A Linguistic and Neuropsychological Approach to Remediation in a German Case of Developmental Dysgraphia

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There have been relatively few single case studies concerned with the remediation of spelling deficits among developmental impairments. Among these there have been a small number that targeted specific components of the spelling process and used linguistic theories as theoretical underpinning for the development of remediation procedures. This single case study examines remediation of writing skills and aims at evaluating two different lexically based intervention methods, one of which used Optimality Theory as its basis. We applied a rule-based remediation and an intervention method using whole-word forms to a child with selective impairments in the lexical-graphemic components. The investigation was done with words in which phoneme-grapheme-correspondences in word final position change due to voicing neutralization. The individual exhibited a method- and item-specific effect with respect to the rule-based method. In addition, a transfer effect to untreated items and a generalization effect to untrained but related tasks was observed. The absence of a method-specific and a generalization effect for the whole-word form intervention and the success of the rule-based method is determined by the specific cognitive component(s)s that constitute the source of the deficit and the appropriateness of Optimality Theory to address this particular deficit.

The present study examines the rehabilitation of writing to dictation of words with irregular phoneme-grapheme-correspondences in word final position due to consonant neutralization. In order to improve the participant's spelling skills of such words, we evaluated two different intervention methods, one using rule-based lexical information (henceforth rule-based method), the other using lexical visual information

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of whole-word forms (henceforth whole-word based method). With respect to the rule-based method, we designed a treatment protocol grounded in the principles of the linguistic phonological framework of Optimality Theory (henceforth OT) (McCarthy & Prince, 1993, 1994; Prince & Smolensky, 1993; for an excellent introduction see Kager, 1999) and we will show that crucial aspects of OT provide a solid theoretical phonological underpinning. For this purpose, we will first describe consonant neutralization (final devoicing) in German phonology within the framework of OT and the realization of the neutralization in orthography. In the following section, we will briefly introduce a theory of spelling and some treatment findings within the framework of cognitive neuropsychology relevant to the present study. This is followed by a detailed description of the participant's deficit and performance pattern within OT and an interpretation on the basis of a word processing model. Thus, the methodological and interpretative approach of the present investigation is based on the general assumptions of the single case paradigm within cognitive neuropsychology, that is, performance dissociations (Shallice, 1988) and the assumption that inter-individual cognitive systems are the same. Moreover, cognitive neuropsychology treats the functional architecture of an impaired cognitive system as an intact cognitive system with one or more of its components damaged or deleted (Caramazza, 1986; Temple, 1985; Temple & Carney, 1996).

THEORETICAL BACKGROUND

FINAL DEVOICING

German obstruents contrast for the phonological feature [voice] in the onset, for example /**d**akel/ (dackshund) and /**t**aker/ (staple), but not in the coda /fel**d**/ (field) and /wel**t**/ (world) where the contrast is neutralized. This neutralization is known as *final devoicing*. Even though it is exceptionless in German phonology (Grijzenhout, 2001; Wiese, 1996), it is not reflected in German orthography. In other words, the alternation of voiced and voiceless phonemes is not present in spelling. The phonetic form [vɛlt] has an underlying form /vɛl**t**/ which is spelled as WEL**T**; whereas the phonetic form [fɛl**t**] has an underlying form /fɛl**d**// which is spelled as FEL**D**. In order to be able to write words with final devoicing correctly, one has to have access not only to the phonetic forms but also and more importantly, to the underlying phonological form of each word; this requires lexical knowledge. If only the phonetic forms are used, incorrect spellings (e.g., *FELT instead of FELD), usually referred to as phonologically plausible errors, are very likely to occur. The possible discrepancy between the phonetic form and its graphemic representation presents a major difficulty for learning correct spellings in German.

FINAL DEVOICING IN OPTIMALITY THEORY

In this remediation study, we use OT as our theoretical paradigm for the following three reasons: First, OT presents a framework for describing final devoicing, which allows a straightforward association of underlying phonological forms (in OT referred to as input) with spoken phonetic form (in OT referred to as output). Second, this association of input and output can be used as a cue for the correct spelling of the word. Third, OT is a theory of grammar based on structural requirements (referred to as constraints), which are assumed to have cognitive relevance in both speech perception and production (Boersma, 1998). Thus, it presents an appropriate framework for describing specific spelling impairments that result from a discrepancy between the phonological input and phonetic output forms, and consequently, OT provides a theoretical basis for developing a remediation program.

