Listening with your cohort

Do bilingual toddlers co-activate cohorts from both languages when hearing words in one language alone?

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Bilingual children, like bilingual adults, co-activate both languages during word recognition and production. But what is the extent of this co-activation? In the present study, we asked whether or not bilingual preschool children activate a shared phonological cohort across languages when hearing words only in their L1. We tested German-English children on a cross-modal priming paradigm. To ensure co-activation of languages, children first heard a short code-switch story. Compared to a monolingual control group, bilingual children in Experiment 1 showed only partial sensitivity to the L1 cohort. Bilingual children who did not hear the code-switch story (Experiment 2) showed priming effects identical to the monolinguals in Experiment 1. Results indicate that under single-language contexts, German-English bilingual preschoolers do not activate the non-target language cohort during word recognition but instead restrict cohort activation to the language of input. In contrast, presentation of the non-target language in the code-switch story appears to shift cohort activation and increase L2 activation, suggesting a highly flexible language system that is in tune to the broader linguistic context. We consider mechanisms of bilingual language control that may enable bilingual toddlers to limit cross-language phonological activation.

1. Introduction

One of the most compelling areas of inquiry in bilingual research has been the question of whether lexical access is fundamentally language-selective or not. In other
words, can the unintended language be turned off in order to enable the bilingual to function as a monolingual? Research from multiple modalities has now provided evidence for language non-selectivity, suggesting that both of a bilingual’s languages are active to some extent at all times (e.g., visual: Dijkstra & Van Heuven, 1998; auditory: Marian & Spivey, 2003; Weber & Cutler, 2004; production: Hermans, Bongaerts, De Bot, & Schreuder, 1998; sign: Morford, Wilkinson, Villwock, Piñar, & Kroll, 2011). Under several accounts of language control, language co-activation leads to lexical competition between languages that subsequently needs to be resolved for the bilingual to fluently use one language alone. It is this conflict resolution that is thought to be at the root of an observed restructuring of the mind and brain that has enduring cognitive consequences for the bilingual (for a recent discussion see Kroll & Bialystok, 2013). Several chapters in this volume address these broader cognitive implications of cross-language activation. In the present chapter, we take a closer look at the organization of the developing bilingual mental lexicon with an eye towards examining the scope of language co-activation and language control and how a bilingual might limit the degree of activity of the non-target language.

In light of the multitude of studies on adult bilingual language processing, only surprisingly few studies have investigated cross-language activation in bilingual children. Two recent studies show that bilingual children, similar to bilingual adults, co-activate both languages during word production and auditory word recognition (Poarch & Van Hell, 2012; Von Holzen & Mani, 2012). In Von Holzen and Mani (2012), German-English bilingual children’s recognition of L1 words was enhanced when preceded by an L2 word that overlapped in phonology [slide–Kleid “dress”, where slide and Kleid rhyme]. This facilitation effect might be caused by pure phonological overlap in the sounds of the L1 and L2 labels (i.e., the final phonemes of slide and Kleid overlap) and does not necessarily require lexical activation in both languages. Crucially, recognition was impaired when the rhyme relationship existed through translation [leg–Stein “stone”, where the German translation of leg is Bein, which rhymes with Stein]. This interference effect implies lexical activation of both L1 and L2 words and could only have been observed in this second condition if leg activated its translation. The results of Von Holzen and Mani (2012) provide strong support for lexical-level language co-activation in bilingual children.

The evidence suggests that co-activation is not purely phonological, activating only sound information, but is also lexical, activating the mental representation of words. But what is the extent of this lexical co-activation? How far does activation spread? To address this question, we look at language cohorts, or words that start with the same consonant, both within and across languages. For instance, from Von Holzen and Mani (2012) we know that at the lexical level, a word in one language will activate its translation equivalent in the other language (see English leg–German Bein above). In the current study, we are interested in whether a word in one language also activates a phonologically
similar word (e.g., leg – leaf), and perhaps an entire cohort of similar overlapping words (e.g., leg – leaf – lake – lemon – lettuce) both within and across languages.

This question is by no means trivial, particularly with respect to language and cognitive control in bilinguals. If the number of activated words across languages extends beyond translations to encompass a broad network of words, the potential competition within and across languages increases significantly, as does the work the bilingual child needs to do to resolve cross-language competition (e.g., Marian & Spivey, 2003) in order to fluently process the intended language. While recent accounts have pointed out that the complexity of the bilingual experience that leads to observed bilingual advantages in executive function cannot be reduced to competition resolution alone (e.g., Kroll & Bialystok, 2013), the “brain exercise” involved in negotiating the demands of two active languages certainly contributes to a constellation of factors, including language exposure, executive control, and metalinguistic ability, that shape the bilingual brain. In the present study, we focus on one particular lexical characteristic, namely the phonological onset of words, to examine the scope of bilingual lexical access and its consequences for auditory word recognition in bilingual children.

According to onset-based models such as the Cohort Model, the organization of words centers on initial phonological overlap between lexical entries (Marslen-Wilson & Welsh, 1978). For example, words such as dog and doll both share the same phonological onset [d] and are therefore predicted to share a closer phonological relationship with each other than with a word such as table. Indeed, evidence from the adult literature suggests that phonological similarity is one of the organizing principles in the mental lexicon. Particularly relevant to the present study is the finding that adults can be slower to identify a word (e.g., jail) when previously exposed to a phonologically similar word (e.g., jar) compared to an unrelated word (e.g., phone) (Goldinger, Luce, Pisoni, & Marcario, 1992; Radeau, Morais, & Segui, 1995; Slowiaczek & Hamburger, 1992).

