Research using electrophysiological responses in bilingual infants and toddlers will help to build up a greater understanding of how speech perception develops with age.

Getting to grips with phonological skills

Language comprehension in a first language feels automatic and effortless to those with typical language abilities. When we attempt to learn and use a second language (L2), however, we recognise how difficult understanding can be – even for those who have learned many words and the grammatical rules of the foreign language – especially identifying words in the nearly continuous speech stream. In our first language, we have developed a highly automatic set of routines – called selective perceptual routines (SPR) – customised for finding word boundaries and identifying lexical forms automatically and effortlessly.

A second language is unlikely to share the same set of speech sounds (phonemes) or patterning of these speech sounds (phonotactics) as the first language (L1). The L2 learner must develop a new set of SPRs or alternative strategies for comprehension. According to the large body of research on L2 learning, earlier L2 learning generally leads to more native-like language skills. However, some research demonstrates that even bilinguals who have learned both languages simultaneously from birth have different phonological processing skills than monolinguals.

We examined the development of speech perception skills in relation to the nature of language input, specifically monolingual versus bilingual input, and the implications of poorer and/or more effortful speech perception for language learning and processing. Our research indicates differences in how monolinguals and bilinguals process speech – even when the L2 is learned before the child enters preschool – and suggests implications for learning an L2 early in life.

SPEECH PERCEPTION

Second-language learners often have accented language and the accent is generally greater the later the language is learned, even for highly proficient L2 learners. This accented speech may be due in part to poor perception of L2 sounds; similarly, poor comprehension of an L2 may also be due to poor L2 speech perception rather than to lack of lexical and grammatical knowledge. Why is it so difficult to perceive (and produce) L2 speech patterns efficiently?

It is often possible to identify the accent of an L2 learner as "Japanese" or "German," suggesting that the L1 is interfering with L2 speech production. However, it also suggests that a listener is highly sensitive to acoustic-phonetic deviations from the expected production of native phonemes.

> **Some research shows that bilinguals have different phonological processing skills**

This sensitivity indicates that listeners have the ability to perceive small phonetic variations. Despite this apparent phonetic sensitivity, considerable evidence indicates that the L1 phonology interferes with L2 speech perception. Examining the nature of L1 speech perception helps explain this interference.

Our goal is to characterise more accurately the relationship between early speech perception development and later language abilities using neurobiological measures. Examining the effects of bilingual versus monolingual input on speech perception allows us to observe the extent to which varying amounts and qualities of input influence the development of speech perception and language development. A second goal is to identify measures that can be used to distinguish between a true language impairment and lack of experience with L2 in bilingual children.

Event-related-potential (ERP) neurophysiological responses provide a sensitive measure of neural processing without a behavioural response. We examined discrimination of the English vowel contrast 'ɛ' (as in 'pet') versus 'I' (as in 'pit'), as indexed by ERP mismatch responses (MMRs). We also examined whether the MMR measures are correlated with the amount of English input in children developing English language skills or with standardised language measures.

Study participants listened to the vowels presented, with one vowel repeated frequently (80% of trials) and occasionally changed to the other vowel (20% of trials). The adult MMR (called the MMN in adults and older children) is sensitive to phonemic status. For example, in one study we found that late learners of English (after 18 years of age) with Spanish as their first language had significantly smaller MMNs to the [ɛ/I] vowel contrast than monolingual English listeners. Some early Spanish-English bilinguals who started learning English before age five also showed smaller or later MMNs than the English monolinguals. In another study we found that adult early bilinguals showed similar MMNs to monolingual. The only differences between monolinguals and the early bilinguals in this study were related to subtle attentional factors.

METHODOLOGY

Measuring electrophysiological responses rather than using behavioural methods can provide information about processes that are automatic or unconscious. They also can give us information on what is happening before the point that a participant makes a decision and do not require the participant to provide an overt response. For example, the mismatch responses reported in this article can be obtained when a participant is ignoring the speech sounds and doing a different task (reading a book, watching a movie and, in some cases, sleeping).

