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Consonant Harmony

1. Research Problem

In both Finnish child language acquisition data and data from adult aphasia there are plenty of word forms that at first sight, at least, could be considered as instances of consonant harmony[1]. The author has personally (unsystematically) observed the following forms in the speech of one little Finnish boy: at the age of one year and six months, he said *kukkuu* instead of "nukkuu" 'sleep(s)', and somewhat later, at the age of one year and nine months, he produced more of these kinds of "errors", e.g. *kalikka* (or ka'ikka) for "palikka" '(building) block'[2], *koika* for "poika" 'boy', *kaketti* for "paketti" 'parcel', *käkää* for "räkää" '(some) snot', and *toittaa* for "soittaa" 'ring(s), (the clock) strikes'. Similar looking forms are rather common in pathological speech both for children with delayed or deviant speech (Jortikka 1993, Mäenpää 1993) and for adult aphasics (Kukkonen 1990). Some examples from aphasic speech are *keekeri* for "neekeri" 'negro', *tilta* for "silta" 'bridge', *poppi* for "koppi" 'hut, hovel', *kalko* for "halko" 'log of wood', *tintu* for "lintu" 'bird', and *saasu* for "kaasu" 'gas' (Kukkonen 1990).

Consonant harmony only occurs in the speech of young children and adult aphasics with a specific type of language disturbance. Consonant harmony might be described as a complex assimilation in which segments (usually consonants but some-

[1] I would like to thank Orvokki Heinämäki and Antti Iivonen for comments on an earlier version of this paper.

[2] The word "kalikka" 'stick' also exists and, furthermore, "kalikka" and "palikka" may be used synonymously in Finnish dialects. The present child, however, was trying to say "palikka", a word used in the sense of 'building block' by all the adults with whom he was in contact.

times even vowels) become identical. There seems to be an assimilation hierarchy, which together with the position of the sound or phoneme in the word, determines which consonants serve as intrusions. Consonant harmony has an articulatory basis: it is a trend towards the repetition of the same articulatory gesture instead of more varied gestures. Furthermore, there is evidence that some aphasic speakers' errors result from a problem of neuromotor control in articulatory timing of gestures. Harmonic errors are not pure phoneme substitutions but several articulatory gestures take place simultaneously in them. There is some indication, however, that mistiming of articulators does not alone account for all instances of consonant harmony (e.g. in slips of the tongue). Prominence to the phonological aspects of harmonic errors is given in an alternative hypothesis; according to this hypothesis harmonic substitutions result from a compensatory strategy reflecting the functioning of an intact phonological system under heavy physiological production constraints.

This paper discusses the nature of harmonic errors as well as the proposed "explanations" of harmonic word forms. First, literature on language acquisition and adult aphasia is briefly reviewed in order to provide background information about the occurrence of consonant harmony. Consonant harmony is then discussed in the framework of traditional, natural, and non-linear phonological theories. Subsequently, the phonetic quality of harmonic errors is addressed as well as their relation to slips of the tongue and Finnish vowel harmony. The last section points out some directions for future research on consonant harmony.

2. Consonant Harmony in Language Acquisition

Consonant harmony is a common phenomenon in children's speech. Iivonen (1986, 1993, 1994) divides phonological acquisition in five stages: the prenatal stage, the postnatal stage, the word-pattern stage, the stage of systematic phonological development, and the final stage of phonological refinement. Of these stages, the three medial ones are most interesting when studying

consonant harmony. The following overview which focuses on the appearance, distribution, and disappearance of consonant harmony draws largely on Iivonen (1986, 1990, 1991, 1993, 1994).

During the postnatal stage, which continues from birth to the acquisition of the first word at around the age of 10 — 12 months, the child acquires motor patterns which serve as the basis for articulation. Several stages of early pre-linguistic vocalization can be distinguished, but only the babbling stage contains some features of consonant harmony. The child first learns to combine single articulatory movements with phonation, and then to repeat the same articulatory movement several times during one respiration period. This usually takes place by the age of 7 — 8 months, and is followed by variegated babbling where the child is able to pronounce more varied combinations of articulatory movements. Around this time the parents often start to interpret the child's articulations as words. Indeed, babbling often includes "protowords" which resemble adult words. However, it is not easy to determine when the child learns the symbolic function, i.e. begins to attach stable meanings to the protowords.

During the word-pattern stage the child imitates the word-patterns of adult language. These word forms have stable meanings, but the child is still unable to analyze the word-patterns as consisting of smaller units such as phonemes. One word-pattern can function as a whole utterance, and the child's meanings may not exactly correspond to adult meanings of the same word forms. It has been estimated that the child has about 25 — 50 word-patterns before he/she learns to further analyze the patterns.

The stage of systematic phonological development begins when the child learns to analyze word-patterns into smaller phonological units. This stage has also been called the stage of phonological processes. It usually begins around the age of 18 months and lasts until the age of three or four when the adult word forms are no longer simplified by the child. The typical word type at the beginning of this stage consists of reduplication,

i.e. doubling of the same syllable. One of the word types is CVCV or alternatively CVCCV (the two are in free variation, even the duration of the vowel in the first syllable can vary). Consonant harmony is one of the phonological processes children make use of, and it describes the fact that the consonants (or obstruents) in a word are identical. Harmonic word forms are common at the age of 18 — 26 months.

Iivonen (1993) describes children's harmonic errors in terms of distant assimilation. He gives examples of both regressive and progressive assimilation, and of both distant and contact assimilation. Consonant harmony is complex assimilation in which consonant segments become identical, only in an exceptional case is the change limited to a few features. The key to the problem may lie in an assimilation hierarchy: it is possible to differentiate between strong consonants that function as intrusions and weak consonants that are subjected to assimilation. The strongest consonant in child language is /k/, which substitutes for other stops /p/ and /t/ (e.g. *koika* for "poika" 'boy', *kiiko* for "kiitos" 'thanks'), /t/ substitutes for /s/, and /m/ substitutes for /v/ and /l/. However, there are exceptions to this hierarchy, such as *katti* for "kaksi" 'two' in contrast to the "regular" *ykki* for "yksi" 'one'. Thus, children do not systematically adhere to the hierarchy. According to Iivonen, the domain of assimilation could be the word or some other unit.

