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13 Cognitive Effects of Bilingualism in Infancy

Exposure to multiple languages is a very common phenomenon even during early childhood. Although learning just one language is a major accomplishment in itself, the challenge for infants born in multilingual environments must be still greater. In contemporary societies many children grow up in bilingual families and have to learn to cope with different languages. However, a single language milieu is still the standard model for investigating language acquisition even though a great proportion of children are raised with more than one language.

As bilingual children presumably have to learn twice as much as their monolingual peers, their language learning could be expected to be somewhat delayed. Yet, infants who acquire two languages simultaneously pass language production milestones at the same age as monolingual infants (see Chapter 4, this volume), and display only minor differences in language processing (see Chapter 3). Thus, the big puzzle becomes uncovering what mechanisms infants exposed to two languages from birth (*crib bilinguals*) use to efficiently deal with a linguistic signal coming from different languages.

Milestones in Bilingual Language Acquisition

While examining bilingual language acquisition one is faced with a *bilingual language acquisition paradox* (Petitto et al., 2001). This refers, on the one hand, to the amazement of parents and scientists observing how effortlessly children acquire two or more languages. On the other hand, it captures the worry that exposing children to two languages might result in language delays and confusion.

Two main theories have been formulated regarding how young children may deal with bilingual input (see Chapter 2, this volume, for an extensive account of this issue). According to the unitary language system account, in the early phases of language learning, children form a single language system for both languages (Leopold, 1978; Volterra & Taeschner, 1978). This account relies on findings showing that bilingual speakers have few translation equivalents across their two languages in the one-word stage (Volterra & Taeschner, 1978), and they frequently mix languages in their word combinations (Vihman, Macken, Miller, Simmons, & Miller, 1985).

Of course, bilingual language acquisition is different from monolingual language acquisition in specific ways; for instance, bilingual speakers tend to have smaller

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vocabularies than monolingual speakers if only one language is considered (Chapter 4, this volume). However, surprisingly, bilingual speakers seem to reach the basic milestones in acquiring both of their languages (first-word stage, first 50 words, and two-word combinations) at the same age as monolingual speakers (see Table 13.1). This is the case even for children who learn two languages that belong to different modalities (e.g., Sign Language and French; Petitto et al., 2001).

In addition, in contrast to the findings that bilingual children produce few translation equivalents (Volterra & Taeschner, 1978), more recent research has found that bilingual speakers' early vocabularies consist on average of 30% of such "doublets" already in the one-word stage (Pearson, Fernández, & Oller, 1995). Furthermore, bilingual children who receive approximately equal input in both languages mix them following their parents' language mixing patterns (Genesee, Nicoladis, & Paradis, 1995). Such results support a differentiated language system hypothesis according to which young bilingual speakers construct two distinct representational systems for the two languages early on.

In sum, crib bilingualism does not appear to significantly alter the course of language development. However, the mechanisms that allow language differentiation are still unclear and it is possible that specific changes in cognitive processes occur as a result of being exposed to and having to learn multiple languages. Mechanisms outside the domain of language such as attention, inhibition and selection might be used to a greater extent when dealing simultaneously with two languages. Before discussing the possible cognitive changes I will first address processes closely related to language learning that may provide the foundation for a fast and efficient acquisition of the language(s) infants hear in their environment.

Tab. 13.1: Linguistic Milestones in Monolingual and Bilingual Children

Study	Participants	First-word stage	First 50 words	First two-word combination
Vihman & McCune, 1994	English monolingual speakers	1 year (range: 9–14 months)	—	—
Petitto, 1987	English monolingual speakers	—	1.6 years (range: 1.5–2.2 years)	1.7 years
Pearson, Fernández, & Oller, 1993	English monolingual speakers	1 year	1.6 years	1.7 years
	Spanish–English bilingual speakers	1.1 year	1.7 years	1.8 years
Petitto et al., 2001	French–English bilingual speakers	1.1 years	1.6 years	1.7 years
	Sign Language–French bilingual speakers	10 months	1.6 years	1.5 years

Cognitive Processes in the Service of Language Learning: Infant Language Discrimination

Monolingual and bilingual infants have to process speech signals to acquire language. However, only bilingual infants are exposed to utterances from two languages. If they were unable to sort utterances into the different source languages, bilingual children would present considerable learning difficulties and display delays. However, such delays and confusions are rare or inexistent (Genesee et al., 1995; Petitto et al., 2001). Likely, infants are equipped with abilities to monitor and segregate the linguistic input into distinct categories from very early on.

Specific processes, such as an automatic rhythmic clustering of the languages, may allow language differentiation even when both are unknown to the listener (Ramus & Mehler, 1999; see also Chapter 3, this volume, for a review of this issue). Already a few days after birth, infants possess impressive language discrimination abilities, distinguishing different languages on the basis of their prosodic properties (Nazzi, Bertoncini, & Mehler, 1998; Ramus, Hauser, Miller, Morris, & Mehler, 2000). However, two languages that share prosodic similarities (e.g., English and Dutch) are difficult to discriminate by young learners. French newborns and two-month-old English learning infants fail indeed to show such differentiation (Christophe & Morton, 1998; Nazzi et al., 1998; see Table 13.2). By their fourth month, however, monolingual and bilingual infants can tell apart two languages that have similar rhythmic characteristics (e.g., Catalan and Spanish; Bosch & Sebastián-Gallés, 1997,