Optimality Theory is based on the assumption of a universal set of constraints which are hierarchically ordered. A constraint is a structural requirement such as a) "codas are never voiced" or b) "features in the phonological input form are identical with features in the phonetic output form." Hierarchical order means that there is a strict domination between constraints. A phonological form that does not comply with a constraint violates it. For example, [fel**d**] violates constraint a) since is has a voiced coda. Violations are rated with respect to the position of the constraint in the hierarchical order, and a phonetic output is optimal when it incurs the least serious violations of the constraint order. Differences between languages are characterized as different orderings of the same constraints. This can be illustrated considering final devoicing as observed in the voicing alternations in inflected [fel**d**er] (field + *plural*) and non-inflected forms [fel**t**] (field) of the same root where the following two constraints play a crucial role (table I).

The first constraint NO VOICED-CODA which requires that coda obstruents are voiceless is a so-called markedness constraint. The second contraint IO-VOICE, which requires that segments in the input (I) to have the same value for the feature

TABLE I. The Importance of Constraints and Their Ordering.

Phonological Input		/feld/	Constraint	Violation	Amount of Violations
	a)	[felt]	NO VOICED-CODA	no	
Phonetic Output			IO-VOICE	yes	1
	b)	[feld]	NO VOICED-CODA	yes	1
			IO-VOICE	no	

[voice] as corresponding segments in the output (O), is a so-called faithfulness constraint. Markedness and faithfulness represent the two basic types of constraints in OT. Markedness refers to speech production and perception whereas faithfulness refers to the relation between the stored lexical items and their corresponding output forms.

With respect to final devoicing, the phonological input /feld/ may result either in the phonetic output form [felt] which satisfies the constraint NO VOICED-CODA, or in the phonetic output form [feld] which would violate it. The phonetic output form [felt] violates the second constraint: IO-VOICE (see table I) since the voiceless coda consonant in the output has a voiced counterpart in the input, whereas the output form [feld] does not violate this constraint. Table I (see examples a & b) illustrates that even if the total amount of violations is the same, it is the order that decides which form is phonologically realized, in this case example a.

In order to account for the German pattern of neutralization, it is necessary to express the fact that the violation of IO-VOICE is less dramatic than the violation of NO VOICED-CODA. In German, NO VOICED-CODA is ranked above IO-VOICE. This means that a violation of NO VOICED-CODA is more serious than a violation of IO-VOICE. The reverse is true for English, in which the feature VOICE is always realized. This is illustrated in dog [dog] with a voiced coda, which contrasts with dock [dok] with a voiceless coda. In OT, this can be captured by the reverse ranking of the above-mentioned constraints. In English, IO-VOICE is more important than NO VOICED-CODA.

In German spelling, the feature VOICE of the inflected form is realized orthographically in the uninflected form: The phonetic output is [felder] (field + plural) and the written form of the uninflected word is therefore FELD (field) even though the spoken form is [felt]. In sum, the ranking NO VOICED-CODA above IO-VOICE accounts for final devoicing in German, whereas the reverse ranking yields a grammar that describes a language without final devoicing, such as English. The innovative aspect of OT in the present single case study is to draw a parallel between the role of violations for the transfer to graphemic output spelling in a remediation program.

NEUROPSYCHOLOGICAL APPROACH TO REMEDIATION OF DEVELOPMENTAL SURFACE DYSGRAPHIA

We will define and discuss the spelling process and dysgraphic deficits within a theory that specifies the cognitive components of the spelling process (Caramazza, 1988; Ellis, 1989). According to this theory, spelling can be achieved by means of two sets of processes: lexical and sublexical. The lexical "route" makes use of information about words that have been stored in long-term memory. The sublexical route makes use of stored knowledge of regular relationships between sounds and letters that is language specific.

