BALANCING BILINGUALS: LEXICAL-SEMANTIC PRODUCTION AND COGNITIVE PROCESSING IN CHILDREN LEARNING SPANISH AND ENGLISH

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Abstract

The present study investigated developmental changes in lexical production skills in early sequential bilinguals, in both Spanish (L1) and English (L2), exploring the effects of age, years of experience and basic-level cognitive processing (specifically the ability to resist interference) within a timed picture-naming task. To assess resistance to interference, naming was compared in low-competition (blocked-single language) vs high-competition (mixed-alternating language) conditions. Participants were 100 individuals, 20 at each of five different age levels (5-7, 8-10, 11-13, 14-16 years & young adults). All had learned Spanish as a first language in the home, with formal English experience beginning at 5 years. Gains were made in both languages across age. However, there was a developmental cross-over from Spanish dominance in the youngest children, through a period of relatively balanced Spanish and English skills in middle childhood, culminating in a clear pattern of English dominance among adolescents and young adults. Although all groups experienced a greater slowing of response times in the mixed-language condition relative to the blocked-language condition, developmental changes in the pattern of speed-accuracy trade-offs in the mixed condition can be interpreted to reflect a change in the ability to resist cognitive interference during word production.

The vast majority of studies of early sequential bilingualism (that is, second-language acquisition beyond the preschool years but prior to adolescence) have profiled the development of linguistic knowledge in the second language (L2), largely ignoring skills in the first language (L1). To date, there has been little systematic research looking at the acquisition and maintenance of basic-level processing skills in *both* the languages of normally developing bilinguals. In the current study we begin to address this issue by profiling the lexical-semantic processing skills of children who learned Spanish as their L1 from birth and English as their L2 at school age. We emphasized the processing of lexical-semantic information (as indexed by response times for accurately named pictures) rather than the breadth of vocabulary knowledge (as commonly indexed by standardized measures of receptive and expressive vocabulary). This was done by using stimulus pictures representing lexical items generally present in the vocabularies of young preschool children. There is also evidence of cross-linguistic effects (e.g., inhibition and transfer) within bilingual adult speakers. Thus, it seems important to explore not only the processing of each language separately in developing bilinguals, but to also explore the effects of dual- (i.e., mixed-) language processing. The current study looks at these cross-language effects at the lexical-semantic level during a high-competition processing condition in which participants are cued to systematically alternate their responses between Spanish and English.

Recent findings in cognitive psychology have also indicated a critical role for basic-level inhibitory processes in nonlinguistic child development (e.g., Dempster, 1993; Harnishfeger, 1995). The development of inhibitory control allows the individual to resist interference from internal and external competitors, to ignore extraneous information (consciously or sub-consciously) and to activate target information to achieve and maintain adequate skill performance. To our knowledge, the development of these basic cognitive processes as they interact with bilingual development has not yet been explored. The current study, then, has two primary purposes: (1) to profile the lexical-semantic production skills of both Spanish (L1) and English (L2) across age and years of language experience in early sequential bilinguals in single-language and mixed-language conditions and (2) to explore the effects of basic-level cognitive processing (specifically the ability to *resist interference*) on this developing linguistic performance. The literature related to these two issues will first be reviewed.

Profiling Lexical-Semantic Skills in Bilingual Adults and Children

Timed Picture Naming as a Lexical-Semantic Measuring Tool

Picture naming has long been used with children and adults in both educational and clinical settings to investigate lexical-semantic knowledge. Picture naming in experimental studies is used as a means of tapping into the cognitive operations underlying the lexical-conceptual systems (Glaser, 1992; Snodgrass, 1993). For a given picture, naming consists of recognizing the meaning or referent, then retrieving the verbal label from the mental lexicon (Glaser, 1992). Off-line (untimed) instruments typically use stimuli graded in difficulty which in turn yield knowledge scores relative to the specific set of items tested. These static tasks are highly experience dependent and thus subject to significant individual, cross-cultural and cross-linguistic bias. During timed (on-line) variants of the picture-naming task, the dependent variables are the response times for accurately named items. In using response times rather than simply an overall accuracy score, researchers are able to qualify and quantify performance on the basis of speed of information processing, rather than on an overall picture/word knowledge quotient. A number of factors have been identified in the monolingual experimental literature as potentially affecting both the accuracy and timing of picture-naming performance. These factors include the frequency of occurrence of the picture names, the age at which these words were acquired, their familiarity, and codability (i.e., the number of different names a given picture could have), the categorical distinctiveness of the word, and the degree of image agreement (i.e., the extent to which a person's image matches the picture itself) (Snodgrass & Yuditsky, 1996; also see Snodgrass 1993 for review). In contrast, the length of the word associated with the pictured object (in terms of both syllables and phonemes) has not produced a reliable effect on the speed with which pictures were named (Snodgrass & Yuditsky, 1996). This latter point becomes significant in bilingual studies when the length of familiar words may vary considerably across languages.

Bilingual researchers have found more response variability on low-frequency as opposed to high-frequency stimuli (von Studnitz & Green, 1997) and increasing name agreement for pictures as proficiency in each language increased (Goggin, Estrada, & Villarreal, 1994). To our knowledge there are no available norms for Spanish-English bilingual children on a specific set of pictures. As such, stimuli for the current study were selected from a set of common pictures accurately identified in both languages by more than 85% of a bilingual (Spanish-English) adult sample in a separate timed picture-naming experiment in our laboratory (Hernandez & Kohnert, 1999). In addition, the lexical referents for 87 of the 100 pictures used in this study are included in both the English and Spanish versions of the MacArthur Communicative Development Inventory (Fenson et al., 1993; Jackson-Maldonado, Bates, & Thal, 1992) and commonly produced by children under three years of age.

