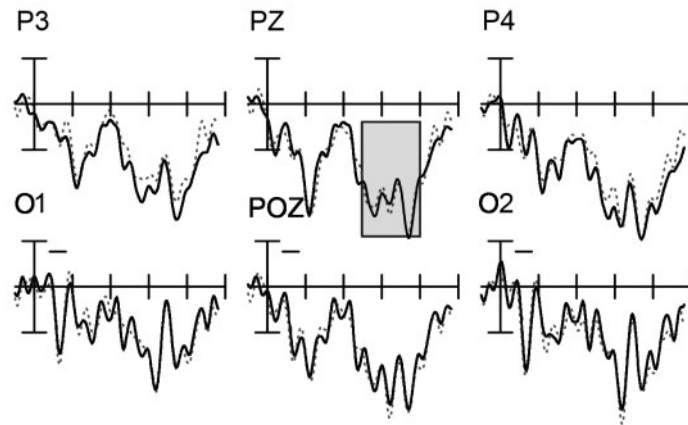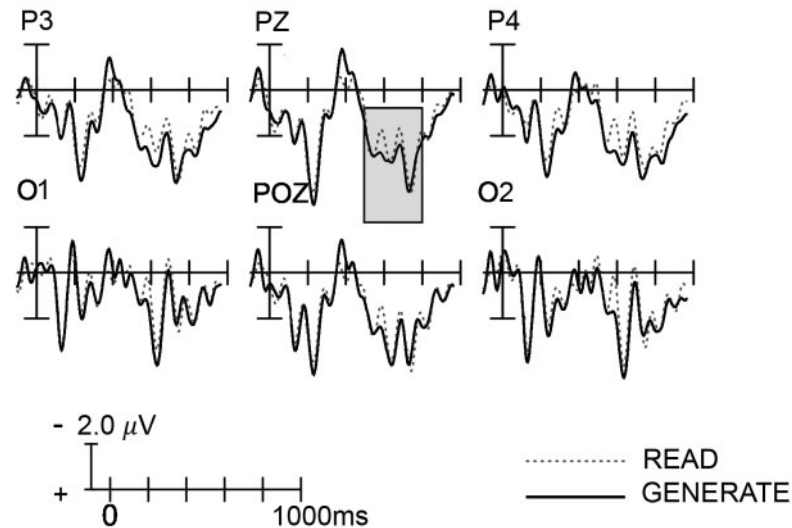
b   REPEATED: orchestra night **Claire/lCaire** each because with **Claire** ....

NOT REPEATED: orchestra night **Robert/oRbert** each because with **Claire** ....

Figure 4.   (b) Posterior old/new effect: There was no effect of generation on critical words in the random word lists in Experiment 1 in the posterior old/new effect region of interest. ERPs are shown for the electrodes included in the statistical analyses of the posterior old/new effect, which was performed in the 500–800 ms epoch. ERPs were time-locked to the names in the second half of the word lists that either were or were not generated earlier in the list. The boxed area highlights the posterior old/new time window at electrode Pz, in both the repeated (top) and unrepeated (bottom) conditions.

normally presented, syntactically nonprominent ante-cedent. Finally, based on the results of Experiment 1, we expected the letter-transposition paradigm to modulate

the anterior old/new effect, and to improve offline recognition memory performance for generated names as shown by familiarity judgments.

Table 2.   Mean corrected remember and familiarity (d') estimates (SE) for Experiment 1.

Item type	Recollection	Familiarity
Repeated name/generate	0.19 (0.03)	0.63 (0.08)
Repeated name/read only	0.14 (0.03)	0.37 (0.11)
No repetition/generate	0.10 (0.02)	0.41 (0.08)
No repetition/read only	0.07 (0.01)	0.43 (0.10)

Table 3.   Examples of experimental items for Experiment 2.

Syntax-prominent/read-only:
Each night **Claire** drove downtown because *Claire* was performing with the symphony orchestra.
Syntax-prominent/generate:
Each night **lCaire** drove downtown because *Claire* was performing with the symphony orchestra.
Syntax-nonprominent/read-only:
Each night **Claire** and Robert drove downtown because *Claire* was performing with the symphony orchestra.
Syntax-nonprominent/generate:
Each night **lCaire** and Robert drove downtown because *Claire* was performing with the symphony orchestra.

Note: antecedent names are boldfaced and critical anaphors are italicised, but were presented to participants without formatting. Generated names were presented in a different font, so that participants knew that the transposed letters were not typographical errors.

Method

Participants

Informed consent was obtained from 24 undergraduates at the University of California, Davis.

Materials

Sentences

Sentence stimuli were adapted from Swaab et al. (2004); see Appendix 1 for a set of examples. Participants received an initial block of practice trials (10 sentences) and then read a total of 240 sentences; 160 of these were experimental sentences and 80 were filler sentences. Each experimental sentence contained two clauses connected by a temporal or causal conjunction (e.g., "when", "after", "so that", "because"). The first clause introduced either a single character or two characters in a conjoined noun phrase. The second clause contained a repeated-name anaphor. When two characters were presented, one was stereotypically male and the other was stereotypically female. Half of the antecedents were male names and half were female names. Each name was used only once within an experimental condition. The filler sentences differed in structure from the experimental sentences, contained names, but did not include anaphors. Half of the filler items contained content words with transposed letters (not names). To encourage comprehension, all sentences were followed by a simple true–false question about the sentences' content.

Four lists were created in the same way as in Experiment 1, in which an experimental item's condition assignment in List 1 determined its condition for the remaining lists, such that each item appeared once per list, in a different condition in each. As in Experiment 1, each list contained 8 blocks of 30 experimental items: 10 filler sentences and 5 sentences from each of the experimental conditions, beginning with three "warm-up" filler sentences.

Recognition test

Participants received a surprise remember/familiar recognition test for all antecedent names. The recognition test consisted of the 160 antecedent names from the experimental sentences and 160 new names that did not appear in any of the sentences. All names were randomised and presented normally (i.e., without transposed letters) in a single block, with each name appearing only once.

Procedure, EEG recording and behavioural sessions, data analysis

Except as noted below, the parameters of this experiment were identical to those of Experiment 1. Participants completed both an EEG recording session and a subsequent surprise recognition test for all antecedent names. ERPs to the critical repeated-name anaphors were analysed for the same ERP components in the same epochs and electrode regions. Trials were screened for artifacts as in the previous experiment; 14.4% of trials were rejected due to artifacts.

Participants were instructed to silently read the sentences presented on the screen for comprehension. As in Experiment 1, each trial began with a fixation cross, which was replaced with words during the presentation of the sentences. Sentences were presented by using RSVP (300 ms presentation, 200 ms ISI). All words appeared in white, 24-point Tahoma font, except for generated antecedents which were presented in white, 24-point Courier New font. The first word of each sentence and all names were capitalised; sentence-final words were presented with a period. A comprehension question appeared 1,000 ms after each sentence-final word and participants were told that they could blink and move their eyes while answering "true" or "false" by pressing a button on a handheld keypad. After participants answered the comprehension question, the prompt "Press for next" appeared on the screen. Participants started the next trial by pressing

any button. Average comprehension accuracy was 95.22%.

Participants were given a short break between each of the eight experimental blocks. Following the final block, participants received instructions for the recognition test, administered as in Experiment 1.

Results

N400 effect

Grand average ERPs to the anaphors are presented in Figures 5–7. The omnibus ANOVA in the N400 time window (300–500 ms) revealed no main effect of generation, $F(1, 23) = 1.14$, $p = .297$. Although there was no main effect of syntactic prominence, $F < 1$, we observed a syntactic prominence × electrode interac-

tion that approached conventional significance, $F(9, 207) = 2.43$, $p = .0530$. Finally, the interaction of syntactic prominence and generation was significant, $F(1, 23) = 4.43$, $p = .046$. Pairwise comparisons were performed for all conditions (syntactic prominence and generation).

Syntactic prominence

In the read-only conditions, we observed a significant effect of syntactic prominence, $F(1, 23) = 4.67$, $p = .0410$. Repeated names that referred to syntactically prominent antecedents elicited a more negative waveform than those referring to an antecedent that was a nonprominent member of a conjoined pair of names (e.g., *Claire* vs. *Claire and Robert*). This is the electro-

Figure 5.   (a) N400 effect: The effect of syntactic prominence on the processing of subsequent coreferential repeated names in Experiment 2. ERPs are shown for the electrodes included in the statistical analyses of the N400 effect, which was performed in the 300–500 ms epoch. ERPs were time-locked to the repeated-name anaphors with antecedents that either were or were not syntactically prominent. The boxed area highlights the N400 repeated-name penalty at electrode Pz in the normally read conditions (top); this effect is absent in the generation conditions (bottom).

b SINGLE: Each night **Claire/lCaire** drove dowtown because **Claire** ....

CONJOINED: Each night **Claire/lCaire and Robert** drove downtown because **Claire** ....