Tab. 13.2: Early Discrimination Abilities in Monolingual and Bilingual Infants

Study	Participants	Language pairs	Discrimination
Nazzi, Bertoncini, & Mehler, 1998	French newborns	Low-pass filtered	
		Japanese–English	√
		Dutch–English	X
		English + Dutch vs. Spanish + Italian	√
Ramus et al., 2000	French newborns	Natural Dutch–Japanese resynthesized	√
		Dutch–Japanese	√
		Japanese–English	√
Christophe & Morton, 1998	2-month-old English monolingual infants	Dutch–English	X
		French–Japanese	X
		Dutch–Japanese	√(X)
Bosch & Sebastián-Gallés, 2001	4-month-old Spanish monolingual infants	Catalan–Spanish	√
	4-month-old Catalan–Spanish bilingual infants	Catalan–Spanish	√

2001), suggesting that, after a certain amount of exposure to their native languages, infants are able to use other cues for discrimination besides the rhythmic properties of their language(s).

Languages also differ in properties other than prosodic (e.g., phonetic repertoire, phonotactic constraints) and young bilingual speakers can make use of these properties to make fine-grained discriminations between rhythmically similar languages (Sebastián-Gallés & Bosch, 2002). These powerful and early abilities, besides other nonlanguage specific processes, may allow crib bilinguals to differentiate their languages prelexically, to avoid delays and confusion, and to reach linguistic milestones at the same age as monolingual peers.

Processing a Bimodal Linguistic Input Enhances Executive Functions in Infancy

How does the infant's developing cognitive system manage to deal with utterances belonging to two different languages? What is the impact of receiving such a complex linguistic input on the development of diverse cognitive abilities? Processing two languages simultaneously may result in specific changes in the cognitive system as well as in structural reorganization at the neuronal level (García-Pentón, Pérez Fernández, Iturria-Medina, Gillon-Dowens, & Carreiras, 2014; Mechelli et al., 2004). Neuroimaging data suggest that bilingual adults indeed have greater gray matter density than monolingual adults in certain brain areas, such as the left inferior parietal cortex (Mechelli et al., 2004). Such reorganization is more pronounced in early bilingual speakers. Behavioral studies further suggest that mastering two languages from an early age influences certain domains of cognitive functioning; bilingual adults and preschool-age children indeed display enhanced cognitive control abilities (executive functions) because of practice in suppressing one language while speaking the other (Bialystok, 1999; Costa, Hernández, & Sebastián-Gallés, 2008). However, how early such a bilingual advantage may start has been investigated little.

Fast learning of new regularities by neglecting or overwriting the old ones is crucial for adjusting behavior to the changing requirements of the environment and for performing daily activities in different domains (Burgess, Veitch, de Lacy Costello, & Shallice, 2000). Such abilities are usually termed *executive function*s (EF), which is an umbrella term for inhibition, monitoring, and attention switching. Because of the continuous monitoring of dual language input, bilingualism could boost executive control before children start producing words. First, to learn two different languages, bilingual speakers have to sort the speech utterances according to the source language. Then, to learn the distinct patterns and regularities that belong to each language and to build different language representations, young learners might recruit complex control and monitoring processes to keep the two representational sets sepa-

rate and avoid conflict and interference between the two language systems. Furthermore, bilingual language learning might also involve a continuous switch of attention between the two language systems. An early and extensive use of EF in young bilingual speakers might thus lead to an accelerated development of the involved abilities. Before describing studies that aimed to test this possibility, I will first discuss data from children and adults that point to advantages of bilingual speakers in EF.

Sharpening Executive Functions Through Language Switching

The daily language switching in bilingual language production could result in specific changes in the cognitive system. Bialystok (1999) found that the experience gained during bilingual language selection and inhibition leads to advantages in performing tasks that require inhibitory functions in preschool-age children. Studies with adults have documented similar advantages for bilingual speakers (Bialystok, Craik, et al., 2005). These studies were motivated by the conjecture that bilingual speakers may involve the same mechanisms for language switching that they recruit for solving different executive function tasks, such as the Stroop task, the Simon task, or the attentional network task.

To communicate efficiently, bilingual speakers have to control which of their languages they currently use and possibly inhibit the lexical items of one language when switching to the other (Green, 1998). The practice bilingual speakers have in managing the two languages seems to lead to more efficient executive control in general. Bilingual adults outperform monolingual adults on diverse EF tasks; for instance, they show reduced interference effect in a Simon task (Bialystok, Craik, et al., 2005) where there is a spatial stimulus-response incompatibility (e.g., responding to a colored stimulus appearing on the *right side* of the screen with the *left hand*, compared to when it appears on the left side). Likewise, bilingual speakers show better attentional control and reduced task switching costs in the Attentional Network Task (Costa et al., 2008). In this task, participants are exposed to five arrows and asked to indicate whether the central arrow points to the right or left. Responses tend to be slower when the central arrow is presented along with distractor arrows pointing to the opposite direction (incongruent trials) rather than the same direction (congruent trials).

The bilingual advantage in executive control tasks seems to persist from toddlerhood and preschool age (Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011; see also Chapter 14, this volume), through young adulthood to elderly ages (Bialystok, Martin, & Viswanathan, 2005; Chapter 16, this volume), although such advantages are not observed in some cases (Duñabeitia et al., 2014). Yet, little is known about whether a comparable enhancement could result from the mere exposure to different languages before language production begins. Processing utterances belonging to two different languages may already be sufficient for the enhancement of such abilities. Hence, an

EF advantage might exist even in bilingually exposed infants who are not yet able to produce words.

