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Journal of Memory and Language 54 (2006) 185–198
Journal of Memory and Language
www.elsevier.com/locate/jml

Do writing and speaking employ the same syntactic representations?

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Received 8 December 2004; revision received 28 October 2005

Abstract

Writing and speaking are clearly related activities, but the acts of production are different. To what extent are the underlying processes shared? This paper reports three experiments that use syntactic priming to investigate whether writing and speaking use the same mechanisms to construct syntactic form. People tended to repeat syntactic form between modality (from writing to speaking and speaking to writing) to the same extent that they did within either modality. The results suggest that the processor employs the same mechanism for syntactic encoding in written and spoken production, and that use of a syntactic form primes structural features concerned with syntactic encoding that are perceptually independent. We interpret the results in terms of current accounts of language production.
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Keywords: Priming; Syntax; Writing; Speaking; Language production; Orthography; Phonology

Introduction

Are the psychological mechanisms employed in speaking and writing shared or are they distinct? Superficially, either answer seems possible. On the one hand, speaking is nearly universal and has a strong innate component, whereas writing is a skill that has been invented relatively recently (c. 5000 years ago), is painstakingly acquired by children, and is far from universal. Also, the end-product is entirely different: Speaking involves producing sounds, whereas writing involves producing marks on a page. But on the other hand, basically the same set of sentences seem to be acceptable in written or spoken language. This might suggest that the underlying mechanisms are the same, and it is only the output that differs. In this paper, our particular concern is whether speaking and writing share mechanisms that lead to the construction of grammatical form.

The relationship between speaking and writing has sometimes been taken for granted, and sometimes dismissed completely. While some have regarded writing as purely secondary to speaking and really just a recording system (e.g., Bloomfield, 1933), others appear to have considered written language as more representative of underlying grammar than spoken language (e.g., Chomsky, 1965). Some have treated spoken and written language as almost separate languages (Olson, 1977), whereas others have regarded them more like different ''dialects'' of English (Sampson, 1985).

Perhaps not surprisingly, psychological arguments can also be made both ways. Language is clearly used differently in written and spoken production (Akinasso,

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doi:10.1016/j.jml.2005.10.003

1982; Biber, 1988). For example, written language tends to make more use of passives than spoken language (e.g., Blankenship, 1962; O'Donnell, 1974), employs longer and more complex constructions (e.g., Chafe, 1982; Drieman, 1962; Woolbert, 1922), and contains longer words and a wider vocabulary (e.g., Drieman, 1962; Gibson, Gruner, Kibler, & Kelly, 1966). In addition, written language appears to use punctuation in some ways that have no equivalent using intonation in spoken language (Nunberg, 1990). However, these distinctions do not necessarily reflect differences in processing, and may simply reflect differences in what people want to say and how they want to say it in speech and writing.

A more complex and interesting possibility is that some components of writing and speaking may be shared, and some may be distinct. In models of spoken production, it is normally assumed that language production involves various stages, with a fundamental division into conceptualization (preparation of the message to be conveyed), and formulation (conversion of this message into linguistic form); see Bock and Levelt (1994), Garrett (1980), and Levelt (1989). Most models assume a major division between syntactic and semantic processing on the one hand and morphological and phonological processing on the other (e.g., Levelt, Roelofs, & Meyer, 1999), with support for this dichotomy coming from tip-of-the-tongue data (e.g., Vigliocco, Antonini, & Garrett, 1997), word-order preferences (e.g., Bock, 1986a), speech errors (e.g., Garrett, 1980), picture naming (e.g., Schriefers, Meyer, & Levelt, 1990), and electrophysiological data (e.g., Van Turennout, Hagoort, & Brown, 1998).

In written production, some researchers assume Levelt's (1989) account (e.g., Pickering & Branigan, 1998), and others likewise adopt distinctions that more-or-less correspond to those assumed in spoken production (e.g., Hayes & Flower, 1986). In contrast, others have argued for at least some dissociation between written and spoken production (e.g., Shelton & Caramazza, 1999). In fact, there has been little research specifically on written sentence production, and what there is mostly concentrates on higher level issues such as composition, planning, and revising (e.g., Bourdin & Fayol, 1994; Brown, McDonald, Brown, & Carr, 1988; Gould & Boies, 1978; Olive & Kellogg, 2002; Martlew, 1983; Scardamalia & Bereiter, 1986; Traxler & Gernsbacher, 1992, 1993), or the relationship between working memory and writing (e.g., Kellogg, 2001a, 2001b, 2004).

We shall assume the stages that are proposed in spoken language production (Levelt, 1989) also hold for written language production, and ask whether each stage is shared between modalities or whether it is represented twice, once for speech and once for writing. There are many possibilities about which components are shared and which are separate, but spoken and written articulation are clearly distinct, whereas some aspects of conceptualization at least must be common to both modalities (e.g., Ellis, 1988; Gould & Boies, 1978).

At the level of morphological and phonological processing, there is evidence of some degree of autonomy between orthography and phonology, both from experimental studies (e.g., Bonin, Fayol, & Gombert, 1998) and neuropsychological data (e.g., Caramazza & Hillis, 1990, 1991; Shelton & Weinrich, 1997). These results are compatible with autonomy between written and spoken syntactic representations as well, but clearly do not necessitate it. Although spoken and written language have identical (or very similar) grammars, people may represent this same grammar twice, once for written production and once for spoken production. Most models of word and sentence production do not explicitly address the issue of whether separate systems of grammatical encoding exist for written and spoken production (e.g., Garrett, 1980; Levelt, 1989; Levelt et al., 1999). However, their silence almost certainly suggests that only one system is assumed. More explicitly, Bonin et al. (1998) tentatively concluded that some syntactic and semantic information would be shared between modalities in word production.