In a task of spelling to dictation, within the lexical route, an auditorily presented word activates a phonological representation of the word in the long-term memory referred to as the phonological input lexicon. Activation of this representation allows the listener to gain access to the representation of a word's meaning in the semantic system. This representation, in turn, can be used to activate a representation of the word's spelling in the orthographic output lexicon, the long-term memory repository of the spelling of familiar words. The sublexical system accepts all phonological strings as input and does not require that the stimulus be a word that is familiar to the listener (nonwords are processed in the same manner as words). This sublexical process applies knowledge of sound-to-spelling correspondences to the input phonological string and yields a phonologically plausible spelling. The spelling representations generated by either route are stored in a short-term working memory component called the graphemic buffer that retains the orthographic representations in active condition while each letter is written down. Research has shown that individual components of spelling process can be selectively affected by neurological damage and in developmental impairments (e.g., Temple 1985, 1990).

The present single case therapy study is designed to examine the effectiveness of two different treatment protocols in addressing deficits affecting cognitive mechanisms of spelling in a child with developmental surface dysgraphia. The dominant characteristics of developmental dysgraphia (Temple 1985, 1986) and acquired dysgraphia (Beauvois & Derouesné, 1981; Behrmann, 1987) are phonologically plausible errors in writing words not following standard language specific sound-to-spelling rules (regularization errors), whereas nonwords and words which follow those rules are spelled correctly. As developmental cognitive neuropsychology, (see Temple, 1997 for an overview) has its most recent origins in adult neuropsychology, we will refer to some single case treatment studies conducted with adult brain lesioned patients.

A number of treatment studies with aphasic patients that are relevant to the present study have targeted specific components of the spelling process: the graphemic buffer (Hillis, 1989), the sublexical conversion system (Carlomagno, Iavarone, & Colombo, 1994), the orthographic representations within the orthographic output lexicon (Aliminosa, McCloskey, Goodman-Schulman, & Sokol, 1993; Beeson, 1999; Behrmann, 1987; Behrmann & Byng 1992), and treatments designed to facilitate the interaction between lexical and sublexical processes (Beeson, Rewega, Vail, and Rapcsak, 2000). Given the focus of the present investigation, we will briefly summarize their findings.

The majority of treatment programs that are directed at strengthening orthographic representations of word spellings in the orthographic output lexicon, although differing in certain details, share the feature that the correct spellings are presented repeatedly. The rationale for this approach is that repeated exposure will activate target words and, therefore, will strengthen their representations in long-term memory. Although these studies all report success in the remediation of targeted items, generalization of the remediation benefits to untreated items varies. It is generally assumed that the representations of specific words in the graphemic output lexicon should not necessarily yield a benefit for similar but untreated items. For example, Aliminosa et al. (1993), DePartz, Seron, and van der Linden (1992), Weekes and Coltheart (1996), and Beeson (1999) all reported successful treatment of target items, but unlike the present study with a developmental dysgraphic child, they found no generalization to untrained items. In fact, Aliminosa et al. (1993) and Beeson (1999) use the absence of such a generalization as evidence that the deficit was indeed localized in the graphemic output-lexicon.

In sum, the lexical whole-word form approach is successful to the extent that participants show positive results to items to which they have been exposed; however, they show no generalization effect. Since an overall effective therapy should generalize beyond treatment items, it would be desirable to design an intervention protocol that focuses at insight in the system of the language specific orthography.

CASE REPORT

PARTICIPANTS

MP is a right-handed monolingual German speaking girl who was 11 years old at the time of investigation. She had no neurological history nor a familial history of dyslexia, specific language impairment (SLI; Leonard, 1998), or left-handedness. She was referred to us by her teacher because of major problems in spelling. Prior to our investigation, she never received language and writing specific remediation. MP's performance in the pre- and post-remediation assessment was compared with a control child (LG) matched in age, sex, and school grade.

PRE-REMEDIATION ASSESSMENT

The aim of MP's pre-remediation assessment was to localize the functional deficit of her dysgraphic impairment on the basis of an uncontroversial version of the neuropsychological route model (Caramazza, 1988; Ellis, 1989; Patterson, 1988) and to interpret her spelling errors within OT. Assessment included phonological processing and tasks such as lexical decision, naming, reading, and writing. Results are interpreted on the basis of a word processing model (Ellis, 1989; Patterson, 1988) and OT (Kager, 1999; Prince & Smolensky, 1993).