Monitoring Two Languages Boosts Executive Control in Infancy

The ability to select between competing stimuli and behavioral responses and override them seems to have a slow development. These abilities reach adult levels only toward puberty (Casey et al., 1997), with important improvements around the end of the first year (Diamond, 1985) and around age 4 (Gerstadt, Hong, & Diamond, 1994). Behavioral studies suggests that inhibitory abilities are still little developed in 7-month-olds, as they perform poorly on the A not B tasks that require the inhibition of a previously rewarded response (e.g., searching for a toy in location B after a delay period and after having previously found it in location A for several times, Diamond, 1985).

There can be special circumstances that boost inhibitory and control abilities in young infants, possibly through accelerating developmental changes in specific brain areas. Such evidence comes from a study by Matthews, Ellis, and Nelson (1996), who compared preterm and full-term infants of the same conception age on a non-reaching type of A not B task. In the A not B tasks infants are exposed to situations in which first an object is repeatedly hidden in location A, and then it is hidden in location B in the full view of the child. Typical errors (searching in location A as a prepotent response) are observed when the delay between the hiding and the search is lengthened (Diamond, 1985). Preterm infants, who had more experience with the events of the surrounding world, tolerated greater delays compared with full-term infants (Matthews et al., 1996). This suggests that they had better-developed inhibition. The results of this study are in favor of the proposal that development of the brain structures that mediate performance in the A not B task may be strongly influenced by postnatal experience. A further enhancing factor may be the rich environment of an infant exposed to two languages from birth. Possibly, the continuous monitoring of a bimodal linguistic input results in an early boost of attentional control and inhibition already in infancy.

In a series of studies we asked whether such enhancements might arise in crib bilinguals prior to language production (Kovács & Mehler, 2009a, 2009b). We tested this possibility by measuring the performance of monolingual and bilingual infants with an eye tracker on tasks that require executive control (Kovács & Mehler, 2009a). If monitoring bilingual input boosts executive control early on, bilingual infants should outperform monolingual infants on such tasks. Additionally, we coupled this investigation with the question of how general such an advantage may be. Crib bilingualism may initially lead to improved control processes only in the language domain because bilingual infants have experience in dealing with conflicting input in language. Alternatively, crib bilingualism may result in a domain general advantage in executive control abilities.

We tested monolingual and bilingual 7-month-old infants on a response-switching task where a previously valid and repeated response (an eye movement to location A

after a cue) had to be inhibited to perform a new response (an eye movement to location B). We hypothesized that both groups would learn the first response equally well (an eye movement to location A) because no control abilities were involved in this phase. However, if bilingual infants had better executive control functions, they would outperform monolingual infants when learning the second response (an eye movement to location B) for which they had to inhibit the earlier learned response (an eye movement to location A).

The participants were infants with parents who addressed them in their respective native languages and with daily exposure to two languages (minimum 35% to each language). The majority of bilingual infants heard Italian and Slovenian from their parents, whereas the rest heard Italian and either Spanish, English, Arabic, Danish, French, or Russian. All monolingual infants heard only Italian in their families. Infants came from upper-middle-class families and were matched for their parents' socioeconomic status and family size (number of siblings). Participants were recruited from Trieste (Italy), where bilingualism has historic roots and has been present for generations.

The study consisted of a preswitch and a postswitch phase (see Figure 13.1A). In the preswitch phase, infants were presented with nine trials where a trisyllabic nonce word was followed by a visual reward always appearing on the same side of the screen one second after the cue. The word-cue was composed from three different syllables in Experiment 1 and from syllables with an AAB or ABB structure in Experiment 2 (e.g., *le-le-mo* or *le-mo-mo*, where As and Bs stand for a syllable; Kovács & Mehler, 2009a). Thus, infants had to learn that the words predicted the appearance of the rewards in a certain location. In the postswitch phase, infants were exposed to an additional nine trials with the words now indicating that the rewards would appear on the other side of the screen. To see the reward object, infants thus had to learn to look to the opposite side of the screen. We measured learning by recording the infants' anticipatory looks for the visual reward with an eye tracker. In Experiment 3 we used visual cue sequences instead of linguistic stimuli.

Data from Experiment 1 and 2 suggest that bilingual infants are more efficient than monolingual infants in inhibiting a previously learned regularity that involves a contingency between a structured or a random linguistic stimulus and the location of a visual stimulus (e.g., look right after a word; see Figure 1B after Kovács & Mehler, 2009a). Thus, they succeed in quickly learning a second regularity that involves a new pairing. Although both groups of infants learned to correctly anticipate the reward in the preswitch phase, only bilingual infants showed learning in the postswitch phase.