Recent research finds that young first language (L1) learners, similar to adults, are sensitive to a word’s phonological cohort. Mani and Plunkett (2011) found that prior activation of phonologically related words influences 24-month-olds’ word recognition. Toddlers saw an image of a concrete and familiar object, which was followed by two images presented side-by-side. One of the images (i.e., the target) was labeled, and the proportion of looks to the target was compared to looks to the distracter image. The prime image and target word/image were either related phonologically or unrelated. Compared to unrelated prime-target pairs (e.g., bowl-cow), target identification was impaired following a phonologically related prime (e.g., bowl-bike).

To investigate the locus of this interference effect, Mani and Plunkett further manipulated the target’s cohort size, that is the number of words in a typical child’s vocabulary that start with the same phonological onset. In English, [b] is a large cohort, with many words in a toddler’s vocabulary starting with [b] (e.g., ball, book, baby, bib, bottle, etc.). In contrast, [p] is a small cohort (e.g., potato, pot, puppy). They found
that by 24 months of age, monolingual toddlers showed impaired word recognition for large target cohorts compared to small target cohorts (Mani & Plunkett, 2011; but see Mani & Plunkett, 2010). To explain the effect, Mani and Plunkett argue that large cohorts inherently have more potential lexical candidates with the same onset that compete for selection than small cohorts, making it more difficult to select the target when it comes from a large cohort than a small cohort. This leads to impaired target recognition as indexed by reduced target looking. An important caveat to this finding is that Mani and Plunkett (2010) used an identical paradigm with 18-month-olds and found facilitation and not interference effects, suggesting that a critical vocabulary size has to be built before cohort activation influences lexical access. We will discuss this idea more in the discussion.

The results of Mani and Plunkett (2011) strongly suggest that, just as in adults, phonological properties are used as a central basis for organizing the emerging lexicon of words once toddlers have reached a larger vocabulary size. But how would such an organizing principle work for bilingual children? For bilinguals, does hearing a word in the L1 activate a shared cohort in the second language (L2)? It is possible that activation stops once it has reached a single related word. But activation may cascade beyond a single word to the rest of the phonological cohort. Similar to results by Mani and Plunkett (2010), do we see developmental changes where toddlers need to reach a critical L2 vocabulary size before being influenced by cohort sizes? Answers to these questions can provide us with fundamental information on the structure of the bilingual lexicon. At the same time, this line of inquiry serves as a tool to investigate the nature of cross-language lexical activation: above and beyond asking whether single words or translation equivalents are accessed in both lexicons (e.g., Von Holzen & Mani, 2012), we can now test the scope of relative language activation.

2. The Present Study

In the present study, we used an adaptation of the inter-modal preferential looking (IPL) paradigm (Golinkoff et al., 1987) that allows for target priming (e.g., Styles, Arias-Trejo, & Plunkett, 2008). German-English bilingual toddlers heard an auditory prime word in their L1 German followed by a pair of images (target, distracter) and then heard the target label in their L1 German. Prime and target label either shared phonological onset (Bild “picture” – Baum “tree”) or not (Kind “child” – Baum “tree”). Images remained on-screen during which we assessed the proportion of time children looked to target versus distracter image. The method allowed us to manipulate cohort relationships between prime and target and, similar to some versions of the visual world paradigm (e.g., Huettig & McQueen, 2007), to gather data on looking behavior without explicit verbal instructions to children (e.g., “Look! A ball!”).
We asked whether or not bilingual toddlers would be sensitive to cohort sizes across both languages when hearing words only in their L1 German. To answer this question, we manipulated cohort size within and across languages. We tested toddlers on four cohorts of varying sizes: [g], [k], [b], and [p].

2.1 Hypothesis

Based on Mani and Plunkett (2011), we predicted an interference effect for large target cohorts but a facilitation effect for small target cohorts (see above and discussion). Given that the experimental language was the L1 German, if only the cohort of the language of testing is activated during word recognition, then results should pattern according to German cohort sizes, with interference effects for the two large cohorts ([b], and [k]) and facilitation effects for the two small cohorts ([g] and [p]). If, however, cohorts are co-activated across languages, then the combined cohort size should matter. A combined cohort size would constitute a crucial difference for the [p] category. While [p] is a small German cohort, it forms a large combined German-English cohort. If only the cohort of the language of testing (L1) is activated during word recognition, [p] should pattern as a small cohort. If the combined cohort should matter, then [p] should pattern as a large cohort.

3. Experiment 1

3.1 Method

3.1.1 Participants

We tested a total of 43 monolingual and bilingual children for this experiment. We included 22 German-English bilingual toddlers (13 girls and 9 boys) from a local bilingual preschool in Göttingen, Germany, in our final analyses. Four additional children were tested but excluded on the basis of the recognition test (see below). Toddlers ranged in age from 21 to 61 months (M = 41.72 months). While this age range is larger than in monolingual IPL studies, it allowed us to test toddlers with a similar daily bilingual language exposure, a factor which was particularly important for the set of questions under investigation in the current study (see Von Holzen & Mani, 2012, for a similar approach). Children spent six to eight hours daily, five days a week, at the preschool and received equal amounts of instruction in English and German, with each classroom having a designated English-speaking teacher and a designated German-speaking teacher (modeled after the one-parent-one-language approach; Bain & Yu, 1980).