At an early stage of phonological acquisition, the harmonic two-syllable sequence is the central word type, where the child exercises the use of new phonemes one by one until the phoneme paradigm has mostly been acquired. Only when the child has mastered a considerable number of phonemes does the development of more complex phonotactic structures begin. In three-syllable items, the assimilation does not always apply to the whole word form. When children start to use three-syllable words, their articulation also improves and the harmonic constraints loose their strength and start to disappear. Consonant harmony gives space to more sophisticated structures where assimilation and other phonological processes do not apply to all

consonants (or obstruents) of the word but only simplify certain elements, e.g. certain consonant clusters. Vowel harmony is not explicitly discussed in any of the sources. However, complete vowel harmony seems to exist only at the stage where word forms consist of repeated syllables. Complete vowel harmony disappears earlier than consonant harmony, and the child's word forms seldom violate the standard vowel harmony of adult Finnish.

3. Consonant Harmony in Disordered Language Development

Consonant harmony is a common process in delayed or deviant speech. According to Nettelbladt (1983), several stages of severity can be distinguished in dysphonology. The most severe problems are characterized by syntagmatic phonological processes whereas in less severe disorders only paradigmatic processes are found. Syntagmatic processes are linked with changes in the structure of word forms whereas in paradigmatic processes only phonological features are changed. In the most severe cases described by Nettelbladt, children produce only one- or two-syllable items which usually follow harmonic constraints of some kind, either syllable harmony, i.e. doubling of the same syllable, or vowel or consonant harmony. In less severe cases, children also produce three-syllable word forms. These forms are no longer subjected to strict syllable harmony but consonant harmony is still common. Nettelbladt's data come from Swedish-speaking children. Crystal (1981: 37) and Grunwell (1982: 170-173) mention reduplication and consonant harmony as common phonological processes among English-speaking children, in both normal and delayed or deviant language acquisition. Similar error types are common in Finnish-speaking children as well.

In normal children consonant harmony only occurs during a short period between 18 and 26 months when the vocabulary is very limited. According to Nettelbladt (1983), children with severe phonological disorders tend to stick to a few limited word-

patterns such as syllable harmony for a much longer period than normal children. They also often have much larger vocabularies than normal children with consonant harmony. The larger vocabulary in combination with more rigid word-patterns, leads to pervasive homonymy. Furthermore, there is great variability of segments: the same target segments can be realized differently from word to word by a particular child. In disordered speech, even longer stretches of speech can be subject to consonant harmony, e.g. *aitti tattet ja aituitet* for "kaikki lapset ja aikuiset" 'all the adults and children' (Mäenpää 1993). For these children, some early assimilated word forms may get stabilized and be used in their harmonic form even when less assimilated forms are also available to the child. An example of this type from Jortikka's (1990) data might be *tato* for "katso, kato" 'look!' when the child also uses such complex items as *kotin* for "kotiin" 'home' or *kelttane* for "kelta(i)ne(n)" 'yellow'. This might indicate that phonological regularities do not generalize through the lexicon in a normal manner but the generalizations only take place word by word which, according to Itkonen (1977), is not true for normal language acquisition.

4. Consonant Harmony in Adult Aphasia

Aphasia is a language disturbance caused by organic brain damage in a person who has already acquired language. The language disturbance can affect comprehension of spoken or written language, speech production or writing. These difficulties are not based on disturbances of vision, hearing, or motor abilities. It is commonplace to divide speech disturbances due to organic brain damage into three types, dysarthria, speech apraxia, and aphasia.

Speech is one of the most complex forms of human behaviour, and it requires the action of major mechanisms at five motor integration levels of the nervous system: cerebral cortex, subcortical nuclei of the cerebrum, brain stem, cerebellum, and spinal

cord (Love & Webb 1986: 83). Dysarthria is a cover term for a wide range of different motor speech disorders, and dysarthria may accompany aphasia in many aphasic patients.

Speech apraxia is a controversial disorder. Some researchers, e.g. Darley, Aronson, and Brown (1975), conceive of speech apraxia as a non-linguistic disorder of speech motor control, whereas many neurologists do not differentiate between it and aphasia but take it as one type of aphasia. Darley & al. describe the errors typical of speech apraxia as phoneme errors, even if they use the terms phoneme, articulatory gesture, and muscle movement interchangeably. Thus, the nature of speech apraxia remains unclear, and in practice it is difficult to differentiate between patients with speech apraxia and aphasia (especially non-fluent aphasia).

Phonological errors are common in both fluent and non-fluent aphasia. Two different types of phonological errors can be distinguished, one of them is associated with non-fluent aphasia and the other with fluent aphasia. The errors in fluent aphasia seem to be "central" in the sense that they come to the surface in both speech production and speech perception or comprehension. This is particularly true of semantic paraphasias[3]. Phonological errors typical of fluent aphasia are neologisms (i.e. phonotactically possible words that do not exist) or sequences of phonological approximations (for examples, see Kukkonen 1990, 1994). Consonant harmony errors were rare in fluent aphasia, and in this context I shall concentrate on errors in non-fluent aphasia.