Many of the infants will return to be tested at three years

Our studies with infants and children show two different types of MMRs: a positive MMR (p-MMR) found from birth up to about 5 ½ years and a negative MMR (n-MMR) that is probably comparable to the adult MMN. Our studies show that the n-MMR becomes more prominent and earlier in latency with increasing age from three months to seven years in monolingual children. The p-MMR diminishes with age and appears to be displaced by the n-MMR. Our results reveal that for four- to seven-year-olds, many bilingual children exhibit later latency of the n-MMR than their age-matched monolingual peers, and for those with the poorest English language scores the n-MMR is absent.

Because the method does not require an overt response, we can use it to examine processing in infant and toddler populations and in clinical populations. There are also many cases where it is interesting to know what was going on in the participant's mind before the response. For example, electrophysiological responses on trials where a participant made an error can be used to see whether the participant was aware of the error or not. Electrophysiology can also give us some information about sources of the responses, although localisation with this method is limited because the actual number of sources and placement of sources cannot be uniquely determined from scalp-recorded electrical activity.

There are a number of brain-imaging methods available, so why use electrophysiology (EEG) as our preferred option? Each of these methods has benefits and limitations. Magnetoecephalography (MEG) serves as a nice complement to EEG because it picks up neural activity in the cortical sulci better, whereas EEG picks up the cortical surface activity better. MEG signals are not distorted by passing through the different layers (skull, skin, etc.). However, they suffer from the same problem as EEG in that the source locations cannot be uniquely determined from the scalp distribution of MEG signals. functional Magnetic Resonance Imaging (fMRI) and Positron Emission Tomography (PET) provide better localisation, but poorer temporal resolution. These methods are also more difficult to use with awake infants and toddlers and PET is invasive. EEG is also considerably cheaper than MEG, fMRI or PET to set-up and to maintain a laboratory. There are currently several newer methods available (for example, near-infrared spectroscopy (NIRS)). These will likely provide interesting information, but will have a different set of advantages and disadvantages to other methods.

CLINICAL APPLICATION

So far our findings suggest that ERPs can be used to gauge a child's speech perception abilities. Better English vocabulary and more English exposure appear to be related to larger and earlier n-MMRs for four- to seven-year-old children. The robustness of this n-MMR may actually be a function of how much the child is paying attention to the speech. When the child is less aware that there is a change in the vowel, we observe a p-MMR that may partially mask the n-MMR. With increased awareness of the change, the p-MMR is diminished. Our results from the six-month-olds suggest that female compared to male infants are more aware of the vowel change, regardless of amount of English exposure. In the coming year many of these infants will return to be tested as three-year-olds.

It will be particularly interesting to see whether the ERP responses collected at six months will predict language abilities at this older age. Our expectations are that children with particularly poor discriminative ERP responses at six months will have the poorest languages scores in English at three-years of age. ■

AT A GLANCE

- Speech perception routines (SPRs) in a native language are highly automatic and effortless. In contrast, SPRs in a second language may never become completely automatic, particularly if the second language is learned later in life.
- Early second language learning can result in highly proficient abilities in the two languages. However, adequate input from both languages is necessary to achieve and maintain high proficiency.
- Even highly proficient L2 users can show differences from monolinguals.
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LANGUAGE LEARNING

Research into the neurodevelopment basis of speech perception in monolingual and bilingual infants and children will help to identify those youngsters who need additional help in coping with second language learning.

HOW RELEVANT IS YOUR RESEARCH FOR IDENTIFYING LANGUAGE DELAYS OR IMPAIRMENTS IN BILINGUAL CHILDREN?

Children learning English as a second language often show errors in English that are similar to monolingual children with specific language impairment (SLI). SLI is a developmental language disorder in which language skills are in the bottom 10th percentile on standardised tests despite the child showing normal non-verbal IQ. The challenge with these bilingual children is to determine which ones have a true language impairment and which will catch up after sufficient experience with English.