Next, we asked how general this advantage in executive control might be and whether it would apply to stimuli from domains other than language by using visual stimuli. If a boost of executive functions extends beyond the language domain from a very early age, bilingual infants should also perform better than monolingual infants on a switching task that involves solely visual stimuli. In contrast, if the advantage is restricted to situations where language is involved, the two groups should perform similarly on the nonlinguistic task. Experiment 3 was structurally similar to the one

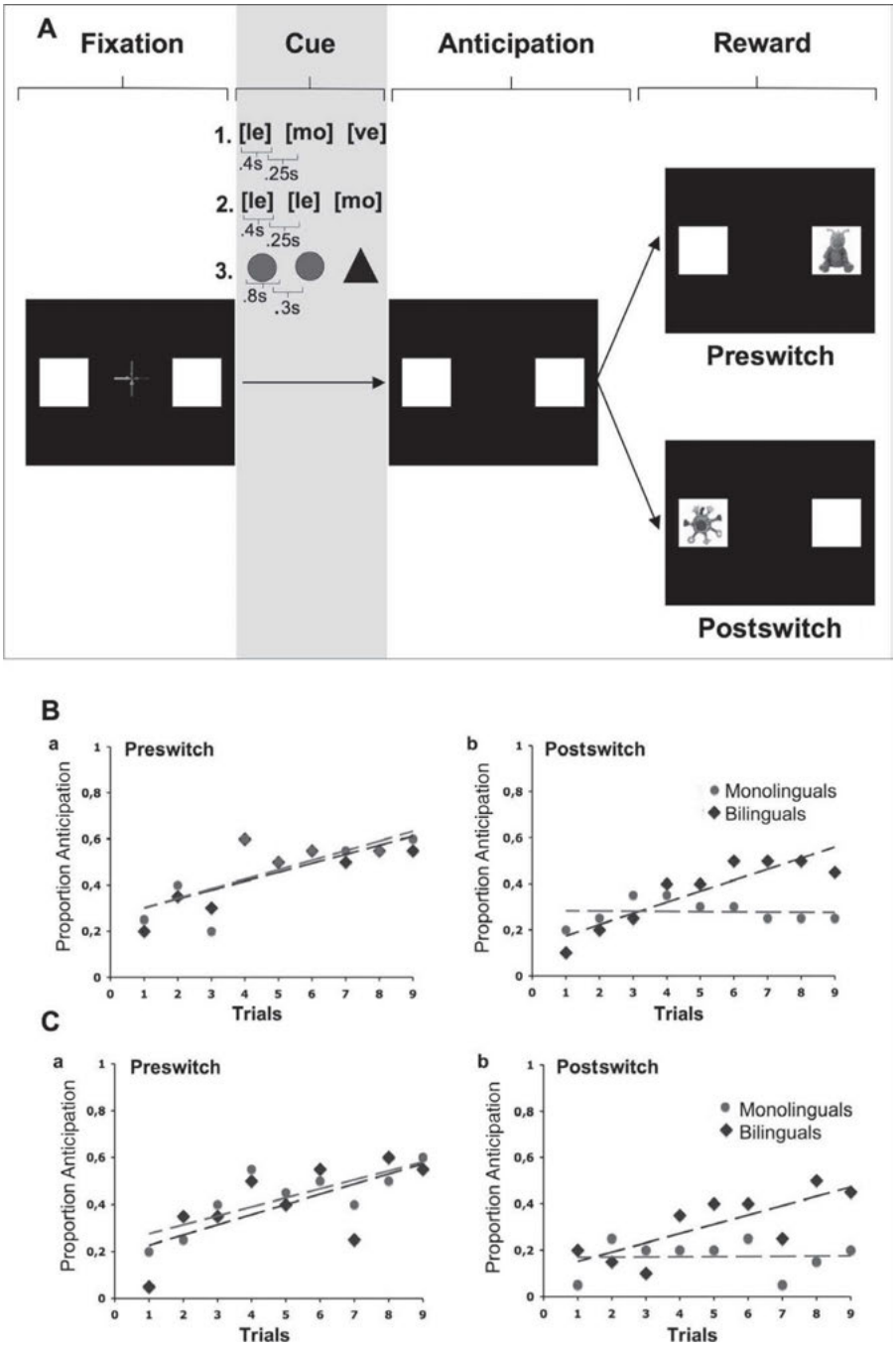

Fig. 13.1: Inhibiting a previously learned response in 7-month-old monolingual and bilingual infants. Trial structure (A) and results of experiments 2 and 3 (B and C) are shown. Proportion of infants with correct anticipatory looks. From "Cognitive Gains in 7-Month-Old Bilingual Infants," by Á. M. Kovács and J. Mehler, 2009, *Proceedings of the National Academy of Sciences of the United States of America*, *106*, pp. 6557–6558. Copyright 2009 by Á. M. Kovács and J. Mehler. Adapted with permission.

described earlier, except that we used visual sequences as cues. These sequences followed the same regularities as the linguistic stimuli; that is, they had identical geometrical shapes at the beginning of the sequence, such as in AAB, or at the end of the sequence, such as in ABB, where As and Bs stand for different shapes. The findings were similar to the previous results, even when using solely visual stimuli: only bilingual infants showed successful learning over the trials of the postswitch phase, whereas both groups learned in the preswitch phase.

These data show that monolingual infants have difficulty overcoming a well-learned response, a finding that fits well with previous results showing that 7-month-olds display difficulties in inhibiting previously rewarded responses because of their immature EF (Diamond, 1985). In our study, however, bilingual infants significantly decreased their perseverative responses and increased anticipations to the new location. This suggests that a multilingual environment improves aspects of EF even in preverbal infants. Whereas monolingual and bilingual infants learned equally well that a speech or visual cue predicted the position of a visual reward in the preswitch phase of each experiment, we observed a significant behavioral difference between the two groups in the respective postswitch phases. Bilingual infants readily suppressed the previously learned response and updated their predictions according to the changing requirements of the task, whereas monolingual infants did not learn to correctly modify their responses during the trials of the postswitch phase. The bilingual infants' enhanced performance cannot be attributed to a systematic difference in general information processing abilities because the performance of the two groups was comparable during the preswitch phases of the experiments.

