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Phonological Processing of Second Language Phonemes: A Selective Deficit in a Bilingual Aphasic

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We present a case study of a Russian-Hebrew bilingual transcortical sensory aphasic. In general, aphasic symptoms are similar in the 2 languages, with Hebrew being somewhat more impaired. However, the patient reveals a difference in her ability to perceive phonemes in the context of Hebrew words that is dependent on whether they are presented in a Russian or a native accent. This finding is interpreted as showing that a mediating mechanism that assimilates second language phonemes to native language phonological categories is differentially damaged. Implications for models of speech perception in general and second language phonetic perception in particular are discussed.

The study of bilingualism has been an important source of both data and theories for models of the organization of language abilities in the brain. The consensus in the field now seems to be that all languages of a multilingual are subserved primarily by the left hemisphere (LH), because lateralized experiments

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with normal monolinguals and bilinguals have revealed more similarities than differences. In the auditory modality, bilinguals (like monolinguals) evince a right-ear advantage in dichotic listening tasks for all of their languages (Obrzut, Conrad, Bryden, & Boliek, 1988; Piazza-Gordon & Zattore, 1981; Gordon, 1980). In visually lateralized experiments bilinguals tend to show a right visual field advantage (RVFA) for verbal materials (Vaid, 1988). In parallel, studies with brain-damaged bilinguals have revealed that LH damage tends to affect all of the patient's languages in similar ways, where dissimilarities can usually be explained by differences in the characteristics of the languages or in competence in the two languages (Paradis, 1990, 1996; Zatorre, 1989). All in all, more than 30 years of intensive study seem to suggest that language abilities, whether mono- or multilingual, are organized in a similar way in the LH of humans (Paradis, 1990).

The majority of psycholinguistic and neuropsychological studies of bilingualism have looked at the relationship between the semantic system and the lexicon(s) of bilinguals. In general, the manner in which and age at which the second language was acquired have been considered important factors, with a variety of models proposed to explain differential lexical/semantic processes in the two languages (e.g., de Groot, 1992; Paradis, 1987). Two principal approaches have been proposed. The classic structural approach places more emphasis on the representation of two languages in the cognitive system of bilinguals, where language serves as a dimension in which concepts are represented. The second approach is the processing approach, which, on the one hand, entails a diminishing value of language as the central factor in concept representation, and, on the other hand, increases the emphasis on linguistic and other factors that affect the bilingual's processing of words from different languages. The outstanding feature of this approach is the assumption that the nature of the interaction between lexical representations of words in different languages is not directly related to the conceptual system, but rather to phonological and morphological factors that exist across languages. These factors have been found to influence the

performance of healthy bilinguals in a number of studies (e.g., de Groot & Nas, 1991).

Research of bilingual aphasia has yielded six proposed patterns of recovery of multiple languages (Paradis, 1987; Perecman, 1984): parallel, differential, successive, selective, mixed, and antagonistic. These patterns are believed to reflect different relationships among languages and among different subsystems of the languages. The case study described here focuses on one of these subsystems and relationships: phonetic perception and phonological processing of a second language that has been learned in adulthood.

Compared to bilingualism research in cognitive psychology (see Keatley, 1992, for a review), bilingual phonology has been studied relatively little. The studies that have been done (e.g., Caramazza, Yeni-Komshian, Zurif, & Carbone, 1973; Mack, 1989; Sheldon & Strange, 1982) have generally looked at specific phonetic contrasts. These studies have shown that bilinguals (most were early bilinguals who acquired their second language before puberty) are similar to monolinguals in the production of phonemic contrasts, but differ from them in perception of these same contrasts. In fact, Caramazza et al. have suggested that "bilinguals appear better able to adapt their production mechanisms than their perceptual mechanisms to the second language" (p. 427), and Mack has suggested that "bilingual production can be more accurate than perception" (p. 197).

The majority of cross-language phonological investigations have been carried out within the framework of developmental psycholinguistics, with the focus on the development of phonological categories. It is known that 6–8-month-old infants are able to discriminate a wide range of phonetic contrasts, and that adults and even 1-year-old infants already show an insensitivity to phonemic contrasts that are not part of the repertoire of their native language (see Werker & Pegg, 1992, for a review). This has been viewed as reflecting the tuning of the phonological system to the relevant categories of the native language. Recent research (Flege, 1992; Werker & Pegg, 1992) has suggested that sensitivity

to foreign phonemic contrasts is not lost but is subject to the organization of the phonological system. The consensus now seems to be that as infants learn their native language, the phonological system becomes tuned to the contrasts of this language, such that when individuals learn a second language (L2) in adulthood, L2 sounds are processed primarily through a system tuned to native language (L1) sounds (e.g., they are assimilated to L1 phonological categories), and that there are certain limits and there is a systematicity in the manner in which the existing phonological system can reorganize to accommodate foreign speech sounds. It has been shown that this reorganization can develop, where, for example, Japanese subjects who have had extensive conversational experience in English are better (although not as good as native English speakers) at perceiving the r/l distinction than those who have had limited English experience (Best & Strange, 1992).