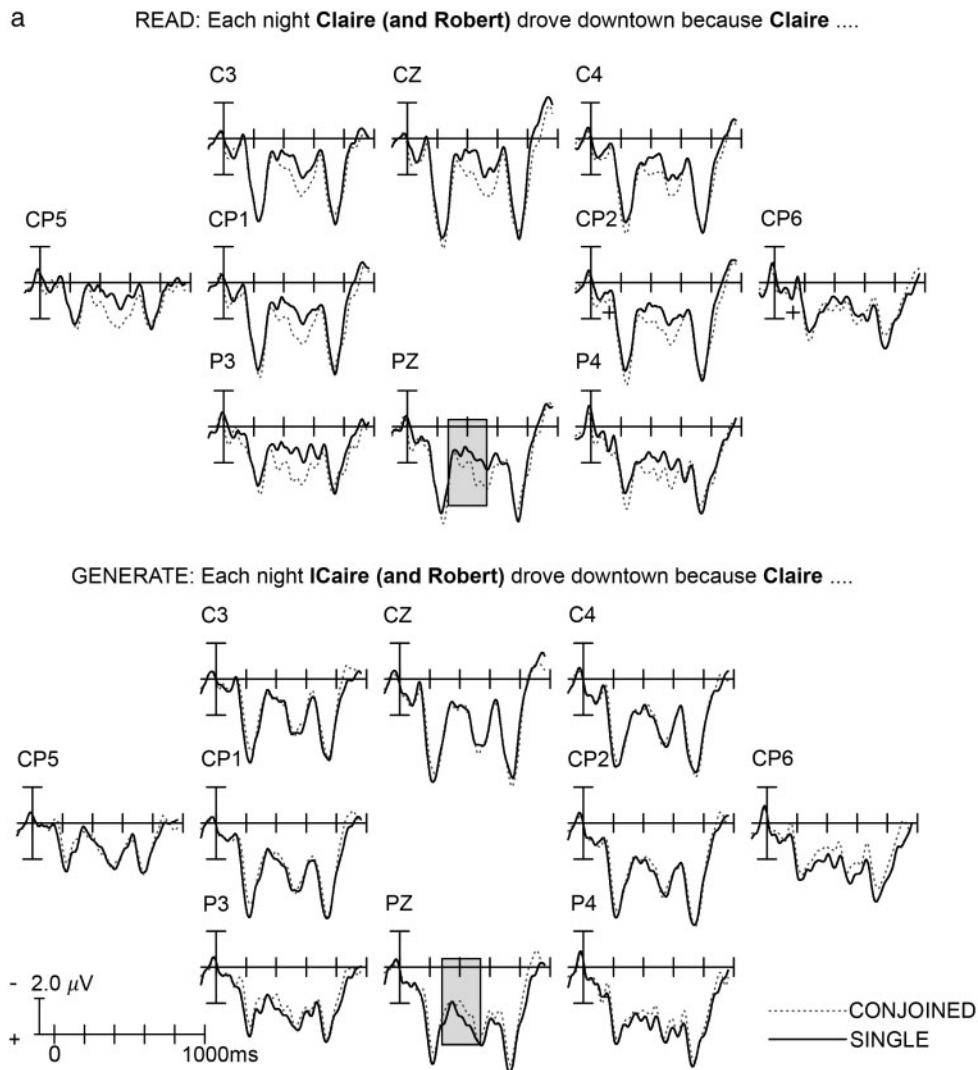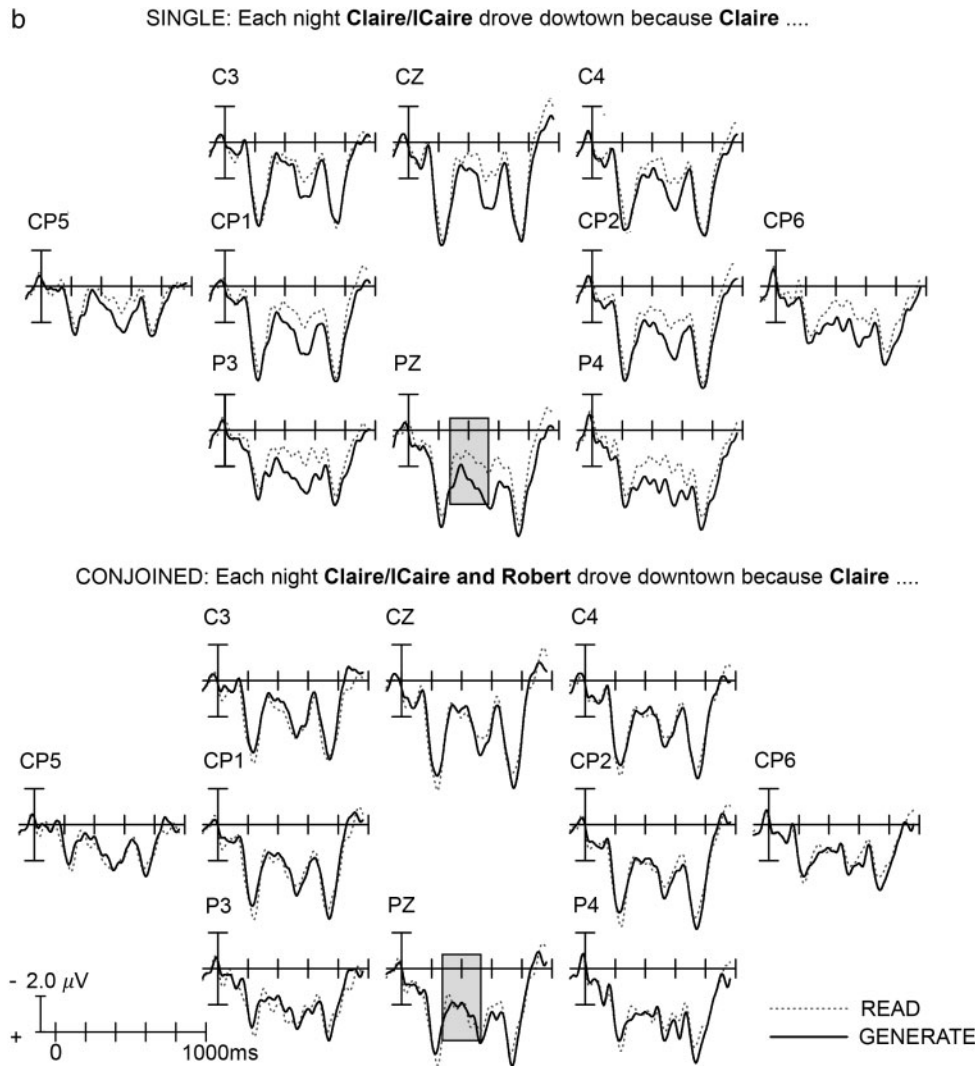
Figure 5.   (b) N400 effect: The effect of generation on the processing of subsequent coreferential repeated names in Experiment 2. ERPs are shown for the electrodes included in the statistical analyses of the N400 effect, which was performed in the 300–500 ms epoch. ERPs were time-locked to the repeated-name anaphors with antecedents that either were or were not generated. The boxed area highlights the N400 effect at electrode Pz in the syntactically prominent conditions (top); this effect is absent in the syntactically nonprominent conditions (bottom).

physiological repeated-name penalty. In contrast, the corresponding generation conditions (e.g., *lCaire* vs. *lCaire and Robert*) showed no evidence of a repeated-name penalty ($F < 1$). These contrasts are depicted in Figure 5a.

Generation

The contrast of repeated-name processing in the syntactically nonprominent conditions (in which the embedded antecedent either was or was not generated, e.g., *Claire and Robert* vs. *lCaire and Robert*) was the crucial comparison for evaluating the predictions of DPT and the ILH; our analysis showed no effect of generation for these two conditions ($F < 1$). However, the syntactically prominent conditions (e.g., *lCaire* vs. *Claire*) showed a significant reduction in the amplitude

of the N400 in response to repeated names with generated antecedents relative to those with antecedents that were read normally, $F(1, 23) = 4.50$, $p = .045$. The generation-based comparisons are shown in Figure 5b.

Anterior old/new effect

We observed no main effect of generation, $F < 1$, but the effect of syntactic prominence approached conventional significance, $F(1, 23) = 4.24$, $p = .051$; the two factors did not interact. A subsequent ANOVA on an earlier time window (300–550) revealed that the effect of generation and the interaction of generation with syntactic prominence remained nonsignificant (Figure 6b), $Fs < 1$, but the effect of syntactic prominence reached significance, $F(1, 23) = 4.34$, $p = .0485$ (Figure 6a). Thus, when an
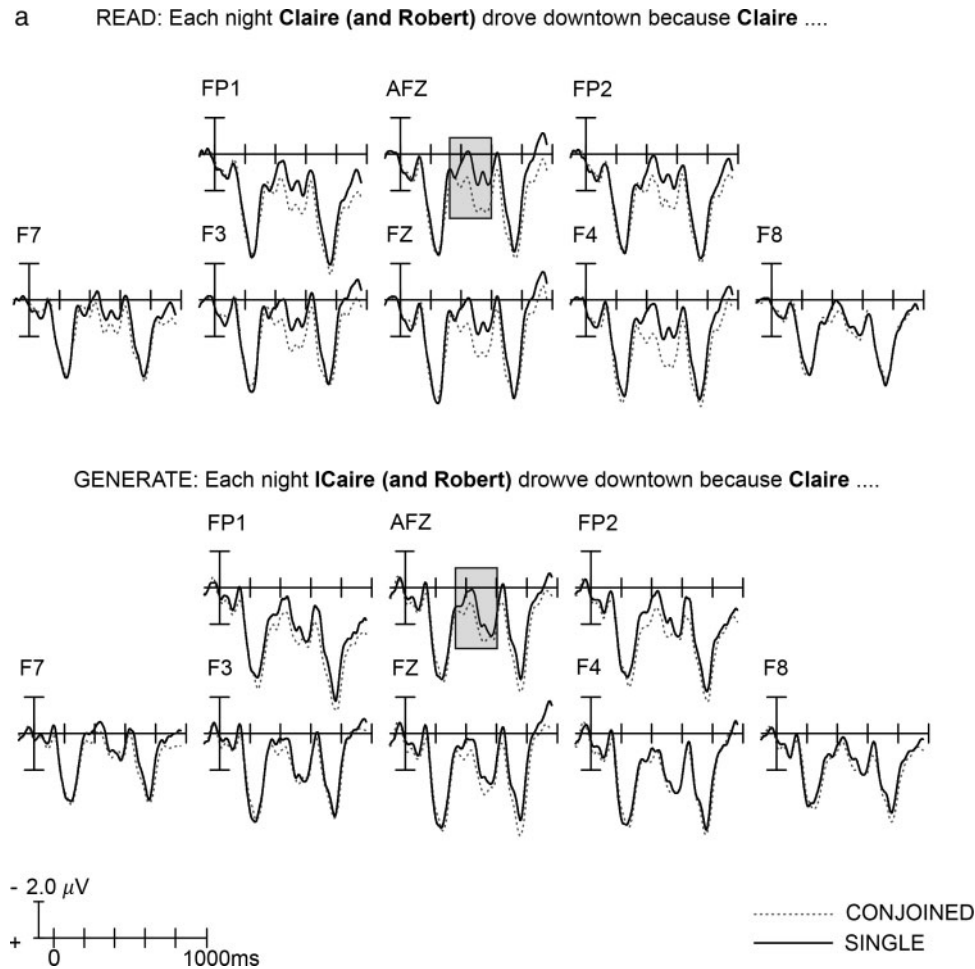
Figure 6. (a) Anterior old/new effect: The effect of syntactic prominence on the recognition of subsequent coreferential repeated names in Experiment 2. ERPs are shown for the electrodes included in the statistical analyses of the anterior old/new effect, which was performed in the 300–550 ms epoch. ERPs were time-locked to the repeated names with antecedents that either were or were not generated. The boxed area highlights the anterior old/new effect at electrode AFz, and shows an effect of syntactic prominence when the repeated names referred to antecedents that were read normally (top) and generated (bottom).