The little research that has addressed the relationship between syntax and modality has largely come from the field of neuropsychology, particularly the work of Caramazza and colleagues (e.g., Rapp & Caramazza, 1998, 2002; Caramazza & Hillis, 1991). For example, Caramazza and Hillis described a dissociation in patients SJD and HW. SJD had difficulties producing verbs in written but not spoken production; in contrast, HW had greater difficult producing verbs than nouns in spoken production but had little problem with written production of either verbs or nouns. From these data, they argued that grammatical category information is represented "separately and redundantly in each modality-specific lexical system" (p. 790). While informative about the representation of grammatical information for single words, this tells us less about the production of sentences; in fact, the majority of reported cases of Broca's aphasia show deficits in sentence production across modalities (see Benson and Ardila, 1996, for a review). An isolated exception was reported by Assal, Buttet, and Jolivet (1981), whose patient had severely agrammatic written production but largely unimpaired spoken production. To further complicate the issue there is evidence that, at least within modality, Broca's aphasics can in fact be primed to produce syntactically complex sentences despite their normal difficulties with production (e.g., Hartsuiker & Kolk, 1998a; Kilborn & Friederici, 1994), so it is possible that they may display processing deficits rather than (or as well as) deficits in grammatical knowledge. Hence, the neuropsychological evidence raises some interesting questions about the

representation of syntactic information, but it cannot discriminate between modality-specific and modality-neutral accounts of syntactic representation.

Syntactic priming

Syntactic priming is the tendency for speakers to reuse previously processed syntactic structure. Following earlier findings of syntactic repetition in everyday discourse (Schenkein, 1980; Weiner and Labov, 1983), Bock (1986b) experimentally demonstrated that speakers tended to repeat syntactic structure during language production. For example, participants tended to describe a picture using a *Prepositional Object* sentence (e.g., *The man is reading a story to the boy*) just after producing an (unrelated) Prepositional-Object sentence (e.g., *A rock star sold some cocaine to an undercover agent*), but tended to describe the same picture using a *Double Object* sentence (e.g., *The man is reading the boy a story*) just after producing a Double-Object sentence (e.g., *A rock star sold an undercover agent some cocaine*). Bock argued that this effect was due to the priming of procedures that produced these syntactic structures. Later research confirmed that explanations based on lexical, semantic, or prosodic repetition cannot adequately explain the data (e.g., Bock, 1989; Bock & Loebell, 1990).

Syntactic priming effects have since been demonstrated in other languages (Hartsuiker & Kolk, 1998b), in a range of constructions (Cleland & Pickering, 2003; Ferreira, 2003; Hartsuiker, Kolk, & Huiskamp, 1999; Hartsuiker & Westenberg, 2000), in written language (Pickering & Branigan, 1998), between comprehension and production in dialogue (Branigan, Pickering, & Cleland, 2000; cf. Levelt & Kelter, 1982), and even between languages (Hartsuiker, Pickering, & Veltkamp, 2004; Loebell & Bock, 2003). A number of different methods have been used, including sentence completion, sentence recall, and picture description (Bock, 1986a; Branigan, Pickering, Stewart, & McLean, 2000; Pickering & Branigan, 1998; Potter & Lombardi, 1998), but all methods produce the same finding that processing of a sentence with a particular structure facilitates the subsequent production of a sentence with the same syntactic structure.

Most accounts of syntactic priming place the locus of the effect at the mechanisms underlying the formulation of syntactic structure. One possibility is that syntactic representations used in processing the prime sentence remain activated, and are hence used more readily in the production of subsequent utterances (e.g., Branigan, Pickering, & Cleland, 1999; Pickering & Branigan, 1998; Potter & Lombardi, 1998). Under the account proposed by Pickering and Branigan (1998), production of a syntactic structure will result in the activation of a corresponding combinatorial node associated with the verb at the lemma level. For example, production of a Prepositional-Object structure using the word *give* will result in the activation of the *NP,PP* node (as opposed to the *NP,NP* node associated with a Double-Object structure). Hence, on subsequent utterances, the residual activation of the *NP,PP* node will result in an increased likelihood of the speaker producing another Prepositional-Object structure.

Syntactic priming has also been attributed to implicit learning of syntactic processes (Bock & Griffin, 2000; Chang, Dell, Bock, & Griffin, 2000; Chang, Bock, & Goldberg, 2003). Implicit learning involves complex and abstract knowledge structures that are not amenable to consciousness and which are an incidental consequence of task performance (Seger, 1994; cf. Cleeremans, Destrebecqz, & Boyer, 1998). Such an account emphasizes long-term adjustments to the language production mechanism, occurring outside the awareness of the speaker. It therefore predicts that syntactic priming can be long lasting. In support of this, Bock and Griffin found that it can occur when there are as many as ten sentences between prime and target (see also Bock & Kroch, 1989; Hartsuiker & Kolk, 1998b; Kaschak, Loney, & Borreggine, in press). Whereas such long-lasting priming is not always found (Branigan et al., 1999; Levelt & Kelter, 1982; Wheeldon & Smith, 2003), the fact that it can occur strongly suggests that at least some component of syntactic priming should be regarded as involving implicit learning. Moreover, syntactic priming appears to be preserved in anterograde amnesia (Ferreira, Bock, Wilson, & Cohen, 2004), which implies an implicit learning mechanism (Seger, 1994).

If syntactic priming leads to long-term adjustments in processing mechanisms associated with syntax, then we might expect those features to be abstracted away from perceptual characteristics such as whether the utterance is spoken or written. Indeed, the evidence for strong priming from comprehension to production (Branigan et al., 2000; Cleland & Pickering, 2003; Potter & Lombardi, 1998) indicates that relevant features must be abstract. It would thus not be surprising if priming occurred between written and spoken production. Indeed, we might predict that priming between spoken and written modalities would be equivalent to priming within either modality.