We also tested a group of age- and gender-matched monolingual German toddlers to confirm the cohort effects that had previously been observed in English (Mani & Plunkett, 2011) for German. We included 21 children (11 girls and 10 boys) in the final
analyses; an additional child was tested but excluded due to external distractions during testing. Monolingual children came from the same wider German community as the bilingual group. Toddlers ranged in age from 21 to 61 months \((M = 42.20\) months). All children came from German-speaking homes and had no exposure to a second language. Children received a small book as a token of appreciation for participating in the study.

3.1.2 **Stimuli**

Four cohorts were chosen based on word counts assessing the cohort size of words in two standardized German and English vocabulary assessment lists, the German FRAKIS (Fragebogen zur Frühkindlichen Sprachentwicklung; Szagun, Stumper, & Schramm, 2009) and the English MacArthur-Bates CDI (The MacArthur Communicative Development Inventories, Fenson et al., 1993). We followed the logic of Mani and Plunkett (2008) and assessed cohorts as small if they were half the size or smaller than the largest cohort \([b]\). Based on cohort sizes in English and German, \([b]\) is one of the largest cohorts. The cohorts \([g]\) and \([k]\) fall somewhere in between, both in English and German. The \([p]\) cohort, however, is a large cohort in English (though not as large as \([b]\)), but a small cohort in German. See Figure 1 for an overview of the cohort sizes across languages.

![Cohort sizes](image.png)

**Figure 1.** Cohort sizes (number of words in the cohort) for English and German based on word counts in the FRAKIS (Szagun, Stumper, & Schramm, 2009) and the MacArthur-Bates CDI (Fenson et al., 1993).

In order to estimate bilingual children’s L2 (English) knowledge of words in the specific cohorts under investigation, we designed a recognition study in which children were tested on English words from each of the four cohorts. This estimate was important
because if children do not show recognition for words in the cohort, we cannot be sure whether the effects in the priming study are due to cohort effects or the children simply not knowing the words. The test was administered after the priming study.

For both the priming and the recognition study, we consulted the FRAKIS (Fragebogen zur Frühkindlichen Sprachentwicklung; Szagun, Stumper, & Schramm, 2009) to select age-appropriate concrete and imageable words from each of the four cohorts (b, p, g, k). We chose the final list of stimuli in discussion with one of the teachers at the preschool who indicated the words children would be familiar with in both English and German. Target and distracter were either both animate or both inanimate and were of the same grammatical gender to avoid a biasing context (e.g., Bobb & Mani, 2013). Target and distracter also did not share onset either within or across languages and were not cognates. Note that because many of the words learned early in German are cognates in English, the auditory prime stimuli did include several cognates (Garage “garage”, Garten “garden”, Papier “paper”, Polizei “police”). Because we were chiefly concerned with activating the phonological cohort, using cognates would, if anything, strengthen the cohort associated with a given prime by co-activating both the German and English cohort.

A highly proficient German-English bilingual produced auditory stimuli both in German (for the priming study) and in English (for the recognition study) in a friendly and child-directed manner. The speaker shared the same language background as the children’s teachers so as to approximate the pronunciation of words children would hear in every day life at the preschool. Auditory stimuli were recorded using Adobe Audition software at a sampling rate of 44.1 kHz and edited post recording to eliminate minor clicks using PRAAT. For each target and distracter word, we found a representative digital photograph image and superimposed it on a neutral gray background.

For the priming study, German auditory primes and their English translations were matched on frequency [German: Quasthoff, 2002; English: subtlexus, Brysbaert & New, 2009] across the four cohort groups (ps >.1). German target labels and their English translations were matched to German distracter labels and their English translations on frequency (ps >.1). Each child heard the same German primes and saw the same target-distracter pairings once during the experiment. For some children, a prime or target-distracter pair appeared in the related condition and for others in the unrelated condition. Across participants, however, a given stimulus appeared with equal frequency in the related and unrelated condition. The prime, target, and distracter items and their groupings by related and unrelated trials can be found in Appendix A.

For the recognition study, we chose four previously unseen target words in English from each cohort with a similar degree of familiarity according to the FRAKIS. Each target word was matched to a distracter word of similar frequency. Distracters did not belong to one of the four cohorts, and none of the words had previously been seen in the experiment. As in the priming study, target and distracter on a given trial were
either both animate or both inanimate. The target and distracter items and their cohort groupings can be found in Appendix B.

Note that past research with adults has shown that it is difficult to find effects of L2 activation under L1-only testing conditions (e.g., Weber & Cutler, 2004). Indeed in Von Holzen and Mani (2012), which showed language co-activation, children heard both languages within every trial in the form of an English auditory prime word and a German auditory target word. In order to enhance language co-activation, while still maintaining an L1-German only testing environment, we (1) tested participants during the school day in their bilingual environment while speaking English to them, and (2) we presented children with a code-switching story before the experiment proper. Children saw pictures on a computer screen and heard a story narrated by the native German speaker who produced the auditory stimuli.

For the code-switch story, we designed sentences following the Matrix Language (ML) theory (Myers-Scotton, 2001). According to the ML theory, one of the languages provides the syntactic frame while words from the other language are slotted into this frame, creating sentences that use both languages but are nevertheless grammatical (e.g., Es ist her birthday “It is her birthday”). To avoid a language bias, sentences alternatingly used German or English as the matrix frame. None of the words used in the story occurred later in the experiment, neither the actual word nor its translation. One of the authors (L. Drummond Nauck) drew child-appropriate pictures to accompany the story. The complete story is available in Appendix C.