IQ. MP was tested with the German version (Weiss & Osterland, 1997) of the Cultural Fair Intelligence Test (CFT-Scale 2, Cattell, 1960) and her IQ was within the normal range.

Phonological Awareness. Performance on phonological awareness and blending was assessed by means of an auditory discrimination task with nonwords (72/72, 100 percent correct), detection tasks for auditorily presented syllables (78/80, 97 percent), phonemes (80/80, 100 percent correct), two syllable repetition backwards (30/32, 93 percent), auditorily presented phonemes (32/32, 100 percent), and a phoneme blending task (10/10, 100 percent). In all tasks, MP's performance was at ceiling and showed no significant differences with respect to the control child LG (see table II). In conclusion, MP's nonlexical phonological processing mechanisms, as well as her phonological short-term buffer mechanisms (reverse repetition tasks), seemed to be unimpaired.

Spoken Language Discrimination, Comprehension, and Production. Performance on single word discrimination, comprehension, and production was evaluated by means of an auditorily discrimination task for words (72/72, 100 percent), an auditory lexical decision task with nonwords and words (80/80, 100 percent), a word-picture matching task (20/20, 100 percent), a synonym decision task (37/40, 92.5 percent), and oral naming (20/20, 100 percent). MP's performances pattern in these tasks was within normal range and did not differ significantly from the control child (see table II), thus revealing the unimpaired functioning of her lexical phonological input and output processing components.

Written Language Discrimination and Comprehension. Performance on visual lexical decision task with pseudohomophones (53/80, 66.2 percent), as well as the participant's performance in a matching task with allographic homophones (11/20, 55 percent, chance level), revealed deficits in the receptive graphemic modality (see table II). Both results differed significantly from the participant's undisturbed performance in the lexical decision task with words and nonwords (80/80, 100 percent) and from the control child (p-level: .001, exact Fisher-Test, two-tailed, Siegel & Castellan, 1988). These results are interpreted as a selective deficit in the lexical graphemic input component. In addition, MP had difficulties in matching written rhyme words. In this task, the subject had to match two written rhyme words; foils consisted of a visually similar word at the onset of either target items (30/45, 66.6 percent). As she had significantly better results in matching pictures (20/20, 100 percent) than in written words that rhyme (p-level: .0029), this deficit could not be attributed to a general phonological deficit.

Spelling. Spelling of single words was assessed throughout written naming of pictures (16/20, 80 percent correct), a task requiring writing homophone allographs after dictation with a disambiguating picture (10/20, 50 percent, chance level). In addition, performance on writing-to-dictation tasks (see table II) was evaluated by means of phoneme-grapheme irregular words (8/20, 40 percent) and nonwords (33/40, 82 percent). All spellings apart from writing nonwords differed significantly from the control child (all p-levels above .01). Spelling errors of the final consonant were all phonologically plausible and indicated that she had not transferred the phonological input information to her writing system. Examples of her spelling errors involved the illegal replacement of voiced by voiceless graphemes and vice versa: *WALT instead of

WALD (forest); *DENG instead of DENK (think), and GUD instead of GUT (good). As shown above (c.f. phonological awareness, spoken language discrimination), this deficit could not be due to impaired phonological processing.

SUMMERY OF THE CASE REPORT

The participant's particular difficulties with spellings of phoneme-grapheme-irregular words or words with final devoicing and homophones, indicated that she was unable to retrieve lexical orthographic information reliably and

TABLE II. Comparison of pre-treatment testing of MP and the control child (LG), and p-value including phonological processing tasks; spoken and written language (Fisher's exact, two-tailed; significance level: < .05 = *).

