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Tracking skill of a deaf person with long-term tactile aid experience: A case study

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Abstract—This paper describes a case study of a single deaf individual who has been using a vibrotactile aid for approximately 13 years. He has acquired the ability to lipread speakers in three languages, using the speech-analyzing device that he and his collaborators have developed. The report describes his communicative abilities with and without the aid in his native language, which is Russian, and in English and Hebrew. When he was tested with the De Filippo-Scott connected-discourse tracking technique, the aid produced a considerable improvement in performance over that for unaided lipreading. The amount of improvement was a function of several factors, in particular his unaided lipreading rates for the different languages.

INTRODUCTION

The tactile senses are used extensively in the training of hearing-impaired persons. Often the student will feel the vibrations of a musical instrument or the pulsations of a balloon when the teacher "speaks" into it. There are also situations in which students place their hands on the teacher-speaker's face or feel the vibrations from their own faces or throats (2). These techniques are used for training in both speech perception and production; they are especially helpful for profoundly deaf persons. One reason for the importance of the sense of touch is that many significant features in speech are not transmitted visually. One system that relies almost exclusively on the sense of touch as the communication channel is called *Tadoma*. The technique, which has been employed by a small number of deaf-blind persons, consists of placing the hand on the face of the talker to sense the vibrations and articulatory movements of speech (see e.g., refs. 10, 12, 13).

The use of mechanical tactile aids to lipread has been confined mostly to brief experimental studies (see e.g., refs. 3, 6, 7, 14), with only a few notable exceptions. This situation has prevailed owing partially to the "bench-top" nature of most of the devices under test, as well as to the limits on the time available from typical laboratory subjects. There are now a few devices, however, that should permit long-term field tests in the natural environment. In this class of "wearable" aids, the Spens MINIVIB3, developed in Sweden, is one of the smallest. It transforms acoustical information into tactual sensations by amplitude-modulating a 220-Hz mechanical vibration so as to match the envelope of the speech signal (15, 17). Nearly 100 of the aids are in use in Sweden, and a smaller number are used elsewhere (16). Another commercially available mechanical aid that is used in the United States is the *Tactaid*, which is also a single-vibrator device, but one that involves a different mode of speech-feature detection. Approximately 200 of these devices are now in use (5).

The experience of any individual with either of the aforementioned aids, or with any of the research devices, has been extremely brief when compared with the number of years the average child spends learning to understand and produce speech. Even the most extended studies, such as those of Brooks and Frost (1) or

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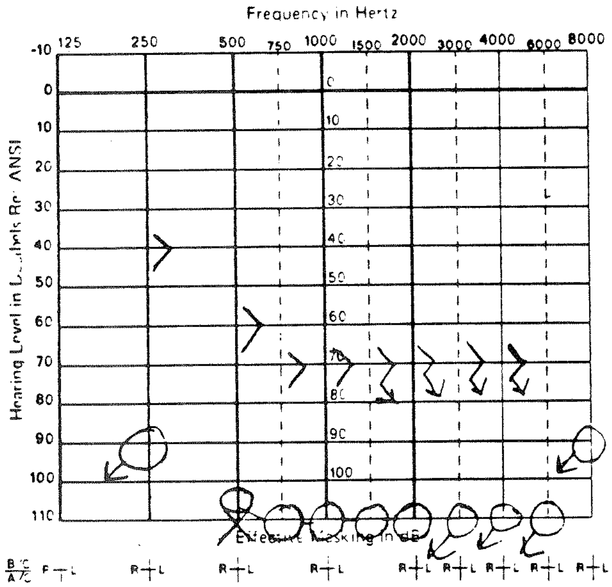
AUDIOLOGIC ANALYSIS

Name D. Kanievsky Type P Age 33 Tester Reath Date 2/19/85
Chief Complaint Audiometer Used GS1704



SUMMARY
Right Ear bilateral profound
Left Ear sensori-neural hearing loss

vibrotactile devices
SAT SF 45dB
PT responses 45 at 250, 60 at 500, 60 at 1500, 50 at 2KHz, 65 at 3KHz, 65 at 4KHz

RELIABILITY excellent

HEARING AID SUMMARY

Aid:	Ear:
Volume: N/A	Tolerance:
Aided SRT:	Aided SAT:
Discrimination:	
Discrim. in Noise:	S/N Ratio:
Discrim. with SR	Date Purchased:

EAR	P/T AV 500–2000	B/C AV 500–2000	SRT/SAT	SL / PB	SL / PB	SL / PB
RIGHT			100			
LEFT			100			

COMMENTS
no other responses AS except 110dB at 500Hz

no responses AU 10, 12, 14, 16 KHz at 100dB

SOUND FIELD

Discrim. List: CM: S/N Ratio: MLV ☐ Tape ☐				

TONE DECAY

FREQ (Hz)				
RIGHT				
LEFT				

EAR	R	L
UNMASKED A/C	○	X
MASKED A/C	△	☐
UNMASKED B/C	<	>
MASKED B/C	[	]
SOUND FIELD WARBLE	W	

AUDIOGRAM KEY

NR – No Response
DNT – Did Not Test
CNT – Could Not Test
SAT – Speech Awareness Threshold
SRT – Speech Reception Threshold
VRA – Visual Reinforcement Audiometry
CPA – Conditioned Play Audiometry
FA – Fletcher Average
EM – Effective Masking
MLV – Monitored Live Voice
PB – Speech Discrimination Test
SL – Sensation Level
CM – Competing Speech Message
SR – Speech Reading

FIGURE 1
Audiogram of Dimitry Kanievski taken on February 19, 1985. Analysis indicates bilateral profound deafness at all frequencies from 250 Hz to 8 KHz. Testing at higher frequencies indicated no response to 10 KHz, 12 KHz, 14 KHz, or 16 KHz at 100 dB. Speech awareness threshold was 100 dB. (Reproduced with permission of Temple University and Janet Reath.)

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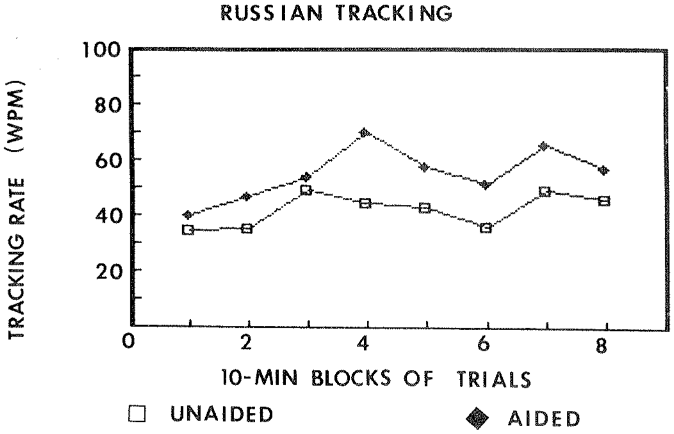

FIGURE 2
Tracking performance over a series of 10-minute trial blocks with and without the vibrotactile aid. Russian was the spoken language.

Engelmann and Rosov (4), have carried on testing for at most two years. As a result, the long-term efficacy of these devices is a matter for speculation; nevertheless, reason for optimism does exist.

Perceptual learning of complex auditory or visual patterns is a slow process (18), but the successful acquisition of tactile skills, such as reading with the *Optacon* (a device for converting inkprint to tactile patterns) or "hearing" with Tadoma, indicates that such difficult tasks can be learned. This paper describes some of the communicative achievements of an individual who has been using a mechanical tactile speech-analyzing aid successfully for over 13 years.

SUBJECT

The subject of the study was Dimitry Kanievski, who was born in Russia in 1952 of normal-hearing parents. There are no clinical details regarding the cause of his deafness, which was diagnosed at the age of 1 or 2 years, although he remembers the onset was preceded by symptoms suggestive of heat stroke. He is now profoundly deaf, as the audiogram of Figure 1 shows.

His only formal training in lipreading took place when he was about 2 years old in a special preschool program. After that brief training, he entered the regular school program and had no further specialized instruction. At the age of 18, while at Moscow University, he participated for about 1 hour a week as a researcher in a program for the rehabilitation of the hearing impaired at the Institute of Defectology. After receiving the doctorate in mathematics from Moscow University at the age of 27, he emigrated to Israel. During the 4 years that he and his wife were in Israel, he spoke Russian and practiced speaking English and some Hebrew. In 1983, the family spent 1 year in Germany before coming to the United States in September 1984. Dr. Kanievski says that his knowledge of German is minimal. He is currently associated with the Institute of Advanced Study in Princeton, New Jersey.