Taken together, the results suggest that perceiving and processing utterances from two languages during the first months of life improves domain-general components of EF well before language production begins. Hence, although suppression of one language when speaking the other is well attested, it is not necessarily required for an EF improvement. Solely processing two languages and having to deal with the representations of each of them seems sufficient for enhancing executive control in 7-month-old infants. Their well-developed EF abilities may help bilingual infants to successfully monitor and keep separate the linguistic representations of the two languages, possibly allowing them to efficiently acquire each language.

Bilingualism Leads to Flexibility in Learning Two Structural Regularities in Infancy

How young children manage to find the crucial regularities in the vast linguistic signal they hear in their environment is still unclear. This problem becomes particularly salient for infants born into bilingual families. In a set of studies (Kovács & Mehler, 2009b), we aimed to explore how monolingual and bilingual infants learn

and generalize repetition-based regularities implemented in speechlike stimuli when they are exposed to two kinds of structures simultaneously. Such simultaneous learning might involve executive control and attentional abilities to a great extent, because infants have to concomitantly monitor and construct representations for each of the two regularities. Thus, if bilingual infants develop better executive functions, they should also outperform monolingual infants in this task.

In two experiments we investigated how 12-month-old monolingual and bilingual infants extract the underlying structure from an ambiguous speech input using an eye-tracker. Previous research suggested that infants are able to generalize repetition-based regularities when trained with speechlike stimuli following a single pattern (e.g., AAB; Marcus et al., 1999). In contrast, we familiarized infants with two structures simultaneously. To facilitate learning in this interleaved task, we used two structures that are easily distinguishable. For instance, in two experiments we used adjacent repetition-based structures (AAB) and nonadjacent repetition-based ones (ABA; Kovács & Mehler, 2009b), whereas in other experiments we used adjacent repetition-based structures (AA) and diversity-based patterns (AB patterns that contain different syllables; Kovács, 2014a).

In a typical trial of the experiments of Kovács and Mehler (2009b), the infant was presented with a nonce word conforming to a specific structure (e.g., AAB, such as *zo-zo-mo*) followed by a visual reward (e.g., a colorful toy) in a specific location (e.g., left). In a different trial, we presented another nonce word conforming to the other structure (e.g., ABA, such as *zo-mo-zo*) followed by a visual reward on the opposite side (e.g., right). The familiarization consisted of 36 such ABA and AAB intermixed trials, followed by eight test trials, where infants heard new words composed of new syllables and no reward appeared (Figure 13.2 A & B). Thus, after repeated trials infants could learn that the structure of the word predicted the location where the reward would appear, and possibly they could also develop expectations about new exemplars of linguistic stimuli that followed the same structure. We asked whether bilingual infants would outperform their monolingual peers in learning two repetition-based regularities simultaneously by measuring their anticipatory looks in the test trials.

Our principal measure to assess learning was infants' first look after hearing a new speech item in the test. If they learned the structures, they should first search for the toy where it used to appear for that specific structure. Second, we measured infants' overall accuracy in looking to the correct side. That is, trials were scored as correct if the infant looked longer to the correct side within the two seconds after hearing a new item and before the start of the next trial. We selected the participants and determined their language status as in Kovács and Mehler (2009a).

Results are shown in Figure 13.2C. Bilingual 12-month-old infants looked more often to the correct side for both structures during the test trials as shown by the first look analysis and by the overall accuracy analysis (Figure 13.2C). Monolingual infants, in contrast, looked more often to the correct side when the speech items had

