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MORPHOLOGICAL PARADIGMS IN LANGUAGE PROCESSING AND LANGUAGE DISORDERS[1]

By Harald Clahsen
University of Essex, UK
Ingrid Sonnenstuhl & Meike Hadler
University of Düsseldorf, Germany
Sonja Eisenbeiss
Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands

Abstract

We present results from two cross-modal morphological priming experiments investigating regular person and number inflection on finite verbs in German. We found asymmetries in the priming patterns between different affixes that can be predicted from the structure of the paradigm. We also report data from language disorders which indicate that inflectional errors produced by language-impaired adults and children tend to occur within a given paradigm dimension, rather than randomly across the paradigm. We conclude that morphological paradigms are used by the human language processor and can be systematically affected in language disorders.

1. Introduction

An inflectional paradigm is a multi-dimensional, potentially recursive matrix which is defined by the morphosyntactic features of word forms or affixes. The theoretical status of inflectional paradigms is

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controversially discussed in morphological theory. Lieber (1992), for example, has argued that paradigms are simply artefacts, parallel to lists of related sentences. Similarly, for Halle and Marantz (1993), paradigms do not have any theoretical status. In most other frameworks, however, an inflectional paradigm is considered to be an important representational device that defines a set of inflected word forms for any lexeme that belongs to a particular syntactic category (see e.g. Wurzel 1984, 1987, Carstairs 1987, Zwicky 1985, Stump 1993, Blevins 1995, Wunderlich 1996, Aronoff 1976, 1994). The formation of paradigms is constrained by general principles, such as Blocking, Specificity (Kiparsky 1982, 1998), Completeness and Uniqueness (Wunderlich 1996). Blocking and Specificity require that if two rules or affixes are in competition for one paradigm slot, the one that is more specific in its application is preferred over the more general one. Completeness requires that every cell of a paradigm must be occupied, and Uniqueness that every cell is uniquely occupied.

A related linguistic controversy concerns the status of affixes. Wunderlich (1996) and Jackendoff (1997, 2000), for example, believe that regular affixes represent lexical entries, and consequently, paradigms are considered to be affix-driven, i.e., directly constituted by the 'combinatory force of the inflectional affixes' (Wunderlich 1996: 96). Other morphologists do not assume lexical entries for inflectional affixes. Instead, they posit what Anderson (1982, 1992) calls 'morpholexical rules' and Stump (1993) 'realisation rules', i.e., rules that specify how a given set of features is to be spelled out. These rules effectively determine a set of slots in a paradigm and show how each slot is to be filled. Thus, irrespective of whether affixes form lexical entries or are better treated as exponents of morphosyntactic features derived from realisation rules, under both views paradigms play an important role in organising related inflected forms.

In psycholinguistic terms, one can think of a paradigm as a matrix or access system for mapping grammatical information, i.e., morphosyntactic features, to their exponents or affixes. The question, then, is whether there is any empirical evidence that the human language processor makes use of such a system. This question has received relatively little attention from psycholinguists. Some researchers have studied processing differences between what were considered to be the 'canonically inflected' or base forms of a given lexeme and 'non-canonically inflected' forms of the same lexeme. In a set of studies on inflected Serbo-Croatian nouns it was found that nominative forms were processed faster than non-nominative forms (Lukatela et al. 1978, 1980, Feldman and Fowler 1987, Katz et al. 1987, Todorović 1988, Kostić 1995). For example, Serbo-Croatian nouns in oblique case forms (instrumentals and datives) take longer response times in visual lexical decision tasks than nominative forms. Similar results have been obtained for German nouns. In a visual lexical decision task, Günther (1988) found that homonyms such as SAGE (which could either be a nominative sing. form of the noun *(die) Sage* 'the myth' or an imperative or 1SG form of the verb *sagen* 'to say') were treated as base forms (i.e. as nominative forms of the corresponding noun) rather than as oblique forms (of the verb), despite the fact that the latter are more frequent than the former. These results have been taken to support a satellite-like representation of inflected word forms in which the inflectional variants of a given lexeme are connected to a nucleus (e.g. the nominative form). According to the satellite model, each lexeme has one designated nucleus, and if access is made via a satellite form, extra time is required, hence the longer response times for non-nominative forms. While these results suggest that non-oblique base forms seem to have some privileged status in word recognition, they leave open the question of how inflectional paradigms are mentally represented and used in language processing.

In the present study, we investigate finite verb forms of German inflected for person, number and tense, focussing on the role of inflectional paradigms in language processing. Results from two lexical priming experiments will be presented that show priming differences between the various person and number forms. The observed priming patterns can be explained by the structure of the inflectional paradigm. Specifically, we will argue that neighbouring cells from the same paradigm may cause inhibitory effects in priming experiments. A second set of data to be investigated with respect to paradigms comes from language-impaired subjects. Data from Broca's aphasics and from Specific Language Impairment indicate that inflectional errors produced by language-impaired subjects are constrained by the structure of the paradigm. For example, errors tend to occur within one paradigm dimension, rather than randomly across the paradigm.

The purpose of the experiments to be presented in sections 3 and 4 is to determine the role of morphological paradigms in on-line language processing. Our focus will be on potential effects of paradigm structure for morphological processing. Before presenting the experimental results, we will provide a brief description of the inflectional paradigm under study.

2. Person and number inflection in German

The grammatical person and number of the subject are marked on the finite verb in German. Person and number marking is found in preterite and present tense forms in the indicative as well as in the subjunctive mood. These features are manifested in terms of suffixes and, at times, in terms of changes in the stem vowel. As the focus of the present study is regular inflection, we will leave aside morphological irregularities, such as the suppletive forms of *sein* 'to be' and stem vowel changes. There are four overt person and number affixes, *-e*, *-st*, *-t* and *-n*. In (1), the full paradigm of the weak verb *lachen* 'to laugh' is shown for illustration.