Phonological errors typical of non-fluent aphasia are deletions of word-initial consonants and other errors that at least superficially resemble those produced by children during the stage of systematic phonological development. Consonant

[3] Semantic paraphasias are errors where semantically related words are confused. In word-picture matching, the subject has difficulties in telling apart items that belong to the same semantic field, such as pieces of clothing, and in spontaneous narration he or she may, for example, call a glove a shoe.

harmony is also a common error category in non-fluent aphasia. (See Kukkonen 1990 for a detailed discussion of the error types.) In errors of consonant harmony, speakers usually retained the correct "word-patterns", there was no deletion of word-final syllables that was common to some fluent aphasics. The errors usually occurred word-initially or word-medially, and consonant errors overwhelmingly exceeded vowel errors. Kukkonen (1990) described errors of consonant harmony, or anticipation errors, in the following way:

> For bisyllabic words, an obstruent that occurred on the border of the first and second syllables substituted the word-initial consonant. For longer words, any obstruent could serve as a substitute for a consonant that occurred earlier in the word. (Kukkonen 1990: 118.)

It was noteworthy that the subjects sometimes began with the correct syllable, but had to stop in the middle of the word and substitute an assimilated syllable for the correct beginning, e.g. *kääp pääpä* for "kääpä" 'shelf bracket fungus', *ll tuuttuu* for "luuttu" 'lute', and *soo kookeri kaa kaakku* for "sokerikakku" 'sponge cake'. These examples show that aphasic speakers were aiming at the correct targets but were unable to pronounce them.

In child language research it is assumed that phonological processes are due to an immature speech production system. As far as consonant harmony in concerned, aphasia data seem to support Jakobson's (1941-42) idea that phonological abilities are lost in aphasia in reverse order as compared to language acquisition. The abilities that are acquired late are lost first, whereas the abilities that are acquired early are most resistant in aphasia. In what follows, children's and aphasics' errors will be compared closely in order to see whether there are any differences between them.

5. Traditional Accounts of Consonant Harmony

In introductory text books on phonology, assimilation is usually listed among phonological processes such as strengthening

(closing and desonorization), weakening, and whole-segment processes (insertion, deletion, and reordering or metathesis). In assimilation one segment becomes similar or identical to another. The assimilation influence can work either to the right or to the left; there is progressive and regressive assimilation. In contact assimilation neighbouring segments become more alike, whereas in distant assimilation the influence moves, either progressively or regressively, across some intervening segment(s). The most characteristic distant assimilation is non-contact vowel assimilation, (regressive) umlaut and (progressive) vowel harmony. Finally, there are "bi-directional" or fusional assimilations. (Lass 1984: 171-3).

There is probably no segmental property that cannot be the target of an assimilation. The major types of parameters are place of articulation, stricture, lip attitude, velic attitude, and glottal state. In complex assimilations more than one parameter may be involved in assimilations. Assimilation is normally conceived of as articulatory adjustment, anticipation or persistence of vocal-tract configurations. (Lass 1984: 173-175).

Consonant harmony is not typically used to exemplify phonological processes in introductory phonology texts. It is not a process observed in language change. Still, it clearly fits under the category of assimilation. It is a complex assimilation as it involves a simultaneous change in several phonological features. In consonant harmony whole segments become identical. It is typically a distant assimilation, even if the examples given in sections 1 — 4 include a few instances of contact assimilation. Regressive assimilation is most typical, but there are instances of progressive assimilation as well (e.g. *kiiko* for "kiitos" 'thanks' or *tiita* for "Tiina" (a name) in child language). Theoretically oriented discussions of assimilation usually focus on contact assimilation (e.g. Nolan 1992, Hayes 1992). Consonant harmony is not simply anticipation or persistence of vocal tract configurations in the sense described by Nolan (1992), who has presented electropalatographic patterns for consonant sequences /tk/ and /kk/ in the utterances "late calls" and "make calls". Here /t/ is

often not produced with complete dental closure but /tk/ resembles /kk/. Rather, consonant harmony is the result of a trend towards the repetition of the same articulatory gesture as opposed to a sequence of more varied gestures.

As discussed earlier, Iivonen tried to describe examples of consonant harmony in normal language acquisition with reference to an assimilation hierarchy, but the hierarchy proposed by him did not work perfectly because the "errors" turned out to be unsystematic. In child language data, consonant /k/ seemed to be the strongest consonant. This may have a phonetic basis, as the motor control of velar movements matures earlier than that of dental or labial movements (Iivonen 1991).

In aphasia data /p/ seems to be stronger than /k/ (e.g. two out of four non-fluent aphasics reported in Kukkonen (1990) produced the word form "kääpä" 'shelf fungus' in the form *pääpä*, it was never produced in the form "kääkä"). However, /k/ may be stronger for acute aphasics than for residual aphasics. The strongest consonants in aphasia data are obstruents that substitute for other consonants. Among the obstruents, the direction of assimilation is more important than the assimilation hierarchy, assimilation is typically regressive. In this respect there may be some differences between aphasics and children. Progressive assimilation may be more common for children. There were very few examples of progressive assimilation in aphasia data, e.g. *kotikoŋkku* for "kotitonttu" 'house elf, brownie' or *titta* for "tippa" 'drop'.

While sometimes only the second half of a compound was affected by regressive assimilation in the aphasia data (e.g. *kuonopoppa* for "kuonokoppa" 'muzzle'), sometimes the whole compound was affected (e.g. *pännympäpyjä* for "männyŋkäpyjä" '(some) pine cones'). It should be noted, however, that in the latter example only word-initial consonants were changed into /p/.

In words with word-medial consonant clusters, the obstruent of the cluster is typically substituted for the word-initial consonant (irrespective of the phonetic quality of the word-initial

consonant), but the sonorant that precedes the obstruent in the consonant cluster either remains unaffected (e.g. *tiltti* for "kiltti" 'good-natured') or is substituted by a nasal which may or may not be homorganic with the following obstruent (e.g. *pänpä* for "sälpä" 'spar'(mineral); *pomppu* for "korppu" 'rusk').

Metathesis was more common than progressive assimilation. In some examples of metathesis, the length of reversed segments was preserved, and in the nasal+stop clusters the nasal assimilation operated normally, e.g. *kiippi* for "piikki" 'thorn' and *sumppi* for "punssi" 'punch'. However, this was not always the case, e.g. *pirspi* for "sirppi" 'sickle'.