During his stay at the Institute of Defectology in Moscow, he developed a single-channel vibrotactile device, which consisted of a Darlington-transistor broadband amplifier system. Later, while still in Russia, Dr. Kanievski developed the prototype of the current device, which has two output transducers. One of these responds to a broad range of speech frequencies, while the other responds only to higher frequencies such as those produced by "*s*" or "*sh*". The system also includes a noise-suppression circuit. The cigarette-pack-sized processor is worn under the shirt or blouse, and the transducers which are similar to Oticon bone vibrators, are worn on the wrists. These sites were chosen *1)* to provide for optimal sensitivity and *2)* to be acceptable cosmetically. There are now over 1,000 of the Kanievski sound devices in use overseas.

PROCEDURE

Our intention was to evaluate the subject's abilities in the three languages with which he is most familiar and to evaluate the effectiveness of the aid. The test method chosen was the tracking procedure developed by De Filippo and Scott (3). In this procedure, the talker reads from a prepared text, and the task of the listener, who sits facing the talker, is to repeat verbatim the material read.

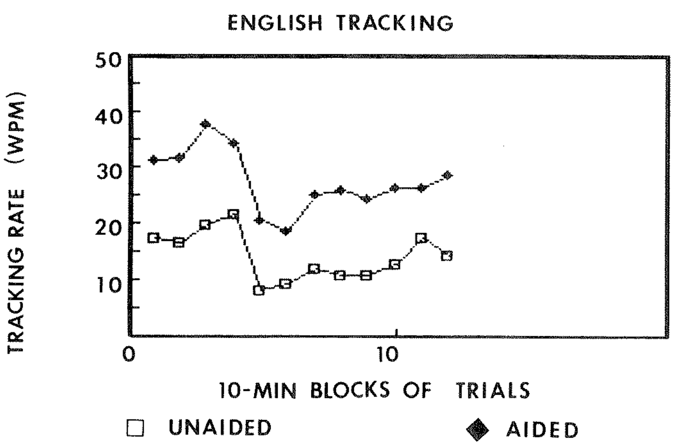

FIGURE 3
Tracking performance over a series of 10-minute trial blocks with and without the vibrotactile aid. English was the spoken language. Note discontinuity between blocks 4 and 5 produced by the change in reading material.

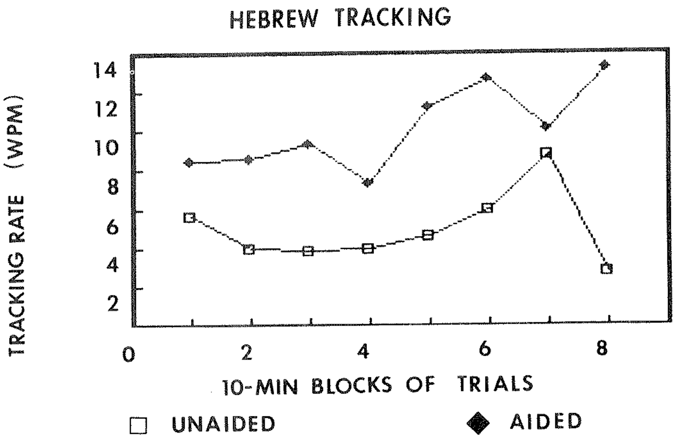

FIGURE 4
Tracking performance over a series of 10-minute trial blocks with and without the vibrotactile aid when Hebrew was the spoken language.

In our study, the typical length of a segment read before repetition was required was 4 to 6 words, so memory was not a factor in tracking. If an error was made, the talker was required either to repeat the text or prompt or cue the listener so as to elicit a correct repetition of the material. In the present study, if an error was not corrected after a maximum of 30 seconds, the talker wrote the word on a piece of paper, the listener repeated it, and the session continued. This adaptation of the original method was introduced to reduce the influence of extremely difficult passages (9, 11). Scoring is based on the average number of words per minute transmitted. With a large number of errors, the total time taken to communicate a segment will be longer, and the score will be reduced. For an extensive discussion of the method, see the study by De Filippo and Scott (3).

TALKERS AND MATERIALS

A novel feature of the present study was the tracking done in several different languages. We were particularly fortunate to enlist the aid of two individuals, one of whom was fluent in English and Russian, the other in English, Russian, and Hebrew. Neither was a professional communicator with deaf persons. The readers were informed of the instructional methods outlined in De Filippo and Scott (3) and were coached when necessary during the trial series. Because of the exceptional clarity of the subject's speech, repetition and instruction were only needed for true mistakes in tracking.