The patient described below evinces a dissociation between her ability to perceive her second language (Hebrew) when it is spoken by a native speaker and when it is spoken by a speaker with an accent like her own (Russian). To our knowledge this is the first report of a breakdown in this process due to brain damage. In addition, the patient was able to write words in her second language only when using the orthography of her native language. Before describing the patient, a brief summary of the different characteristics of Russian and Hebrew is presented.

Phonetics and Phonology of Russian and Hebrew

Russian and Hebrew differ in both their phonology and their phonetics (articulation). These differences are expressed in several ways:

1. an absence of definite phonemes in one or the other language (e.g., the Hebrew phonological system does not include the phonemes affricate /tč/ and postalveolar /ž/, which occur in

Russian, whereas the Russian phonological system does not have the glottal fricative consonant /h/);

2. the Russian phonological system uses the distinctive phonological feature of palatalization (e.g., /s̄/ vs. /s/; such oppositions are successively shown in most Russian consonants), whereas, in Hebrew, this distinction appears (if ever) only as an allophone;

3. even consonants that sound similar in the two languages differ in their articulation (phonetic features). For example, the consonant /t/ is more frontal in Russian than in Hebrew. In articulation of the consonants /s/ and /z/, in Russian the tip of the tongue approximates to the lower teeth, whereas in Hebrew it usually approximates to the upper teeth. The liquid /r/ in Russian is a dental-alveolar trill consonant. In Hebrew there are two dialect allophonic variations of this consonant: The first is approximately like the Russian /r/ and the second is a velar (or even uvular) trill /R/. In our case, the native Hebrew speaker who tested the patient pronounces just such a second variant (i.e., uvular /r/).

There are significant differences between Russian and Hebrew phonotactics. All of the perceptual tests described below involved the presentation of target sounds in the context of a word. Therefore, it is probable that differences in the effects of coarticulation on the target phonemes were critical in the performance of the patient.

Orthography of Russian and Hebrew

Both the Russian and Hebrew orthographies are alphabetic. In Russian there is a close one-to-one relationship between graphemes and phonemes. Russian is an inflected language with some analytic features. Most roots are morphemes that express the meaning of the word and consist of two or more phonemes (usually from three to six) including consonants and vowels, similar to

English. Russian is written from left to right. In Hebrew, on the other hand, all verbs and most nouns are written primarily as consonantal roots that are differently affixed and voweled to form the words of the lexicon (Berman, 1978). There are four letters in Hebrew that, in addition to their role in signifying specific consonants, also specify long vowels. However, in some cases it is difficult for the reader to determine whether these dual-function letters represent a vowel or a consonant. When they appear (in poetry, children's books, and liturgical texts), vowels are signified by diacritical marks above, below, or within the body of the word. Inclusion of these marks completely specifies the phonological form of the orthographic string, making it completely transparent in terms of orthography-phonology relations. As the majority of written materials do not include the diacritical marks, a single printed word not only is ambiguous between different lexical items (this ambiguity is normally solved by semantic and syntactic processes in text comprehension), but also does not specify the phonological form of the letter string. Thus the Hebrew alphabet specifies all of the consonants but almost none of the vowels. In contrast to Russian, Hebrew is written from right to left.

Case Report

R.K. is a 68-year-old, right-handed female physician, a native speaker of Russian, who immigrated to Israel 20 years ago. In Israel she acquired and used the Hebrew language in professional and private settings. Premorbidly (as reported by former colleagues) her Hebrew competence was very high. On June 29, 1994, she developed an acute onset of a neurological deficit with aphasia[1] and right hemiparesis[2] (improved) while traveling by air from Israel to Canada. She was hospitalized in North York General Hospital, Ontario, between June 29, 1995, and July 15, 1995. A computed tomography scan revealed two areas of diminished attenuation deep in the LH. One involved the basal ganglia and the other was in the posterior left corona radiata. Three months later she was admitted to the Flieman Geriatric Hospital, Haifa,