In the experiments reported here, we employed the sentence completion method, which has been used to demonstrate strong within-modality priming in written production (Branigan et al., 1999; Hartsuiker & Westenberg, 2000; Pickering & Branigan, 1998; Pickering, Branigan, & McLean, 2002) and spoken production (Branigan et al., 2000; Hartsuiker & Westenberg, 2000; Pickering et al., 2002). In our experiments prime sentences could either be written or spoken. In Experiments 1 and 2, the target sentence was spoken, and in Experiment 3, the target sentence was written. We employed dative-alternating verbs such as *give* (i.e., verbs that are compat-

ible with both the Prepositional-Object and the Double-Object constructions) as in many previous experiments (e.g., Bock, 1986b; Pickering & Branigan, 1998), because priming effects are strong, and because non-syntactic differences between the forms (e.g., discourse focus) are minimal. In Experiments 1 and 3, the verb was repeated between the prime and target fragments. According to Pickering and Branigan (1998), verb repetition leads to particularly strong priming effects (see also Branigan et al., 2000). In Experiment 2, different verbs were used in the prime and target fragments.

Experiment 1

Method

Participants

Sixteen students at the University of Glasgow were paid to participate.

Items

There were 24 items, each consisting of one of two prime fragments and a target fragment (see Appendix A).

1a. The neighbour lends the mower (*Prepositional-Object-inducing prime*)
1b. The neighbour lends the friend (*Double-Object-inducing prime*)
2. The cook lends (*target*)

Prime and target fragments each contained a subject followed by a dative-alternating verb. Prime fragments also contained a post-verbal noun phrase. In (1a), the post-verbal noun phrase was a plausible patient for the action denoted by the verb, so it encouraged Prepositional-Object completions (e.g., … *to the friend*); in (1b), it was a plausible beneficiary, so it encouraged Double-Object completions (e.g., … *a new lawnmower*). We employed six verbs (*gives*, *hands*, *loans*, *shows*, *lends*, and *sends*). Previous experiments demonstrated reliable priming effects with a wider range of verbs, but these six verbs produced particularly low proportions of Other (non-Prepositional and non-Double Object) completions (Pickering & Branigan, 1998). Some nouns were repeated once in the entire item set (*woman*, *child*, *writer*, *assistant*, *driver*, *nurse*, and *student*), but nouns were never repeated between prime and target sentences.

Each prime fragment appeared in a spoken and a written form. Target fragments were always spoken. Thus, the prime sentences were presented in four conditions: Spoken Prepositional-Object-inducing, Spoken Double-Object-inducing, Written Prepositional-Object-inducing, and Written Double-Object-inducing. We constructed four lists of items, such that each list contained exactly six items from each condition, and exactly one version of each item. Each list also included the same 96 filler fragments, consisting of approximately even proportions of noun phrases, noun phrases plus verbs, and noun phrases plus verbs followed by another noun phrase. The ratio of spoken to written responses in the experimental trials was 3–1, so this proportion was maintained for the fillers; in other words, 72 of the filler fragments were spoken trials and 24 were written trials. No ditransitive verbs (i.e., taking two post-verbal arguments) were used in the fillers. Lists were individually randomized for each participant, with the constraint that at least three fillers occurred between each item.

Every participant completed 24 target fragments, six in each of the four priming conditions defined by the two levels of the Prime Structure factor (Prepositional Object vs. Double Object) and the two levels of the Prime Modality factor (written vs. spoken). Every experimental item was presented to all sixteen participants, with four participants seeing any one version of an item.

Procedure

The experimental files were presented on a Macintosh computer using PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993). Participants were seated in front of the computer in a quiet booth and were given a set of written instructions. They were told that we were interested in what kinds of sentences people produce and that their task was to complete the sentences as quickly as possible, with the first grammatical completion that came to mind. They were also told that they would either have to write down the sentence fragments and complete them, or read them out loud and complete them, and that a prompt would indicate which they were to do. A practice session of five sentences preceded the experiment proper, and allowed participants to ask questions about the procedure.

On each trial, the computer first presented a red prompt for 2000 ms. The prompt – – – – – – – – – – indicated that a written sentence was required, and + + + + + + + + + + + indicated that a spoken response was required. A fixation point (in black) was then presented for 500 ms. Finally, the sentence fragment was presented in black. After producing the sentence fragment and completing the sentence, the participant pressed the space bar to move onto the next trial. Participants were provided with a folder of paper for written completions, and were told to write one sentence per page and then to fold over the page. Spoken responses were tape recorded. The experiment lasted about 35 min.

Scoring

Participants' responses to the experimental items were transcribed from the tape recordings and scored as *Prepositional-Object*, *Double-Object*, or *Other* (as in

Pickering & Branigan, 1998). Prime responses were scored as Prepositional-Objects if the completion contained a beneficiary noun phrase which was the object of the preposition to. Prime responses were scored as Double-Objects if the completion contained a patient (or theme) noun phrase. To be scored as either a Prepositional-Object or a Double-Object response, the verb provided in the fragment could not form part of a phrasal verb (e.g., *the banker hands the money over to the customer*). All other responses were scored as Other. In the unusual instance of a participant producing a Prepositional-Object completion to a Double-Object-inducing prime fragment or a Double-Object completion to a Prepositional-Object-inducing prime fragment, the completion was also scored as an Other.

Target responses were scored as Prepositional-Objects if the verb in the fragment was immediately followed by a noun phrase which acted as the patient and then by a prepositional phrase beginning with *to* which acted as the beneficiary. Target responses were scored as Double-Objects if the verb was immediately followed by a noun phrase which acted as a beneficiary and then by a noun phrase which acted as a patient. To be scored in either category, a completion had to have a grammatical alternative in the other category, where the order of the patient and beneficiary was reversed. As for the prime completions, the verb provided in the fragment could not form part of a phrasal verb. All other target responses were scored as Other.