antecedent was syntactically nonprominent, a repeated-name anaphor elicited a more positive-going waveform than when its antecedent was syntactically prominent, regardless of whether or not the antecedent was generated.

Posterior old/new effect

There was a main effect of generation, $F(1, 23) = 4.95$, $p = .036$. The effect of syntactic prominence was not significant, $F < 1$, but there was a significant interaction of syntactic prominence $\times$ electrode, $F(5, 115) = 6.51$, $p = .003$. There was no interaction between syntactic prominence and generation, $F < 1$. Thus, when an antecedent was generated, a repeated-name anaphor elicited a positive shift in the waveforms relative to names that were not generated, regardless of whether the antecedent was syntactically prominent or not (Figure 7b). In addition, the syntactic

prominence $\times$ electrode interaction offers some evidence that repeated names following prominent antecedents also elicited a positive shift relative to those followed conjoined antecedents. This effect is depicted in Figure 7a.

Recognition test

Recognition performance appears in Table 4. For familiarity judgments, our analyses yielded no reliable effects of generation, $F(1, 23) = 1.984$, $p = .172$, or syntactic prominence, $F < 1$; in addition, the factors did not interact, $F < 1$. In contrast, for remember judgments there were main effects of both generation, $F(1, 23) = 10.329$, $p = .004$, and syntactic prominence, $F(1, 23) = 4.686$, $p = .041$, but these factors again did not interact, $F < 1$. Thus, generating antecedent names from their transposed forms enhanced recollection irrespective of syntactic prominence; furthermore,

b SINGLE: Each night **Claire/lCaire** drove downtown because **Claire** ....

CONJOINED: Each night **Claire/lCaire and Robert** drove downtown because **Claire** ....
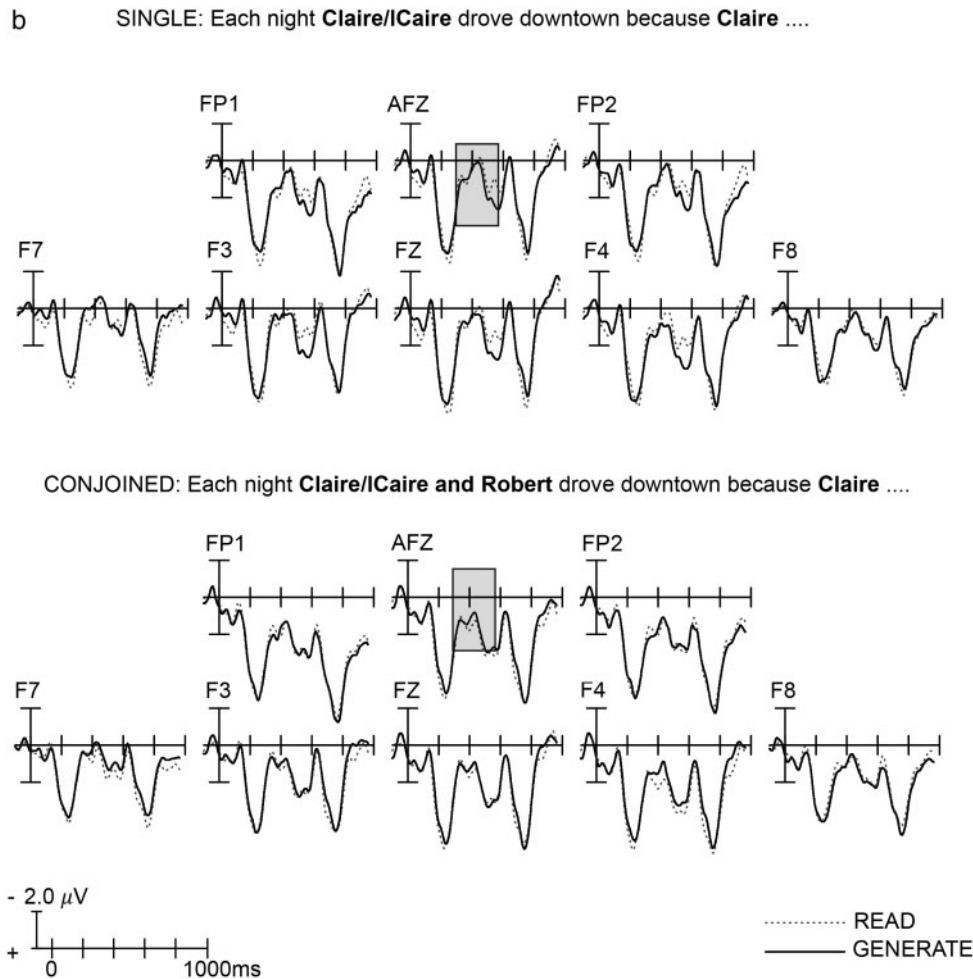
Figure 6. (b) Anterior old/new effect: There was no effect of generation on the recognition of subsequent coreferential repeated names in Experiment 2. ERPs are shown for the electrodes included in the statistical analyses of the anterior old/new effect, which was performed in the 300–550 ms epoch. ERPs were time-locked to the repeated names with antecedents that either were or were not syntactically prominent. The boxed area highlights the anterior old/new time window at electrode AFz in both the syntactically prominent (top) and nonprominent (bottom) conditions.

antecedent names that were syntactically prominent were better recollected than those that were embedded in a conjoined noun phrase.

Discussion

Both DPT and the ILH predicted a repeated-name penalty in the read-only conditions. Previous ERP research (Camblin et al., 2007; Ditman et al., 2009; Ledoux et al., 2007; Swaab et al., 2004) has shown that this penalty is indexed by the N400 effect, with repeated names with syntactically nonprominent referents eliciting reduced N400 amplitude compared to those with syntactically prominent referents. We observed this electrophysiological hallmark of the repeated-name penalty (Figure 5a, top), replicating previous findings. Both our online and offline recognition memory data also replicate previous findings that syntactically prominent information is more easily

retrieved than syntactically nonprominent information (e.g., Birch & Garnsey, 1995; Birch et al., 2000; Birch & Rayner, 2010; Sturt et al., 2004; Ward & Sturt, 2007): both syntactic prominence and generation resulted in increased offline remember judgments (reflecting retrieval on the basis of recollection, rather than familiarity) and both conditions elicited an online posterior old/new effect (also associated with recollection, rather than familiarity). Taken as whole, these results suggest that syntactic prominence increased the online accessibility of the antecedent memory trace, paradoxically resulting in integration difficulty during repeated name processing.

In addition to the N400 repeated-name penalty, our analysis of the anterior old/new regions of interest (ROI) revealed an anterior maximum in the N400 time window (Figure 6). However, this finding was driven not by generation, but by syntactic prominence. This is,

a READ: Each night **Claire (and Robert)** drove downtown because **Claire** ....
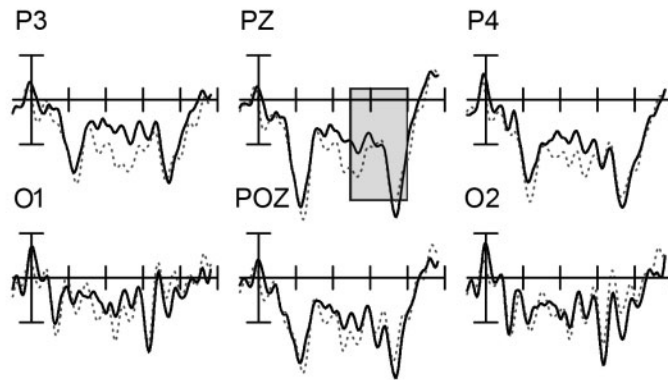
GENERATE: Each night **lCaire (and Robert)** drove downtown because **Claire** ....
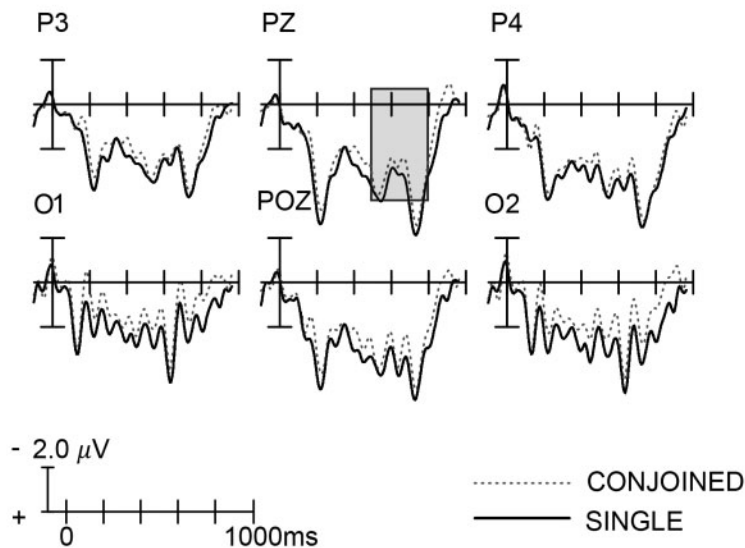