(1)

	Imperative	Present	Preterite	Present Subj.	Past Subj.	Infinitive	Past Participle
1SG		*lache*	*lachte*	*lache*	*lachte*		
2SG	*lach(e)*	*lachst*	*lachtest*	*lachest*	*lachtest*		
3SG		*lacht*	*lachte*	*lache*	*lachte*		
						lachen	*gelacht*
1PL		*lachen*	*lachten*	*lachen*	*lachten*		
2PL	*lacht*	*lacht*	*lachtet*	*lachet*	*lachtet*		
3PL		*lachen*	*lachten*	*lachen*	*lachten*		

Note that in all tenses and moods the 2SG has the exponent *-st* and the 2PL has the exponent *-t*, while the 1PL and the 3PL have the same exponent throughout (*-n*). Note also that the 1SG and the 3SG do not have overt person/number affixes in the preterite and the subjunctive. Only in the present tense indicative do the 1SG and 3SG have different exponents, namely -*e* and -*t* respectively.

There are different ways of describing these person and number forms in terms of morphological paradigms. Adopting an affix-based approach, Wunderlich and Fabri (1995) distinguish between a general paradigm that applies to all tenses and moods, and a subparadigm that is embedded in one cell of the general paradigm for the present tense, indicative, as shown in (2).

(2) a.

	+PL	–PL
+2	/t/	/st/
–2	/n/	→ [–subj, –pret] → (b)

b.

+1	**–1**
/e/	/t/

In their model, inflectional paradigms may have a recursive structure in that a cell in the paradigm may be occupied by another paradigm, and (2) is an example of a recursive paradigm structure. In this account, the affixes that apply to all tenses and moods, i.e., -*st*, -*t* and -*n*, define the general paradigm in (2a). To capture the fact that the 1/3SG do not have overt person/number affixes in the preterite and the subjunctive, one cell in the general paradigm (2a) is left empty, namely [–2, –PL]. The general paradigm accounts for all finite verb forms illustrated in (1), except for the present tense, singular, indicative where 1SG and 3SG have different affixes. The paradigm in (2b) accounts for these forms by introducing the extra dimension [$\pm$1], which fills the gap in the general paradigm (2a) and is restricted to present tense indicative.

Blevins (2000) proposes an exponence-based analysis of the German conjugational system. This system involves the root (e.g. *lach*-), a second stem (e.g. *lacht*), which constitutes the basis for all preterite forms, and stem-formation and agreement rules. The two stem-formation rules add -*e* to the root or to the second stem to form the present tense subjunctive stem (e.g. *lache*) and the preterite stem (e.g. *lacht-e*). The three agreement rules derive the 2SG forms ending in *-st*, the 2PL forms ending in *-t*, and the 1/3PL forms ending in *-n*; these rules are parallel to Wunderlich and Fabri's general paradigm. The contrast between 1SG and 3SG which is only distinctive for present indicatives is mediated in terms of different stems, i.e., 3SG present forms in *-t* and 1SG indicative and first person subjunctive forms are said to 'select' particular stems: 3SG forms select the *-t* stem (e.g. *lacht*), while 1SG forms select the secondary stem in *-e*. These patterns could be expressed in terms of feature co-occurrence restrictions in Blevins's account; while in Wunderlich and Fabri's analysis these forms constitute the subparadigm.

In the so-called Natural Morphology approach (see e.g. Wurzel 1984), the properties of inflectional affixes are described in terms of paradigm structure constraints (PSCs) (see e.g. Wurzel 1987), and an account of person and number inflection is available from Bittner and Bittner (1990). They define a general PSC for the 2SG *-st*, the 2PL *-t* and 1/3PL *-n* and a second PSC which contains among other affixes the 1SG present *-e* and the 3SG present *-t*. The latter PSC is the more specific one and takes precedence over the general PSC which applies to all verbs.

What is common to these accounts is that they posit two different paradigmatic representations for the various person and number forms of German. The 2SG, the 2PL and the 1/3PL are based on general agreement rules in Blevins's analysis, they form a general paradigm in Wunderlich and Fabri's account, and they constitute the most general PSC which applies to all verbs in Bittner and Bittner's analysis. By contrast, the 1SG and the 3SG of the present tense are based on stem forms in Blevins's account, they form a subparadigm in Wunderlich and Fabri's model, and they are part of a specific PSC for Bittner and Bittner. Thus, there seems to be agreement among these accounts in that the paradigmatic representation of the 1SG *-e* and the 3SG *-t* is different from those of the other person and number forms: *-e* and *-t* are represented in a different subparadigm, rule block or PSC from the other person and number forms. The empirical question we will address is whether this paradigmatic difference has any effect on morphological processing. We examined this question in two lexical priming experiments.

3. Experiment I

We adopted the cross-modal immediate repetition priming paradigm (Marslen-Wilson et al. 1993, 1994), in which subjects hear a spoken prime immediately followed by a visually presented target form to which they make a word/non-word decision. This technique has two main advantages. Firstly, since the task is cross-modal, any priming effects are likely to be due to the lexical representations themselves, rather than to effects of modality-specific access procedures. Secondly, since all targets are presented immediately at the offset of the prime, the task is likely to tap on-line processes of morphological priming, while unwanted effects of episodic memory are reduced.

The priming conditions are shown in (3). The visual target in all conditions was the 1SG -*e*, i.e., a subparadigm form in terms of (2). For ease of exposition, we will describe the priming conditions using Wunderlich and Fabri's (1995) terminology. It should be clear from the previous section, however, that these notions are translatable into other frameworks. Priming condition I provides the baseline, identical repetition. In conditions II and III, a form from the general paradigm was taken as a prime, i.e., the priming route is from the general towards the subparadigm. In condition IV we tested for priming within the subparadigm; here, both prime and target are taken from the subparadigm. Thus, in condition IV primes and targets are closely related paradigmatically, whereas in conditions II and III primes and targets are paradigmatically different.