Results

Table 1 provides a summary of the raw data for Experiment 1. Participants produced a Prepositional-Object or Double-Object completion for the prime fragment on 88% of trials (338 out of the total of 384). Of these, 71 were written Prepositional-Object completions (21%), 88 were written Double-Object completions (26%), 88 were spoken Prepositional-Object completions (26%), and 91 were spoken Double-Object completions (27%).

Trials on which participants produced an Other completion for the prime fragment were excluded from the analysis (as in all Experiments). For all of the results reported below, analyses of variance with Prime Structure (Prepositional-Object vs. Double-Object) and Prime Modality (spoken vs. written) were conducted, separately treating participants ($F1$) and items ($F2$) as random effects. Analyses were within-participants and within-items. These were then combined to produce the $MinF'$ statistic (Clark, 1973). Table 2 presents all effects that were significant by either $F1$ or $F2$, for all experiments. Confidence intervals for the differences between the means are reported for all significant effects (following Masson & Loftus, 2003), and are based on the participants analysis, as are all reported means. Unless stated otherwise, all reported effects are significant at $p < .05$.

Table 1
Number of responses across conditions for Experiment 1

Sentence Condition	Structure		
	PO	DO	Other
Prime Completions			
Written	71	88	33
Spoken	21	52	15
Target Completions			
Written PO Prime	37	19	15
Written DO Prime	21	52	15
Spoken PO Prime	50	22	16
Spoken DO Prime	29	46	16

Target other analysis

To determine whether the combined proportion of Prepositional-Object and Double-Object target responses was comparable across conditions, we first conducted a preliminary analysis of the proportions of Other target responses across conditions. Thus, we compared the proportion of Other responses following written Prepositional-Object prime completions, written Double-Object prime completions, spoken Prepositional-Object prime completions, and spoken Double-Object prime completions. We computed the relevant proportions by dividing the number of Other target completions following written Prepositional-Object prime completions by the total number of written Prepositional-Object prime completions (i.e., Prepositional-Object prime completions followed by Prepositional-Object, and Double-Object, and Other target completions); the number of Other target completions following written Double-Object prime completions (i.e., Double-Object completions followed by Prepositional-Object, and Double-Object, and Other target completions); and similarly for the spoken prime completions. These proportions were calculated for each participant and item. The proportion of Others produced in the target completions was equivalent across all conditions (all Fs < 1).

Prepositional-object target proportion analysis

Having established that the proportion of Other target responses was comparable across conditions, the crucial analysis of the level of priming across conditions was performed. We computed a measure, the *Prepositional-Object target proportion*, which determined the relative proportions of Prepositional-Object and Double-Object target responses in each of the priming conditions (Branigan et al., 2000; Hartsuiker et al., 2004). This measure was the proportion of Prepositional-Object target responses divided by the sum of the proportion of Prepositional-Object target responses and the proportion of Double-Object target responses (hence the choice of Prepositional Object rather than Double Object is arbitrary). The reason for employing the Prepositional-Object target proportion

Table 2
Analysis of variance summary for all experiments

Effect	By participants ($F1$)			By items ($F2$)		Min F'	
	df	$F1$	*MSe*	*df*	$F2$	*df*	*min*F'
Experiment 1							
PO Target Proportion							
Prime Structure	1,15	52.06**	0.035	1,23	14.69**	1,34	11.46**
Experiment 2							
PO Target Proportion							
Prime Structure	1,31	10.09**	0.051	1,23	9.97**	1,53	5.01*
Experiments 1 and 2							
PO Target Proportion							
Prime Structure	1,46	44.10**	0.035	1,23	24.59**	1,48	15.79**
Prime Structure × Verb	1,46	26.87**	0.035	1,23	3.65***	1,29	3.21
Experiment 3							
PO Target Proportion							
Prime Structure	1,15	5.73*	0.078	1,23	17.70**	1,25	4.33*
Experiment 1 and 3							
Target Other Analysis							
Target Modality	1,30	6.02*	0.16	1,23	17.73**	1,47	4.49*
PO Target Proportion							
Target Modality	1,30	6.21*	0.20	1,23	29.04**	1,42	5.12*
Prime Structure	1,30	36.02**	0.057	1,23	32.00**	1,51	16.94**

F values are reported to two decimal places; *MSe* values are reported to two significant figures.
* $p < .05$
** $p < .01$
*** $p < .06$.

was to allow comparison between conditions even if participants have produced different numbers of Other completions to the prime fragment (as mentioned above, such cases were excluded from the analysis). Fig. 1 shows the Prepositional-Object target proportions across all conditions, for all experiments.

When a Prepositional-Object prime was produced, the Prepositional-Object target proportion was larger than when a Double-Object prime was produced (0.67 vs. 0.33). The difference of 0.34 between the proportion of target completions following the same structure versus following the alternative structure was significant, with a confidence interval of 0.08. No other effects were statistically reliable. In particular, there was no interaction of Prime Structure by Modality (all Fs < 1, CI = 0.11). When the prime and target sentences were produced in the same modality (i.e., both were spoken), the difference in Prepositional-Object target proportions was similar to when the prime and target sentences were produced in different modalities (i.e., the prime was written and the target spoken). There was a 0.31 within-modality priming effect and a 0.37 between-modality priming effect. Hence, the magnitude of priming was similar for spoken targets produced following spoken primes and spoken targets following written prime sentences.

Experiment 2

Experiment 2 also compared the effects of written and spoken primes on spoken target completion, but did not repeat the verb between prime and target fragments. According to Pickering and Branigan (1998), this should lead to smaller priming effects than if the verb is repeated.