Figure 7.   (a) Posterior old/new effect: The effect of syntactic prominence on the recognition of subsequent coreferential repeated names in Experiment 2. ERPs are shown for the electrodes included in the statistical analyses of the posterior old/new effect, which was performed in the 500–800 ms epoch. ERPs were time-locked to the repeated names with antecedents that either were or were not generated. The boxed area highlights the posterior old/new effect at electrode Pz when the repeated names referred to antecedents that were read normally (top) and generated (bottom).

in part, consistent with our offline recognition test results: generation elicited no offline increase in familiarity judgments, and so no generation-based anterior old/new effect was expected. However, syntactic prominence also did not affect offline familiarity performance, and yet we observed a frontal negative shift to repeated names referring to prominent antecedents. There is some reason to believe that this frontal effect is qualitatively different from the anterior effect observed in Experiment 1, which we suggested indexes recognition memory processes. First, this effect has an earlier onset latency than the anterior effect observed in the earlier experiment. In addition—and as

claimed by both DPT and the ILH —we note that repeated-name anaphors first evoke new representations, which must then be integrated with an antecedent representation, with greater processing costs associated with syntactic prominence, which requires working memory resources. Previous language research has shown that frontal negative shifts are associated with each aspect of our prominent/nonprominent comparison: working memory processes (e.g., Fiebach, Schlesewsky, & Friederici, 2002; King & Kutas, 1995; Münte, Schiltz, & Kutas, 1998); semantic integration processes (Sitnikova, Holcomb, Kiyonaga, & Kuperberg, 2008; Sitnikova, Kuperberg, & Holcomb, 2003);
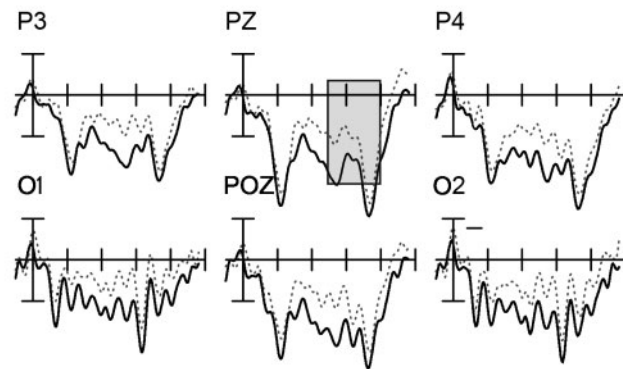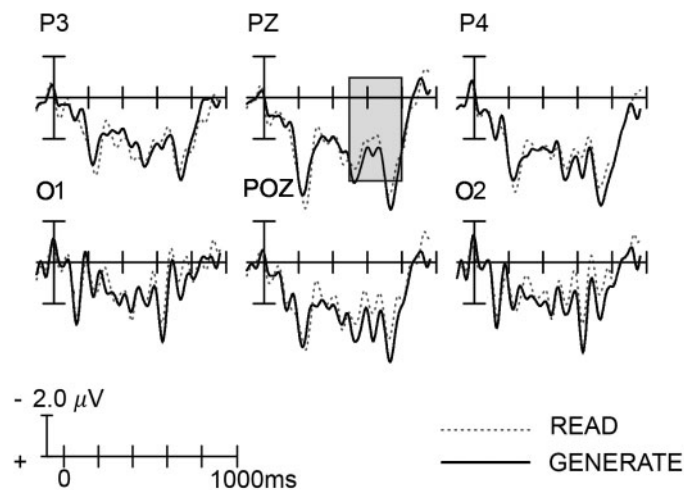
b   SINGLE: Each night **Claire/lCaire** drove downtown because **Claire** ....

CONJOINED: Each night **Claire/lCaire and Robert** drove downtown because **Claire** ....

Figure 7.   (b) Posterior old/new effect: The effect of generation on the recognition of subsequent coreferential repeated names in Experiment 2. ERPs are shown for the electrodes included in the statistical analyses of the posterior old/new effect, which was performed in the 500–800 ms epoch. ERPs were time-locked to the repeated names with antecedents that either were or were not syntactically prominent. The boxed area highlights the posterior old/new effect at electrode Pz, and shows a generation effect when the repeated names referred to antecedents that were syntactically prominent (top) and nonprominent (bottom).

and concrete noun processing, a category that typically includes proper names (Holcomb, Kounios, Anderson, & West, 1999; Kounios & Holcomb, 1994; Swaab, Baynes & Knight, 2002; West & Holcomb, 2000, 2002).

The critical comparison in the syntactically non-prominent conditions (in which the antecedent was embedded in a conjoined noun phrase) provided no evidence that generation modulated online coreferential processing (Figure 5b, bottom). That is, generation, unlike syntactic prominence, did not result in a repeated-name penalty (i.e., no N400 effect when repeated names referred to generated, syntactically nonprominent antecedents relative to normally presented, syntactically nonprominent antecedents). However, the posterior old/new effects suggest that both

generation and syntactic prominence rendered antecedent memory traces more accessible during processing of the repeated name. According to the ILH, the cost of processing of an anaphor is determined by two factors: the amount of semantic detail in the antecedent representation and its accessibility (salience) in memory. Since letter-transposition seems to have resulted in increased online accessibility of the antecedent while holding semantic content constant (consistent with Kinoshita, 1989; Mulligan, 2002a, 2006, 2011), referring to it with a semantically identical anaphor should have been more difficult. Thus, this result is unexpected in light of the ILH. Rather, this result is in line with DPT, which suggests that position in syntactic structure is critical to how repeated

Table 4.   Mean corrected remember and familiarity (d') estimates (*SE*) for Experiment 2.

Item type	Recollection	Familiarity
Syntax-prominent/generate	0.17 (0.03)	0.56 (0.09)
Syntax-prominent/read-only	0.11 (0.02)	0.47 (0.06)
Syntax-nonprominent/generate	0.17 (0.03)	0.61 (0.09)
Syntax-nonprominent/read-only	0.08 (0.01)	0.50 (0.08)

references are processed. These data indicate that enhancing the distinctiveness of the antecedent memory trace in a nonsemantic way, while facilitating retrieval, does not render it prominent in the discourse representation, and thus does not elicit a repeated-name penalty.

Turning to the ancillary contrasts, we observed a generation effect in the comparison of the syntactic prominence conditions, in which repeated names referring to generated antecedents elicited a reduced N400 effect compared to those with antecedents that were read normally (Figure 5b, top). This is the opposite of what might be expected according to the ILH: the same disparity between accessibility and semantic content of the anaphor that predicts a repeated-name penalty for syntactically nonprominent conditions also predicts the same penalty for syntactically prominent conditions. However, this finding also does not follow from DPT, inasmuch as there was no difference in the antecedents' position in the syntactic tree; as such, DPT predicts no processing difference between these conditions. One possible explanation for this effect is that engaging in the generation task improved memory accessibility, but prevented a full syntactic parse, such that single names that were generated were not integrated into the syntactic tree. However, incomplete parsing might be expected to result in impaired comprehension, and this was not the case: comprehension rates were uniformly high, with no accuracy differences among the conditions (all *F*s < 1). In addition, if generation disrupted normal syntactic processing, this effect should also have been observed in the comparison of the conjoined conditions, resulting in a main effect of generation; instead, no such difference was evident in the conjoined comparison, and the main effect of generation was nonsignificant. A second possibility is that this N400 reflects facilitated referential access. However, given that no differences in the ERPs were observed between the nonprominent/generation, nonprominent/read only, and prominent/generation conditions, this is dubious evidence for enhanced coreferential processing. Finally, it may be that the generation task improved memory access at the expense of discourse-level processing, perhaps due to some qualitative difference at encoding. That is, single names that were generated, even when focused by syntax, were

not encoded prominently *in the discourse representation*. If the addition of the generation task rendered these antecedents nonprominent in the discourse, repeated-name anaphors that refer to them would be processed without difficulty. This N400 effect would, therefore, still be a repeated-name penalty, this time reflecting difficulty processing repeated names referring to syntactically-prominent-and-normally-presented antecedents relative to those referencing syntactically-prominent-and-generated antecedents. This interpretation has the additional benefit of explaining the absence of a repeated-name penalty in the generation conditions (also not predicted by either the ILH or DPT; Figure 5a, bottom), which would be the obvious result if discourse prominence did not differ across conditions. Thus, this interpretation—that this effect is a repeated-name penalty due to impeded referential access in the syntactic prominence/read only condition—better fits the pattern of our data.