There is a lot of unsystematicity among the errors in the aphasic speakers. Even if most of the examples are accounted for by calling the changes "regressive distant assimilation of obstruents" this generalization does not catch all the errors or fully account for their appearance, for example *mäpihytty* for "mäkihyppy" 'ski-jump', *silki* for "kilpi" 'shield', *sipusi* for "kipusi" 'climbed', or *rarsi* for "varsi" 'stem' (instead of the typical error type *sylsy* for "hylsy" 'case, shell'). Degrees of error severity might account for some variation, as is indicated by the aphasics' spontaneous attempts at correction, e.g. *pu lulppa* for "tulppa" 'plug'. Extralinguistic factors such as time post-onset of aphasia may also be of importance: progressive assimilation and the preference for /k/ as an intrusion may be more common in acute aphasia. However, to some extent at least, it seems necessary to allow for random variation and unsystematicity.

6. Consonant Harmony in Natural Phonology

Consonant harmony simplifies the movement sequences required in speech production. These kinds of phenomena are referred to as phonological processes in natural phonology. According to Donegan (1978), Stampe defines the natural phonological process as follows:

> a mental operation that applies in speech to substitute, for a class of sounds or sound sequences presenting a specific common difficulty to the speech capacity of the individual, an alternative class identical <in all other respects> but lacking the difficult property. (Donegan 1978: 3.)

Natural phonological processes are considered to be the speaker's automatic adaptations to the articulatory and perceptual difficulties of sounds and sound sequences. In natural phonology, phonetic (motor) functions and phonological (central) functions are considered to operate separately. The natural phonological process forms a part of the planning phase and as such it does not refer directly to the actual production of the sound (Stampe 1969, Ohala 1974). Nettelbladt (1983) regards phonological processes as an attempt to explain Jakobson's hierarchy of segmental complexity.

When children or second language learners are unable to produce sounds correctly their errors are accounted for by natural phonological processes that have not been retained in the adult language. These processes are innate and automatic strategies that the learner makes use of when confronted with new and difficult sounds or sound sequences.

Traditionally, natural phonology does not deal with long-distance phenomena such as consonant harmony. While conceptually it is not difficult to extend the theory to long-distance phenomena, the theory gives hardly any predictions concerning the exact nature of such phenomena. In the case of consonant harmony, the child adapts the memorized word forms to the word-patterns at his/her disposal. The processes describe modifications the child has had to make. Thus, the processes need not be seen simply in terms of correspondence rules between the adult word forms and the word forms produced by the child, they could also be considered to be "psychologically real".

Adherents of natural phonology think that, in addition to the phonological processes, one needs to have an "idea" of what one is trying to pronounce. The child obviously perceives the words better than he or she can produce them, but it is not known if the

items are perceived in all their detail. Rather, the child's phonological representations can be based on only the most salient properties of adult speech. Restrictions on the child's perceptual capabilities set limits on his/her representations of words. According to the present data, it was often the case that aphasic patients also aimed at the correct targets, as was indicated by the substitutions of harmonic word forms for correct beginnings.

In addition to on-line production constraints, Nettelbladt (1983) assumes that the differences between adult pronunciation and the child's production can be due to either restrictions on the amount and the kind of information the child can take into account (i.e. cognitive constraints) or restrictions in the current phonological system of the child.

Substitutions due to natural phonological processes are considered to be systematic. According to Donegan, slips of the tongue cannot be analyzed in terms of phonological processes because slips are not systematic. Systematicity, however, has at least two interpretations. Donegan obviously had in mind the sporadic occurrence of slips of the tongue. On the other hand, slips of the tongue are systematic in the sense that the errors fall in linguistic patterns. Aphasic errors are systematic and unsystematic in much the same way as slips of the tongue (there may be some problems in detailed descriptions of the error types, as discussed earlier). Despite this unsystematicity, Wurzel (1984: 18) has tried to find evidence for natural phonological processes in the speech of aphasic patients. The systematicity of "errors" in normal language acquisition and second language learning should be subjected to closer scrutiny.

In his writings, Iivonen concludes that the phonological process as a concept does not alone account for the differences between adult and child phonology. Even if it is obvious that he is correct, he may have a somewhat narrow conception of a phonological process. He lists the "changes" that he conceives of as phonological processes as addition, omission, insertion, metathesis, and distortion. Even if Iivonen's discussion of children's simplifications pays a lot of attention to the often

neglected syntagmatic features of development, this emphasis is not fully extended to such traditionally well-known phenomena as, for example, compensatory lengthening. It might be more interesting to try to catch these kinds of phenomena as wholes and not to divide them into more elementary processes, as Jortikka (1993) does. She codes compensatory lengthening as three separate processes (change in quantity, omission, and simplification of a consonant cluster). However, long-distance phenomena such as consonant harmony can be conceived of as a type of phonological distortion. These kinds of long-distance simplifications might be better accounted for by non-linear phonology than by the more traditional approaches to phonology.

7. A Non-Linear Account of Consonant Harmony

Several attempts have been made to describe the aphasic speakers' phonological errors in terms of non-linear phonology. Béland, Caplan & Nespoulous (1990) analyzed phonological errors made by a reproduction conduction aphasic. Only simple errors, i.e. errors involving one segment at a time (omission, substitution, or addition of a segment), were discussed. Simple errors represented 83 % of errors in repetition and 93 % of errors in reading for this French-speaking aphasic. Moen (1993) analyzed phonological errors in conduction aphasics' spontaneous speech. Her Norwegian subjects made substitution, deletion, and transposition errors. The analyzed error categories, substitutions of single consonants and deletions which did not result in a reduction of the number of syllables in the word, were the most common error types in the data.