(3)

Identity (Baseline)	**Morphological Primes**			**Visual Targets**
Condition I	Condition II	Condition III	Condition IV	
1SG	2SG	2PL	3SG	1SG
(ich) lackiere	*(du) lackierst*	*(ihr) lackiert*	*(er) lackiert*	*lackiere*

Response latencies on the visual targets should vary depending on which auditory prime is previously presented. If paradigm structure plays a role in morphological processing, we should find priming asymmetries corresponding to paradigmatic differences. Thus, our experimental conditions II and III should produce a priming pattern different from the one in condition IV. This was tested in our first cross-modal priming experiment.

3.1. Materials

Forty quadruplets of regularly inflected verb forms were constructed as shown in (3). The target verb form in all conditions was the 1SG form, and for each target four types of primes were used. In all conditions, the primes were presented together with appropriate personal pronouns in order to make it possible for subjects to distinguish 2PL forms, e.g., *(ihr) lackiert,* from 3SG forms, e.g., *(er) lackiert.* So that no participant should see the same target more than once, four experimental versions were constructed. The forty quadruplets were divided into four groups, matched for mean stem frequency and syllable length; the frequencies were taken from the CELEX database (Baayen et al. 1993). The items were distributed over four versions in a Latin Square design (Winer 1971). Thus each version included forty different prime–target pairs (ten from each of the conditions I–IV). No target appeared more than once in any version. The experimental targets including their stem frequencies are shown in Appendix A.

In order to keep the proportion of related pairs low and to deter the participants from developing strategies based on expectations about likely relations between primes and targets, 440 filler items were included in the experiment. We constructed 200 prime–target pairs in which primes and targets had different verb stems (to counterbalance the 160 experimental items in which both primes and targets had the same verb stem). We also constructed 240 prime–target pairs in which the target verb was a nonsense word. The nonsense verbs were constructed by changing two or three letters of an existing verb. In total, the stimulus set of each experimental version consisted of 480 prime–target pairs.

In order to eliminate undesired priming effects across items, these pairs were pseudo-randomised making sure that no semantic associations of any kind existed between consecutive items, and that not more than four items of the same type occurred in sequence. Each of the four versions exhibited the same order of test and filler items.

3.2. Method

76 students of the University of Düsseldorf were paid for their participation in the experiment (48 women and 28 men, mean age 26). Nineteen students participated in each version, none of them participated in more than one experimental version.

Procedure: The primes were spoken by a female native speaker of German and recorded on digital audiotape. The resulting data were stored on a computer and cut by marking the onsets and offsets of the primes with a sound editor. Each prime was compiled into an audio wav-file. The presentation of the stimuli and the measurement of the reaction times were controlled by the NESU software package (Baumann et al. 1993). The sequence of stimulus events within each trial was as follows. A short attention tone (250ms.) was presented over headphones. The attention tone was followed by a fixation point that was displayed on a computer screen in front of the participant for 800ms. The fixation point was followed by the auditory prime, which was presented over headphones. Immediately at the offset of the (spoken) prime, the visual target was presented on a 17″ computer monitor in Arial 24pt in white letters on a dark background. The target stayed on the computer screen for 200ms. The measurement of the reaction times began with the presentation of the target. The participants reacted by pressing a green button (for a word) or a red button (for a nonsense word) on a dual box. The green button was on the right side for right-handed and on the left side for left-handed participants. 1,400ms. after the reaction the next trial was initiated.

Written instructions with detailed descriptions of the task and some examples for prime–target pairs were given to the participants before the experiment. The experiment itself started with a short practice phase. After this phase, the participants had the opportunity to ask questions about the procedure. Two further breaks were provided. During each break and at the end of the experiment the participants were asked to read a list of fifteen words, and to mark those words they had heard during the experiment. For each of these lists, nine words had been presented as auditory primes in the preceding experiment phase. The remaining six words did not occur in the experiment at all. The answers to this task were not analysed, since it was only included to ensure that the participants paid attention to the auditory stimuli. The overall duration of the experiment was about one hour per subject.

Analysis: Errors, i.e., non-word responses to existing words and word responses to nonsense words, were removed before the statistical analyses. For the test items, the error rate did not exceed 2% in any of the four test conditions. In addition extreme outliers for each subject were removed from the data set. These outliers were determined by using stem-and-leaf plots. They made up between 4.5% and 5.1% of the data set for each of conditions I to IV. Mean response times for each subject and each item in each condition were then computed. The mean scores were entered into two separate (one-way) Analyses of Variance (ANOVA) with the factor ‘Prime Type’.

3.3. Results

The results are shown in Figure 1. This figure presents the mean lexical decision times for the visual targets in each of the four priming conditions tested. The first column shows that the shortest reaction times were found in the Identity condition. Unsurprisingly, a prime that is identical to the target form produces shorter response times than any other condition. In this experiment, the response times in the Identity condition provide the baseline for the comparison between general and subparadigm forms with respect to priming. Figure 1 shows that forms from the general paradigm, i.e., 2SG and 2PL, were effective primes for the visual targets. After hearing a 2SG or a 2PL form, the mean response times to the visual stimuli were similar to those of the Identity condition, i.e., 592 and 593ms. In contrast, prior presentation of a subparadigm form (= 3SG) produced much longer response times on the same visual targets.