3.1.3 Procedure

To encourage toddlers to be in a bilingual language mode (Grosjean, 1985), bilingual toddlers were tested on-site at the daycare during the course of their school day. The experimenter only spoke English to the children, as requested by the preschool teachers. Testing took place in a separate room in the preschool, where each child was tested individually. The child sat at a small desk facing a computer monitor placed 60 cm away at eye-level. Target and distractor pictures (17.5 × 13 cm each) appeared side-by-side on the screen. Two loud speakers, one on each side of the computer monitor, presented auditory target words. A video camera mounted centrally above the computer screen recorded the experimental session.

Age-matched monolingual German toddlers were tested individually in a laboratory setting. Because the monolingual children did not know any English, the experimenter only spoke German with the children. Each child sat either alone or on the lap of a caregiver 100 cm away from a large TV screen (92 × 50 cm). Target and distractor pictures (27 × 20 cm each) appeared side-by-side on the screen. Two loud speakers, one on each side of the TV screen, presented auditory target words. Two video cameras mounted centrally above the TV screen recorded the experimental session.
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The testing session was similar for bilingual and monolingual children. It began with the code-switch story. The code-switch story lasted three minutes. Monolingual children were exposed to the code-switch story in order to keep the experimental setup comparable across language groups. Following the code-switch story, we tested children on the priming test. For the priming test, each child was presented with 16 trials, 2 phonologically related and 2 unrelated trials per phonological cohort. Each trial lasted 3750 ms. The trial started with a fixation sign (+) that was followed by the presentation of the auditory prime after 100 ms. At 1700 ms into the trial, the fixation sign disappeared and two pictures appeared side-by-side followed immediately by the auditory target label at 1750 ms. Pictures remained on the screen until the end of the trial. Across participants, target and distracter pictures appeared equally often on the left or right side.

After the priming test, only bilingual children completed an additional recognition test to assess their L2 English cohort knowledge and L2 proficiency. The recognition test consisted of 16 trials, 4 trials from each cohort category [b, p, g, k]. On each trial, two pictures appeared side-by-side and remained on screen the entire trial. Trials lasted 5000 ms. At 2500 ms, we presented the English auditory target label of one of the two pictures. The label divided the trial into two equal prenaming and postnaming phases of approximately 2500 ms each, which allowed us to compare looks to the target before and after the target was labeled. The target is considered correctly identified when looks to the target increase after target labeling.

3.1.4 Data coding

The video data we collected from the children were coded offline frame-by-frame in 40 ms intervals by a trained coder using LOOK (Meints & Woodford, 2008). A second trained coder independently coded the data of 10% of the participants to assess inter-rater reliability ($r = .99$). For each phase of a trial, we then determined the proportion of time children looked to the target (PTL). We began analyzing a trial’s phase 240 ms after target word onset to ensure we included actual responses to the auditory stimuli (e.g., Mani & Plunkett, 2010; Swingley & Aslin, 2002). For the priming study, we were interested in the PTL after the onset of the target label to assess the impact of the prime on subsequent target recognition and therefore examined target looking behavior from 1990 to 3750 ms after the onset of the target label. For the recognition study, the phases of interest were pre- and post-target label onset in order to assess whether children’s target looking increased after hearing the label, which would indicate recognition of the target. The prenaming phase ran from 240 to 2500 ms and the postnaming phase from 2740 to 5000 ms. Each child’s looking times in each phase were then aggregated by condition creating a mean PTL per condition.
3.2. Results

3.2.1 Bilingual recognition study
In order to evaluate children’s knowledge of English words in the cohorts [b], [p], [g], and [k], we tested to see whether there was an overall recognition effect for the cohort words, that is whether children’s looks to target increased after hearing the English target label. Looking to target more post label indicates successful recognition and identification of the English target word. A paired samples $t$-test indicated that there was a general recognition effect, with more looks to target post-label compared to pre-label ($t(25) = 3.216, p = .004$). Looking at individual participants, however, 4 children failed to provide any data for one or more of the cohorts, suggesting limited knowledge of the given cohort and potentially low English vocabulary fluency. These children were excluded from subsequent analyses because we could not be sure that their L2 cohort knowledge and L2 proficiency was adequate enough to show priming effects (see Arias-Trejo & Plunkett, 2009, for a similar approach).

3.2.2 Bilingual priming study
A 4 (cohort) × 2 (relatedness) repeated-measures analysis of variance (ANOVA) showed a marginal effect of cohort [$F(3,63) = 2.66, p = .056, \eta^2 = .112$] and no main effect of relatedness [$F(1,21) = 1.06, p = .314, \eta^2 = .048$]. Critically, there was a significant interaction between cohort and relatedness [$F(3,63) = 3.13, p = .032, \eta^2 = .13$]. To assess proportion of looks to target in related versus unrelated trials for each cohort, planned comparisons using paired-sample $t$-tests investigated whether pairing a prime and target of the same cohort (“related” trials) facilitated or interfered with target looking compared to pairing a prime and target that did not share the same cohort (“unrelated” trials). Recall that large cohorts were predicted to show interference effects, while small cohorts were predicted to show facilitation effects. In line with a large cohort, children showed an interference effect for the [b] cohort, orienting significantly more to the target on unrelated than related trials [$t(21) = –2.55, p = .019, d = –0.68$]. None of the other comparisons were significant ([$p$]: $t(21) = –.41, p = .682, d = –0.07$; [g]: $t(21) = –.187, p = .85, d = –0.03$; [k]: $t(21) = 1.76, p = .093, d = 0.4$), suggesting that the prime did not substantially modulate target word recognition for words from these cohorts. Table 1 presents the priming effect (PTL related trials minus PTL unrelated trials) for each of the four cohorts that were tested.