Israel, for rehabilitation. Diagnoses included cerebrovascular accident, or stroke (CVA) with right slight hemiparesis and dysphasia. Upon admission R.K. was active, cooperative, and oriented to place, situation, and partially time. Visual fields and auditory abilities were intact. R.K. was administered the Western Aphasia Battery (WAB; Kertesz, 1982) and the Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 1983) in Russian and Hebrew. The language status that emerged from these tests was consistent with transcortical sensory aphasia[3] (Albert, Goodglass, Helm, Runens, & Alexander, 1981) with severe dyslexia and dysgraphia,[4] that is, fluent speech, at times circumlocutory, with limited content and paraphasic errors,[5] decreased abilities in auditory comprehension, severe anomia,[6] and intact repetition.

These patterns are presented in Table 1. As can be seen, similar patterns emerged in both languages, though they were somewhat more severe in Hebrew. In addition, some preserved abilities were observed in single-word reading and some writing to dictation in Russian. R.K. received intensive therapy in Russian and in Hebrew for 4 months. During the treatment period she showed significant improvement in both languages in her spontaneous speech and auditory comprehension, whereas naming ability remained without changes. Her reading and writing abilities improved significantly only in Russian. At the beginning of February of 1995, her speech was described as fluent and grammatically correct with occasional paraphasias and prominent word-finding difficulties, and it corresponded to moderate to light transcortical sensory aphasia.

Thus, the results of the standard examination showed that R.K. suffered from similar language impairment in Russian and Hebrew, with a slightly more prominent disorder in Hebrew. Moreover, she displayed parallel progress in both languages in consequence of language therapy, though progress in Russian was greater. This clinical picture is of interest because Russian is structurally distant from Hebrew (especially in terms of syntax and morphology). Likewise, prior level of language competence in the two languages was not equivalent. During the period of the

Table 1

Degree of language impairments on the Western Aphasia Battery

Subtests	Russian	Hebrew
Fluency	5/10	4/10
Comprehension	5.8/10	4.5/10
Repetition	10/10	9/10
Naming	1/10	1/10
Aphasia quotient	70.4	67.3

language treatment, R.K. was administered various tests to investigate further the nature of her impairments in the two languages.

Naming

R.K.'s most evident initial as well as residual aphasic symptom was a marked difficulty in confrontation naming[7] in both languages. Her initial score for the BNT was 1/60 in Russian and 0/60 in Hebrew. During treatment the clinical picture of R.K.'s anomic disorders changed, whereas the degree of her anomic impairment remained constant. Initially (at least during September–November 1994), R.K. demonstrated an almost typical pattern of semantic anomia (Benson, 1979; Luria, 1975): She not only failed to name an object or picture but also showed prominent difficulties in auditory word recognition (on Hebrew and Russian equivalents of the Peabody Picture Vocabulary Test [Dunn, 1965]) together with preserved repetition ability. This pattern concurs with transcortial sensory aphasia (Albert et al., 1981; Benson, 1979). With treatment, another type of anomia, namely, word selection anomia (Benson, 1979), gradually appeared. R.K. looked intently at a picture for a long time and tried to find the appropriate word, explaining what it was and producing a number of paraphasias. She frequently demonstrated an object's use by spontaneous gestures. She also exhibited word-finding pauses and compensatory

circumlocutions in parallel with significant improvement of auditory comprehension (including single-word comprehension). Semantic cueing did not facilitate naming but sometimes led to semantic paraphasias (e.g., "case" instead of "wallet"). Phonemic priming was also ineffective but R.K.'s performance often improved if she received more than one syllable. These patterns are presented in Table 2.

R.K.'s naming abilities were impaired in all modalities and in all types of naming tasks. These deficits were relatively equivalent in the two languages, with the exception of the word generation task, where Russian was more productive, especially in the letter generation task. The word association task and the antonym generation tasks revealed that when tested in Hebrew, R.K. spontaneously translated the target words into Russian, or at least tried to do so, and responded inappropriately in Russian. Interestingly, in the face of this spontaneous translation, she was unable to perform a translation task in either direction. In this task, R.K. was required to translate Russian words to Hebrew and vice versa. The lists of target words from the word association task (see paragraph above) were utilized. R.K. was unable to perform this task. However, as noted above, she carried out such translation spontaneously in many cases but always only in one direction: from Hebrew to Russian.