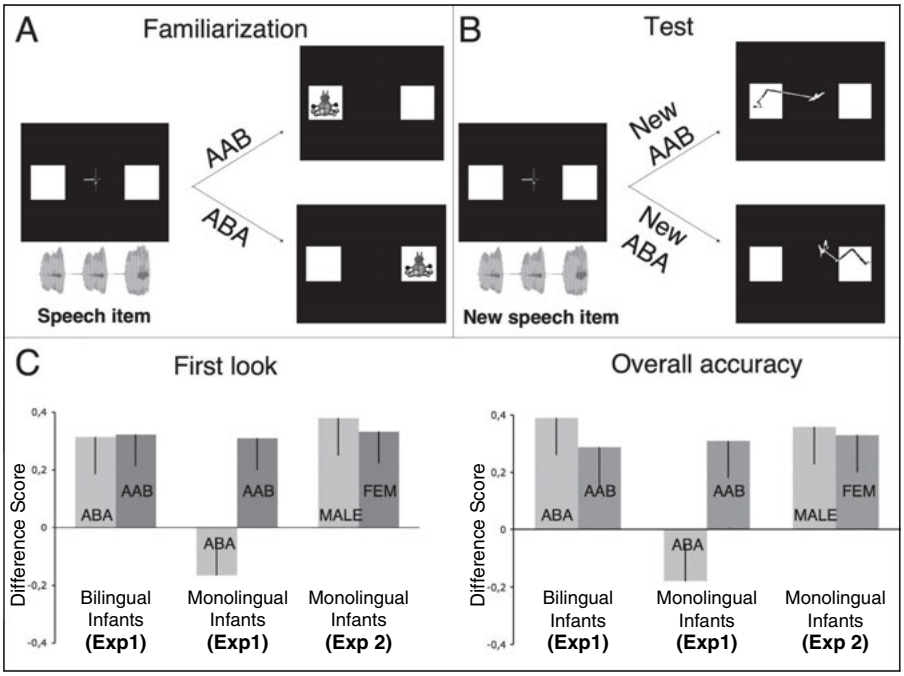

Fig. 13.2: Learning multiple rules simultaneously. Familiarization phase of experiment 1 (A); test phase of experiment 1 (B). On the right, two scan paths of an infant are depicted on two trials. Measures of learning for the two structures or the two voice cues (C). On the left are difference scores for first looks ([number of correct looks – number of incorrect looks]/[number of correct looks + number of incorrect looks]) related to the chance level of 0 for ABA and AAB structures (experiment 1); and for male and female voices (experiment 2). On the right are difference scores for overall accuracy. Error bars represent *SE*. From "Flexible Learning of Multiple Speech Structures in Bilingual Infants," by A. M. Kovács and J. Mehler, 2009, *Science*, *325*, p. 611. Copyright 2009 by A. M. Kovács and J. Mehler. Reprinted with permission.

the structure AAB, but not when they had the structure ABA. When faced with two regularities, both consisting of well-defined structures (AAB and ABA), monolingual 12-months-olds generalized only the AAB structure. However, they failed to learn the nonadjacent repetitions. Keeping in mind two regularities simultaneously might be too difficult for infants and they might focus on only one regularity and disregard the other.

These results also suggest that close and distant identity relations may involve different processing demands. Seemingly, adjacent repetitions are easier or more salient than nonadjacent repetitions. The asymmetry we found is in line with recent neuroimaging studies showing that even newborns can detect adjacent repetitions, but they fail with nonadjacent ones (Gervain et al., 2008). In contrast, preverbal bilingual 12-month-olds learned both structures and seemed to be more efficient in learning two regularities simultaneously than their monolingual peers.

Next, we asked whether exposure to rhythmically similar or dissimilar languages leads to a different performance in simultaneously learning two regularities. When two languages share rhythmic properties, bilingual infants might have a more difficult task because they must find other cues to discriminate them. Thus, we analyzed the bilingual infants' performance as a function of the similarity of the languages they learned at home, that is, whether they were exposed to two languages from different rhythmic classes (e.g., Slovenian and Italian), or two languages belonging to the same rhythmic class (e.g., Italian and Spanish). However, we found no main effect of language similarity and no other effects or interactions. Further studies involving larger samples are needed to explore how language similarity may influence learning in bilingual infants.

To control for the possibility that the bilingual infants' advantage reflects just a better learning of contingencies between sounds and locations, rather than their ability to learn multiple structural regularities, we ran an additional experiment involving only monolingual infants. In Experiment 2, a new group of monolingual 12-month-olds heard speech items that differed not only in their structure, but also in their pitch (e.g., female voice for ABA and male for AAB). Infants successfully learned to predict the toy locations based on the voices as shown by the first look analysis and the overall accuracy analysis (Figure 13.2C). Together, the results of these experiments show that, in contrast to bilingual infants, monolingual infants cannot extract two structures, although they can associate two speakers to different locations.

Thus, these data suggest that preverbal 12-month-old bilingual infants are more efficient in learning two regularities simultaneously than their monolingual peers. In a situation where infants had the opportunity to learn two mutually inconsistent regularities, bilingual infants learned both, whereas monolingual infants learned only one. This advantage is likely related to a precocious development of control and selection abilities, which we have discussed in the previous parts (Kovács & Mehler, 2009a), and which has also been documented in bilingual preschoolers and adults (Bialystok, Craik, et al., 2005; see also Chapters 14–16, this volume). Such abilities may allow bilingual speakers to deal more efficiently with two conflicting representations in the domain of language.

In the studies previously described, we investigated how different domain-specific and domain-general processes interact in the service of language acquisition, and how these are shaped by early bilingual exposure. According to the findings, bilingual language learning seems to involve domain-general EF abilities, even at an age when infants do not yet produce words. The practice of using such abilities during language acquisition results in their enhancement even outside the domain of language. Improved EF will, in turn, be used to deal more efficiently with conflicting linguistic representations and possibly also with nonlinguistic ones.

In addition to revealing differences in EF between monolingual and bilingual infants, these results also speak to the long-standing debate whether bilingual infants

start out constructing only one language system comprising both of the languages they acquire, or whether they represent their two languages separately from the start. Our results seem to support the differentiated language system hypothesis. We conjecture that the EF enhancement observed in bilingual 7-month-olds (Kovács & Mehler, 2009a) is possible only if preverbal infants process the two languages distinctively. Only if infants can represent the two languages differently, will they be able to selectively attend to them.

Yet, one might argue that an EF enhancement could arise even if infants do not separate the two languages at the age of 7 months; if so, these results would be consistent with the unitary language system hypothesis. For example, learning from a more complex linguistic input might require more attentional resources as the input is more variable. Bilingual infants would thus have to deploy greater attentional control during language acquisition. Because attentional processes are part of the EF system, such practice might also enhance the development of EF abilities, even if bilingual infants have not yet succeeded to separate the two languages.