3.2.3 Monolingual priming study
A 4 (cohort) × 2 (relatedness) repeated-measures analysis of variance (ANOVA) showed no main effects of cohort or relatedness ($Fs < 2$). There was a significant interaction between cohort and relatedness [$F(3,57) = 3.32, p = .026, \eta^2 = .15$]. In line
with a large cohort, children showed an interference effect for the [b] cohort, orienting significantly more to the target on unrelated than related trials \(t(19) = -2.12, p = .048, d = -0.57\). In line with a small cohort, children showed a facilitation effect for the [p] cohort ([p]: \(t(19) = 2.05, p = .055, d = 0.51\)). None of the other comparisons were significant ([g]: \(t(19) = 1.56, p = .13, d = 0.53\); [k]: \(t(19) = .462, p = .65, d = 0.16\)). Table 1 shows the means for related and unrelated trials in each condition.

Table 1 shows the means for related and unrelated trials in each condition.

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3.3 Discussion of Experiment 1

The results of Experiment 1 show priming effects in the expected direction for German monolingual children for the largest cohort [b] and the smallest cohort [p]. Specifically, children showed an interference effect for [b] and a facilitation effect for [p]. The cohorts [g] and [k] did not show significant effects, most likely because their size had either exceeded or not yet met critical sizes for small/large cohorts (see Mayor & Plunkett, 2014, for evidence that the number of known words influences priming effects). Their mean trends, however, were in the expected direction, with [k] patterning as a large cohort and [g] patterning as a small cohort. In contrast, bilingual children only showed a priming effect for the [b] category, which is a large cohort in both German and English. The [p] category, which is a small cohort in German but a large cohort in English and a large cohort when combined across languages, showed neither a facilitation nor an interference effect, similar to the [g] and [k] cohorts. The
results suggest that the \([p]\) cohort size had exceeded the size of a small cohort but not yet reached the size of a large cohort, indicating the possibility that the magnitude of the cohort may have been in flux, either because the code-switch story had increased activation of the English lexicon to some degree or because children's English vocabulary was still growing.

Evidence from the adult bilingual literature supports the idea that bilinguals adjust activation levels of each language in response to the language environment. Elston-Güttler and colleagues (Elston-Güttler, Gunter, & Kotz, 2005) presented native-German speaking participants with a silent movie that was narrated either in English or German. Following the movie, participants completed an L2-only semantic priming experiment in English in which they read sentences followed by words and had to decide whether the word was a real word or not e.g., “The woman gave her friend an expensive item” “poison”. In the critical condition, the final word of the sentence was a cross-lingual homograph (e.g., “The woman gave her friend an expensive gift” where gift is the German translation equivalent of “poison”) followed by English words that were the translation of the German meaning (poison) of the target homograph. Previous work had shown that interlingual homographs such as gift prime their translation when they are presented as isolated words (Elston-Güttler, 2000). Priming effects disappear, however, when homographs are presented in sentence contexts, presumably because the sentence context constrains activation of the unintended language. Elston-Güttler and colleagues found, in contrast to previous work, that participants were faster to respond to related targets in sentence contexts, but only if they first heard the German narration to the movie. These results suggest that the semantic context, coupled with task demands, modulates the relative activation of both languages. In effect, previously hearing German increased the relevance of German to the English-only experiment, leading to increased activation of the homograph's German meaning (see also Elston-Güttler & Gunter, 2009, but see counter-evidence with single word environments in Paulmann, Elston-Güttler, Gunter, & Kotz, 2006).

While the direction of the language testing in Elston-Güttler et al. (2005) was different from ours (testing was done in the L2), these results strongly indicate that the testing environment is crucial to the relative activation of a bilingual's languages. To test the possibility that the code-switch story had changed cohort activation levels across languages, we tested bilingual children who completed the same priming study, but without first hearing the code-switch story. If the code-switch story lead to increased English cohort activation in Experiment 1, then not presenting the code-switch story should allow bilingual children in Experiment 2 to zoom into the German language of the experiment. If this is the case, we predicted that bilingual children should pattern like the monolingual German children in Experiment 1, showing interference effects for the \([b]\) cohort and facilitation effects for the \([p]\) cohorts.
4. Experiment 2

4.1 Method

4.1.1 Participants
We included 15 German-English bilingual toddlers (6 girls and 9 boys) in our final analyses. Children were from the same local bilingual preschool in Göttingen, Germany from which participants were recruited in Experiment 1. Toddlers ranged in age from 27 to 46 months ($M = 37.73$ months, $SD = 5.27$, $Mdn = 38.00$). An additional child was tested but excluded because of talking to the experimenter during testing. As in Experiment 1, toddlers received equal amounts of daily instruction in English and German, with each classroom having a designated English-speaking teacher and a designated German-speaking teacher.

4.1.2 Stimuli and Experimental Design.
The same stimuli and experimental design were used as in Experiment 1. This group of participants only completed the priming test, without first hearing the code-switch story. The experimenter again only spoke English to the children. Following the priming test, children then completed additional tests for another experiment that is not reported here.