Both studies support phonological theories which posit hierarchical structures both below and above the segmental level. The errors are shown to arise at several stages in the mapping from underlying to lexical and from lexical to surface phonological representations. Phonological substitutions may arise because the patient has access to the number of slots on the skeletal tier without having access to full specification of the

phonetic information linked to each slot. In the case of substitutions of phonetically similar segments the subject has access to an incomplete specification of the segment. Substitutions of phonetically dissimilar segments, on the other hand, arise when the subject has no access to the phonetic content of the segment and the syllabic slot is filled at random. Deletions of non-branching onsets and codas arise when the subject has access to an incomplete specification of the elements on the syllable tier. Deletions of an element in a branching onset or coda arise as the result of incomplete information about the association between the syllable tier and the skeletal tier. In the French data, compensatory lengthening of a vowel segment was observed when consonants were omitted in word-medial positions. Addition errors arise during the process of syllabification.

Stark & Stark (1990) analyzed phonemic jargon produced by two German-speaking Wernicke's aphasics. The data were elicited in naming and repetition tests, and the neologisms were analyzed in terms of syllable structure in the framework of metrical phonology. The difficulties experienced by the Wernicke's aphasics increase in relation to the structural complexity and number of syllables, and the later a syllable occurs in a word the greater the probability of its impairment and deletion. Furthermore, the various constituents of a syllable differ in their susceptibility to error. The nucleus is the least impaired and the coda is the most impaired structure, the onset falling in between. The rhyme is less impaired than the onset. The errors illustrated that the aphasics were sensitive to structural variables on the level of syllable constituent structure, and the application of metrical phonology provided a more adequate description of the jargon aphasic's performance.

The aphasics discussed in this article are non-fluent aphasics with consonant harmony errors that have not been described in previous studies. Non-fluent aphasics have articulation problems that need not be purely phonological in nature. However, non-linear phonology might offer a useful means of describing

complex phonological phenomena, such as compensatory lengthening and consonant harmony.

The most straightforward description of consonant harmony mirrors the non-linear accounts of vowel harmony. The following ideas are based on Goldsmith's (1990) discussion of vowel harmony in autosegmental phonology. Vowel harmony is accounted for by an autosegmental tier, which is linked with association lines to the segmental tier, and a mechanism of feature spreading. Most of the aphasia data mentioned above was elicited in repetition or naming tasks which required only single word answers. Normal children with heavy consonant harmony constraints also use one-word utterances only. However, children with delayed or deviant speech often use even more complex utterances, and for them there were examples of consonant harmony spreading over larger domains than words. Adult aphasics also produce complex utterances, but for them there was relatively less consonant harmony in narrative speech than in the single word data elicited in the repetition and naming tests.

In consonant harmony, all the obstruents within the harmonic domain become identical. This "rule" variably applies to sonorant consonants. Word-initial sonorants are easily subjected to assimilation in aphasia. In contrast, liquids and nasals forming the initial part of a word-medial consonant cluster (i.e. occupying a coda position) are rather seldom subjected to pathological assimilation. In aphasia data, the strong obstruent that substitutes for other consonants typically occurs in a word-medial position and assimilation is regressive. In child language data there was evidence for a consonant hierarchy: /k/ in any position in the word substituted for other consonants, other stops intruding when there was no /k/ in the word. Here not only single obstruent features but whole feature bundles (both manner and place of articulation) act autosegmentally, spreading over the word (or a larger domain) — regressively in adult aphasia and both regressively and progressively in child language data. Thus, obstruent feature bundles start to loose their strict one-to-one association with the skeletal tier. Sometimes even consonants other than

obstruents can spread, e.g. *rorsu* for "norsu" 'elephant', or *pu lulppa* for "tulppa" 'plug'.

There was a strong preference for obstruents to substitute for other obstruents. Thus, at least some manner features remained intact and the place of articulation features were spreading. In word-initial position, however, any consonant was often substituted by a stop, feature-spreading thus affecting both manner and place features. In word-medial consonant clusters in which a liquid is followed by a stop, the liquid is sometimes retained, sometimes it is substituted by a nasal which either may retain its place of articulation (thus resulting in a non-homorganic nasal +stop cluster) or both the manner and place of articulation may be changed (resulting in a homorganic nasal+stop cluster) in the aphasia data. Iivonen (1993) gives similar examples from child language data where e.g. /nt/ clusters are substituted for /lt/ clusters. Thus, the number of features undergoing assimilation varies, but consonants are always substituted by consonants and vowels are substituted by other vowels, except for compensatory lengthening where a consonant is substituted by vowel lengthening[4]. Thus, some features of the original segment are usually retained.

Sometimes feature spreading in consonant harmony takes into account the consonant's position in the word, not only whether it occurs in an onset or coda position but also whether it is word-initial or word-medial, e.g. *kappulapio* for "kakkulapio" 'cake server' (a compound of kakku + lapio) in non-fluent aphasia (for more examples, see section 5). Sometimes, however, only certain liquids are left unassimilated, as in *pälpempäin* for "jälkeempäin" 'afterwards' in aphasia data or *kalikka* (or ka'ikka) for "palikka" '(building) block' in child language. A detailed description of these errors would require more data, which should be collected by presenting the subjects with items where phono-

[4] For a non-linear account of compensatory lengthening, see Goldsmith (1990: 73-76).

logical variables such as syllable structure are systematically varied, thus enabling a systematic comparison of error types and error frequencies.

It is not very feasible to assume that babies or adults with brain lesions suddenly acquire tiers and structures that normal adult speakers do not possess. Differences in the behaviour of obstruent and sonorant consonants can, in principle, be accounted for either by assuming that some features are equipollent and others are privative, or by assuming that some features are present underlyingly (e.g. obstruent features) while others (e.g. sonorant features) are present at the lexical level only. However, it might be more natural to account for the types of harmony errors by a spreading hierarchy, the strongest consonants (stops, affricates, voiceless fricatives) being the favourite spreaders. The hierarchy would mirror one proposed by Lass (1984: 178) for language change (lenition and fortition). Thus, we could explain the error *pu lulppa* by assuming that the strong stop /p/ starts spreading first; when the speaker then succeeds in preventing its spread, another consonant /l/ starts to spread. We could further assume that the spreading hierarchy is the same for both adults and children, with possibly /k/ being more dominant for children due to its early maturation, whereas all the stops are of equal strength for adults. For children, the spreading hierarchy is the primary explaining factor for the errors, whereas for adults (and possibly for older children with language disorders) spreading is almost exclusively regressive. However, for children with language disorders some words obviously are memorized in early harmonic forms and the spreading is not a phenomenon that takes place during the production process. For memorized word forms consonant harmony is systematic whereas in the other cases it tends to occur sporadically.