Finally, we have reported electrophysiological evidence suggesting that both manipulations improved online availability (Figure 7), and behavioural evidence confirming that both manipulations improved offline retrieval of antecedent representations. However, the effect of generation in this experiment differs from that observed in Experiment 1. In that experiment, generation only resulted in a familiarity-based memory benefit. In the current experiment, generation effects manifested on online and offline measures associated with recollection, and not familiarity. As we previously noted, recognition based on recollection is thought to reflect a retrieval experience that includes episodic information; otherwise, successful retrieval will be based on familiarity (Gardiner, 1988; Tulving, 1985; Yonelinas, 2002). Reder, Park, and Kieffaber (2009) have developed a computational model of recognition memory that suggests that recollection depends on the activation of an episodic "node" during encoding. Importantly, the activation of an episode node depends upon contextual information available during encoding, including "aspects of the context that are idiosyncratic to a particular stimulus presentation" (Reder et al., 2009, p. 25). Thus, the differences in the experimental materials (word lists in Experiment 1, sentences in Experiment 2) may account for the different patterns of recognition performance. In the word lists in the first

experiment, there was no requirement for participants to establish a connection between the second iteration of name and the first. Participants either read or generated a name in a list, which was unconnected to any other word in the list. In contrast, in the sentences in the second experiment, our participants knew that the names they encountered in the sentences' first clauses might subsequently be retrieved during sentence comprehension. As such, they may have encoded episodic details that would allow the integration of a repeated-name anaphor with an identifiable, previously established representation. Such episodic details would form the basis for retrieval by means of recollection, but not familiarity. Put another way, the task and materials in Experiment 2 licensed activation of episodic links that ultimately facilitated the joining of mental representations in a qualitatively different way than did the task and materials in Experiment 1. This explanation is consistent with a growing number of studies using sentence and discourse stimuli in which effects manifest on recollection, but not on familiarity (e.g., Brandt, Cooper, & Dewhurst, 2005; Long, Johns, & Jonathan, 2011; Long & Prat, 2002; Long, Prat, Johns, Morris, & Jonathan, 2008; Long, Wilson, Hurley, & Prat, 2006; Mirandola, Del Prete, Ghetti, & Cornoldi, 2010; Singer & Remillard, 2004).

General discussion

Discourse coherence depends critically on comprehenders' ability to keep track of who is doing what to whom. This requires efficient, accurate coreferential processing, in which anaphors elicit access to entities in the discourse model, allowing it to be updated and actively maintained. Thus, accessibility is central to most theories of coreference, in which the general consensus is that increased accessibility facilitates referential access (Gernsbacher, 1989, 1990; McKoon & Ratcliff, 1980; Stewart et al., 2000). Although many "linguistic" factors modulate referential access, the goal of the current study was to determine the effect—if any—of nonlinguistic factors. We used both language-specific (syntax) and memory-specific (generation) manipulations to affect the psychological status of antecedent names, and recorded event-related potentials to subsequent anaphors. Our results showed that both manipulations improved online availability of antecedent representations, as demonstrated by the posterior old/new effects of generation and syntactic prominence; that this improved availability extended to performance on subsequent, offline recognition memory tests; but that only the linguistic factor had consequences for online coreferential access, indexed by the N400 effect.

These results suggest that a more nuanced approach to referential "accessibility" is warranted, which takes into account a qualitative difference between being available in memory, and being accessible for the purposes of coreferential processing. To our knowledge, there is only one other study addressing the distinction between the referential accessibility and the availability of an antecedent representation in memory. In that study, Foraker and McElree (2007) used Speed-Accuracy Tradeoff (SAT) modelling to test whether or not syntactic prominence improved the likelihood of retrieving an anaphor's referent, and whether syntactic prominence affected the speed with which the antecedent representation was accessed. Using syntactic clefting (it- and what-clefts) to render antecedent entities prominent, Foraker and McElree found that clefted antecedents were more likely to be retrieved than those that were not. But, although such antecedents were more available, they found no evidence that syntactic prominence affected accessibility (indexed by speed of processing, rather than likelihood of retrieval). Rather, they found that the form of the referring expression modulated referential accessibility: the use of a gendered pronoun (e.g., "he" or "she") increased antecedent accessibility relative to a more ambiguous pronoun (e.g., "it").

This finer-grained distinction among memory processes highlights the fact that theories of coreference have generally not made close contact with memory research, and thus do not incorporate much of what is known about the memory mechanisms that support sentence comprehension. For example, and contrary to accounts of anaphor resolution that assign a decisive role to working memory, there is increasing evidence that the amount of information that is actively maintained during sentence comprehension is severely limited, perhaps only to the most recently parsed item (McElree, 2000; McElree, Foraker, & Dyer, 2003; for review see McElree, 2006; see also Lewis, Vasishth, & Van Dyke, 2006, for a computational implementation); this mirrors recent scholarship in the memory literature (McElree, 2001; for review see Cowan, 2006). Given this, antecedent entities must, therefore, be *passively* represented in memory, and so must be retrieved when an anaphor is encountered. Thus, and also in line with observations from the memory literature, manipulations of the level of activation of a representation affect its strength (i.e., distinctiveness) in memory, which in turn modulates availability, but not accessibility (see, e.g., Nairne, 1996). Furthermore, there is increasing evidence that retrieval from memory is guided by a content-addressable mechanism that, rather than searching among items in memory, directly accesses the relevant representations via the match between retrieval cues and encoded information (for review, see

McElree, 2006; see also McElree & Dosher, 1989). The match between the features of the retrieval cue and features of the to-be-retrieved item determines how efficiently that item may be accessed, especially in the presence of other, potentially similar items in memory; interference from such items has been proposed as a significant obstacle to successful retrieval and, consequently, comprehension (for review, see Van Dyke & Johns, 2012).

Consistent with Foraker and McElree (2007), our results are in line with this account of the relation between activation and availability: representations that were more distinctive, either by virtue of generation or syntactic prominence, were more available during both online and offline processing. The results of Foraker and McElree (2007) also support a cue-based retrieval mechanism: in their study, anaphoric form modulated accessibility, with faster access for gendered pronouns relative to neutral pronouns. Pronouns like "he", for example, include information about the animacy (living), number (single entity), and biological sex (male) of the antecedent representation, which unambiguously identified the referent in their stimuli. In contrast, "it" has a much larger number of potential antecedents ("it" can refer to situations rather than single entities; "it" need not only refer to inanimate objects), but offers only a single source of information (number), which leaves it more vulnerable to interference effects; furthermore, "it" does not have to be an anaphor at all, which could lead to misinterpretation ("It began to rain"). Thus, Foraker and McElree argued that the semantic content of the gendered pronouns increased the correspondence of anaphor–antecedent features, which reduced potential interference due to referential ambiguity, thus facilitating referential access.

However, Foraker and McElree (2007) found no evidence that syntactic prominence affected antecedent accessibility. Our results, in contrast, indicate the opposite: that syntactic prominence *does* have cognitively important consequences for referential access. This is likely due to a critical difference between Foraker and McElree (2007) and the current study: whereas their experiments focused solely on reduced referring expressions (pronouns), ours was an investigation of repeated-name anaphors. Moreover, the possibility that repeated coreference might interact with syntax was not unanticipated: Foraker and McElree explicitly acknowledged that, although syntactic prominence did not place antecedent entities in a "special cognitive state" in their study, such a state might be induced by coreferential repeated names. What is surprising, however, is that rather than facilitating accessibility, the close feature match between the repeated-name anaphor and its antecedent

resulted in *impaired* access: the repeated-name penalty. This processing decrement cannot be explained by cue mismatch, since the features of the anaphor and antecedent matched exactly; it seems unlikely that the penalty can be explained by interference, since it manifests when there are no nonantecedent entities that might potentially interfere with retrieval; and finally, as we have shown, the penalty also cannot be explained by differences in the level of antecedent activation.

How then to explain the repeated-name penalty? One important aspect of the penalty was suggested by Swaab and colleagues (Swaab et al., 2004), and received support in this study via the contrast between the N400 effects observed in the first and second experiments: namely, that the repeated-name penalty reflects not the operation of memory mechanisms, but rather the effect of syntactic prominence *overriding* such mechanisms. If this is the case, then memory mechanisms alone may be unable to adequately characterise the penalty, because they are not its source; rather, the explanation may rely directly on language-specific factors. Turning to the theoretical models of coreferential processing we tested, only DPT proposes that syntactic prominence confers a "special cognitive state" on an antecedent, which subsequently interacts with repeated coreferential expressions to elicit a repeated-name penalty. However, DPT also incorporates a "search" mechanism that is at odds with the principle of content-addressable direct access. In contrast, the ILH describes the penalty in terms of the relative differences in the activation of antecedents and anaphors; however, in light of what is now known about the memory mechanisms underpinning coreference, as well as studies such as Foraker and McElree (2007) and our own, such an account seems untenable as an explanation for modulating referential *access*. It is apparent that both theories of coreference require further development: both must better integrate the evidence from the memory literature with their psycholinguistic elements.

This will be increasingly important in light of research investigating commonly used, more contextually strategic ways to enhance the representation of discourse information. For example, prosodic stress improves probe verification latency for words that are not anaphoric (Gernsbacher & Jescheniak, 1995; Sanford, Sanford, Molle, & Emmott, 2006). More recently, research has shown that highlighting words in discourse using devices such as italicisation improves memory for the words (e.g., Sanford et al., 2006). These effects may reflect the same type of elaboration as occurs in our letter-transposition paradigm. As such, our finding that repeated names that referred to generated, syntactically prominent antecedents (relative

to prominent antecedents that were read normally) were more easily processed may be relevant to this kind of research. Our interpretation of this effect (that engaging in nonlinguistic activity during encoding ultimately had consequences for the construction of a discourse representation) suggests that such research may be assessing recognition memory, rather than language-specific effects. However, because such para-linguistic cues are often related to message-level meaning, their effect on discourse-level processes may differ. Strategic devices such as italicisation or prosodic stress may influence coreferential processing, perhaps by influencing the discourse status of the referent, or perhaps by modulating anaphoric expressions' influence on referential accessibility. Whether such devices affect readers' discourse representations—how text information is represented and retrieved at later times, once online comprehension is complete—is an open question for future research.