Method

Participants

Thirty-two students at the University of Glasgow were paid to participate.

Items

The same fragments were used as in Experiment 1, but each item consisted of prime and target fragments that employed different verbs, as in:

3a. The writer gives the script (*Prepositional-Object-inducing prime*)

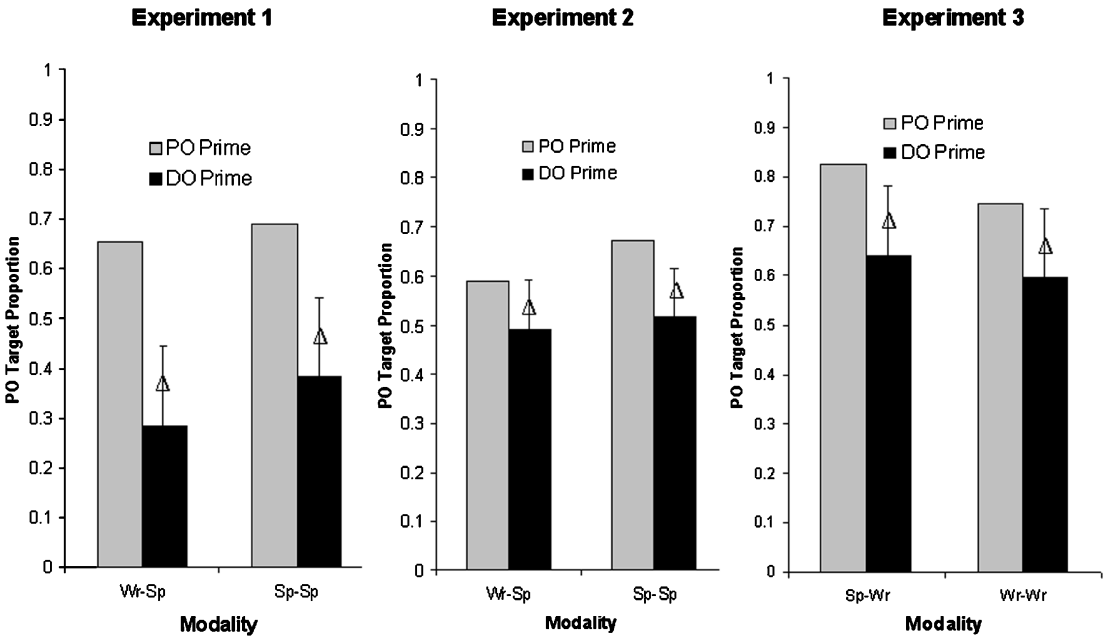

Fig. 1. Prepositional-Object Target Proportions across all experiments and across all conditions. PO: Prepositional Object; DO: Double Object; Wr-Sp: Written prime, spoken target; Sp-Sp: Spoken prime, spoken target; Sp-Wr: Spoken prime, written target; Wr-Wr: Written prime, written target. Error bars represent 95% confidence intervals for the differences between means (Δ).

3b. The writer gives the publisher (*Double-Object-inducing prime*)
4. The cook lends (*target*)

The same set of fillers were used as in Experiment 1, and the experimental design was identical (except that eight participants saw any one version of an item).

Procedure and scoring

These were the same as in Experiment 1.

Results

Table 3 provides a summary of the raw data for Experiment 2, and Table 2 summarizes all significant effects. Participants produced a Prepositional-Object or Double-Object completion for the prime fragment on 90% of trials (693 out of 768); of these, 166 were written Prepositional-Object completions (24%), 178 were written Double-Object completions (26%), 178 were spoken Prepositional-Object completions (26%), and 171 were spoken Double-Object completions (25%).

Target Other analysis

As in Experiment 1, the proportion of Others produced in the target completions was equivalent across all conditions (all Fs < 1.2).

Table 3
Number of responses across conditions for Experiment 2

Sentence condition	Structure		
	PO	DO	Other
Prime completions			
Written	166	178	40
Spoken	178	171	35
Target completions			
Written PO Prime	75	53	38
Written DO Prime	69	72	37
Spoken PO Prime	91	44	43
Spoken DO Prime	66	62	43

Prepositional-Object Target Proportion analysis

Fig. 1 describes the Prepositional-Object target proportions across all conditions. When a Prepositional-Object prime was produced, the Prepositional-Object target proportion was larger than when a Double-Object prime was produced (0.63 vs. 0.50, CI = 0.07). This amounted to an overall priming effect of 0.13. No other effects were statistically reliable. In particular, there was no interaction of Prime Structure by Modality (all Fs < 1, CI = .09). When the prime and target sentences were produced in the same modality, the difference in Prepositional-Object target proportions was similar to when the prime and target sentences were produced in different modalities (i.e., the prime was written and the

target was spoken). There was a within-modality priming effect of 0.17 and a between-modality effect of 0.10. As in Experiment 1, this experiment found equivalent within- and between-modality priming.

Combined analysis of Experiments 1 and 2

To compare priming in conditions where prime and target employed the same verb and conditions where they did not, and to increase our confidence in the pattern of results, we carried out a between-experiments comparison, including Verb (repeated vs. different) as a third factor, together with Prime Structure and Prime Modality. All factors were within-items, Prime Structure and Prime Modality were within-participants, and Verb was between-participants.

Target Other analysis

The proportion of Others produced in the target completions was equivalent across all conditions (all Fs < 2.7, all ps $> .10$).