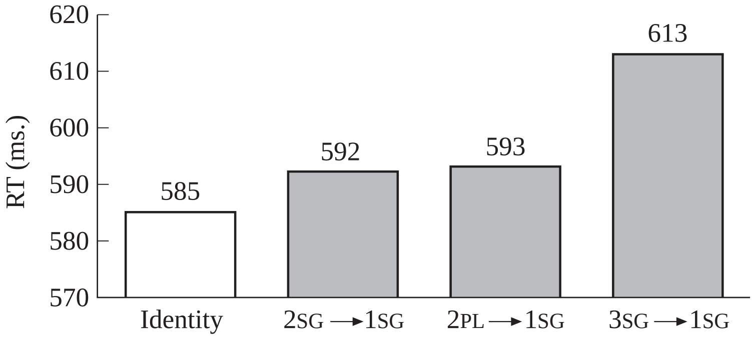

Figure 1 Mean lexical decision times on visual targets

The priming differences between general and subparadigm forms were also confirmed statistically. The ANOVA produced a significant main effect of Prime Type, both in the subject and in the item analysis (F1=12.85, p<.001, F2=6.63, p<.001). Paired t-tests for subjects and for items (see Appendix B) showed that the Identity condition and the two general paradigm forms (2SG, 2PL) did not yield a statistically significant difference. By contrast, the differences between the Identity condition and the 3SG condition are highly significant.

3.4. Discussion

This experiment demonstrates priming differences between the various inflected verb forms. Full priming was found for general paradigm forms, i.e., prior presentation of a 2SG or a 2PL form of a given verb produced the same facilitation in recognising a visually presented 1SG form of that verb as prior presentation of the target (1SG) form itself. By contrast, prior presentation of the 3SG form of a given verb was less effective than prior presentation of the target form itself.

Paradigmatic analyses of German verb inflection provide a straightforward explanation of these findings. Consider first Wunderlich and Fabri's (1995) account according to which we can distinguish two different priming routes as shown in (4):

(4)	Primes		Targets
a. Cond. II/III:	general paradigm	—FULL PRIMING—>	subparadigm
b. Cond. IV:	subparadigm	—REDUCED PRIMING—>	subparadigm

In (4a) primes and targets come from different paradigm regions and the priming route goes from the general towards the subparadigm. In (4b) primes and targets come from the same paradigm region. Moreover, the two subparadigm forms in (4b) compete for the same cell in the general paradigm; see (2) above. Given the recursive structure of the paradigm, it is likely that when one of the subparadigm forms is heard, it temporarily inhibits its competitor; hence the reduced priming in (4b). This is not the case in (4a), since primes and targets come from different paradigm regions. There is no competition and therefore no inhibition in priming.

In Blevins's (2000) account, the prime–target pairs 2SG → -*e* and 2PL → -*e* come from different rule blocks. The target form with the exponent -*e* is based on a stem-formation rule, whereas the 2SG and the 2PL are derived from agreement rules. Since the -*e* stem is compatible with the -*st* and -*t* forms, there is no competition between primes and targets, hence effective priming. This is not the case for the prime–target pair 3SG → -*e*. These forms are based on different stem-formation rules which are incompatible with each other, hence the inhibitory (reduced) priming effect observed in our experiment. These considerations show that the observed priming differences correspond to paradigmatic differences, indicating that paradigm structure does indeed play a role in morphological processing.

Are there any alternative ways of explaining the observed priming differences that would not necessarily rely on paradigm structures? One relevant observation is that it was only 3SG forms that produced a reduced priming effect in the experiment. It might be the case that this particular form has properties that are fundamentally different from the other person and number forms (see e.g. Bybee 1985: 50). Moreover, 3SG forms are typically more frequent than other person and number forms. Hence, it might be that the priming differences we found are caused by the special status of the 3SG present tense forms rather than by the structure of the paradigm. To address this question, we performed another priming experiment the results of which are presented in the next section.

4. Experiment II

The purpose of this experiment is to tease apart the role of paradigm structure for morphological priming from potential effects caused by the particular forms that were used as primes and targets in the previous experiment. We therefore performed another cross-modal lexical priming experiment in which we used the same verb forms as in the previous experiment, but this time we changed the priming routes. Instead of 1SG forms, we used 2SG forms as visual targets, i.e., a form from the general paradigm. Primes were 2SG, 2PL, 1SG and 3SG forms. As in the previous experiment, the verb forms used as primes were presented together with personal pronouns; in this way, the primes were clearly identifiable as 2SG, 1SG and 3SG present tense forms. In contrast to the previous experiment, however, the visual targets we used in the present experiment are root forms affixed with -*st*, e.g., *lach-st* 'laugh-2SG:PRES', and these are clearly identifiable as 2SG present tense forms. These target forms are incompatible with any of the person and number forms presented as morphological primes. We would therefore expect reduced priming (compared to the Identity condition) for the prime–target pairs 1SG → -*st* and 3SG → -*st*. Moreover, we would expect that in the present experiment, the 3SG forms demonstrate the same kind of priming pattern as the other forms. If, on the other hand, the priming differences found in the previous experiment are due to the special status of 3SG forms, this should be reflected in different priming patterns in the present experiment as well, irrespective of the fact that we have changed the priming route.

4.1. Materials

The target verb form in all conditions was the 2SG present tense form. For each target, four types of primes were constructed, as shown in (5). Again, as in the previous experiment, the verb forms used as primes were presented together with appropriate personal pronouns.

(5)

Identity (Baseline)	**Morphological Primes**			**Visual Target**
Condition I	Condition II	Condition III	Condition IV	
2SG	1SG	3SG	2PL	2SG
(du) spionierst	*(ich) spioniere*	*(er) spioniert*	*(ihr) spioniert*	*spionierst*

The design was taken over from the previous experiment. There were 160 prime–target pairs such as those shown in (5), divided into four groups, and matched for mean stem frequency and syllable length, as well as 440 filler items.