	MP Dysgraphic Child	LG Control Child	p-value
Phonological Awareness			
auditory discrimination: nonwords (*n* = 72)	72	72	1.000
auditory detection: syllables (*n* = 80)	74	78	.2765
auditory detection: phonemes (*n* = 80)	79	80	1.000
reverse repeating: phonemes (*n* = 32)	32	32	1.000
reverse repeating: syllables (*n* = 32)	30	3	1.000
blending: phonemes (*n* = 10)	10	10	1.000
Spoken Language Discrimination, Comprehension, and Production			
auditory discrimination: words (*n* = 72)	72	72	1.000
auditory lexical decision (*n* = 80)	80	80	1.000
auditory word-picture matching (*n* = 20)	20	20	1.000
auditory synonym decision (*n* = 40)	39	39	1.000
oral naming (*n* = 20)	20	20	1.000
rhyme picture matching (*n* = 20)	20	20	1.000
Written Language Discrimination and Comprehension			
visual lexical decision (*n* = 80)	77	80	.2453
visual lexical decision: pseudohomophones (*n* = 80)	53	78	**.0000***
matching allographic homophones (*n* = 20)	11	19	**.0084***
Spelling			
written naming (*n* = 20)	16	20	.1060
written rhyme word matching (*n* = 45)	30	44	**.0002***
writing allographic homophones (*n* = 20)	10	19	**.0033***
writing PGC- regular words (*n* = 20)	20	20	1.000
writing PGC- irregular words (*n* = 20)	8	19	**.0004***
writing nonwords (*n* = 40)	38	39	.6203

misspellings showed that she relied heavily on phonological writing strategies. Consequently, she was unable to distinguish between correctly and incorrectly spelled versions of written words (pseudohomophones).

In sum, MP's writing performance was clearly consistent with the characteristics of a deficit in the lexical graphemic components whereas nonlexical writing mechanisms remain undisturbed, which resembles the characteristics of patients with acquired and developmental surface dysgraphia (Beauvois & Derouesné, 1981; Hatfield & Patterson, 1983; Temple, 1997).

In terms of Optimality Theory, her spelling errors can be described as a failure to transfer information from constraint violations and not as a failure of phonological processing per se, as both her phonological perception (see above) and production are unimpaired. She never produced incorrect voiced endings in monomorphemic words such as *[tag] for [tak] (day) or incorrect voiceless stem endings in inflected forms such as *[takes] instead of [tages] (day + genetive). Thus, she seemed not to be aware of the fact that voicing alternations between noninflected and inflected forms of the same stem signalize an IO-VOICE constraint violation and that this violation is reflected in the spelling of the final consonant which has the voicing value of the phonological input form. Evidence for this impaired transfer of correct phonological information to spellings is also clearly demonstrated by her evenly distributed error pattern. In other words, falsely written voiced obstruents (e.g. *ALD instead of ALT) are observed in 50 percent of the cases, just as the reverse pattern (e.g. *FELT instead of FELD).

INTERVENTION STUDY

DESIGN AND HYPOTHESES

The intervention plan of the present single case study (Barlow & Hersen, 1984) was designed to evaluate the following: (1) a method-specific treatment effect for trained items, (2) a method-specific treatment effect for untrained items, and (3) a generalized learning effect in related control tasks. In order to do so, a cross-over item-specific design (Coltheart, 1983) was used with baseline testing before, between, and after the therapy sessions. Three control tasks, one related to each specific intervention procedure (method A: rule-based and method B: whole-word treatment) to be described below, and one unrelated task were administered before and after remediation. In addition, misspellings that were the focus of remediation were compared with other misspellings that remained untreated. Given the stimulus types and the evaluation structure, establishing the effects of interest requires the following: (1) An item-specific treatment effect for method A and/or B: better spelling performance on treated words at the end of treatment method A and/or B than at the beginning of treatment method A and/or B; (2) A transfer effect on untrained items: better spelling performance on untrained words at the end of the remediation than at the beginning of a remediation phase; (3) A generalized learning effect: better performance on a task related to method A and/or B at the end of the intervention than before. Furthermore, no improvement should be observable in the untreated misspellings and in tasks that are unrelated to either remediation procedure.

With respect to the present remediation study, we hypothesized the following: An item-specific treatment effect is expected for both a rule-based intervention and a whole-word form treatment. A transfer effect, however, to untrained items is only expected after administering the rule-based treatment and not at the end of the whole-word treatment. Finally, we assumed to observe only a generalized learning effect in a task related to the rule-based method. With respect to the participant's error pattern of falsely transferred voicing characteristics, we hypothesized that there would be no change in bias after intervention since the deficit is attributed to impaired transfer of correct phonological information to graphemic forms (as described in the participant's pre-remediation misspelling pattern).