Prepositional-Object Target Proportion analysis

When a Prepositional-Object prime was produced, the Prepositional-Object target proportion was larger than when a Double-Object prime was produced (0.65 vs. 0.42, CI = 0.05). There was also an interaction of Prime Structure by Verb, although this was marginal by items ($p = 0.058$). This indicated that the magnitude of priming in Experiment 1, when the verb was repeated between prime and target, was greater than the magnitude of priming in Experiment 2, when the verb was different (0.34 priming effect vs. 0.13 priming effect, CI = 0.05). This accords with previous findings that repetition of the verb enhances priming (e.g., Branigan et al., 2000; Pickering & Branigan, 1998). Importantly, the Prime Modality by Prime Structure interaction remained non-significant (all Fs < 1, CI = 0.09), so there was no evidence that within- and between-modality priming differed in magnitude. Finally, there was no three-way interaction (all Fs < 1). This meant that there was no sign of a greater effect of verb repetition on priming within modality than between modality.

Discussion of Experiments 1 and 2

Experiments 1 and 2 demonstrated that participants were more likely to produce a target utterance which was of the same syntactic structure as the prime utterance than was of the alternative structure. Crucially, the magnitude of this syntactic priming effect was not influenced by whether the prime and target sentences were in the same or different modalities. Written prime responses primed spoken target responses to the same extent that spoken prime response primed spoken target responses. The fact that we found a (between-participants) difference in the magnitude of priming depending on whether the verb was repeated or not is evidence of the sensitivity of the method, and therefore gives us more confidence that the lack of an effect of the prime modality is not a Type II error. Hence, the results are consistent with the hypothesis that the same syntactic representation is accessed in spoken and written production.

However, it is conceivable that participants re-read what they had just written after writing a prime response. It might be that this act of re-reading activates phonological representations and hence the syntactic information associated with spoken language processing. This would then lead to an apparent cross-modality priming effect. For this to be correct, participants would need to re-read the prime on a high proportion of trials, and for the mere act of reading to strongly activate the spoken syntactic representations. To investigate this possibility, Experiment 3 was a replication of Experiment 1, except that target responses were written instead of spoken. Any cross-modality priming could therefore not be attributed to the activation of spoken syntactic representations during re-reading of the prime sentence.

Experiment 3

Method

Participants

Sixteen students from the University of Edinburgh were paid to participate.

Items

The items were the same as Experiment 1, except that the target fragment was written rather than spoken. In addition, the proportion of written to spoken filler fragments was adjusted to match the experimental items, so that 72 of the filler fragments were written trials and 24 were spoken trials. Items were rotated across conditions and participant lists as in Experiment 1.

Procedure and scoring

These were the same as in Experiment 1.

Results and discussion

Table 4 shows the raw data for Experiment 3, and Table 2 summarizes all significant effects. Participants produced a Prepositional-Object or Double-Object completion for the prime fragment on 89% of trials (342 out of 384); of these, 77 were written Prepositional-Object completions (23%), 95 were written Double-Object completions (28%), 82 were spoken Prepositional-Object completions (24%), and 88 were spoken Double-Object completions (26%).

Table 4
Number of responses across conditions for Experiment 3

Sentence condition	Structure		
	PO	DO	Other
Prime Completions			
Written	77	95	20
Spoken	82	88	22
Target Completions			
Written PO Prime	40	14	23
Written DO Prime	38	26	31
Spoken PO Prime	47	10	25
Spoken DO Prime	34	19	35

Target Other analysis

The proportion of Others produced in the target sentences was equivalent across all conditions (all Fs<1.1).

Prepositional-Object Target Proportion analysis

Fig. 1 shows the Prepositional-Object target proportions across all conditions. When a Prepositional-Object prime was produced, the Prepositional-Object target proportion was larger than when a Double-Object prime was produced (0.79 vs. 0.62, CI = 0.12). In other words, there was an overall priming effect of 0.17. No other effects were statistically reliable. Most importantly, there was no interaction of Prime Structure by Modality (all Fs < 1, CI = 0.14). When the prime and target were within the same modality (i.e., the prime and target were both written), the magnitude of priming was 0.15 and when they differed in modality the magnitude of priming was 0.18.

Experiment 3 demonstrated again that participants were more likely to produce a target utterance with the same structure as the prime utterance than with the alternative structure, and that the magnitude of priming was unaffected by the modality of the prime. We argue that these findings rule out the possibility that cross-modality priming effects could be due to participants re-reading the prime sentence and thereby activating phonological representations.

Combined analysis of Experiments 1 and 3

As Experiment 1 involved spoken target production and Experiment 3 involved written target production with the same items, we were able to compare priming of spoken and written targets. Hence we carried out a between-experiments comparison, including Target Modality (spoken vs. written) as a third factor, together with Prime Structure and Prime Modality. All factors were within-items, Target Modality was between-participants, and Prime Structure and Prime Modality were within-participants.

Target Other analysis

There was a main effect of Target Modality, with participants producing more Others in the written Target responses than the spoken Target responses (0.34 vs. 0.19, CI = 0.12). This may be because Other responses tend to be short (e.g., *the cook lends some cups*), and the increased effort of writing may make short completions more likely (such differences probably did not occur in the prime sentences because the sentence fragments included an additional noun phrase). No other differences were statistically reliable; in particular there was no difference in the proportion of Others produced following Prepositional-Object and Double-Object primes (all Fs < 1).

Prepositional-Object Target Proportion analysis

There was a main effect of Target Modality, with the Prepositional-Object target proportion greater in Experiment 3 than Experiment 1 (0.70 vs. 0.50, CI = 0.15). In other words, participants produced more Prepositional-Object completions for written targets than spoken targets. There was also a priming effect; when a Prepositional-Object prime was produced, the Prepositional-Object target proportion was larger than when a Double-Object prime was produced (0.73 vs. 0.48, CI = 0.07). There was numerically greater priming for spoken target completions (0.34) than written target completions (0.17). Although this effect was marginally significant by participants ($F1(1,30) = 4.09$, $p = 0.052$), it was non-significant by items and $minF'$ (both Fs < 1.2). No other effects were statistically reliable.