The text materials were judged by the subject to be appropriate to his level of familiarity with each language. A preliminary session in Russian used Tolstoy's *War and Peace*, which proved to be quite difficult. In the experimental sessions, however, a somewhat easier text was used which contained passages describing Russian cities and historical figures. Initial testing in English was conducted with a mathematics dissertation on cubic surfaces, which is Kanievski's area of specialization. The remaining trial blocks were tested using the section of the geography of Russia from an American secondary-school atlas. Finally, Hebrew was tested with selections from an Israeli newspaper which is written at several different levels of difficulty for emigrants and covers materials of current interest.

To provide baseline measurements, the same materials were also read to normal-hearing individuals familiar with the language, using exactly the same procedures and readers. These listeners, of course, did not have to rely on lipreading. Finally, the subject's spouse served as the talker in Russian and English in one session to demonstrate performance between individuals who are extremely familiar with one another.

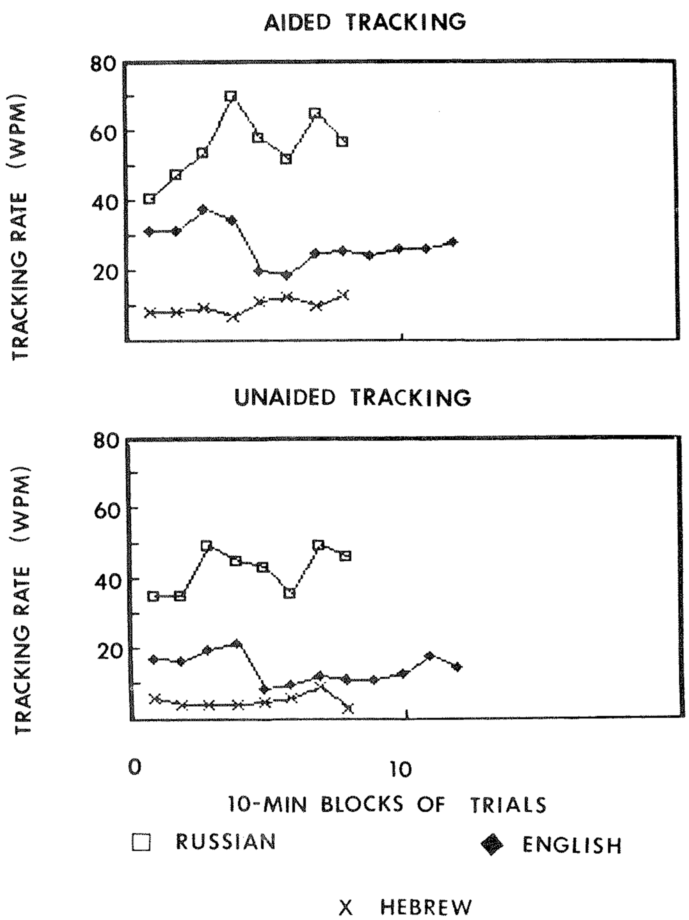

FIGURE 5
Data from Figs. 2, 3, and 4 replotted according to use of vibrotactile aid. *Upper graph* describes aided performance across languages, *lower graph* describes unaided performance functions.

CONDITIONS

The sessions were videotaped for later evaluation. In all cases, two conditions were studied: tracking with and without the Kanievski vibrotactile aid. The power for the aid, a 9-volt battery pack, was connected to a switch controlled by the experimenter. The same switch controlled an LED, not visible to the talker, that was in the camera field. The LED was only turned on when the device was on. A clock with a second hand was also visible in the videotape frame.

Four 10-minute blocks made up a single session, with 5-minute breaks in between. In two of the (randomly chosen) blocks the device was turned on; in the remaining two, it was off.

RESULTS

The results of the tracking series can be summarized by the learning curves in Figures 2, 3, and 4, for Russian, English, and Hebrew, respectively. Each figure shows the improvement in tracking performance over the series of 10-minute blocks under both the aided and unaided conditions. Note the change in the range of values for the ordinate over languages.

The highest overall tracking rate was recorded when Russian was the tested language. In one exceptional block with the aid on, the tracking rate exceeded 70 words per minute (wpm), although over the last four blocks the aided level averaged a somewhat lower 58.2 wpm. The unaided rate averaged 44.0 wpm. When a normal-hearing individual was tested in the same situation, the baseline tracking rate for these materials was 80 wpm. When the subject was tested with his wife, his average rate increased to an aided level of 78.6 wpm and an unaided level of 64.4 wpm. Over the last four trial blocks, a 32 percent improvement resulted from the use of the aid.