Finally, the results of this study also contribute to our understanding of inconsistencies in the literature on coreferential processing. Many studies have supported the view that coreferential access is facilitated when an anaphor and its antecedent have many features in common (e.g., Chang, 1980; Corbett & Chang, 1983; Gernsbacher, 1989; Greene, McKoon, & Ratcliff, 1992; MacDonald & MacWhinney, 1990). Participants in these studies read or heard sentences that were periodically interrupted by a probe word (usually a name), and verified whether the probe word had appeared previously in the sentence. Faster responses to probes after repeated names were interpreted as evidence that antecedents were more accessible after a repeated name than before it. The results of these studies run counter to the many demonstrations of the repeated-name penalty, and it is notable that the penalty has been demonstrated using diverse paradigms including probe verification, self-paced reading, coherence judgments, and priming (Gordon et al., 1993; see also Cloitre & Bever, 1988; Gordon & Hendrick, 1997). Gordon, Hendrick, and Foster (2000) have criticised the probe verification paradigm's effectiveness as a tool for examining coreferential processing, showing that faster reaction times to proper name probes following both repeated names that are coreferential *and* repeated names that are not. For example, reaction time to the name *Bill* is equally enhanced at the end of sentences such as (2a) and (2b), even though *Bill* is not coreferential in the second sentence:

2a. Bill handed John some tickets to a concert but Bill took them back immediately.
2b. Bill Jones handed John Smith some tickets to a concert but Bill Darden said they were counterfeit.

Gordon and colleagues assert that this finding reflects a strategy that they term *probe-list memory*, and argue that principles of recognition memory explain this processing advantage. The results of the current study extend this line of reasoning: we suggest that facilitated reaction times to antecedent probes following repeated names likely reflect increased availability in memory, rather than enhanced coreferential access. However, despite additional evidence that other phenomena attributed to coreferential processing may instead simply be by-products of online recognition memory processes (e.g., suppression effects, in which reaction times to probes of nonantecedent names are slowed following repeated-name anaphors; Dopkins & Ngo, 2002, 2005; Dopkins, Ngo, & Sargent, 2006; Dopkins & Nordlie, 2011), some research has suggested that the probe verification paradigm may sometimes be sensitive to discourse factors (e.g., Dopkins & Ngo, 2005). At minimum, the current study suggests that the choice of experimental paradigm that is used to study coference should be considered carefully; tasks that tap memory processes may produce results that are based on recognition memory (encoding and retrieval) phenomena, whereas tasks that tap linguistic processes may produce very different results, reflecting language-related factors.

Note

1. Our characterization of the remember/know task is expressed in terms of dual-process models of memory (e.g., Yonelinas, 2002; see also Surprenant & Neath, 2009). There are also single-process models, in which recollection is assumed to reflect the retrieval of strong, content-rich memories, whereas familiarity is associated with weaker, less specific memories (e.g., Donaldson, 1996; Dunn, 2004; Wixted, 2007). Our predictions do not depend on the validity of the dual-process model approach; for example, the distinction between *recollection* and the retrieval of *strong, content-rich memories* is not central to our predictions.

References

Almor, A. (1999). Noun-phrase anaphora and focus: The informational load hypothesis. *Psychological Review, 106*, 748–765.

Almor, A. (2004). A computational investigation of reference in production and comprehension. In J. C. Trueswell & M. K. Tanenhaus (Eds.), *Approaches to studying world-situated language use: Bridging the language-as-product and language-as-action traditions* (pp. 285–301). Cambridge, MA: MIT Press.

Almor, A. (2005). Phonological and semantic interference in serial recall: Bringing in the lexicon. Paper presented at the 46th annual meeting of the Psychonomic Society, Toronto, Canada.

Almor, A., & Nair, V. (2007). The form of referential expressions in discourse. *Language and Linguistics Compass, 1*(1–2), 84–99.

Almor, A., Smith, D. V., Bonilha, L., Fridriksson, J., & Rorden, C. (2007). What is in a name? Spatial brain circuits are used to track discourse references. *Neuroreport, 18*(12), 1215–1219.

Bertsch, S., Pesta, B. J., Wiscott, R., & McDaniel, M. A. (2007). The generation effect: A meta-analytic review. *Memory & Cognition, 35*(2), 201–210.

Bever, T. G., & Townsend, D. (1979). Perceptual mechanisms and formal properties of main and subordinate clauses. In W. E. Cooper & E. C. T. Walker (Eds.), *Sentence processing: Psycholinguistic studies presented to Merrill Garrett* (pp. 159–226). Hillsdale, NJ: Erlbaum.

Birch, S. L., Albrecht, J. E., & Myers, J. L. (2000). Syntactic focusing structures influence discourse processing. *Discourse Processes, 30*, 285–304.

Birch, S. L., & Garnsey, S. M. (1995). The effect of focus on memory for words in sentences. *Journal of Memory and Language, 34*, 232–267.

Birch, S. L., & Rayner, K. (2010). Effects of syntactic prominence on eye movements during reading. *Memory & Cognition, 38*(6), 740–752.

Brandt, K. R., Cooper, L. M., & Dewhurst, S. A. (2005). Expertise and recollective experience: Recognition memory for familiar and unfamiliar academic subjects. *Applied Cognitive Psychology, 19*(9), 1113–1125.

Camblin, C. C., Ledoux, K., Boudewyn, M. A., Gordon, P. C., & Swaab, T. Y. (2007). The interplay of discourse congruence and lexical association during sentence processing: Evidence from ERPs and eye tracking. *Journal of Memory and Language, 56*(1), 103–128.

Chang, F. R. (1980). Active memory processes in visual sentence comprehension: Clause effects and pronominal reference. *Memory and Cognition, 8*, 58–64.

Chwilla, D. J., Brown, C. M., & Hagoort, P. (1995). The N400 as a function of the level of processing. *Psychophysiology, 32*, 274–285.

Clark, H. H., & Sengul, C. J. (1979). In search of referents for nouns and pronouns. *Memory and Cognition, 7*, 35–41.

Cloitre, M., & Bever, T. G. (1988). Linguistic anaphors, levels of representation, and discourse. *Language and Cognitive Processes, 3*, 293–322.

Corbett, A. T., & Chang, F. R. (1983). Pronoun disambiguation: Accessing potential antecedents. *Memory & Cognition, 11*, 283–294.

Cowan, N. (2006). *Working memory capacity*. New York: Psychology Press.

Curran, T. (2000). Brain potentials of recollections and familiarity. *Memory & Cognition, 28*(6), 923–938.

Curran, T. (2004). Effects of attention and confidence on the hypothesized ERP correlates of recollection and familiarity. *Neuropsychologia, 42*, 1088–1106.

Curran, T., Tepe, K. L., & Piatt, C. (2006). ERP explorations of dual processes in recognition memory. In H. D. Zimmer, A. Mecklinger & U. Lindenberger (Eds.), *Binding in human memory: A neurocognitive approach* (pp. 467–492). Oxford: Oxford University Press.

Ditman, T., Nieuwland, M., & Kuperberg, G. R. (2009). An ERP examination of a pragmatic repeated-name penalty. Poster presented at the 50th annual meeting of the Psychonomic Society, Boston, MA.

Donaldson, W. (1996). The role of decision processes in remembering and knowing. *Memory & Cognition, 24*, 523–533.

Donaldson, W., & Bass, M. (1980). Relational information and memory for problem solutions. *Journal of Verbal Learning & Verbal Behavior, 19*, 26–35.

Dopkins, S., & Ngo, C. T. (2002). Inhibition of verbal memory retrieval as a consequence of prior retrieval. *Journal of Memory and Language, 46*(3), 606–621.

Dopkins, S., & Ngo, C. T. (2005). The role of recognition memory in anaphor identification. *Journal of Memory and Language, 53*(2), 186–203.

Dopkins, S., Ngo, C. T., & Sargent, J. (2006). Exploring a recognition-induced recognition decrement. *Memory & Cognition, 34*(4), 839–853.

Dopkins, S., & Nordlie, J. (2011). Exploring a decrease in recognition performance for non-antecedents following the processing of anaphors. *Discourse Processes, 48*(6), 432–451.

Dunn, J. C. (2004). Remember-know: A matter of confidence. *Psychological Review, 111*, 524–542.

Düzel, E., Yonelinas, A. P., Mangun, G. R., Heinze, H.-J., & Tulving, E. (1997). Event-related potential correlates of two states of conscious awareness in memory. *Proceedings of the National Academy of Science, 94*, 5973–5978.

Fiebach, C., Schlesewsky, M., & Friederici, A. (2002). Separating syntactic memory costs and syntactic integration costs during parsing: The processing of German *wh*-questions. *Journal of Memory and Language, 47*, 250–272.

Fiedler, K., Lachnit, H., Fay, D., & Krug, C. (1992). Mobilization of cognitive resources and the generation effect. *Quarterly Journal of Experimental Psychology, 45A*, 149–171.

Foraker, S., & McElree, B. M. (2007). The role of prominence in pronoun resolution: Active versus passive representations. *Journal of Memory and Language, 56*(3), 357–383.

Friedman, D., & Johnson, R., Jr (2000). Event-related potential (ERP) studies of memory encoding and retrieval: A selective review. *Microscopy Research and Technique, 51*, 6–28.

Gardiner, J. M. (1988). Functional aspects of recollective experience. *Memory & Cognition, 16*, 309–313.