As before, the interaction of Prime Structure by Prime Modality was not significant (both Fs < 1, CI = .09). When the Prime and Target were produced in the same modality (both spoken in Experiment 1 and both written in Experiment 3), there was a 0.23 priming effect; when the Prime and Target were produced in a different modality (a written prime and spoken target in Experiment 1 and a spoken prime and written target in Experiment 3), there was a 0.28 priming effect.

The main effect of Target Modality reported above occurred because participants were more likely to use a Prepositional-Object structure (vs. a Double-Object structure) in written production than in spoken production. This accords with corpus data: Gries (2005) found that the Prepositional-Object construction was numerically more common in written English (53% of Prepositional-Object and Double-Object constructions) than spoken English (42%), though he did not directly analyze this comparison. It may be that this reflects tendencies for spoken and written language to favor different structures (e.g., passives in writing; Blankenship, 1962; O'Donnell, 1974).

General discussion

All three experiments demonstrated syntactic priming effects between modalities. The same results occurred whether the prime and target sentences contained the same or different verbs: The magnitude of priming was unaffected by whether the prime and target were in the same modality or in different modalities. In contrast, priming was enhanced when the verb was repeated between prime and target, replicating previous findings (Branigan et al., 2000; Pickering & Branigan, 1998). This finding makes it very unlikely that the lack of a modality effect is due to insufficient power in our experiments (with effects of modality being tested three times in within-participants designs, and effects of verb repetition being tested once in a between-participants design). In addition, priming did of course occur between modalities, which should not have happened if syntax were represented independently for each modality. The results therefore support a model of language production where syntactic information is shared between written and spoken production.

One possible counter-argument is that writers might activate not only written syntactic representations but also spoken syntactic representations for written production. Conversely, speakers might activate not only spoken syntactic representations but also written syntactic representations for spoken production. Indeed, there is evidence for automatic activation of orthographic codes during speech production (Damian & Bowers, 2003), just as there is evidence for automatic activation of orthographic codes during speech comprehension (e.g., Donnenwerth-Nolan, Tanenhaus, & Seidenberg, 1981). However, such an account would require very strong transfer between written and spoken representations in both directions to explain our results. Most crucially it appears that, regardless of the underlying mechanisms, syntax is accessed in the same way for spoken and written production.

Let us now interpret the results in terms of a lexically based account of the representation and use of syntactic information during production. In accord with most current theories of language production, we postulate that syntactic information is represented at the lemma stratum. Here we follow Levelt et al. (1999) in assuming that the lemma stratum is restricted to syntactic information, and that it is linked to a conceptual stratum, representing semantic information, on the one hand, and a word-form stratum, representing morphophonological information, on the other (see Kempen & Huijbers, 1983; Levelt, 1989; Zorzi & Vigliocco, 1999 for slightly different proposals). Lemma nodes are abstract representations of words which are not specified for phonological or orthographic properties. These nodes are linked to nodes specifying grammatical category, grammatical gender, and so on. Such an account is compatible, for instance, with data showing that people are able to report the grammatical gender of a word that they cannot produce, either because they are in a tip-of-the-tongue state (Vigliocco et al., 1997) or suffer from anomia (Badecker, Miozzo, & Zanuttini, 1995).

Pickering and Branigan (1998) extended Levelt et al.'s model of the lemma stratum to include more detailed syntactic information. Most importantly, they assumed that a lemma node is linked to combinatorial nodes, which specify the ways in which the word can combine with other elements to form possible expressions. For example, the lemma for a dative-alternating verb like *give* is linked to a *NP,PP* node associated with the Prepositional-Object construction and a *NP,NP* node associated with the Double-Object construction. Other dative-alternating verbs (e.g., *lend*) are also linked to the same nodes. On their account, production of an utterance such as *The neighbour gives the mower to his friend* requires the activation of the lemma node *give* and the combinatorial node *NP,PP*, together with the link between them. Syntactic priming occurs because the activated nodes do not return to their resting level of activation immediately, and nodes with a higher level of activation are more likely to be selected than a competitor. So the activation of *give* and *NP,PP* explains the subsequent preference for use of the Prepositional-Object construction, and a particularly strong preference for use of the Prepositional-Object construction with the same verb (as found by Pickering and Branigan, 1998, and Branigan et al., 2000). Cleland and Pickering (2003) integrated this model of the lemma stratum with the conceptual stratum and word-form stratum. However, they did not differentiate between written and spoken production. The current results suggest that the model can be further refined to specify a modality-neutral lemma level linked to modality-specific word-form levels (see Fig. 2).

Our results rule out an alternative account where the lemma stratum contains modality specific "phonologi-

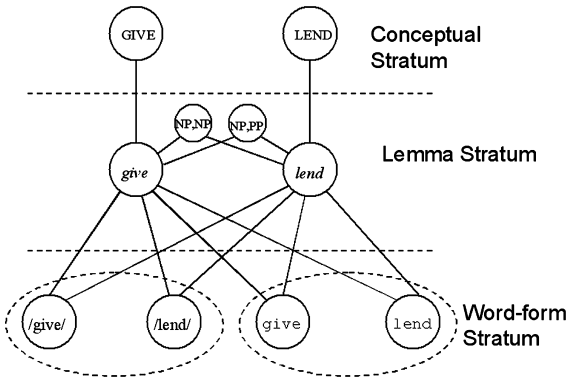

Fig. 2. Model of lexical access based on Levelt et al. (1999), in which the conceptual and lemma strata are modality neutral but the word-form stratum is modality specific.

cal'' lemma nodes and ''phonological'' combinatorial nodes linked to phonological word-forms and ''orthographic'' lemma nodes and ''orthographic'' combinatorial nodes linked to orthographic word-forms. This model would predict no syntactic priming between modalities (as the priming effect would be dependent on different combinatorial nodes in the different modalities).