It has been suggested by Béland & al. (1990) and by Moen (1993) that the different error types (deletion, substitution, etc.) of conduction aphasics were best accounted for by assuming that for any aphasic patient the errors can arise at several stages of the production process. As far the present non-fluent aphasics are

concerned, it may be necessary to treat errors such as metathesis differently from harmony errors. However, a more detailed qualitative analysis of the errors is needed, and it may lead to more comprehensive generalizations.

There may be some extralinguistic variables involved such as the time post-onset of brain damage (differences between acute and residual aphasia) or the etiology of brain damage (differences between aphasia due to e.g. brain infarction and trauma), but at best, these factors account for preferences for error types. The same aphasic patient can commit different errors even in the same item during one testing session.

There were differences between the aphasic patients: one aphasic patient with non-fluent aphasia often deleted word-initial consonants, whereas another patient made harmonic errors. These two error types might suggest that feature specifications for some consonants (word-initial consonants or obstruents occupying an onset position) might be particularly difficult to retrieve, and as a consequence some patients might delete these consonants, others might fill in the empty slots by feature spreading. However, erroneous corrections such as *kääp pääpä* for "kääpä" show that the correct and complete feature specifications were first retrieved, but for some reason the correct pronunciation was abandoned. This leads one to think about a neuromotor speech production problem as an underlying cause for the errors, and consonant harmony as a compensatory strategy which enables the patient to produce the item in a simplified form when the complex form is out of his or her capabilities. Thus, consonant harmony might reflect intact phonology which is made use of in a clever way to solve the production problem under very specific circumstances due to abnormal neuromotor problems. Kolk & al. (1985) have also suggested that telegraphic speech in non-fluent aphasia does not result from the impairment itself but is a consequence of the particular way in which the patient, by means of an unimpaired system, adapts to the impairment.

8. Articulatory Characteristics of Consonant Harmony

A test of articulatory agility called diadochokinesis is often presented to adults with acquired speech language disorders. This test of the ability to perform rapid repetitions of relatively simple patterns of oppositional contractions consists of two parts, repetition of the same syllable (e.g. *pa*) and repetition of a syllable sequence (e.g. *pa-ta-ka*). Tests of diadochokinesis are viewed as providing information about the adequacy of the patient's neuromotor maturation and integration (Baken 1987: 445). The non-fluent aphasics with consonant harmony experienced difficulties in diadochokinesis when they had to quickly change between different places and manners of articulation, and their speech sounded awkwardly articulated (Kukkonen 1990). The aphasic patients' inability to swiftly change from the articulation of *pa* to that of *ta* and *ka* often leads to harmonic errors.

In addition to harmonic errors, a sequence of three syllables may be substituted by a string of four syllables, as in *a-te-ti-ti* for "ta-ke-li" by one of the subjects reported in Kukkonen (1990). Similarly, young children repeat the syllables for more than two times in their babbling before they learn to control the number of repetitions and to pronounce bisyllabic protowords. A baby observed by the author was asked to say *äiti* 'mother' and she babbled *äitäitäitäitäi* (the number of *täi*-syllables is uncertain). All the adults laughed noting that it was pretty good but the *täi* was simply repeated too many times. Thus, in very severe consonant harmony, syllables are not only rendered reduplicative but they may also be repeated many times, which reflects a severe problem in the neuromotor control of speech articulations.

Hardcastle (1987) has provided electropalatographic evidence for deviant articulatory gestures for some aphasic patients with speech apraxia (or non-fluent aphasia). Their errors were not pure phoneme substitutions but the phonemes had been correctly selected. A word-initial /k/ instead of a /t/ in a word like *tick*

resulted from a disturbance in the serial ordering of articulatory gestures. The raising of the body of the tongue appropriate for /k/ occurred prematurely in relation to the initial tongue tip gesture for /t/ and resulted in a double alveolar-velar stop which sounded more like a /k/ than a /t/.

Some evidence for ill-timed articulatory movements was obtained by Kukkonen (1990) during the acoustic analysis, where different segmentations of one item provided forms sounding like *talo* or *kalo* for "talo" 'house'[5]. Sometimes any listener can detect the simultaneous articulations in everyday listening conditions. The sounds may then be interpreted to occur one after another, as in *pseepra* for "seepra" 'zebra' or *parperi* for "paperi" 'paper'. An alternative explanation for such forms is that they are true phoneme anticipations. Articulatory timing difficulties may be more pronounced in acute aphasia as compared to residual aphasia. According to Love and Webb (1986: 42) there is evidence for compensatory mechanisms of articulation. A detailed comparison of errors in acute and residual aphasia should be performed.

There were no physiological data available for the consonant harmony errors discussed in the present paper. However, 11 harmonic errors were included in the rating experiment[6] reported by Kukkonen (1990, chapter 6.2). In the experiment, words were selected from the aphasia and control data, randomized, and recorded on tapes. Each item consisted of a given token recorded twice in succession, followed by a pause before the next item. During the pause the listeners were asked to rate the item for fluency of articulation on a five-point rating scale and to write down the item according to Finnish orthography which is fairly

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[5] This kind of a phenomenon may also occur during the acoustic analysis of normal speech. For some non-fluent aphasics, however, the phenomenon was extremely common and abnormally clear.