Visual Abilities

The patient demonstrated good copying and construction abilities (WAB). Matching for all types of visual stimuli (including letters, words, and sentences in both languages) was excellent. R.K.'s score of 25/36 on the Raven's Matrices was near to her age norms, consistent with intact visual perception and reasoning skills (Spreen & Strauss, 1991). These data are presented in Table 3. However, to rule out nonlinguistic causes of R.K.'s naming deficit two additional tests were administered to her:

Table 2

R.K.'s performance on naming tasks in Russian and Hebrew

Tasks	Russian	Hebrew
Visual confrontation naming[a]	9/120	5/120
Naming from definition[b]	6/20	4/20
Category generation task[c]	3.7	1.0
Letter generation task *(M)*[d]	7.0	2.0
Word association[e]	65%	8%
Antonym generation[f]	40%	30%
Tactile naming[g]	5/10	2/10

[a] One hundred twenty line drawings of objects belonging to 12 categories; 10 objects per category and 60 high-frequency and 60 low- or middle-frequency words were presented. Categories included vegetables, animals, fruits, body parts, office items, personal items, tools, transportation, clothing, kitchen utensils, furniture, and geometric shapes. The same list of the pictures was presented to R.K. in Hebrew (without taking into account word frequency). [b]Twenty items for which clear definitions could be formulated were administered. R.K. was asked to name the defined item. For example, "What is the name of the big horned animal which is kept by farmers for producing milk?" It must be noted that in all cases R.K. understood the definition (this was verified by the matching for auditory presentation task). Many of R.K.'s responses (both correct and incorrect) were phrases rather than single words. For example, for target "dog," she said, "Who is shouting at the dog?" [c] R.K. was asked to name as many members of a specified semantic category as possible in 1 minute. The list of categories included body parts, animals, clothing, fruit, colors, food, and domestic animals. [d] R.K. was asked to name all the words she could that began with letter (sound) *M*. [e] R.K.'s performance on word generation by association was assessed with a list of 60 adjectives, 60 nouns, and 60 verbs. The items in each grammatical category were controlled for frequency and concreteness. The patient was required to find a word associated with an orally presented target word (e.g., for the target word "big" the word "house" or another word may be produced). In the Hebrew version of this task the translation of the stimuli list was utilized (without taking into account word frequency). [f] R.K.'s ability to produce antonyms was assessed with a list of 100 words given orally. The list of words included nouns, verbs, adjectives, adverbs, and prepositions. The items in each grammatical category, except prepositions and adverbs, were controlled for frequency and concreteness. Order of presentation was randomized across all stimuli. The patient was asked to find a word with the opposite meaning. Only original word production was taken into account as a correct response (e.g., for the stimuli "big," the word "little" may be produced, but not "not big"). [g] Ability to name through the tactile modality was compared with visual naming, using the same 10-item set of household objects the use of which R.K. had been able to gesture. R.K. examined the objects for a long time with both hands.

1. R.K.'s ability to classify pictures in accordance with a specific category was investigated in a pictorial classification task. In this task, she was presented with three category pairs: birds/insects, domestic/wild animals, carnivore/herbivore (15 pictures per category). R.K. performed the task without difficulties and errors.

2. In a semantic attribute judgments task, R.K. was presented with 30 pairs of black-and-white pictures. Fifteen of the pairs were used for a cost judgment (e.g., TV set/pen) and 15 for a size judgment (e.g., horse/rabbit). The pictures themselves bore no clues as to cost or size. R.K. performed correctly in 100% of the trials without naming the presented pictures.

Thus, the findings showed that R.K. did not have any disorders in visual processing and visual representation. Moreover, her nonlanguage behavior and the results of some tasks (e.g., Raven's Matrices) indicated that her conceptual memory was mostly intact.

Phonological/Phonetic Abilities

R.K. was presented with four auditory tasks following Luria (1970): (a) counting the number of letters in individual words (i.e., saying how many letters there are in a spoken word), (b) spelling (i.e., identifying the letters that make up a spoken word), (c)

Table 3

The results of the investigation of visual ability

Tasks	Results
Matching pictures	10/10
Matching colors	10/10
Matching shapes	10/10
Matching letters[a]	10/10
Matching words[a]	10/10
Matching sentences[a]	10/10

[a] For both languages.

counting the numbers of syllables in an individual word, and (d) synthesizing words from individually pronounced letters (i.e., recognizing an auditorily spelled word). The mouth movements of the examiner were hidden in all of these tests. The results of these tasks appear in Table 4.