4.2 Results
A $4 \times 2$ (cohort \times relatedness) repeated-measures analysis of variance (ANOVA) showed a significant main effect of cohort [$F(3,42) = 6.38, p = .001, \eta^2 = .313$] but no main effect of relatedness ($F < 1$). Importantly, the interaction between cohort and relatedness was significant [$F(3,42) = 5.92, p = .002, \eta^2 = .297$].

As in previous comparisons, planned paired-sample $t$-tests investigated whether pairing a prime and target of the same cohort (“related” trials) facilitated or interfered with target looking compared to when prime and target did not share the same cohort (“unrelated” trials). In line with a large cohort, children oriented significantly more to the target on unrelated than related trials for the [b] cohort [$t(14) = –3.07, p = .008, d = –1.04$]. Critically, for the [p] cohort, children oriented more to the target on related than unrelated trials [$t(14) = 2.52, p = .025, d = 0.98$]. This facilitation effect is in line with a small cohort and therefore activation of the L1 German cohort alone. While not significant, the [g] category means are in line with a small cohort [$t(14) = 1.15, p = .267, d = 0.47$], while [k] was in line with a large cohort [$t(14) = –.429, p = .674, d = –0.11$] (see Table 1 for condition means).
Table 1. Mean PTL scores and their SD for related and unrelated conditions in each cohort across experiments for bilinguals (bi) and monolinguals (mono)

<table>
<thead>
<tr>
<th></th>
<th>b</th>
<th></th>
<th>g</th>
<th></th>
<th>k</th>
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<tr>
<td></td>
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<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
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<td>SD</td>
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<tr>
<td>Bi. (Exp 1)</td>
<td>0.41</td>
<td>0.17</td>
<td>0.53</td>
<td>0.18</td>
<td>0.47</td>
<td>0.12</td>
<td>0.48</td>
<td>0.19</td>
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<tr>
<td>Mono. (Exp 1)</td>
<td>0.42</td>
<td>0.17</td>
<td>0.52</td>
<td>0.16</td>
<td>0.48</td>
<td>0.14</td>
<td>0.4</td>
<td>0.16</td>
</tr>
<tr>
<td>Bi. (Exp 2)</td>
<td>0.42</td>
<td>0.12</td>
<td>0.55</td>
<td>0.11</td>
<td>0.57</td>
<td>0.19</td>
<td>0.49</td>
<td>0.15</td>
</tr>
</tbody>
</table>

4.3 Discussion of experiment 2

When not presented with a code-switch story before the experiment proper, German-English bilingual children patterned similar to the monolingual German-speaking children tested in Experiment 1. The results suggest that rather than combining cohorts from both languages, children restricted cohort activation to the language of input, the L1 German, and did not activate the phonological cohorts of the non-target language, the L2 English, during word recognition. These results qualify previous findings on language co-activation, suggesting there are limits to the extent of language co-activation and that perhaps only closely related words, but not entire cohorts, are co-activated. Importantly, children were tested in a bilingual preschool environment, which should have placed them in a bilingual testing mode (Grosjean, 1988). Because the wider language environment is German, however, the L2 English cohort may be active to a weaker extent, so that testing in the L1 did not reveal cohort co-activation.

5. General discussion

Previous bilingual work has provided strong support for the idea that both languages are active even when only one language is in use. While only a few studies exist to date, recent work with bilingual children has demonstrated a similar permeability to the emerging bilingual language system. The present experiments aimed to expand this area of inquiry by addressing the extent to which both languages are activated and whether lexical co-activation can be constrained. Experiment 1 showed that monolingual German children were sensitive to the German distribution of cohorts under the current experimental conditions, which included a code-switch story before the experiment proper. Hearing a member of a large cohort (in this study, [b]) interfered with...
target recognition of a word from the same cohort. This is expected if activating members from a large cohort increases the search field of potential lexical candidates during word recognition, making it more difficult to hone in on the appropriate word (e.g., Luce & Pisoni, 1998). Hearing a member of a small cohort (in this study, [p]) facilitated subsequent target recognition of a word from the same cohort. According to the Cohort Model, this is because activation of the small cohort boosts activation of other members in the cohort, easing lexical access of the target word after hearing the prime.

In contrast to the monolinguals, the bilingual children of Experiment 1 showed neither facilitation nor interference effects for the [p] cohort, suggesting that they were not sensitive to a German cohort distribution nor a combined German-English [p] cohort. This non-significant [p] result for the bilingual children of Experiment 1 suggests that compared to monolingual German children, bilinguals exposed to the code-switch story experienced a shift in their cohort distribution such that pre-lexical facilitative effects and lexical competitive effects cancelled each other out. Results from Experiment 2 confirmed that in the absence of the code-switch story, bilingual children from the same sample show cohort sensitivity analogous to German monolingual children. Taken together, the results from Experiments 1 and 2 indicate that for bilingual children from this sample, the extent of L2 activation can be constrained so that the L2 English is only minimally active during L1 German processing. Only when L2 activation is enhanced through a previous code-switch story does the overall cohort sensitivity begin to shift.

In the present study, the experimenter always addressed the children in their L2 (English). It is interesting to note that not only the code-switch story but also speaking English to the bilingual children before test should in theory make it more likely that the children activate both languages (i.e., are in a bilingual mode). With the experimenter speaking English and the test being German, there is a real language switch; thus, children might tune into one language. Our results suggest that the code-switching story was more effective than the experimenter speaking (only) English, perhaps because code-switching is inherently bilingual and therefore better supports co-activation.