Electrophysiological measures show promise in helping discriminate between these two possibilities. In previous research, we have shown that many children with SLI show absent or late negative mismatch responses. The current study suggests that bilinguals with poor English language skills also show absent negative mismatch responses. So this does not appear to be the measure that will help identify SLI. However, along with my colleagues Richard Schwartz and Brett Martin, we have also looked at brain responses at electrodes over the temporal sites in four of our studies examining children with SLI. We found that 75% of children with SLI show poor responses compared to only 25% of the children with typical language skills. We believe that by looking at more than one brain measure, we will be able to identify whether a bilingual child should be classified as SLI and receive intervention services.

We feel that there is considerable interest in funding this type of research. The sensitivity and specificity of many standardised behavioural tests for identifying SLI are poor, and performing a complete battery of standardised language testing in both the first and second language of a child is lengthy.

Our electrophysiology paradigm can be completed in less than 45 minutes and works with all ages. The results provide information about stimulus discrimination (mismatch responses) and stimulus encoding.

CAN TRAINING LEAD TO IMPROVED SPEECH PERCEPTION IN A SECOND LANGUAGE?

A number of studies now show that training can improve speech perception in an L2 (second language), but only to a limited extent in late learners of an L2. Little direct research has examined L2 speech perception training in children, beyond the general findings that earlier learning of an L2 results in apparently better speech perception and speech production skills. Even so, some studies suggest that early L2 learning does not necessarily lead to native-like L2 speech perception. This appears to be a function of how much the L1 continues to be used. Researchers continue to attempt to develop better training protocols.

WHAT FACTORS INFLUENCE SKILL LEVEL IN THE TWO LANGUAGES OF A BILINGUAL PERSON?

The two main factors are Age of Acquisition (AofA) and Amount of Use (AoU). Research has fairly conclusively demonstrated that an earlier start to learning a second language is more likely to result in better speech and language skills in the L2. This is also true of other language areas, such as syntax. Nonetheless, there is still a great deal of variability in second language ability. Some of this variance appears to be due to individual talent for L2 learning, but sociolinguistic factors, such as motivation, also appear to be important.

CAN BILINGUALS EVER ATTAIN EQUIVALENT LANGUAGE ABILITIES TO A MONOLINGUAL SPEAKER, FOR EITHER LANGUAGE?

It is unlikely that the L1 and L2 of a bilingual will be equivalent, across the board, with a monolingual's L1 abilities. The more common scenario is that a highly proficient bilingual shows gaps in L1 or L2 lexical knowledge based on the situations in which each language is used. For example, if a speaker learned to sail using L2 vocabulary, then he may never learn the corresponding L1 vocabulary, and even if he does, he may feel more comfortable using L2 sailing terms. In terms of speech perception, studies carried out at the University of Barcelona have shown that highly proficient Spanish-Catalan bilinguals who learned Catalan between three and five years of age have poorer perception of the Catalan vowel contrast 'e' and 'ɛ' ('bait' versus 'bet' for the English equivalent) than bilinguals with Catalan as the first language. It seems that the L2 Catalan learners are using Spanish vowel categories for Catalan words, but this does not interfere with developing excellent Catalan language skills.

IS THERE A COGNITIVE BENEFIT TO RAISING A CHILD BILINGUALLY RATHER THAN MONOLINGUALLY?

There are studies suggesting better executive processing in bilinguals. For example, bilinguals perform better on tasks than monolinguals in which they need to inhibit conflicting information. However, research by Bialystok has shown that intensive musical experience can provide the same advantage. To me, this suggests that the choice to raise a child bilingually should not be made for the purposes of improving cognitive skills. This choice should be related to socio-cultural factors, including whether the second language is a heritage language (a parent or grandparent speaks the L2), or a language of the community (for example, Spanish in New York City). I believe that it is important to introduce a second language to a child fairly early in school (before age 10) to allow reaching a reasonable level of proficiency, but it is very difficult for monolingual parents to facilitate bilingualism in their children, since the L2 will not be spoken in the home environment. I do not believe that parents should feel that their child is losing out because they are not being raised bilingually. ■

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