Performance here was dependent on word length, with better performance on short words (three to five letters). In Russian there is no word for "spell." Instead, the phrase *perachisli bukvi,* "list letters," is used. This is what R.K. was asked to do. Many Russian speakers use "popular letter names" (e.g., /mé/ for letter *M* instead of normative /ém/), which are not sounds but syllables. R.K. used these popular terms instead of the official letter names. For example, in the identification of the Russian word *dom,* "house" (three letters, three phonemes) she responded: "de [dè] . . . o [ö] . . . me [mè]." In Russian there is nearly a one-to-one correspondence between letters and sounds, and this is probably reflected in her relatively better performance in Russian. This correspondence does not occur in Hebrew (most Hebrew vowels are not instantiated as letters). In addition, Hebrew does have a word for "spell," and this is what R.K. was asked to do. In Hebrew, R.K. was often not able to count letters, but she counted phonemes. It is interesting that in naming Hebrew phonemes R.K. also used the Russian "popular terms"; that is, she referred to the sounds related to these letters. For example, [bé] for the letter ב instead of bét. For the Hebrew word *dag,* "fish" (two letters, three phonemes), she

Table 4

The results of four auditory tasks of phonological ability

Tasks	Russian	Hebrew
Counting letters	17/20	11/20
Spelling	11/20	9/20
Counting syllables	20/20	20/20
Spelled word recognition	3/10	1/10

said "de [dè] . . . a [ã] . . . ge [gè]." In many cases, R.K. counted syllables instead of sounds or letters. Note that her ability to calculate syllables was intact.

Reading and Writing

R.K.'s reading aloud in Russian revealed two strategies. In some cases of single and short words (11/30, 18/30) she seemed to use a direct visual strategy—immediately recognizing the word. If this strategy was not successful, she turned to letter-by-letter reading, resulting in many literal paralexias (for example, the word *korova,* "cow," was read as *koroza,* which is not a word) and a few verbal paralexias (mostly semantic; for example, the word *glaz,* "eye," was read as *gaz,* "gas"). Her strategy for reading in Hebrew was similar, but resulted in poor performance (8/30, 7/30). This is probably due to two factors. The first is the general inappropriateness of letter-by-letter reading for unvoweled Hebrew (see Birnboim, 1995, for the implications of this feature for the symptoms of surface dyslexia). The second is that because of her transliteration of Hebrew letters to Russian phonological categories and the absence of vowels, R.K. was not able to identify Hebrew words according to their phonological form.

Spontaneous writing (in Russian) was possible only at the level of single words and word combinations (with literal paragraphias; for example, the word *gora,* "mountain" was written as *goka*). In Hebrew, she could only write her name. Writing to dictation in Russian was possible only at the level of sentences up to eight words (with literal paragraphias). Most importantly, R.K. was able to write to dictation in Hebrew—in Russian letters. From the beginning she wrote Hebrew words in Russian letters from right to left (i.e., in the correct direction for Hebrew) with many paragraphias. However, when asked to write Hebrew from left to right (as in Russian), she was able to write Hebrew words in Russian letters almost without errors (there was only one error). In all these cases, R.K. wrote all vowels in agreement with Russian

grapheme-phoneme relational rules. Thus, she was able to translate Hebrew phonemes to Russian graphemes, but not to Hebrew graphemes.

This finding, together with her performance on tasks of phonological ability (shown in Table 5), suggest that R.K. suffered from impairments at the level of phonological representation in both languages, with Hebrew being more impaired. We believe that these patterns demonstrate that R.K. used one and the same phonological system, namely the Russian phonological system, for both languages.

As do most adult second language learners, R.K. acquired Hebrew grammatical structure and lexical items utilizing the Russian phonological system. Premorbidly, this did not result in great difficulties with the phonetic quality of her speech (although she spoke with a Russian accent) nor in her ability to understand Hebrew speech. Informational redundancy of language production allows compensation for a deficiency in the perception of phonological distinctive features received in comprehension. However, this probably resulted in weak phonological representation of items in the Hebrew lexicon and weak representations of grapheme-phoneme relations in Hebrew. In the presence of aphasic disorders, this situation may have caused additional difficulties in comprehension as well as in speech production in Hebrew. We therefore carried out all subsequent tests of phonological ability in Hebrew twice: They were presented, first, by a native Russian speaker speaking accented Hebrew (a male speech pathologist) and, second, by a native Hebrew speaker speaking unaccented Hebrew (a female speech pathologist). The results of these tests are presented in Table 5.