Gardiner, J. M., & Hampton, J. A. (1988). Item-specific processing and the generation effect: Support for a distinctiveness account. *American Journal of Psychology, 101*, 495–504.

Garrod, S., Freudenthal, D., & Boyle, E. A. (1994). The role of different types of anaphor in the on-line resolution of sentences in discourse. *Journal of Memory and Language, 33*, 39–68.

Gernsbacher, M. A. (1989). Mechanisms that improve referential access. *Cognition, 32*, 99–156.

Gernsbacher, M. A. (1990). *Language comprehension as structure building*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Gernsbacher, M. A., & Hargreaves, J. D. (1988). Accessing sentence participants: The advantage of first mention. *Journal of Memory & Language, 27*, 699–717.

Gernsbacher, M. A., & Jescheniak, J. D. (1995). Cataphoric devices in spoken discourse. *Cognitive Psychology, 29*, 24–58.

Geva, A., Moscovitch, M., & Leach, L. (1997). Perceptual priming of proper names in younger and older adults and a patient with prosopanomia. *Neuropsychology, 11*(2), 232–242.

Givón, T. (1979). *On understanding grammar*. New York: Academic Press.

Gomez, P., Ratcliff, R., & Perea, M. (2008). The overlap model: A model of letter position coding. *Psychological Review, 115*(3), 577–600.

Gordon, P. C., Grosz, B. J., & Gilliom, L. A. (1993). Pronouns, names, and the centering of discourse. *Cognitive Science*, 17, 311–347.

Gordon, P. C., & Hendrick, R. (1997). Intuitive knowledge of linguistic coreference. *Cognition*, 62, 325–370.

Gordon, P. C., & Hendrick, R. (1998). The representation and processing of coreference in discourse. *Cognitive Science*, 22, 389–424.

Gordon, P. C., Hendrick, R., & Foster, K. L. (2000). Language comprehension and probe-list memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 26(3), 766–775.

Gordon, P. C., Hendrick, R., Ledoux, K., & Yang, C. L. (1999). Processing of reference and the structure of language: An analysis of complex noun phrases. *Language and Cognitive Processes*, 14, 353–379.

Gordon, P. C., & Scearce, K. A. (1995). Pronominalization and discourse coherence, discourse structure and pronoun interpretation. *Memory & Cognition*, 23, 313–323.

Greene, S. B., McKoon, G., & Ratcliff, R. (1992). Pronoun resolution and discourse models. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18, 266–283.

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika*, 24, 95–112.

Grice, H. P. (1975). Logic and conversation. In P. Coles & J. Morgan (Eds.), *Syntax and semantics III: Speech acts* (pp. 41–58). New York, NY: Academic Press.

Holcomb, P. J. (1993). Semantic priming and stimulus degradation: Implications for the role of the N400 in language processing. *Psychophysiology*, 30, 47–61.

Holcomb, P. J., Kounios, J, Anderson, J. E., & West, W. C. (1999). Dual coding, context availability, and concreteness effects in sentence comprehension: an electrophysiological investigation. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 25(3), 721–742.

Hollis, J., & Valentine, T. (2001). Proper-name processing: Are proper names pure referencing expressions? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 27(1), 99–116.

Hunt, R. R., & McDaniel, M. A. (1993). The enigma of organization and distinctiveness. *Journal of Memory & Language*, 32, 421–445.

Jacoby, L. L. (1978). On interpreting the effects of repetition: Solving a problem versus remembering a solution. *Journal of Verbal Learning and Verbal Behavior*, 17, 649–667.

Kennison, S. M., & Gordon, P. C. (1997). Comprehending referential expressions during reading: Evidence from eye tracking. *Discourse Processes*, 24, 229–252.

King, J. W., & Kutas, M. (1995). Who did what and when? Using word- and clause-level ERPs to monitor working memory usage in reading. *Journal of Cognitive Neuroscience*, 7(3), 376–395.

Kinoshita, S. (1989). Generation enhances semantic processing? The role of distinctiveness in the generation effect. *Memory & Cognition*, 17(5), 563–571.

Kounios, J, & Holcomb, P. J. (1994). Concreteness effects in semantic processing: ERP evidence supporting dual-coding theory. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 20(4), 804–823.

Kutas, M., & Federmeier, K. D. (2001). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Science*, 4, 463–470.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentence: Brain potentials reflect semantic incongruity. *Science*, 207, 203–205.

Ledoux, K., & Camblin, C. C. (2008). The neural mechanisms of coreference. *Language and Linguistics Compass*, 2(5), 1013–1037.

Ledoux, K., Camblin, C. C., Swaab, T. Y., & Gordon, P. C. (2006). Reading words in discourse: The modulation of lexical priming effects by message-level context. *Behavioral and Cognitive Neuroscience Reviews*, 5(3), 107–127.

Ledoux, K., Gordon, P. C., Camblin, C. C., & Swaab, T. Y. (2007). Coreference and lexical repetition: Mechanisms of discourse integration. *Memory & Cognition*, 35(4), 801–815.

Lewis, R. L., Vasishth, S., & Van Dyke, J. A. (2006). Computational principles of working memory in sentence processing. *Trends in Cognitive Science*, 10(10), 447–454.

Li, C. N., & Thompson, S. A. (1981). *Mandarin Chinese: A functional reference grammar*. Berkeley, CA: University of California Press.

Long, D. L., Johns, C. L., & Jonathan, E. (2011). A memory-retrieval view of discourse representation: The recollection and familiarity of text ideas. *Language and Cognitive Processes*, 27(6), 821–843.

Long, D. L., & Prat, C. S. (2002). Memory for Star Trek: The role of prior knowledge in recognition revisited. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 28, 1073–1082.

Long, D. L., Prat, C. S., Johns, C. L., Morris, P. E., & Jonathan, E. (2008). The importance of knowledge in vivid text memory. *Psychonomic Bulletin and Review*, 15(3), 604–609.

Long, D. L., Wilson, J., Hurley, R., & Prat, C. S. (2006). Assessing text representations with recognition: The interaction of domain knowledge and text coherence. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 32, 816–827.

Luck, S. J. (in press). Event-related potentials. In D. L. Long (Ed.), *APA handbook of research methods in psychology*. Washington, DC: American Psychological Association.

MacDonald, M. C., & MacWhinney, B. (1990). Measuring inhibition and facilitation from pronouns. *Journal of Memory and Language*, 29, 469–492.

McElree, B. (2000). Sentence comprehension is mediated by content-addressable memory structures. *Journal of Psycholinguistic Research*, 29, 111–123.

McElree, B. (2001). Working memory and focal attention. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 27, 817–835.

McElree, B. (2006). Accessing recent events. In B. H. Ross (Ed.), *The psychology of learning and motivation* (Vol. 46, pp. 155–200). San Diego: Academic Press.

McElree, B., & Dosher, B. A. (1989). Serial position and set size in short-term memory: Time course of recognition. *Journal of Experimental Psychology: General*, 18, 346–373.

McElree, B., Foraker, S., & Dyer, L. (2003). Memory structures that subserve sentence comprehension. *Journal of Memory and Language*, 48(1), 67–91.

McFarland, C. E., Jr, Frey, T. J., & Rhodes, D. D. (1980). Retrieval of internally versus externally generated words in episodic memory. *Journal of Verbal Learning & Verbal Behavior*, 19, 210–225.

McKoon, G., & Ratcliff, R. (1980). The comprehension processes and memory structures involved in anaphoric reference. *Journal of Verbal Learning & Verbal Behavior*, 19, 668–682.

McKoon, G., Ward, G., Ratcliff, R., & Sproat, R. (1993). Morpho-syntactic and pragmatic factors affecting the accessibility of discourse entities. *Journal of Memory and Language*, 32, 56–75.

Mecklinger, A. (2000). Interfacing mind and brain: A neurocognitive model of recognition memory. *Psychophysiology*, 37, 565–582.

Mirandola, C., Del Prete, F., Ghetti, S., & Cornoldi, C. (2010). Recollection but not familiarity differentiates memory for text in students with and without learning difficulties. *Learning and Individual Differences*, 21(2), 206–209.

Müller, H. M., & Kutas, M. (1996). What's in a name? Electrophysiological differences between spoken nouns, proper names, and one's own name. *Neuroreport*, 8(1), 221–225.

Mulligan, N. W. (2002a). The emergent generation effect and hypermnesia: Influences and nonsemantic generation tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 28(3), 541–554.

Mulligan, N. W. (2002b). The effects of generation on conceptual implicit memory. *Journal of Memory and Language*, 47, 327–342.

Mulligan, N. W. (2002c). The generation effect: Dissociating enhanced item memory from disrupted order memory. *Memory & Cognition*, *30*(6), 850–861.

Mulligan, N. W. (2006). Conceptual Implicit Memory and the Item-specific—Relational Distinction. In R. R. Hunt & J. B. Worthen, *Distinctiveness and Memory* (pp. 183–210). New York: Oxford University Press.

Mulligan, N. W. (2011). Generation Disrupts Memory for Intrinsic but not Extrinsic Contextual Details. *Quarterly Journal of Experimental Psychology*, *64*(8), 1543–1562.

Mulligan, N. W., & Lozito, J. P. (2004). Self-generation and memory. In B. Ross (Ed.), *Psychology of learning and motivation* (Vol. 45, pp. 175–214). San Diego, CA: Elsevier Academic Press.

Münte, T. F., Schiltz, K., & Kutas, M. (1998). When temporal terms belie conceptual order. *Nature*, *395*, 71–73.

Nagy, M. E., & Rugg, M. D. (1989). Modulation of event-related potentials by word repetition: The effects of inter-item lag. *Psychophysiology*, *26*, 431–436.