However, it is unlikely that bilingual infants are unable to separate the two languages they are exposed to by their seventh month. Previous evidence shows that infants discriminate rhythmically different languages at birth, and prosodically similar languages by their fourth month (Bosch & Sebastián-Gallés, 1997; Nazzi et al., 1998). Thus, infants might use different cues early on (e.g., prosodic, phonetic, or phonotactic differences) to separate the languages; this might allow them to selectively attend to the two languages and construct different systems.

Also, the finding that bilingual infants could simultaneously extract two regularities (Kovács & Mehler, 2009b) is not consistent with the predictions of a unitary language system hypothesis either. This hypothesis would assume that bilingual infants should construct a single system also when confronted with artificial speechlike stimuli that contain two regularities. However, the 12-month-old bilingual infants in our study extracted and generalized simultaneously two structural regularities. In contrast, monolingual infants systematically learned only one regularity from the artificial stream, irrespective of whether the signal contained two structures or a structure and a random pattern (Kovács, 2014a; Kovács & Mehler, 2009b). In other words, monolingual infants managed to extract only one structure and presumably considered contrary evidence (e.g., the other structure) as noise.

Such findings open the field for a further conjecture. Infants exposed to a monolingual language input, which contains a well-defined system of regularities, might be tuned to search for a single consistent pattern in speechlike stimuli. This might explain why they might fail to simultaneously learn multiple patterns. Thus, early on, monolingual infants might expect that the speech input they hear has a single coherent system of regularities. This expectation, of course, will be modified by experience. As described earlier, infants exposed to two languages demonstrated the ability to learn two conflicting regularities simultaneously. Thus, bilingual infants presumably allow multiple conflicting sets of regularities in speechlike input.

It is possible that infants start the task of language acquisition with some expectations about the consistency of the linguistic signal. This expectancy will undergo an exposure-dependent specialization, in the sense that it will allow a single set of regularities or multiple ones depending on whether infants are exposed to one language or two. Developing such an expectancy would help rapid language acquisition. It would also diminish the amount of cognitive resources allocated to language learning, because it would permit considering as noise any evidence that does not exactly fit with the current "conjectures" of the infant learner. Such a possibility remains hypothetical until further studies provide support for the framework that infants have specific expectations about the coherence of the linguistic input.

Further Cognitive Effects of Early Bilingualism

Although the studies previously discussed suggest that there are specific enhancements in how bilingual infants deal with learning new regularities after having already learned one and in extracting two rules simultaneously, recent studies suggest that there might be other changes in the cognitive system that seem to be triggered by bilingual input from very early on in childhood. Such changes might, for instance, result in a boost in visual language discrimination (Sebastián-Gallés, Albareda-Castellot, Weikum, & Werker, 2012), in different word learning strategies (Byers-Heinlein & Werker, 2009, 2013) and habituation patterns (Singh et al., 2015), or in enhanced memory flexibility (Brito & Barr, 2012).

Research by Sebastián-Gallés et al. (2012) suggests, for instance, that bilingual 8-month-olds can visually discriminate two languages they are not familiar with, whereas monolingual infants cannot. This study investigated whether bilingual exposure enhances the attentional system because of the need to pay attention to the distinctive perceptual information in the language input. More specifically, two alternative hypotheses were tested. Earlier studies found that whereas monolingual 8-month-olds could not discriminate the visual features of their native language and a new language, bilingual infants of the same age succeeded in the discrimination of their two native languages (Weikum et al., 2007). Sebastián-Gallés et al. asked whether such a bilingual advantage is because of perceptual narrowing to the exact languages of exposure or to increased perceptual attentiveness to visual language-related cues even for unfamiliar languages. Bilingual infants could discriminate visual speech even for two foreign languages, a finding that supports the greater perceptual attentiveness hypothesis (see also Chapter 3, this volume). However, it is still unclear how processes of perceptual narrowing and perceptual attentiveness interact in bilingual language acquisition.

Further changes in cognitive processing in bilingual infants are also observed in the domain of word learning. Early work targeting monolingual infants suggests that they use specific disambiguation heuristics to identify referents for words. For

instance, if they encounter a new label (e.g., *dax*) together with a familiar object for which they already have a lexical referent (e.g., *shoe*) and a new object, they will infer that the new word's referent must be the new object. This is also referred to as the *mutual exclusivity principle*, according to which infants assume that one object has only one label (Markman & Wachtel, 1988). Although monolingual infants can successfully use mutual exclusivity to learn new labels for new referents, infants exposed to bilingual or multilingual input are often exposed to lexical equivalents in two languages. Thus, in their case, the one object–one label strategy does not seem to be easily applicable. Experimental data suggest that multilingual children seem to apply the principle of mutual exclusivity less than monolingual children (Byers-Heinlein & Werker, 2009; Houston-Price, Caloghiris, & Raviglione, 2010; see also Chapter 4, this volume). However, it is not clear whether this is because of the fact that they accept that an object can have multiple verbal referents. Recent studies provide evidence in this direction, suggesting that infants exposed to multiple languages seem to accept that one object can have multiple referents more frequently than monolingual infants in a synonym task (Kovács, 2014b). Furthermore, Byers-Heinlein and Werker (2013) investigated whether bilingual infants' use of mutual exclusivity as a disambiguation strategy is related to the extent to which their lexicons had a one-to-one versus a many-to-one mapping structure, as operationalized by their knowledge of translation equivalents in their two languages. The data show that bilingual infants who understood translation equivalents for more than half the words in their vocabularies applied the principle of mutual exclusivity less compared to those bilingual children who knew fewer translation equivalents.