It can be seen that both detection and discrimination of sounds in the two languages are similar when presented by a native Russian speaker, and that they drop drastically when the stimuli are presented in a native Israeli accent. We believe that this drop in performance is beyond what would be expected as a result of the different acoustic characteristics resulting from the gender of the speakers and results in large part from the difference

Table 5

The results of two tasks of phonological ability

	Russian	Hebrew	
Tasks		Russian accent	Native accent
1. Identification of a target sound in the word			
/S/	93%	89%	58%
/M/	97%	96%	71%
/T/	91%	83%	42%
/R/	96%	93%	19%
2. Phonemic differentiation between sibilants /S, Z, tč, ts/			
	98%	85%	69%

in accent between the two speakers. We are currently testing additional bilingual aphasic patients with a better controlled version of this test, where gender is held constant across the foreign and native accent conditions.

Discussion

The results of the naming and visual tasks suggest that R.K.'s semantic system was intact. Her naming difficulties probably arose as a result of damage to a lexical retrieval mechanism. The finding that naming deficits were similar in the two languages suggests that she had a single retrieval mechanism that accessed both lexicons. This formulation fits the Hybrid Model of lexical representation in the bilingual brain (de Bot, 1992; de Groot, 1992). According to this model, a common semantic system is connected to two independent lexical systems corresponding to each of the two languages known by the bilingual. The ease of access to each lexicon from semantic memory depends on such factors as the age at which the lexical item was acquired and the frequency and recency of access (Snodgrass & Tsivkin, 1995). In other words, the lexicon of the native language will have easier

access to the common semantic store. This will create a preference for choosing the native lexical item, particularly in the presence of aphasic disturbances. R.K. demonstrated such preference for Russian in all the naming tasks.

R.K.'s anomia and perception deficits suggest that bilinguals may possess two separate switching mechanisms: a lexical/semantic mechanism that is intentional and is closely related to the production system, and a second, phonetic/phonological mechanism that is automatic and related to the perceptual system. R.K. provides evidence for this distinction, because although both were impaired, the semantic switching mechanism was relatively more preserved. There are two possible hypotheses about the organization of R.K.'s phonological system. The first, which we have suggested, is that premorbidly, L2 phonology was processed via assimilation to Russian phonological categories, and that this assimilation process was damaged. The second is that Hebrew phonological input was processed via a Hebrew subsystem that was subordinate to the Russian mechanism, and that this Hebrew subsystem was more fragile, and, therefore, more sensitive to damage. We are aware that a single case study does not provide unequivocal evidence for one or the other model. However, R.K.'s writing difficulties (e.g., writing Hebrew words in Russian letters according to Russian grapheme-phoneme rules) strongly suggest that she had no access to a Hebrew phonological system (if one existed premorbidly).

We believe that the acquisition of a second language in adulthood together with a certain phonetic similarity between spoken Russian and Hebrew may have been responsible for the fact that R.K. acquired Hebrew grammatical structure and lexical items utilizing the Russian phonological system. This may explain R.K.'s premorbid ability to produce Hebrew with an adequate phonetic quality and to comprehend Hebrew spoken language. She developed a system by which native Hebrew phonemes were assimilated to Russian phonological categories. Empirical evidence for this hypothesis can be found in studies showing priming relations between words in different languages that share

phonological characteristics (de Groot & Nas, 1991; Ibrahim, 1997). For R.K., this system was damaged such that her comprehension of Hebrew now depended on identity between L2 articulation and phonetic features and L1 categories. When faced with native L2 speech, phonemic perception broke down. Premorbidly, this system also subserved the linkage between phonemes and letters in her Hebrew lexicon. Damage to this system may also account for R.K.'s greater difficulties with Hebrew writing tasks compared with tasks in Russian. She had been writing premorbidly in Hebrew more than in Russian for the last two decades. Nevertheless, she preferred to use the Russian phonological and graphic systems when attempting to write in Hebrew after the CVA.

The data presented here support the hypothesis that late L2 learners perceive L2 sounds via the phonological categories of their L1. A number of researchers have shown that extensive L2 experience and specific training may modulate this assimilation process, both for production and perception (Best & Strange, 1992; Flege, 1992; Werker, Frost, & McGurk, 1992). The case study presented here suggests that this assimilation procedure can be differentially damaged such that L2 speech that conforms to L1 phonology (accented speech) is better perceived than phonemically correct L2 speech. The results may also suggest the existence of a separate, automatic switching or mediating mechanism that subserves L2 phonemic perception via the existing L1 phonological system that is distinct from the lexical/semantic subsystems of the bilingual's language system.