The current results extend the limited body of research on bilingual children and language co-activation while also supporting previous findings in the adult bilingual literature (Elston-Güttler, Gunter, & Kotz, 2005). The present results suggest a flexible access to the language system that can adapt to a given linguistic context. Evidence at the sentence level with adults has shown that lexical access can be modulated at least to some extent by speaker accent and sentence context, reducing, but not eliminating, cross-language activation (e.g., Lagrou, Hartsuiker, & Duyck, 2013; see also Ju & Luce, 2004; Weber & Cutler, 2004). Our results suggest that the experimental settings similarly affect the relative lexical activation level of both languages. Under monolingual settings, the experimental environment acts to constrain activation of the non-target language. When the experimental settings emphasize the relevance of both languages,
we see a pattern of results suggestive of broader language co-activation that encompasses the phonological cohorts of both languages.

This possibility is in-line with recent proposals, such as the Adaptive Control Hypothesis (ACH, Green & Abutalebi, 2013), which emphasizes interactional context with differing demands on control processes. While the ACH focuses on predictions for language production, it is a hypothesis based on conversational interaction and thus suitable to explain the present findings. Bilinguals increase cognitive control depending on their linguistic context so that control processes adapt to situational demands. Under this proposal, Green and Abutalebi contrast three interactional levels: (1) single-language, (2) dual-language, and (3) dense code-switching. Each context of language use increases demands on a subset of 7 identified control processes: goal maintenance, interference control, cue detection, selective response inhibition, task disengagement, task engagement, and opportunistic planning. A dual-language situation, for instance, requires recurrent interference control and goal maintenance that subsequently lead to adaptive changes on a behavioral and neural level.

Our data also provide evidence for important constraints to the extent of lexical co-activation. With respect to the scope of activation, previous research with bilingual children has shown co-activation to the lexical level, encompassing cognates and rhyme words (Poarch & Van Hell, 2012; Von Holzen & Mani, 2012). Our results suggest that unless influenced by environmental conditions, bilingual children’s activation of both languages does not extend to entire cohorts. That is, hearing a word in one language does not necessarily co-activate words from the same cohort in the other language, at least when the dominant (L1) is in use. This finding is important, because limiting the number of co-activated words would decrease sources of cross-language competition that would subsequently need to be resolved. For bilinguals operating under single language settings, the cognitive demands of negotiating co-activated languages could thus be greatly reduced. An open question is whether the linguistic context constrains non-target activation so that activation never spreads to the cross-language cohort in the first place or whether cross-language cohort activation is subsequently reactively controlled via executive control networks. On the flip side, namely under situations that enhance activation of both languages such as our code-switch story, co-activation of more words in both languages would increase potential sources of language competition, placing higher demands on cognitive resources to resolve competition.

An alternative explanation for why cross-language cohort effects may be tenuous, particularly without a testing context that encourages co-activation, is because the bilingual children had not developed a large enough English vocabulary. Although we used the same stimuli in Experiments 1 and 2, and all items were designated as typically known by an early age (18-month-olds according to the FRAKIS), it is possible that children had not yet reached a critical English vocabulary size to show competitive effects of the English cohort. Monolingual work supports the idea that children need to have reached a critical vocabulary size for lexical interference and
cohort effects to emerge. Mani and Plunkett (2010), using a comparable experimental paradigm to Mani and Plunkett (2011), showed facilitation rather than interference effects and no cohort effects for 18-month-old infants. They point to converging evidence from studies on semantic priming to argue for a developmental change in the emerging lexical structure in which organization moves from lexical islands to a lexico-semantic network as a child’s vocabulary increases. In smaller vocabularies, there may not be enough words to activate a strong enough competitive environment that would show effects of interference. Consistent with this idea, Mayor and Plunkett (2014) apply the TRACE model of word recognition (McClelland & Elman, 1986) to provide converging evidence from computational modeling for age-related differences in infant spoken word recognition patterns. Specifically, they were able to account for effects of vocabulary growth and cohort competition on phoneme perception. With increasing lexicon size, particularly at the age of the vocabulary spurt (18–21 months), the pool of potential competitors and by extension cohort competitors increases dramatically (see also evidence from bilingual language production in children by Poarch & Van Hell, 2012). In future work, it will therefore be crucial to test older children with longer bilingual immersion and larger lexicons in both languages.

While previous studies have identified cross-language activation in children, based on the present results, this co-activation does not appear to extend to entire language cohorts, at least not under all testing environments. By the time activation spreads to the non-target language, the intended language may have been selected, in effect shutting down further activation of the non-target language cohort. Such a possibility is most parsimonious with bilingual models such as BLINCS (Shook & Marian, 2013), which can simulate bilingual speech comprehension and captures the co-activation of cross-linguistic stimuli such as words that share phonological onset. When the model was presented with phonological stimuli, words from both languages became active, such as the English word road and the Spanish word ropa (meaning clothes). Within language, words with denser neighborhoods (i.e., words that differ from each other by only one letter like pill and pull) were activated more slowly and faced greater competition than words with sparser neighborhoods. These previous findings suggest that BLINCS could account for the present results as well. Future simulations will need to test cohort sizes across languages directly. It should be noted that the present interpretation moves from an assumption that the underlying language system is fundamentally permeable (cf. e.g., Kroll, Bobb, & Wodniecka, 2006), but can under certain circumstances limit the extent of such cross-language activation. Other models such as the bilingual model of lexical access (BIMOLA; Grosjean, 1988) do not share this assumption. Instead, two separate but interconnected language networks make up the bilingual lexicon. The present results cannot adjudicate between these alternatives but suggest, regardless of the language architecture, that language co-activation in early development can be constrained to one language cohort alone.
While the present study appears to have captured a shift in cohort sensitivity in response to a top-down cue (i.e., the experimental setting), future work using other methods sensitive to the time-course of processing such as event-related potentials (ERPs) may be able to document this change more concretely. Like Elston-Güttler et al., bilingual children should also be tested on their L2, which may increase the likelihood of cohort activation across languages. In this respect the present study’s approach to design was conservative, aiming to test children in their dominant language (German), which is known to make effects of language co-activation more difficult to observe (e.g., Weber & Cutler, 2004).