MATERIALS

A set of 120 monomorphemic words was developed, half of which had a voiced consonant grapheme in word final position ($n = 60$) and the other half a voiceless consonant grapheme ($n = 60$). Verbal stimuli are listed in the Appendix. All possible graphemic voicing contrasts were used (P/B, T/D, K/G, S/Z, F/V). The set of voiced and voiceless items were divided in three word classes: nouns, verbs, and adjectives ($n = 20$ for each word class). Target stimuli were distributed in parallel fashion over the two therapy methods, resulting in $n = 30$ voiced and $n = 30$ voiceless items trained with the rule-based intervention (method A), and the same number of items treated with the whole-word form procedure (method B).

PROCEDURE

During the intervention, treated words were written to dictation. Items were trained throughout three different conditions: (1) as single words, (2) in short sentences (four to five words), and (3) in long sentences (seven to eight words). During the study and in all three conditions, spelling accuracy was evaluated by the number of correct spellings. Correct responses were scored according to whether two correct spellings occurred in both sentence types. Each method was administered in eight to 10 sessions lasting 45 minutes (35 minute specific, 10 minute nonspecific intervention). In sum, eight to 10 targets words were trained per session and word category was systematically varied over the intervention sessions. Treatment was administered twice a week over a period of 10 weeks. The intervention methods varied with respect to the cues administered in case of a misspelling of the final consonant; other misspellings were not considered. All writing errors were either detected by the participant or pointed out to her by the experimenter.

Rule-based Treatment (Method A). When a target was misspelled, the subject had to pronounce either the plural form for nouns, an inflected form for verbs, and the comparative form for adjectives in order to reveal the underlying phonological form of the target. Thus, the focus of this remediation is on the awareness of constraint: IO-VOICE (i.e., segments in the input (I) have the same value for the feature [voice] as corresponding segments in the output (O). In other words, the information of the graphemic form is identical with the phonological output of the inflected form (see bold faced consonants in table III).

Whole-word Treatment (Method B). When the subject misspelled a word, she had to look up the target word written on single cards, all of which are placed in a box. The aim of this repeated exposure is to strengthen the visual graphemic input of all target items by means of its activation. Thus, this method aims at establishing visual representation of words in long-term memory because correct realization of the word final grapheme can also be realized by retrieving the whole-word form in the orthographic lexicon.

TABLE III. Rule-based treatment procedure: target items, elicited cues, and correct spelling.

Target	Elicited Cue (underlying form)	Spelling
[vɛl**t**] (world)	[vɛl**t**en] (world+plural)	WEL**T** (world)
[fɛl**t**] (field)	[fɛl**d**er] (field+plural)	FEL**D** (field)

Pre-, Between, and Post-remediation Baselines. Spelling performance on the treated and untreated items was evaluated in two pre-remediation sessions, as well as after application of the rule-based and whole-word based intervention. During these phases, items were simply read aloud by the experimenter and the subject wrote the words down without receiving any feedback. The same holds true for the assessment of the control tasks. Reading nonwords was chosen as a control task for the unrelated condition to both intervention procedures as this ability should not benefit from the remediation protocols. A task requiring writing allographic homophones was related to the rule-based treatment, whereas matching allographic homophones was assumed to make use of components involved in the whole-word approach

RESULTS

In baseline 1, the participant's total amount of misspellings consisted of 56.7 percent of misspellings of the voicing characteristics of the final graphemic consonants. This effect is not due to word class, as the writing errors are equally distributed over nouns, verbs, and adjectives (all p-levels: 1, Fisher Exact Test, two-tailed). Figure 1 demonstrates the total amount of incorrect responses in all three baselines as well as the number of failures to trained and untrained items.