These data raise an interesting question about the relationship between second language production (i.e., speaking with a strong or mild accent) and speech perception. The logic of the question is the following: the ability to learn a new set of phonological production rules and subsequently speak with a mild accent or even no accent implies a flexibility in the phonological production system of the individual. Is this rigidity or flexibility of the production system related to rigidity or flexibility in the perceptual system for speech? The well-known phenomenon of "Conradism" (after Joseph Conrad) reveals that there can be a

large dissociation between the phonological aspects of L2 production (speaking with a heavy accent) and lexical, syntactic, and even metalinguistic facility in the second language. Does such a dissociation exist between the phonological production and perception systems as well, or can phonological flexibility be considered a source of individual differences in second language acquisition (see Flege, 1992, for a similar view)? This hypothesis is currently being tested with healthy bilinguals and additional aphasic bilinguals in our lab.

These data are also relevant to the current controversy about the objects of speech perception (e.g., Best, 1994; Diehl & Kluender, 1989; Fowler, 1989; Remez, 1989, 1994). It is beyond the scope of this article to go into this issue in detail. Briefly, there are currently three major models of speech perception: the motor theory (Liberman & Mattingly, 1985), the direct realist model (Best, 1994; Fowler, 1989), and the acoustic enhancement model (Diehl & Kluender, 1989). These differ in their definition of the object of speech perception, with the motor theory proposing that articulatory gestures are primary, the direct realist model proposing that both gestural and spectral features are primary, and the acoustic enhancement model suggesting that sounds are primary. Klein, Zatorre, Milner, and Meyer (1994) reported that the left putamen (this structure is part of the basal ganglia) is differentially involved in articulation of a second language as compared to the native language. Given that R.K. had left basal ganglia damage, and evinced deficits in L2 perception that were dependent on accent (which differs in both articulatory and spectral features from native speech), our data support the position of the direct realist model of speech perception.

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Notes

[1]Dysphasia or aphasia are disorders of language that are caused by diseases of the brain (Caplan, 1987).

[2]Hemiparesis is "incomplete, partial paralysis of organic origin" (Reber, 1985, p. 518) on one body side.
[3]Transcortical sensory aphasia is "characterized by impaired comprehension abilities in conjunction with preserved repetition and a fluent speech output" (Murdoch, 1988, p. 81).
[4]Dysgraphia is "inability to write properly or to express oneself through writing" (Reber, 1985, p. 220).
[5]Paraphasic errors are substitutions of words or sounds.
[6]Anomia is difficulty in naming objects.
[7]Confrontation naming is visual naming (i.e., oral naming of visually presented pictures or real objects).

References

Albert, M. L., Goodglass, H., Helm, N. A., Runens, A. B., & Alexander, M. P. (1981). *Clinical aspects of dysphasia*. New York: Springer-Verlag.

Benson, D. F. (1979). Neurologic correlates of anomia. In H.Whitaker & H. A.Whitaker (Eds.), *Studies in neurolinguistics: Vol. 4.* New York: Academic Press.

Berman, R. A. (1978). *Modern Hebrew structure.* Tel Aviv, Israel: University Publishing Projects.

Best, C. T. (1994). The emergence of native-language phonological influences in infants: A perceptual assimilation model. In J. C. Goodman & H. C. Nusbaum (Eds.), *The development of speech perception: The transition from speech sounds to spoken words* (pp. 167–224). Cambridge, MA: MIT Press.

Best, C. T., & Strange, W. (1992). Effects of phonological and phonetic factors on cross-language perception of approximates. *Journal of Phonetics, 20,* 305–330.

Birnboim, S. (1995). Acquired surface dyslexia: The evidence from Hebrew. *Applied Psycholinguistics, 16,* 83–102.

Caplan, D. (1987). *Neurolinguistics and linguistic aphasiology: An introduction*. New York: Cambridge University Press.

Caramazza, A., Yeni-Komshian, G. H., Zurif, E. B., & Carbone, E. (1973). The acquisition of a new phonological contrast: The case of stop consonants in French-english bilinguals. *Journal of Acoustical Society of America, 54*(2), 421–428.

de Bot, K. (1992). A bilingual production model: Levelt's "speaking" model adapted. *Applied Linguistics, 13,* 1–24.

de Groot, A. M. B. (1992). Determinants of word translation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 1001–1018.

de Groot, A. M. B., & Nas, L. J. G. (1991). Lexical representation of cognates and noncognates in compound bilinguals. *Journal of Memory and Language, 30,* 90–123.