It is not very surprising that multilingual infants do not apply the one object–one label heuristic as they usually encounter two labels for the same object—one in each language. However, as pointed out by Costa and Sebastián-Gallés (2014), it is unclear how bilingual infants compensate for the lack of this principle during word learning, what alternative strategies they use, and whether early vocabulary development is compromised in some way by its absence.

A further study investigating other possible advantages of bilingualism in infancy found that bilingual but not monolingual 18-month-old infants showed generalization in a deferred imitation task, pointing to a cognitive advantage in memory generalization for bilingual infants (Brito & Barr, 2012). Bilingual infants showed better memory flexibility, generalizing successfully when a demonstration was performed on object A, while the test involved object B. Although the mechanisms through which a better generalization ability emerges from learning simultaneously two languages are not clear, the study found a relation between the degree of how balanced bilingual children were in their two languages and their generalization performance.

Regarding other possible advantages, Singh et al. (2015) found differences in how bilingual and monolingual 6-month-olds habituated to visual stimuli in a visual discrimination task. Similar to the studies mentioned previously, a relation was found here as well between habituation performance and the amount of second language

exposure. Although more and more studies point to specific advantages of bilingual infants in various cognitive domains, it is unlikely that a generalized bilingual advantage will be uncovered by future studies. It is unclear whether the observed advantages persist throughout childhood and adulthood providing overall learning benefits, whether they reach a plateau at some point (e.g., when the two languages were acquired), and why no general learning benefits are usually observed in bilingual children and adults in previous studies.

New Perspectives: Effects of Bilingualism as Cognitive Adaptations

One possible way to conceptualize the changes induced by the bilingual environment is to think of them similarly to other adaptations in the cognitive system, for instance, visual adaptations. Wearing prism glasses that lead to an inversion of the left and right or the up and down dimensions certainly lead to adaptation costs. Performance initially decreases followed by an improvement that signals that the visual system adapted to the new input. Analogously, one would expect that when exposed to two languages the developing brain would quickly adapt to processing two mutually exclusive language systems (Kovács, 2015). Behavioral observations, according to which bilingual language acquisition follows the same milestones as the monolingual one despite the more complex input, point to such plasticity. However, the analogy between visual adaptation and a possible bilingual adaptation becomes problematic when one realizes that in contrast to a situation where the prism glasses are removed at the end of a study, bilingual individuals will likely continue using "the prism glass of bilingualism" for the rest of their lives.

Importantly, besides having to extract patterns from a complex and variable dual language input, bilingual infants likely need yet another, possibly separate adaptation that allows them to flexibly switch attention between two languages systems, to be able to distinctively acquire both of them. To continue with the prism glasses comparison, one would need to ask participants in a visual adaptation study to put on and off the prism glasses many times a day, and consequently to constantly switch between upright and upside down visual input. Likely, the cognitive system will optimize such switches, and minimize adaptation times. This should also be valid for cases in which the language input contains frequent between-language switches. Bilingual adults change from one language to another rather smoothly and even young bilingual children must be able to successfully deal with these frequent switches.

In the earlier parts of this chapter, I discussed different studies that could be reframed as possible adaptations involved in dealing with a multilingual input. Various results pointing to advantages or disadvantages in specific domains might all be seen as cognitive adaptations to a bilingual environment (see Kovács, 2015).

For instance, better attention switching and simultaneous learning of two regularities (Kovács & Mehler, 2009a, 2009b) and better memory generalization (Brito & Barr, 2012) may allow bilingual speakers to successfully cope with the rapidly changing bilingual input. Additionally, more fine-tuned visual language discrimination abilities observed in bilingual 8-month-olds even for languages they are not familiar with (Sebastián-Gallés et al., 2012) might be an adaptation that stems from greater attention to nonfamiliar languages and leads to more efficient language learning in the case of scarcer input.

Furthermore, even studies that highlight "costs" of bilingualism may point to possible adaptations. For instance, in a study by Fennell, Byers-Heinlein, and Werker (2007), bilingual infants only learned word–object associations with nonwords that were minimal pairs (e.g., bih/dih) at 20 months, lagging behind monolingual infants by about 3 months. One could argue that a later emerging sensitivity to minimal pairs in learning word–object associations might be explained by a flexibility of bilingual infants in forming broader phonological categories. In line with an earlier proposal, these results may reflect an adaptive strategy to learn two languages (Sebastián-Gallés, 2010; see also Chapters 3 and 4, this volume). In a similar vein, bilingual speakers' smaller vocabulary when only one language is measured may be explained with a possible adaptation that ensures a "fair" division of the possibly limited cognitive resources between the two languages. Interestingly, however, when bilingual speakers' vocabulary is measured taking together both languages, their cumulative scores are equal to or higher than those of monolingual speakers, pointing to a possibly more general memory enhancement (as documented in some studies; Brito & Barr, 2012).

In sum, early exposure to more than one language seems to lead to specific adaptations in the cognitive system, which will influence, in turn, how language is acquired, and might result in changes in other domains as well. However, these presumably do not imply that bilingualism leads to radical representational changes in the human mind. Instead, they indicate that the cognitive system of a young child is ready to successfully deal with the challenge coming from multiple languages.

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