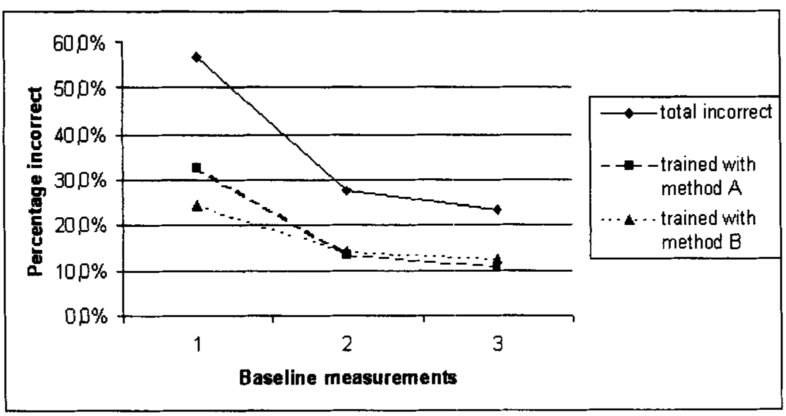

Figure 1 Incorrect responses in all three baselines.

In baseline 2, a method-specific effect for the rule-based treatment is shown by significant better results for items both trained (McNemar's Test (χ^2 = 11.53, p = .000) and untrained with this method (McNemar's Test (χ^2 = 6.75, p = .009) . In baseline 3, though, no significant results are observable after the application of the whole-word form method. This is true for both items trained (McNemar's Test (χ^2 = .75, p = .386) and untrained with the whole-word intervention (McNemar's Test (χ^2 = .25, p = .617).

Evidence for a generalized learning effect is shown in table IV as only performance related to the rule-based method (writing allographic homophones) increased (Fisher's exact, two-tailed, p = .0084). Further evidence for a method specific treatment effect which was not due to spontaneous improvement is also shown in table IV. Results in the unrelated control tasks (reading nonwords, matching allographic homophones) showed no significant outcome (all p-levels above .05) and additionally the amount of writing errors in untreated items remained stable (Fisher's exact, two-tailed, p = .5614).

An in-depth analysis of MP's misspellings revealed a complete lack of a bias in favor of either incorrectly spelled final voiced or voiceless consonants in all baselines (Fisher's exact test, two-tailed: all p-levels: 1.000). This result supports the hypothesis of impaired transfer of the phonological output into the graphemic form.

DISCUSSION

Results of the present evaluation can be interpreted as a method specific intervention effect of the rule-based treatment and its

TABLE IV. Total amount of correct responses in control tasks pre- and post-treatment (Fisher's exact, two-tailed; significance level: < .05 = *).

Related and Unrelated Control Tasks	Treatment pre	Treatment post-	p-value
unrelated to both methods			
reading nonwords (n = 40)	33 (82%)	33 (82%)	1.000
untreated writing errors (n = 120)	30 (25%)	35 (29%)	.5614
related to rule-based method			
writing allographic homophones (n = 20	10 (50%)	19 (95%)	**.0084***
related to whole-word based method			
matching allographic homophones (n = 20)	11 (55%)	12 (69%)	1.000

cueing strategy, that is, detecting the voicing characteristics of the stem of the inflected form and transferring these to the uninflected graphemic form of the target. It seems that this method was also effective in remediating the common underlying processing difficulties as performance in the untrained but related task increased.

Implications arising from this single case remediation study is that treatment of developmental surface dysgraphia may benefit from training rule-based cueing even if the whole-word approach fails. Although this study focuses on a specific problem of the relationship between phonology, as presented within the framework of OT, and the spelling in German, (i.e., voicing neutralization), it can be generalized to other languages in the following way: In all languages where a transfer from an abstract phonological form to spelling is necessary, it seems useful to make the subject aware of language specific alternations using its inflectional paradigm as a cue. Since such alternations are signalled by constraint violations, the implication arising from this is to use information arising from constraint violations as a tool in order to provide insight into the graphemic system of the native language. For example, in case of a constraint violation such as IO-VOICE, insight into the graphemic system can be gained by means of the underlying phonological form. This input form can be accessed by inflecting the output form, thus eliminating the violation.