Diehl, R. L., & Kluender, K. (1989). On the objects of speech perception. *Ecological Psychology, 1,* 121–144.

Dunn, L. M. (1965). *Expanded manual for the Peabody Picture Vocabulary Test.* Circle Pines, MN: American Guidance Service.

Flege, J. E. (1992). Speech learning in a second language. In C. A. Ferguson, L. Menn, & C. Stoel-Cannon (Eds.), *Phonological development: Models, research, and implications* (pp. 565–604). Timonium, MD: York Press.

Fowler, C. A. (1989). Real objects of speech perception: A commentary on Diehl and Kluender. *Ecological Psychology, 1,* 145–160.

Gordon, H. W. (1980). Cerebral organization in bilinguals. *Brain and Language, 9,* 225–268.

Ibrahim, R. (1997). *The cognitive representation of literate and spoken Arabic languages: A comparison within and between languages*. Unpublished doctoral dissertation, Hebrew University, Israel.

Kaplan, E., Goodglass, H., & Weintraub, S. (1983). *Boston Naming Test*. Philadelphia: Lea and Febiger.

Keatley, C. W. (1992). History of bilingualism research in cognitive psychology. In R. J. Harris (Ed.), *Cognitive processing in bilinguals* (pp. 15–49). Amsterdam: North Holland.

Kertesz, A. (1982). *Western aphasia battery.* New York: Grune and Stratton.

Klein, D., Zatorre, R. J., Milner, B., & Meyer, E. (1994). Left putamen activation when speaking a second language: Evidence from PET. *Neuroreport, 5,* 2295–2297.

Liberman, A. M., & Mattingly, I. (1985). The motor theory of speech perception revised. *Cognition, 21,* 1–36.

Luria, A. R. (1970). *Traumatic aphasia: Its syndromes, psychology, and treatment.* The Hague: Mouton.

Luria, A. R. (1975). A note on the organization of fluent speech in a semantic kind of amnestic aphasia. *Linguistics, 154/155,* 57–60.

Murdoch, B. E. (1988). *Acquired speech and language disorders*. London: Chapman and Hall.

Obrzut, J., Conrad, P., Bryden, M. P., & Boliek, C. (1988). Cued dichotic listening with right-handed, left-handed, bilingual and learning disabled children. *Neuropsychologia, 26,* 119–131.

Paradis, M. (1987). *The assessment of bilingual aphasia.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Paradis, M. (1990). Language lateralization in bilinguals: Enough already! *Brain and Language, 39,* 576–586.

Paradis, M. (1996). Selective deficit in one language is not a demonstration of different anatomical representation: Comments on Gomez-Tortosa et al. (1995). *Brain and Language, 54,* 170–173.

Perecman, E. (1984). Spontaneous translation and language mixing in a polyglot aphasic. *Brain and Language, 23,* 43–63.

Piazza-Gordon, D., & Zattore, R. J. (1981). A right ear advantage for dichotic listening in bilingual children. *Brain and Language, 13*, 389–396.

Reber, A. S. (1985). *Dictionary of psychology.* New York: Penguin Books.

Remez, R. E. (1989). When the objects of perception are spoken. *Ecological Psychology, 1,* 161–180.

Remez, R. E. (1994). A guide to the perception of speech. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 145–170). San Diego, CA: Academic Press.

Snodgrass, J. G., & Tsivkin, S. (1995). Organization of the bilingual lexicon: Categorical versus alphabetic cuing in Russian-English bilinguals. *Journal of Psycholinguistic Research, 24,* 145–162.

Spreen, O., & Strauss, E. (1991). *A compendium of neuropsychological tests*. New York: Oxford University Press.

Vaid, J. (1988). Asymmetries in tachstoscopic word recognition: Scanning effects reexamined. *International Journal of Neuroscience, 42,* 253–258.

Werker, J. F., Frost, P. E., & McGurk, H. (1992). Cross language influences on bimodal speech perception. *Canadian Journal of Psychology, 46,* 551–568.

Werker, J. F., & Pegg, J. E. (1992). Infant speech perception and phonological acquisition. In C. A. Ferguson, L. Menn, & C. Stoel-Cannon (Eds.), *Phonological development: Models, research, and implications* (pp. 285–311). Timonium, MD: York Press.

Zatorre, R. J. (1989). On the representation of multiple languages in the brain: Old problems and new directions. *Brain and Language, 38,* 127–147.