4.2. Method

The methods, procedures, time settings and statistical analyses for this experiment were taken over from the previous cross-modal priming experiment. Fifty-two students from the University of Düsseldorf were paid for their participation in the experiment (40 women and 12 men; mean age 24). None of the subjects participated in more than one experimental version. Errors were removed from the data set before the statistical analyses. For the test items the error rate did not exceed 2.7% in any of the four test conditions. In addition, extreme outliers for each subject were removed from the data set, using stem-and-leaf plots as in the previous experiment. Outliers made up between 1.8% and 3.9% of the data set for each of the conditions I to IV.

4.3. Results

Figure 2 presents the results. As in the previous experiment, the Identity condition in the first column produced the shortest reaction time. All other experimental conditions led to longer response times than the Identity condition. Moreover, in this experiment, the 3SG condition does not behave any differently from the other experimental conditions with respect to priming. These results are also confirmed statistically. Both in the subject and in the item analyses, there was a significant main effect of Prime Type, $F1=5.27$, $p<.002$, $F2=3.40$, $p=.020$. Subsequent two-way comparisons using paired *t*-tests (see Appendix C) showed that this main effect is due to the Identity condition, which produced significantly shorter response times than all other conditions. By contrast, response times to the other conditions, i.e., the 1SG, the 2PL and the 3SG, did not differ significantly from each other.

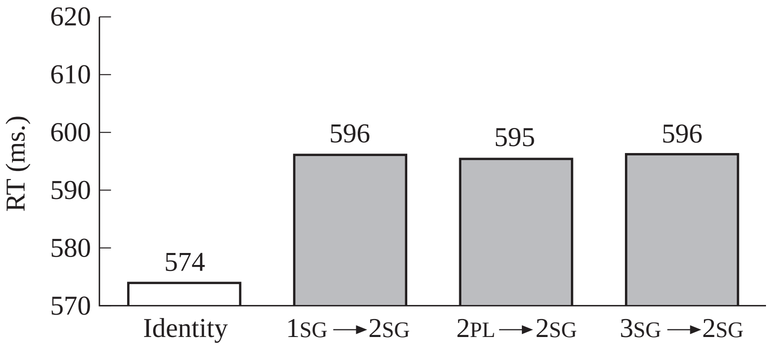

Figure 2 Mean lexical decision times on visual targets

4.4. Discussion

This second cross-modal priming experiment shows that 3SG forms do not have priming properties that differ from those of other person and number forms. Thus the idea that the priming differences found in the first experiment are due to the special status of 3SG forms can be ruled out. The same can be said for the different pronoun forms in the primes used in the two experiments. Recall that all auditory primes were presented with appropriate personal pronouns in both experiments. Thus, one might attribute the observed priming differences in the first priming experiment to the different pronouns used, rather than to the different verb forms, such that (for some unknown reason) the pronoun *er* 'he' produces a different priming pattern than the pronouns *ihr* 'you:PL', *du* 'you:SG' and *ich* 'I'. The control experiment shows that this cannot be the case. The same pronoun and verb forms were used in both experiments, but in the control experiment the condition that comprises the pronoun *er* produced the same priming pattern as the conditions with the other personal pronouns. Hence, the priming differences found in the first priming experiment cannot be due to particular properties of 3SG verb forms or 3SG pronouns.

Leaving aside the 3SG condition for a moment, a comparison of the results from the other conditions reveals an interesting difference between the two priming experiments. As shown in Figure 1, priming from the 2SG or 2PL forms towards the 1SG proved to be as effective as the Identity condition, hence we got full priming under these circumstances. In the control experiment, however (see Figure 2), all experimental conditions produced significantly longer response times than the Identity condition, even though the verb forms used were the same as those in the first experiment. How can we account for this difference?

Recall that the visual targets in the two experiments were different, 1SG forms such as *lackier-e* '(I) varnish' in the first priming study and 2SG forms such as *lackier-st* '(you:2SG) varnish' in the control experiment. One important difference between these forms is that in contrast to the 2SG *-st* (as well as all other person and number suffixes), the 1SG present tense ending *-e* (i.e. schwa) is optional in spoken German. Indeed many speakers prefer 1SG forms without the schwa, e.g., *ich sag, trag, werd* 'I say, wear, will'. By contrast, elision of *-st* in 2SG forms is simply ungrammatical (*du* **sag,* **trag,* **werd*). Thus, the schwa-final forms we used in our first priming experiment as visual targets are phonological variants of unmarked bare stem forms for the 1SG present tense; see Wiese (1986, 1996) for further analysis. It is conceivable that this particular property of 1SG forms led to the full priming effect in our first cross-modal priming experiment. To see this, note first that regularly inflected word forms have been shown to produce full priming effects towards their corresponding stem forms, e.g., *walked* primes *walk* as effectively as the stem itself (see Sonnenstuhl et al. 1999 for a review). This has been attributed to morphological decomposition such that by segmenting *walked* into stem and affix, the lexical entry for the stem (*walk*) is activated, which then primes the target stem.

In the present set of experiments, we only used regularly inflected verbs as primes, hence we would expect to find full priming towards the stem form. In our second priming experiment, however, the *target* forms we used had a separate affix, the 2SG -*st*. Consequently, none of the experimental conditions produced full priming. By contrast, in our first cross-modal priming experiment, we used 1SG present tense forms as targets, e.g. *lackiere* '(I) varnish', i.e., phonological variants of the unmarked bare stems, which are perfectly grammatical for this particular paradigm slot. Hence, the decomposition of the primes into stems and affixes makes a legitimate form for the targets directly available and therefore effectively primes the target. In this way, the full priming effect for 2SG and 2PL forms can be explained. Note, finally, that 3SG primes did not produce full priming in the first experiment, even though these forms can be just as easily decomposed as 2SG and 2PL forms. We argue that this difference follows from the structure of the paradigm. In the 3SG condition of the first priming experiment, both primes and targets are incompatible; in Wunderlich and Fabri's (1995) terminology, for example, they are both subparadigm forms which compete for the same cell in the general paradigm. Competition leads to inhibition in priming, and hence the reduced priming effect for 3SG forms.