[6] Listening tapes were made at Haskins Laboratories under NICHD Contract NO1-HD-5-2910.

phonemic. The analysis of these "transcriptions" of harmonic errors provide some information about the accuracy of articulation. When there is little variation in transcriptions provided by the listeners, it is less likely that several gestures take place simultaneously.

The analysis revealed one item where the majority of the listeners had provided a transcription that differed from the one provided by the author and the harmonic error was a minority perception. This item was produced by a fluent aphasic. All the other ten harmonic errors were produced by non-fluent aphasics. The articulation of these patients was generally rated as awkward, and there was a lot of variation in the transcriptions. In order to analyze the nature of the intruding segments, the items were compared for harmonic transcriptions (allowing for some variation in the voicing and strength of the stricture) as compared to other transcriptions. For three of the ten harmonic errors, all the 25 listeners had provided a harmonic transcription, and for two further items the great majority of the listeners had provided a harmonic transcription. For three items there seemed to be rather convincing evidence for a double stricture. One of these items was the *parperi* example given above. Twelve of the 25 listeners had transcribed the word-medial consonant as a consonant cluster of a liquid followed by /p/, other common transcriptions were consonant clusters, such as nasal + stop or liquid + /t/ or /d/. Half of the listeners had provided a harmonic transcription for the item *kikka* for "tikka" 'woodpecker', others had perceived the correct form *tikka*. For the item *kaakka* for "taakka" 'burden', there were many transcriptions with /t/ but plenty of transcriptions with either /k/, /j/, /tj/ or /dj/ suggesting that in addition to a dental closure there was also a simultaneous velar closure or stricture. This seems to be similar to the alveo-velar double articulation as reported by Hardcastle (1987: 121). For the remaining items, the transcriptions were extremely variable. Thus, there was evidence for both unanimous harmonic perceptions for some items and for abnormal double articulations for other items. There might be different mechanisms underlying

different harmonic errors, although it is also possible to account for some variation in the listeners' transcriptions by the relative strength of the double-articulated gestures and by perceptual factors.

Normal children differ from aphasics and (at least some) children with speech disorders in that their speech sounds are relatively well articulated even if they may be at times somewhat clumsy. This suggests that the nature of the neuromotor control problem may be slightly different in pathological cases as compared to normal language acquisition.

9. Additional Observations about Consonant Harmony

Examples of consonant harmony are hardly ever present in normal adult speech. Consonant harmony errors do not generally occur as slips of the tongue (Cohen 1973, Fromkin 1973, Nooteboom 1973, van den Broecke & Goldstein 1980, Shattuck-Hufnagel 1980, Crompton 1982, Garnham & al. 1982, Ahti-Virtanen 1990, Dufva 1992, Stemberger 1992). Some anticipation or perseveration errors resemble harmonic errors, e.g. *spiirre-spesifikaatiolta* for "piirrespesifikaaltiolta" 'as feature specification' (Ahti-Virtanen 1990) or *corkical* 'cortical' (Fromkin 1973, appendix) but there were no harmonic errors among the within-word errors of Fromkin (1973). Distant assimilations were more common across word boundaries, e.g. *meal mystery* 'real mystery' (Fromkin 1973, appendix) or *pitkiä ketkuja* for "pitkiä ketjuja" 'some long chains' (Ahti-Virtanen 1990).

Something similar to consonant harmony or the simplification of movement sequences is observed in tongue twisters. One Finnish tongue twister is given below. The target is at the top, with the twisted variant beneath it[7].

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[7] The following abbreviations are used in the glosses: 3IMPERF - imperfect, 3rd person singular, INESS - inessive.

(target)	vesihiisi the water devil	sihisi hiss+3IMPERF	hississä elevator+INESS
(twisted)	vesisiihi	hihisi	sihhissä

'the water devil was hissing in the elevator'

This example resembles slips of the tongue where phonemes in content words are transposed but the grammatical suffixes remain unchanged. These phoneme transpositions may have an articulatory motivation as they simplify the sequence of movements with six changes from /s/ to /h/ or from /h/ to /s/ to one with only four such changes. These simplifications may or may not be similar to slips of the tongue such as *fonal phonology* 'tonal phonology' or *black bloxes* 'black boxes' (Crompton 1982). The errors resemble consonant harmony in that they render the movement sequence more repetitive but it remains unclear if these errors should be accounted for in terms of feature spreading. The errors differ from the harmonic errors of adult aphasics in that they are not due to double articulated gestures but reflect the tendency to substitute a sequence of varied closing gestures by the repetition of one gesture. It should be noted, however, that even in the case of a double-articulated gesture, the intruding gesture is repeated twice (e.g. in Hardcastle's *tick* example the velar closure occurs twice).

It is interesting to compare consonant harmony to vowel harmony which, contrary to consonant harmony, is a feature of both spoken and written standard Finnish. Consonant harmony was not usually observed in healthy adult speakers, except for some marginal examples of slips of the tongue and tongue-twisters. In contrast to errors of consonant harmony, vowel harmony errors (e.g. *puukkipoika* for "pyykkipoika" 'clothes peg', *purppu* for "korppu" 'rusk', and *poippi* for "koppi" 'hovel') were rare in the present aphasia data. The examples of vowel harmony errors closely resemble the errors with consonant harmony. These errors do not violate Finnish vowel harmony but they result from an overgeneralization of vowel harmony so that the vowels of a

word are rendered identical. The *poippi* example in particular suggests that the overgeneralizations of vowel harmony might be accounted for by mistiming of two relatively independent articulators: the tongue takes the articulatory position of [i] too early in relation to the bilabial closure of [pp] which gives rise to a perception of [i] even word-medially.