6. Conclusion

Our results underscore developing bilinguals’ sensitivity to their immediate discourse environment, suggesting the ability for in-the-moment adaptation and a high level of mental agility. By testing a young population of bilinguals, we show that this cognitive flexibility is evident at early stages of language development. By testing phonological cohorts, the current data also provide a further avenue for investigating the scope of lexical co-activation in bilinguals. Future work will need to consider different age groups and modalities in order to clarify the extent of language co-activation and its modulation under diverse linguistic and interactional contexts. While the implications for cognitive control discussed here have been necessarily speculative, our results point to exciting possibilities for exploring the cognitive consequences of a highly permeable and interactive language system.

References


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Appendix A

<table>
<thead>
<tr>
<th>Kohorte</th>
<th>Related Prime</th>
<th>Unrelated Prime</th>
<th>Target</th>
<th>Distractor</th>
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<td>a_1 g</td>
<td>Geschichte</td>
<td>f story</td>
<td>Katze</td>
<td>f playdough</td>
</tr>
<tr>
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<td>f garage</td>
<td>Bahn</td>
<td>f train</td>
</tr>
<tr>
<td>a_3 g</td>
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<td>m garden</td>
<td>Pappo</td>
<td>m battsy</td>
</tr>
<tr>
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<td>Papier</td>
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<td>Bild</td>
<td>n picture</td>
</tr>
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<td>m basket</td>
<td>Bissen</td>
<td>m broom</td>
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<td>Polizei</td>
<td>f police</td>
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<td>liecher</td>
<td>m cup</td>
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<td>m cup</td>
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<td>f garage</td>
</tr>
<tr>
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<td>Bissen</td>
<td>m broom</td>
<td>Korb</td>
<td>m basket</td>
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m = männlich
f = weiblich
n = neutral

Appendix B

<table>
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<tr>
<th>Kohorte</th>
<th>Auditory Naming</th>
<th>Visual Target</th>
<th>Visual Distractor</th>
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<td>n donkey</td>
</tr>
<tr>
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<td>glove</td>
<td>Handschuh</td>
<td>m spade</td>
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<td>Weintrauben</td>
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</tr>
<tr>
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<td>biscuit</td>
<td>Keks</td>
<td>m door</td>
</tr>
</tbody>
</table>

m = männlich
f = weiblich
n = neutral
Appendix C

Das ist Lynn. Sie ist very friendly und always has gute Laune.

Sie lives in a blue house am Rande der Stadt.

Today ist ein wunderschöner Tag. Lynn steht früh auf. She is excited und freut sich sehr.

Denn today ist ein besonderer Tag. Es ist her birthday. Sie wird five years old.

Sie hatte viele Wünsche for her birthday. Lynn hat sich a real horse gewünscht. But this is leider nicht possible. Dafür haben sie at home zu wenig Platz.

Als Lynn in the morning die Kerzen auspustet, singen her parents ihr ein tolles birthday song. They tell her. dass sie nach dem Frühstück einen Ausflug machen werden. Aber sie verraten nicht, where they are going to take her.

Lynn cannot wait for her surprise weil sie sehr gespannt ist und sich so sehr freut. Sie beeilt sich with breakfast. damit sie schnell los fahren können.
Dann ist es endlich soweit. Her parents holten the bicycles. Zusammen machen sie sich auf den Weg und they ride through a forest and pass many Wiesen und Felder. Lynn überlegt die ganze Zeit, what the surprise for her could be about.

When her parents tell her, dass sie hinter der nächsten Kurve endlich an ihrem Ziel ankommen, klopft her heart vor lauter Glück very fast. Lynn rides her bike so schnell wie noch nie. Sie rast um die Kurve und steht suddenly in the center of a big Reiterhof. Überall stehen beautiful horses, auf denen man reiten darf.

When her parents arrive, nehmen sie Lynn in den Arm. Sie sagen ihr, dass she may choose a horse, auf dem sie fue whole afternoon reiten kann.

Lynn hüpfst vor Freude in die Luft. Sie klopscht her hands, weil sie so happy ist. Es ist die tollste Geburtstagsüberraschung, she could think of!

Lynn sucht sich the most beautiful Pferd von allen aus – es sieht aus exactly the way the horse of her dreams looks like. Sie reitet darauf bis es abends dunkel wird. Dann erst fahren Lynn und ihre Eltern back home.

At night, als Lynn in ihrem Bett liegt, ist sie von dem exciting Ausflug ganz müde. Tonight she will surely dream of the beautiful horse, auf dem sie heute geritten ist…