Further support for the role of paradigmatic relationships in morphological processing comes from the results of a sentence-matching experiment on person and number inflection in German (Janssen et al. 2001). In this task, subjects were presented with pairs of sentences containing verb forms that were either correct or incorrect with respect to person and/or number agreement. The subjects' task was to decide as quickly and accurately as possible whether the two visually presented sentences were the same or different. Previous studies found that the sentence-matching task is sensitive to subject–verb agreement violations, and that matching a pair of ungrammatical sentences with incorrect subject–verb agreement takes longer than matching a pair of grammatically well-formed sentences (Freedman and Forster 1985, Clahsen et al. 1995). In their sentence-matching task, Janssen et al. (2001) found that violations with -*st* that contained a person and a number error (e.g., **wir park-te-st* 'we park-PRET-2SG') produced significantly longer response times than violations of either person or number (e.g. **ich park-te-st* 'I park-PRET-2SG' or *ihr park-te-st* 'you:2PL park-PRET-2SG'), indicating that the paradigmatic specifications of the affixes affect the subjects' response times. An error in both dimensions, person and number, seems to be a more severe violation than an error in just one dimension, and hence the observed difference in the subjects' response times.

5. Morphological paradigms in language impairments

Paradigms capture relationships between different inflected word forms of the same lexeme. In the previous sections, we saw that different degrees of relatedness between inflected word forms correspond to differences in morphological priming. In this section, we will show how morphological paradigms constrain the inflectional errors produced by language-impaired subjects.

The most detailed linguistic analyses of language impairments are available on Broca's aphasia and on Specific Language Impairment (SLI), and there seems to be a consensus that inflectional morphology is affected in both Broca's aphasics and SLI subjects. In this section, we will discuss some relevant findings on these two impairments focussing on the question of how inflectional paradigms are affected.

5.1. Paradigms in agrammatic aphasia

Agrammatism is considered to be the characteristic symptom of Broca's aphasia (Caramazza and Berndt 1985). Agrammatism affects function words such as articles, auxiliaries, complementisers, bound morphemes marking tense, gender, case, agreement, but not content words such as nouns, verbs and adjectives. The most striking characteristic of agrammatism are omissions and substitutions of inflectional affixes (Grodzinsky 1990). English-speaking agrammatics have been shown to omit inflectional endings and to produce bare stems (Caplan 1987, Kean 1985). While these can function as words in English (e.g. *walks* → *walk*), in other languages, for example in Hebrew, the omission of inflectional affixes would violate word-structure properties. Cross-linguistic studies of agrammatism in e.g. Hebrew, Italian and Russian have shown that agrammatics do not produce illegal words (Grodzinsky 1990). It appears therefore that the broad distinction between word-based morphology (e.g. English) and stem-based morphology (e.g. Italian, Hebrew) is retained in the grammars of agrammatics.

Two observations have been made on the inflectional errors produced by agrammatic aphasics. First, substitution errors are not cross-categorical, that is, verb inflections, e.g., infinitive endings, are only attached to verbs, never to nouns; conversely, case suffixes are never attached to verbs but only to nouns (Grodzinsky 1984). Thus, it seems that agrammatics know the categorical identity of affixes, in the sense that they retain knowledge of the categories to which specific affixes can be attached. Second, substitution errors are not random, but typically involve an exchange of one morphosyntactic feature for another (see Bates and Wulfeck 1989). Consider, for example, results from a study (Penke 1998) examining person and number inflection on verbs in five German-speaking Broca's aphasics. Penke found that the patients only produced a subset of the logically possible affixation errors. The agreement errors produced by the aphasics (n = 32) involve the exchange of either person or number, but not the exchange of both person *and* number. There were, for example, fifteen cases in which the patients produced a 1SG instead of a 3SG form, but no case in which they used a 2SG form instead of a 3/1PL form. Penke (1998) argued that the structure of the paradigm constrains the substitutions. Inflectional errors occur within a given paradigm region, e.g., subparadigm errors such as 3SG instead of 1SG, but errors do not occur randomly. The paradigm representation in (2) provides a straightforward account of these error patterns. Similar observations have been made by Sanchez (1997, 1998) in a cross-linguistic study of agrammatic substitution errors of inflection. Random substitutions that involve more than one feature are not attested in the speech of agrammatic aphasics according to Sanchez. Instead, one typically finds errors that involve one mis-selection. Consider, for illustration, the utterances in (6), quoted from different studies of agrammatism in Italian (6a, b), French (6c) and German (6d):

(6) a. e allora sviene (svengo)
and then faint.3SG (1SG)
(Miceli and Mazzucchi 1990: 793)
b. il contadino mangia i (il) granone
the farmer eats the.PL (SG) *grain*
(Miceli and Mazzucchi 1990: 803)
c. l'image représente un (une) cuisine
the picture represents a.MASC (FEM) *kitchen*
(Nespoulous et al. 1990: 683)
d. hatte einem (einen) Korb gepackt
had a.DAT/MASC/SG (ACC/MASC/SG) *basket packed*
(Stark and Dressler 1990: 371f.)

The required form is given in parentheses in (6). Example (6a) illustrates a person error in which number is correct, (6b) is a pure number error and (6c) a gender error with correct number. (6d) illustrates a case substitution where gender and number are both maintained.

These observations can be accounted for in terms of morphological paradigms. The inflectional errors illustrated in (6) indicate that the inflectional errors which agrammatic aphasics produce are constrained by the structure of the paradigms. The substitution errors result from exchanges between individual cells of a paradigm, e.g., dative case mis-selected for accusative case while maintaining the correct number and gender features (see (6d)). It is as if the agrammatic knows that a case feature needs to be specified in (6d), but makes the incorrect choice from a particular cell of the paradigm. Furthermore, the fact that the substitution errors do not seem to be cross-categorical also supports the view that the contents of inflectional paradigms are basically intact in agrammatism, as knowledge of the paradigms rules out the replacement of, for example, a nominal affix with a verbal one, or vice versa.