Consonant harmony in language acquisition has its basis in reduplicative word structures which again are developmentally based on the repetitive articulatory movements of babbling. Consonant harmony is a very common phenomenon in children of a certain age. There were fewer examples of corresponding overgeneralizations of vowel harmony. However, according to the author's personal (unsystematic) observations, children sometimes overgeneralize vowel harmony to compounds, such as *pölkypyörä* for "polkupyörä" 'bicycle' and may stick to such harmonic forms for a while. Similar overgeneralizations occurred in adult aphasia and as slips of the tongue, e.g. *luistelutuuli* for "luistelutyyli" 'skating style', *suuskuun* for "syyskuun" 'of September', *hiilipöly-syödätin* for "hiilipölysuodatin" 'carbon dust filter' (Ahti-Virtanen 1990). Nettelbladt (1983) presented some examples of abnormal vowel harmony in the speech of language delayed Swedish children.

All the above examples from both normal and pathological speech in adults and children in several languages — in addition to Finnish, consonant harmony was reported to take place at least in Swedish and English during language acquisition — propose that feature spreading is not only a characteristic of vowel systems of some languages, but similar organization should be provided for consonant systems as well, with a universal possibility for feature spreading.

If we describe Finnish vowel harmony in different terms from consonant harmony, this leads to a "two-level" description, where a linguistic stage accounts for systematic features of language and a processing stage accounts for sporadic errors such as slips of the tongue, pathological errors, and even for language

acquisition data. The similarity of vowel and consonant harmony errors suggest a common explanation whereas their different frequencies suggest that there are some differences between the mechanisms for consonant and vowel harmony. The vowel harmony of standard Finnish is restricted to frontness vs. backness of vowels, resulting in word forms in which this property is shared by all the vowels. Consonant harmony and the non-fluent aphasics' overgeneralizations of vowel harmony, in contrast, result in identical consonants or vowels, i.e. the repetition of exactly the same articulatory gesture. Thus, consonant harmony as a phenomenon is far less fine-grained than the standard Finnish vowel harmony. Furthermore, vowel harmony is (by definition, Lass 1984) progressive, whereas consonant harmony is regressive and resembles vowel umlaut rather than vowel harmony.

The difference between consonant harmony and vowel harmony bears a certain resemblance to sound changes in progress where some of the phonetic variations turn into systematic allophonic variations and may finally change into phonological ones and become parts of the language system (Anttila 1989, chapter 4). In certain languages, such as Finnish, vowel harmony has stabilized in the language system. Consonant harmony, however, is not an attested type of sound change, and there obviously are no languages with consonant harmony. Consonants seem to bear a heavier functional load than vowels and for this reason languages may more easily allow for harmonic constraints in their vowel systems as compared to their consonant systems.

Except for some fossilized forms of deviant language acquisition, the harmonic errors were created on-line during the speech-language production process. It is only during a short period of early language acquisition that this harmony process can be systematically applied to all word forms. In all other instances, consonant harmony is a sporadic process. The possible task-specific differences in aphasia data are difficult to account for: consonant harmony seems to be more pronounced in single

word data from naming and repetition tasks as compared to descriptive or spontaneous speech.

10. Directions for Future Research

Consonant harmony is a piece of evidence for Jakobson's (Malmberg 1967: 173) or Ribot's (Villiers 1978) rule which says that language loss in adult aphasia mirrors language acquisition. The speech language disturbance in non-fluent aphasia is predominantly "expressive", confined to language production. For these patients comprehension is relatively well preserved. It is obvious that children also aim at correct targets which are simplified to harmonic forms due to production constraints.

The major difference between the harmonic errors produced by children and by adult aphasics lies in the auditory impression of their articulation. A child's articulation is fluent and "normal" (even if at times somewhat clumsy) whereas the non-fluent aphasics' articulation is abnormal (slow, awkward, and extremely clumsy). Consonant harmony is a mechanism which renders the sequence of phonemes to be articulated more repetitive, i.e. reduplicative. It might be possible to account for some harmonic errors by a neuromotor timing disturbance. At some level there is a mechanism which controls for the sequentiality of articulatory gestures and prevents them from taking place simultaneously. If this mechanism does not function normally — when it is still unmatured as for children or when it is disturbed due to brain damage — the speaker is unable to prevent the articulatory gestures from taking place simultaneously, and consequently within the domain of control (words or phonological phrases) the "strongest" gestures tend to "spread". The listener may also have his or her strategies (or perceptual limitations) for coping with simultaneous articulations and may tend to perceive them as being linearly ordered.

The harmonic forms could also reflect the preference for repetitive articulatory gestures. A preference for repetition or reduplication of gestures is reflected in certain slips of the tongue

and tongue-twisters. In slips of the tongue the simplifications often occur across word boundaries in noun phrases or phonological phrases. In these cases the errors seem to be well articulated without a tendency for double articulations, and the errors are not due to a mistiming of articulatory gestures but to a false repetition of one gesture instead of more varied gestures.

In their early attempts at repeating bisyllabic protowords children may produce multisyllabic items with too many repetitions of a syllable. Similarly, aphasics with difficulties in the test of diadochokinesis may repeat a syllable too many times, thus being unable to prevent multiple repetitions of the same articulatory gesture.

Consonant harmony could also be conceived of as a compensatory strategy reflecting the functioning of an intact phonological system under heavy physiological production constraints. Due to the neuromotor control problem, the speaker is forced to simplify the production in one way or another. In order to be able to communicate, it would be useful for the speaker to try to preserve the word-pattern but substitute some simple elements for the difficult ones.

Before one can select among the proposed explanations or estimate their explanatory power in different types of data both the exact phonological characteristics and the phonetic quality of harmonic errors should be determined in great detail. This analysis might also help to remove the unsystematicity of harmonic errors as some exceptions, for example, might be accounted for by overlap of gestures, others by the repetition of one gesture or one phoneme. The analysis of consonant harmony may be of great importance to our understanding of speech production and the organization of phonology. However, it has to be kept in mind that consonant harmony errors are only one error type produced by children and adult aphasics; it might be more valid to try to catch generalizations that account for not only consonant harmony errors but for all the phonological errors (including phoneme substitutions, additions, deletions, metathesis errors) committed by these speakers.

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