The results for English (Fig. 3) illustrate the influence of a change in materials, as well as the effect of practice, and of the presence of the tactile aid. The first four blocks show the data collected with the mathematics text material. The high performance level resulted from the fact that the word set was relatively limited and the subject was quite familiar with the topic. In these blocks, aided performance averaged 33.9 wpm, whereas the unaided level averaged 18.9 wpm. With the introduction of the less-familiar material from the atlas, rates in both conditions dropped more than 10 wpm but gradually increased over the remaining sessions. The average aided rate over the last four blocks was 25.5 wpm, whereas the

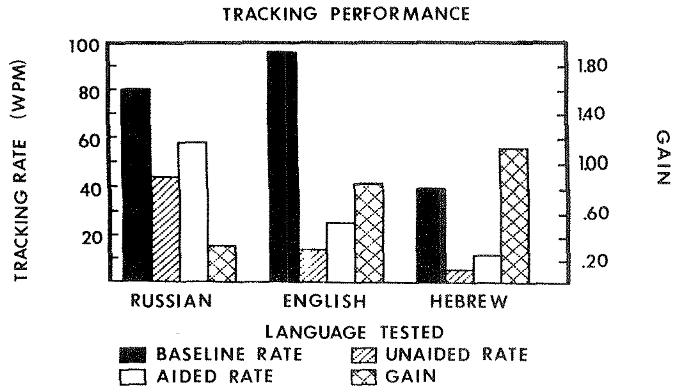

FIGURE 6
Histogram showing, in the first column for each language, the baseline rate obtained for materials and talker used in these studies, but with normal-hearing persons. Next two columns show average tracking rates over the last four blocks of aided and unaided testing for each language. Resulting gain is also indicated, referred to the right ordinate.

unaided rate was 14.0 wpm (an 82 percent gain, where gain is defined as the percent difference between the aided and unaided performance). English rates recorded with the same talker and a normal-hearing listener were 92.6 and 95.4 wpm for the mathematics text and the world atlas, respectively. When the subject's wife was the talker, his English tracking rates for the aided and unaided conditions rose to 26.3 and 18.3 wpm.

The rates for Hebrew (Fig. 4) were the lowest overall, yet they still showed the gradual improvement typical of performance with the other languages. The data also illustrate that use of the aid leads to improved tracking performance. Over the last four blocks, aided performance averaged 11.9 wpm, whereas unaided tracking averaged 5.6 wpm for an average gain of 112 percent. The unaided levels (and the gain) are affected by the aberrant performance during the last trial block, but even over blocks 4–7 aided led unaided performance 10.4 to 5.9 wpm, with an average gain of 76 percent. It is suspected that fatigue and the onset of mild illness probably interacted with the difficulty of the unaided condition to produce the unusually poor performance in that last block. Tracking rates for a normal-hearing individual who had about the same level of training as the subject and who used these materials and this talker averaged 39.5 wpm.

Figure 5 shows these data replotted to illustrate the comparison across languages. The upper panel contains the data for the aided condition, the lower panel shows the unaided performance. This comparison should be made with caution due to the number of differences in conditions across languages: The materials were different for each language, two different talkers were used, and the subject's familiarity with the languages varied.

Finally, Figure 6 summarizes the data from the last four blocks of trials in each session and compares the performance against the baseline rates established with normal-hearing tracking performance. The gain over the last four blocks of trials is also shown for comparison. As with Figure 5, comparisons across languages should be made with caution. Note, however, that the gain increases with decreasing tracking performance.

DISCUSSION

In every comparison, these results show an improvement in lipreading performance when the subject was using the vibrotactile aid. These findings are not unexpected. Single- and dual-channel aids of even the simplest type have been shown to produce some improvement in lipreading skills, but these gains have generally been modest (12). In the present case, the degree of gain was primarily dependent on the unaided performance level. An attempt was made to present materials in the three languages of roughly equal familiarity to the subject, but we make a point of noting that his skills over the three languages varied considerably. The data reflect this fact and are ordered, as the subject suggested they might, at the onset of the series of studies. Data for the three languages and both familiar and unfamiliar readers are shown in Figure 7, where the ratio of aided to unaided performance is plotted as a function of unaided rate; see the study by Levitt et al. (9) for a discussion of this method for describing such data. Note that this measure, though different from "gain" as described above, is related to it and accurately represents the advantage realized from use of an aid.

The function appears to approach an asymptote at 1.10 at high unaided lipreading rates, although it is assumed that the function will eventually drop to 1.00 as normal-hearing tracking rates are approached (approximately 90-100 wpm for English). The points appear to fit a power function that is more clearly seen by replotting the data on log-log coordinates. By fitting the points with the method of least squares, it was possible to determine the equation best describing the data. Figure 8 illustrates the resulting function.