5.2. Paradigms in SLI

Specific Language Impairment (SLI) is a developmental language disorder characterised by morphosyntactic errors in the absence of neurological trauma, cognitive impairment, psycho-emotional disturbance or motor–articulatory disorders (see Leonard 1998, Levy and Kavé 1999, Clahsen 1999 for review). SLI is a genetically determined delay and/or disorder of the normal acquisition of grammar. It must be clearly distinguished from aphasias, which are *acquired* as the result of damage to the brain. The nature of the linguistic impairment displayed by SLI subjects seems to be fairly narrow in scope, affecting aspects of inflectional morphology and certain complex syntactic processes. The role of inflectional paradigms in SLI has been the subject of a recent case study of SLI in Greek (Clahsen and Dalalakis 2001). Investigating subject–verb agreement (person, number) and tense marking on verbs, it was found that the former was more impaired than the latter. While there were many subject–verb agreement errors, there was no single tense error in the data. There were two types of error in the SLI data. The first one involved the use of the 3SG present tense or participle form of adult Greek (e.g. *ghraf-i* 'write-3SG') in contexts in which some other agreement ending would have been required. This type of error is familiar from unimpaired 2-to-3-year-old Greek children (Varlokosta et al. 1996). During this age period children acquiring other languages frequently produce so-called root infinitives, i.e., sentences with non-finite stem or infinitive forms (*daddy want beer*); see e.g. Wexler (1994, 1998). This option is not available to children learning Greek, as this language does not have infinitive forms and stem forms alone do not constitute legal words. Varlokosta et al. (1996), however, argued that in child Greek verbs inflected with the suffix *-i* function as non-finite default forms and that in this sense unimpaired Greek children also go through a root-infinitive stage. In the Greek SLI data investigated by Clahsen and Dalalakis (2001), 27% of the verb forms used (491 out of 1,791) were incorrectly used *-i* forms, i.e., cases in which the syntactic context required some other person and number affix on the verb. This fits in with findings from studies on other languages in which SLI children were found to produce (non-finite) default forms of verbs (infinitives, participles and bare stems) instead of finite verb forms (Rice et al. 1995).

The second type of inflectional error found in the SLI data involved incorrect occurrences of other person and number forms. Consider the examples in (7) and note that there were 99 such errors against 803 correct forms (excluding *-i* forms).

(7) Person error:

a. miriz-ume (miriz-ete)
smell.1PL (*smell*.2PL)

b. irth-ane (irth-ate)
arrive.3PL (*arrive*.2PL)

Number error:

c. pin-is (pin-ete)
drink.2SG (*drink*.2PL)

Person and number error:

d. din-o (din-este)
dress.1SG (*dress*.2PL)

A quantitative analysis of the inflectional errors is shown in (8), where the error types are indicated by superscripts, 'p' for a person error, 'n' for a number error and 'pn' for an error of person and number. As mentioned above, 3SG forms were analysed separately.

(8)

	Forms required by context					
Forms used	1SG	2SG	3SG	1PL	2PL	3PL
1SG	381	6 [p]			1 [pn]	
2SG		85			5 [n]	
1PL	4 [n]		7 [pn]	173	11 [p]	1 [p]
2PL		2 [n]		1 [p]	5	
3PL	1 [pn]	5 [pn]	3 [n]	16 [p]	36 [p]	159

As indicated by the superscripts in (8), there is an interesting asymmetry in these data: 86% of the inflectional errors were one-dimensional in the sense that at least one of the grammatical features, either person or number, was correct. There were only 14 cases of type (7d) in which both person and number were incorrect. Of the one-dimensional errors, 84% were person errors, against 14 instances of pure number errors. Note that if the substitution errors were random, we would have expected any number of features to be substituted. This is not the case, however. Instead, only a subset of the logically possible agreement errors were produced and most of the errors occurred within a given paradigm dimension, rather than randomly across the paradigm. More particularly, the frequency data in (8) show that 3PL forms are often used in 1PL and 2PL contexts (n = 52). Moreover, most of the substitution errors feed the 2nd person, particularly the 2PL (n = 66). Note also that there were only five instances of a correctly used 2PL form against 53 substitution errors. Thus these SLI data differ in at least three ways from the agreement paradigm of the adult language. First, 3SG forms seem to lack person and number specifications and can therefore substitute any other agreement form, hence the use of 3SG forms as overall defaults. Second, 3PL forms seem to be specified for [+PL], but not for [PERSON]; hence the frequent use of this affix in 1PL and 2PL contexts. Finally, the rare use of 2PL forms may be due to a gap in the general agreement paradigm; hence the frequent substitutions. Taken together, these findings indicate that inflectional paradigms can be selectively impaired in SLI and that (like in agrammatism) the substitution errors are constrained by the structure of the paradigm.

6. Conclusion

In the present study, we have investigated the question of how paradigmatic relations between regularly inflected word forms are represented in the mental lexicon. Results from two psycholinguistic experiments were presented investigating regularly inflected verb forms of German. Using the cross-modal immediate repetition priming technique, we found priming differences between the various person and number affixes. Full priming was found for 2SG and 2PL forms, but not for 3SG forms. These differences were attributed to different priming routes defined in terms of the structure of the paradigm for person and number inflection in German. We interpreted the reduced priming effect in the 3SG condition as an inhibitory reaction which is due to the fact that in this condition both the prime and the target are incompatible. In the 2SG and 2PL conditions, however, primes and targets come from different paradigms or rule blocks and therefore do not inhibit each other. The second experiment revealed that if primes and targets are incompatible, all forms produce the same (reduced) priming pattern. We conclude that morphological paradigms are used by the human language processor and that models of the mental lexicon which try to do without morphological paradigms are not supported.