A more interesting possibility would be to have modality specific lemma nodes but modality neutral combinatorial nodes. Such an account bears some similarity to Caramazza (1997), who assumes that a conceptual node is linked to two separate lexical nodes, one for each modality. These are linked to shared syntactic nodes which represent information such as grammatical gender (note that he does not assume lemma nodes at all). This model was developed to address modality-specific deficits in single word production, and Caramazza does not speculate on the representation of combinatorial information. However our results suggest that combinatorial information is not represented in this way. The finding of enhanced priming when the verb was repeated versus when it was not (cf. Pickering & Branigan, 1998) must be due to the co-activation of the verb lemma nodes and the combinatorial nodes as well as activation of the combinatorial nodes themselves; if priming were solely due to residual activation of the combinatorial nodes, it would be unaffected by repetition of the verb. As Caramazza's model postulates separate links from the modality specific lexical nodes to the syntactic nodes, it predicts enhanced priming when the prime and target were produced in the same modality (based on the residual co-activation of the modality-specific lexical node and the combinatorial node). However, there was no evidence that this occurred, even though verb repetition itself did enhance priming (see combined analysis of Experiments 1 and 2).

We have also argued that the treatment of priming as implicit learning (Bock & Griffin, 2000; Chang et al., 2000, 2003) predicts priming between modalities. These accounts attribute syntactic priming to long-term adjustments to processing mechanisms associated with syntax. Such priming would not be influenced by whether the utterance is spoken or written, because syntactic features are not modality dependent. As we found equivalent within- and between-modality priming, our results are compatible with such accounts.

Bock and Griffin (2000) conjectured that priming might involve a component of short-term activation and long-term implicit learning. Lexical repetition enhances syntactic priming, both in the current study (comparison of Experiments 1 and 2), and in previous work (Branigan et al., 2000; Pickering & Branigan, 1998), and it is possible that this enhancement depends (partly or entirely) on explicit memory for repeated words, which would decay fairly rapidly. Based on this account, we might also predict stronger priming within than between modality when the verb was repeated, as it would involve some explicit memory for the words. The data do not provide any evidence for this claim, with the two same verb experiments (Experiments 1 and 3) showing non-significantly less priming within than between modality (and the different-verb Experiment 2 showing the opposite trend). The relationship between lexical repetition and priming mechanisms therefore remains an avenue for further research.

In conclusion, we have demonstrated that syntactic priming is unaffected by whether prime and target sentences are produced in the same or different modalities, and therefore propose that syntax is accessed in the same way in spoken and written production. It is likely that the syntactic representations underlying sentence production are shared between spoken and written production. This is consistent with a model of language production where syntactic information is represented at a modality-neutral lemma level which is linked to modality-specific word-form levels.

Appendix A

The primes are presented in the order Prepositional-Object-inducing prime/Double-Object-inducing prime. The targets are presented after the primes.

Experiment 1 and 3 items

1. The woman sends the form/company. The boyfriend sends.
2. The blackmailer sends the photos/MP. The sailor sends.
3. The man sends the donation/charity. The fan sends.
4. The child sends the picture/grandfather. The writer sends.
5. The mother gives the toy/baby. The bus driver gives.
6. The lecturer gives the book/student. The zoo keeper gives.
7. The writer gives the script/publisher. The shop assistant gives.
8. The cowboy gives the guns/indian. The air-hostess gives.
9. The cricketer shows the ball/umpire. The child shows.
10. The youngster shows the toy/teacher. The patient shows.
11. The nurse shows the chart/doctor. The jeweller shows.
12. The lawyer shows the evidence/jury. The artist shows.
13. The millionaire loans the painting/museum. The musician loans.
14. The swimmer loans the towel/diver. The teenager loans.
15. The father loans the car/daughter. The student loans.
16. The hairdresser loans the scissors/assistant. The banker loans.
17. The neighbour lends the mower/friend. The cook lends.
18. The builder lends the plans/surveyor. The trainee lends.
19. The salesman lends the car/woman. The wife lends.
20. The designer lends the jacket/model. The driver lends.
21. The barman hands the pint/customer. The surgeon hands.
22. The courier hands the package/receptionist. The waitress hands.
23. The assistant hands the bag/shopper. The soldier hands.
24. The nurse hands the scalpel/dentist. The newsagent hands.

Experiment 2 items

1. The mother gives the toy/baby. The boyfriend sends.
2. The cricketer shows the ball/umpire. The sailor sends.
3. The millionaire loans the painting/museum. The fan sends.
4. The neighbour lends the mower/friend. The writer sends.
5. The barman hands the pint/customer. The bus driver gives.
6. The woman sends the form/company. The zoo keeper gives.
7. The youngster shows the toy/teacher. The shop assistant gives.
8. The swimmer loans the towel/diver. The air-hostess gives.
9. The builder lends the plans/surveyor. The child shows.
10. The courier hands the package/receptionist. The patient shows.
11. The blackmailer sends the photos/MP. The jeweller shows.
12. The lecturer gives the book/student. The artist shows.
13. The nurse shows the chart/doctor. The musician loans.
14. The salesman lends the car/woman. The teenager loans.
15. The assistant hands the bag/shopper. The student loans.
16. The man sends the donation/charity. The banker loans.
17. The writer gives the script/publisher. The cook lends.
18. The lawyer shows the evidence/jury. The trainee lends.
19. The father loans the car/daughter. The wife lends.
20. The nurse hands the scalpel/dentist. The driver lends.
21. The child sends the picture/grandfather. The surgeon hands.
22. The cowboy gives the gun/indian. The waitress hands.
23. The hairdresser loans the scissors/assistant. The soldier hands.
24. The designer lends the jacket/model. The newsagent hands.

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