These data are similar to those described by Levitt (8) when he examined the degree of improvement in lipreading over a group of subjects using a variety of aids. Although the data from only one individual are shown here, because he lipreads at different rates for different languages and for different readers, a similar function

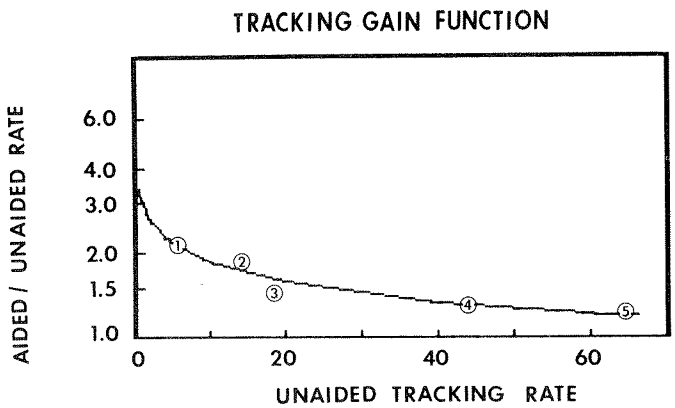

FIGURE 7
Tracking gain function describing log ratio of aided to unaided performance as a function of unaided rate. Power function best fitting raw data is drawn through the averages over the last four blocks of trials for Hebrew (1), English (2) and Russian (4). Remaining points were obtained when subject's spouse was the talker in English (3) and Russian (5).

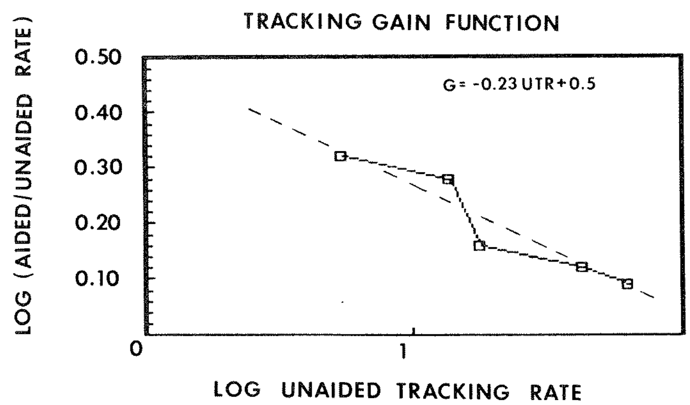

FIGURE 8
Tracking gain function from Fig. 7 redrawn on logarithmic coordinates. Power function fitted to data by method of least squares is described in *inset*.

can be described. In this case, one must assume that the points generated by the subject with different combinations of talker and language are independent measurements. In Levitt's case (9), the points were generated by different subjects, each of whom had a different unaided tracking rate.

It should be noted that the absolute increases in tracking rate with the aid, over talkers and languages, were quite similar. During the final sessions in Russian the difference in favor of aided performance was 14.2 wpm for both readers; in English the improvement was 11.5 wpm for the new talker and 8.0 wpm for the familiar talker. Finally, in Hebrew, the difference was, at most, 6.3 wpm with the new talker. Although the unaided rates covered almost a 16.5:1 range, from best Russian block (64.4 wpm) to poorest reliable Hebrew block (3.9), the ratio varied over only a 2.3:1 range.

There are many factors that could account for differences in rate, and the resulting differences in gain. De Filippo and Scott (3) describe several of these, including the type of material, skill of the talker, and, we can add, the talker and listener's level of familiarity with the language and with one another. The effect of text familiarity is shown in Figure 3 (between blocks 4 and 5) where a change was made from the English mathematical text to the atlas (an initial 57 percent drop in unaided rate and a 46 percent drop in aided rate). We attribute the improvement in performance with all of the languages over this relatively short practice period to the listener's simply becoming familiar with the talker. (The subject indicated that he routinely needs several days of contact with a new acquaintance before he can converse at normal rates.) In this series, a large difference in the listener's familiarity with the talker (wife vs. new speaker) was reflected in an improvement of over 30 percent when Russian was the tested language. Indeed, the aided rate in Russian for the subject when his wife was the speaker was equivalent to the normal-hearing listener's score. It is interesting to note that under the same conditions, the improvement in English was almost nil. Perhaps this is because the family language is still mostly Russian.

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