A second source of psycholinguistic evidence for inflectional paradigms comes from studies of language impairments. It was found that inflectional paradigms can be selectively affected in Broca's aphasia and in Specific Language Impairment and that the inflectional errors produced by these subjects are constrained by the structure of the paradigms. Errors do not occur randomly across the paradigms, but tend to occur within a given paradigm dimension indicating that individual cells of a paradigm are exchanged or misselected. Moreover, errors are not cross-categorical, i.e., Broca's aphasics and SLI children do not combine a verbal affix with a noun or a noun affix with a verb indicating that they have retained knowledge of the categories to which specific affixes can be attached. These findings show that morphological paradigms and/or their access mechanisms are selectively rather than globally impaired in Broca's aphasics and SLI, with occasional mis-selections and gaps in particular paradigm cells.

We conclude that morphological paradigms are not only useful descriptive tools for linguists, but that they may also contribute to a better understanding of how inflected word forms are used by the human language processor and how they are impaired in language disorders. The evidence reported here provides further support for the view that morphological structure plays an important role in the organisation of the mental lexicon.

Harald Clahsen
Department of Language and Linguistics
University of Essex
Colchester, CO4 3SQ, UK
United Kingdom
Email: harald@essex.ac.uk

Appendices

A. Verb forms used as targets in the first cross-modal priming experiment

1	**stem frequency**	**2**	**stem** frequency
verdufte '(I) clear off'	0	*verbrühe* '(I) scald'	0
häkele '(I) crotchet'	4	*töpfere* '(I) make pottery'	0
tuschele '(I) whisper (behind s.o. back)'	5	*rodele* '(I) toboggan'	0
wackele '(I) wag'	0	*trödele* '(I) dawdle'	5
taktiere '(I) manoeuvre'	4	*kutschiere* '(I) drive (in) a coach'	4
lackiere '(I) paint'	0	*grundiere* '(I) ground'	0
justiere '(I) adjust'	0	*spioniere* '(I) spy'	1
flambiere '(I) flambé'	0	*frankiere* '(I) stamp'	4
pokere '(I) play poker'	4	*trimme* '(I) trim'	2
revoltiere '(I) revolt'	4	*abonniere* '(I) subscribe'	5
	21		**21**

A. (*cont.*)

3	**stem frequency**	**4**	**stem frequency**
verjubele '(I) blow'	0	*vernähe* '(I) sew up'	0
tüftele '(I) tinker with'	3	*krabbele* '(I) crawl'	5
kleckere '(I) make a mess'	1	*wickele* '(I) wrap'	1
knausere '(I) be stingy'	2	*spachtele* '(I) fill (with mortar)'	2
zentriere '(I) centre'	1	*blockiere* '(I) block'	0
radiere '(I) erase'	2	*schraffiere* '(I) hatch'	2
brüskiere '(I) snub'	3	*schockiere* '(I) shock'	0
blondiere '(I) dye blond'	0	*paniere* '(I) coat with breadcrums'	3
strande '(I) run aground'	4	*pruste* '(I) snort'	4
meditiere '(I) meditate'	5	*tapeziere* '(I) wallpaper'	4
	21		**21**

B. Paired t-tests for the first priming experiment

Subject analysis

cc	Mean RT	Condition I (1SG) Identity	Condition II (2SG)	Condition III (3SG)	Condition IV (2PL)
Mean RT		585	592	613	593
Condition I (1SG) Identity	585		–7 t(75) = 1.58; *p* = .117	**–28 t(75) = 6.50; *p* = .000**	–8 t(75) = 1.92; *p* = .059
Condition II (2SG)	592			**–21 t(75) = 3.96; *p* = .000**	–1 t(75) = .22; *p* = .827
Condition III (3SG)	613				**20 t(75) = 4.38; *p* = .000**

Item analysis

cc	Mean RT	Condition I (1SG) Identity	Condition II (2SG)	Condition III (3SG)	Condition IV (2PL)
Mean RT		585	592	614	593
Condition I (1SG) Identity	585		–7 t(39) = .87; *p* = .391	**–29 t(39) = 4.16; *p* = .000**	–8 t(39) = 1.06; *p* = .295
Condition II (2SG)	592			**–22 t(39) = 2.98; *p* = .005**	–1 t(39) = .22; *p* = .829
Condition III (3SG)	614				**21 t(39) = 2.89; *p* = .006**

C. Paired t-tests for the second priming experiment

Subject analysis

cc	Mean RT	Condition I (2SG) Identity	Condition II (1SG)	Condition III (3SG)	Condition IV (2PL)
Mean RT		574	596	596	595
Condition I (2SG) Identity	574		**–22 t(51) = 3.94; *p* = .000**	**–22 t(51) = 3.03; *p* = .004**	**–21 t(51) = 2.84; *p* = .006**
Condition II (1SG)	596			0 t(51) = .01; *p* = .991	1 t(51) = .20; *p* = .841
Condition III (3SG)	596				1 t(51) = .20; *p* = .838

Item analysis

cc	Mean RT	Condition I (2SG) Identity	Condition II (1SG)	Condition III (3SG)	Condition IV (2PL)
Mean RT		573	595	596	594
Condition I (2SG) Identity	573		**–22 t(39) = 2.44; *p* = .019**	**–23 t(39) = 2.54; *p* = .015**	**–21 t(39) = 2.40; *p* = .021**
Condition II (1SG)	595			–1 t(39) = .18; *p* = .862	1 t(39) = .06; *p* = .952
Condition III (3SG)	596				2 t(39) = .25; *p* = .807

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