Nairne, J. S. (1996). Short-term/working memory. In E. L. Bjork & R. A. Bjork (Eds.), *Memory* (pp. 160–169). San Diego: Academic Press.

Nessler, D., Mecklinger, A., & Penney, T. B. (2005). Perceptual fluency, semantic familiarity and recognition-related familiarity: An electrophysiological exploration. *Cognitive Brain Research*, *22*(2), 265–288.

Paller, K. A., & Kutas, M. (1992). Brain potentials during memory retrieval provide neurophysiological support for the distinction between conscious recollection and priming. *Journal of Cognitive Neuroscience*, *4*, 375–391.

Pickering, E. C., & Schweinberger, S. R. (2003). N200, N250r, and N400 event-related brain potentials reveal three loci of repetition priming for familiar names. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*(6), 1298–1311.

Reder, L. M., Park, H., & Kieffaber, P. D. (2009). Memory systems do not divide on consciousness: Reinterpreting memory in terms of activation and binding. *Psychological Bulletin*, *135*(1), 23–49.

Rugg, M. D. (1985). The effects of semantic priming and word repetition on event-related potentials. *Psychophysiology*, *22*, 642–647.

Rugg, M. D., & Curran, T. (2007). Event-related potentials and recognition memory. *Trends in Cognitive Sciences*, *11*(6), 251–257.

Rugg, M. D., Mark, R. E., Walla, P., Schloerscheidt, A. M., Birch, C. S., & Allan, K. (1998). Dissociation of the neural correlates of implicit and explicit memory. *Nature*, *392*, 595–598.

Sanford, A. J. S., Price, J., & Sanford, A. J. (2009). Enhancement and suppression effects resulting from information structuring in sentences. *Memory & Cognition*, *37*(6), 880–888.

Sanford, A. J. S., Sanford, A. J., Molle, J., & Emmott, C. (2006). Shallow processing and attention capture in written and spoken discourse. *Discourse Processes*, *42*(2), 109–130.

Singer, M., & Remillard, G. (2004). Retrieving text inferences: Controlled and automatic influences. *Memory & Cognition*, *32*(8), 1223–1237.

Sitnikova, T., Holcomb, P. J., Kiyonaga, K. A., & Kuperberg, G. R. (2008). Two neurocognitive mechanisms of semantic integration during the comprehension of visual real-world events. *Journal of Cognitive Neuroscience*, *20*(11), 2037–2057.

Sitnikova, T., Kuperberg, G., R., & Holcomb, P. J. (2003). Semantic integration in videos of real-world events: An electrophysiological investigation. *Psychophysiology*, *40*(1), 160–164.

Smith, M. E. (1993). Neurophysiological manifestations of recollective experience during recognition memory judgments. *Journal of Cognitive Neuroscience*, *5*, 1–13.

Soraci, S. A., Franks, J. J., Bransford, J. D., Chechile, R. A., Belli, R. F., Carr, M., & Carlin, M. (1994). Incongruous item generation effects: A multiple-cue perspective. *Journal of Experimental Psychology: Learning, Memory, Cognition*, *20*, 67–78.

Stewart, A. J., Pickering, M. J., & Sanford, A. J. (2000). The time course of the influence of implicit causality information: Focusing versus integration accounts. *Journal of Memory and Language*, *42*, 423–443.

Sturt, P., Sanford, A. J., Stewart, A., & Dawydiak, E. (2004). Linguistic focus and good-enough representations: An application of the change-detection paradigm. *Psychonomic Bulletin & Review*, *11*(5), 882–888.

Surprenant, A. M., & Neath, I. (2009). *Principles of memory*. New York: Psychology Press.

Swaab, T. Y., Baynes, K., & Knight, R. T. (2002). Separable effects of priming and imageability on word processing: An ERP study. *Cognitive Brain Research*, *15*(1), 99–103.

Swaab, T. Y., Camblin, C. C., & Gordon, P. C. (2004). Electrophysiological evidence or reversed lexical repetition effects in language processing. *Journal of Cognitive Neuroscience*, *16*(5), 715–726.

Tulving, E. (1985). Memory and consciousness. *Canadian Psychology*, *26*, 1–12.

van Berkum, J. J. A., Hagoort, P., & Brown, C. M. (1999). Semantic integration in sentences and discourse: Evidence from N400. *Journal of Cognitive Neuroscience*, *11*(6), 657–671.

van Dijk, T., & Kintsch, W. (1983). *Strategies of discourse comprehension*. New York: Academic Press.

Van Dyke, J. A., & Johns, C. L. (2012). Memory interference as a determinant of language comprehension. *Language and Linguistics Compass*, *6*(4), 193–211.

Valentine, T., Hollis, J., & Moore, V. (1998). On the relationship between reading, listening, and speaking: It's different for people's names. *Memory & Cognition*, *26*, 740–753.

Ward, P., & Sturt, P. (2007). Linguistic focus and memory: An eye movement study. *Memory & Cognition*, *35*, 73–86.

West, W. C., & Holcomb, P. J. (2000). Imaginal, semantic, and surface-level processing of concrete and abstract words: an electrophysiological investigation. *Journal of Cognitive Neuroscience*, *12*(6), 1024–1037.

West, W. C., & Holcomb, P. J. (2002). Event-related potentials during discourse-level semantic integration of complex pictures. *Cognitive Brain Research*, *13*(3), 363–375.

Wilding, E. L., & Sharpe, H. (2003). Episodic memory encoding and retrieval: Recent insights from event-related potentials. In A. Zani & A. M. Proverbio (Eds.), *The cognitive electrophysiology of mind and brain* (pp. 169–196). San Diego, CA: Academic Press.

Wixted, J. T. (2007). Dual-process theory and signal-detection theory of recognition memory. *Psychological Review*, *114*(1), 152–176.

Woodruff, C. C., Hayama, H. R., & Rugg, M. D. (2006). Electrophysiological dissociation of the neural correlates of recollection and familiarity. *Brain Research*, *1100*, 125–135.

Yasuda, K., Nakamura, T., & Beckman, B. (2000). Brain processing of proper names. *Aphasiology*, *14*(11), 1067–1089.

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language*, *42*, 441–517.

Yonelinas, A. P., & Jacoby, L. L. (1995). The relation between remembering and knowing as bases for recognition: Effects of size congruency. *Journal of Memory and Language*, *34*(5), 622–643.

Yu, S. S., & Rugg, M. D. (2011). Dissociation of the electrophysiological correlates of familiarity strength and item repetition. *Brain Research*, *1320*, 74–84.

Appendix 1. Sample sentences from Experiment 2.

1. With effort Holly/Holly and Vince strained to hear the speaker until Holly/she fixed the sound system.
   - T or F: Initially the speaker was hard to hear.
2. According to the memo Craig/Craig and Heidi had plans to research the subject before Craig wrote the proposal.
   - T or F: Craig didn't think any research was necessary.
3. In the garage Dustin/Dustin and Simone looked for a ladder because Dustin/he need a box from the top shelf.
   - T or F: A ladder was needed to get the box.
4. With reluctance Daniel/Daniel and Nicole washed the dishes while Daniel/he talked about the upcoming election.
   - T or F: Daniel never talked about politics.
5. For the mailing Julie/Julie and Dan addressed the letters before Julie/she stuck on the stamps.
   - T or F: The mailings did not require postage.
6. At about noon Garrett/Garrett and Catherine turned onto a side road because Garrett/he warned of the danger of the highway.
   - T or F: Garrett believed the highway was unsafe.
7. By email Mitch/Mitch and Nora asked everyone to arrive early for the movie because Mitch/he said that it might sell out.
   - T or F: The movie was very popular.
8. For a long time Greg/Greg and Phoebe worried about burglary after Greg/he saw the report on property crime.
   - T or F: The report on property crime was disturbing.
9. Every summer Albert/Albert and Jenna had a lovely garden because Albert/he gave good advice about what to plant.
   - T or F: Albert knew what to grow in the garden.
10. During the storm Stuart/Stuart and Joanna leapt over the puddles while Stuart/he giggled happily.
    - T or F: Stuart walked through the puddles.
11. Using the cage Conrad/Conrad and Sophia trapped the snake so Conrad/he could transport it to a safe habitat.
    - T or F: The snake was going to be destroyed.
12. Nearly every day Donald/Donald and Elaine hung the clothes on the line after Donald/he finished washing them.
    - T or F: The clothes were put in a dryer.
13. Out of necessity Carlos/Carlos and Rhonda redrew the map after Carlos/he noticed that the scale was wrong on the original.
    - T or F: The map was redrawn to include a new trail.
14. After work Tamara/Tamara and Gregory cleaned the house because Tamara/she invited clients over for dinner.
    - T or F: Tamara took the clients out for an expensive dinner.
15. To save time Marshall/Marshall and Gretchen never traveled by car once Marshall/he bought the company a private jet.
    - T or F: The private jet was never used.
16. In Rome Suzanne/Suzanne and Matthew sketched the cathedrals while Suzanne/she commented on the unique buildings.
    - T or F: Suzanne commented on the sculpture.
17. Very carefully Erica/Erica and Clint glued the broken plate together after Erica/she salvaged all the pieces.
    - T or F: The broken plate could not be repaired.
18. At the station Roger/Roger and Liz waited nervously after Roger/he announced that the train was late.
    - T or F: Roger waited for a flight.
19. Despite the distance Sheila/Sheila and Eugene looked for a house near the college after Sheila/she was mugged downtown.
    - T or F: Sheila checked out houses in the university area.
20. Each night Claire/Claire and Robert drove downtown because Claire/she was performing with the symphony orchestra.
    - T or F: Claire plays with the symphony.