Furthermore, Optimality Theory can be used as a guide to the analysis of spelling errors with respect to the voicing problem. In the present case, an analysis of the misspellings revealed no bias in favor of either incorrectly spelled final voiced or voiceless consonants. When phonological processing is undisturbed, the absence of a bias is evidence for an impaired transfer into the graphemic forms of the constraints NO-VOICED-CODA and IO-VOICE. The presence of a bias in favor of, for example, incorrectly spelled final voiced consonants would be evidence for an impaired transfer into the graphemic form of only one constraint, most likely to be IO-VOICE in the case of German. In both cases, though, we would hypothesize that the remediation applied in this investigation leads to improvement. In the latter, though, two steps are necessary. First, insight into the role of inflection in spelling needs to be provided, and second, the information contained in the violation of IO-VOICE should be transferred into the spelling.

Finally, this study shows that the neuropsychological single case paradigm is an appropriate method in evaluating the effectiveness of different intervention procedures within cognitive developmental disorders. Although the number of studies showing the effectiveness of specific model-guided and theoretically based intervention procedures in single cases, especially within neuropsychological impaired patients has increased (e.g., Riddoch & Humphreys, 1994; Seron & Deloche, 1989), there is still a lack of such single case studies within the field of developmental disorders. We need to address the issue of the reasons for choosing one method over another one for a particular child. In other words, does a specific intervention method lead to significant improvement as compared with another remediation program? A further issue is, does this optimal intervention method allow generalization to the entire population that has the same functional deficit? These issues are still unclear and need to be investigated. When these questions have been studied, it may be possible to close the gap between cognitive models describing cognitive functioning and the application of specific remediation procedures involving different aspects of learning (Baddeley, 1993). The closing of the gap should contribute to the development of a theory of remediation of cognitive deficits (Caramazza & Hillis, 1993; Wilson, 2002).

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APPENDIX

Target Items			
Method A		**Method B**	
	Nouns		
Zwerg	midget	Berg	montain
Trog	trough	Flug	flight
Sarg	coffin	Zug	train
Wald	forest	Land	country
Wand	wall	Mund	mouth
Mond	moon	Grund	ground
Korb	basket	Hand	hand
Dieb	thief	Hieb	stroke

Target Items			
Method A		**Method B**	
Weib	woman	Stab	stick/rod
Pilz	mushrom	Archiv	archive
Bock	ram	Rock	skirt
Sack	sack	Stock	stick
Frack	tailcoat	Zweck	purpose
Not	need	Hut	hat
Glut	heat	Welt	world
Staat	state	Saat	seed
Trupp	troop	Typ	type
Lump	scoundrel	Prinzip	principle
Gestrüpp	thicket	Galopp	gallop
Hof	courtyard	Huf	hoof
Glas	glass	Hals	neck
Verbs			
Schweig	be quiet	Trag	wear
Frag	ask	Klag	weep
Jag	hunt	Flieg	fly
Red	speak	Find	find
Schneid	cut	Zünd	ignite
Meld	call	Bind	tighten
Glaub	believe	Schreib	write
Reib	rub	Kleb	glue
Schnaub	blow	Bleib	stay
Stütz	prop	Kurv	curve
Guck	look	Schick	send
Merk	memorize	Rück	pull
Knack	break	Denk	think
Wart	wait	Fecht	fence
Sput	hurry	Schalt	turn
Hust	cough	Leist	fulfill
Kipp	tipp over	Klapp	bang
Schnapp	snap	Hup	honk
Pump	pump	Schlepp	drag
Schnief	sniff	Schlaf	sleep
Ras	race	Lös	solve

Target Items			
Method A		**Method B**	
	Adjectives		
Nötig	necessary	Flüssig	liquid
Saftig	juicy	Niedrig	low
Richtig	right	Fähig	able
Blind	blind	Rund	round
Wund	sore	Gesund	healthy
Mild	mild	Fremd	strange
Lieb	dear	Derb	coarse
Gelb	yellow	Grob	clumsy
Herb	bitter	Mürb	crumbly
Aktiv	active	Passiv	passive
Spitz	sharp	Kurz	short
Krank	ill	Antik	antique
Welk	withered	Stark	strong
Dick	fat	Keck	daring
Link	awkward	Blank	blank
Leicht	light	Spät	late
Dicht	dense	Breit	broad
Echt	true	Alt	old
Satt	full	Gut	good
Schlapp	slack	Knapp	tight
Steif	stiff	Schief	oblique
Mies	poor	Fies	mean