Picture Naming and Lexical-Semantic Skills in Bilingual Children

To our knowledge, a single previous study has looked at timed responses for basic-level encoding skills in both languages of bilingual school-age children (Mägiste 1992). In her study, Mägiste used response times on picture- and number-naming tasks of German immigrant children learning Swedish in school to test the predictions of the critical period hypothesis for L2 acquisition (e.g., Johnson & Newport, 1989). Mägiste's results indicated that elementary school children achieved a "balanced form of bilingualism" two years earlier than high school students at the same stage of L2 learning, on the same picture-naming task. These results were interpreted as supporting the critical period hypothesis for second-language acquisition. Interestingly, the published data also showed that, after several years of residence in Sweden, both groups of children showed faster response times on the picture-naming task in L2 than in L1. Although this L1/L2 trade-off was not the focus of the study, Mägiste's data clearly showed that "balanced bilingualism" was simply a point in time, and that the L2 did have a clear impact on lexical-semantic processing in L1. The single-language (blocked) task in the current study will expand on these preliminary data, looking at developmental change in the temporal microstructure (fluency as measured in speed of access) of lexical-semantic processing in children who are learning English as a second language. In contrast to the Mägiste study, the age of acquisition and context of L1 and L2 learning was consistent for all individuals across the five age groups represented in our experimental sample. That is, our interest was in L1/L2 cognitive-linguistic interplay and not in critical period effects, *per se*.

In addition to looking at relative access time for specific lexical-semantic information in each of the bilingual's languages, it is important to consider how this representational system is regulated and controlled during mixed-language production tasks (e.g., Green, 1993; von Studnitz & Green, 1997). That is, how do a bilingual's languages come together during real-time production tasks, including tasks that involve a code switch (i.e., a shift from one language to the other in midstream)? What are the costs of inhibiting one of a speaker's languages when engaged in single-language-processing tasks?

Mixed-language Processing in Bilingual Adults, and Theoretical Perspectives

Current bilingual theories fall into two general categories: those that view the underlying linguistic representation in bilinguals as either *fractionated* or *wholistic*. The fractionated view considers the bilingual to be essentially two monolinguals in one person. That is, the bilingual is believed to have two separate and isolated language competencies which are similar to those of monolinguals in each language. The ability of fluent bilinguals to effectively "switch off" the unneeded language to communicate fluently with monolinguals supports this separate-systems hypothesis. In contrast, the wholistic view of bilingualism claims that the two (or more) languages coexist and interact within a single representational system. This cross-linguistic interplay thus produces a unique and specific speaker-hearer who may not be comparable to monolinguals across linguistic processing levels in either of his languages.

Support for this interactive view comes from the bilinguals' ability to code-switch during communicative interactions.

A substantial amount of research has looked at this issue of separate vs. interactive language systems in bilingual adults (e.g., see Keatley, 1992 and Kroll & de Groot, 1997 for reviews). Empirical findings of cross-language transfer effects during automatic processing tasks (e.g., facilitation or inhibition effects across languages in bilinguals, similar to the effects found within a single language) would support a wholistic account of bilingualism. In contrast, if studies failed to find such cross-linguistic interaction during automatic processing tasks, the notion of separate, independent linguistic systems would be upheld (Grainger & Beauvillain, 1988). Considerable support has, in fact, been found for cross-linguistic interference and facilitation during lexical processing tasks in adult bilinguals (e.g., Altarriba, 1992; Fox, 1996; Hernandez, Bates, & Avila, 1996; Hernandez & Kohnert, 1999; von Studnitz & Green, 1997). However, a number of studies have also failed to find such cross-linguistic effects (de Groot & Nas, 1991; Grainger & Beauvillain, 1988). Methodological concerns specifically related to the complexities of bilingual research have been implicated as a likely cause for these equivocal findings (Grosjean, 1998).

The wholistic view of bilingualism falls within the more general theoretical framework of language processing referred to as interactive activation, or functionalism. An interactive-activation approach to language processing explores the roles of general cognitive mechanisms (e.g., attention, perception, memory, emotion) in language learning and performance (Bates & MacWhinney, 1989; MacWhinney, 1997; Segalowitz, 1997). The general underlying idea is that cognition and language are linked at some very fundamental level and that, in fact, specific linguistic functions are acquired and maintained through the application of the more general cognitive processes. Interactive-activation models view bilingualism as a dynamic system in which there is constant interplay between the languages (both positive and negative transfer, as well as some competition for resources). This general theoretical framework views bilingualism as a matter of degree, with relative levels of L1 and L2 proficiency potentially shifting across the lifespan as a function of both social and cognitive influences. This highly interactive perspective emphasizes change and plasticity over time, in direct contrast to static typologies of bilingualism (consistent with modular notions of language and strict notions of critical periods for L2 acquisition). The current study was developed within a general interactive-activation account of language, extending the bilingual-specific view of wholistic language processing to early sequential bilinguals.

In extending both the theoretical claims of the interactive-activation accounts and the experimental paradigms looking at cross-linguistic interference in bilingual children across a wide age range, we must also consider the potential role of developing cognitive skills. With respect to mixed-language processing in the developing child, the role of cross-language inhibition can be placed within a broader framework of cognitive skill development. The next section will review the developmental literature relevant to one posited cognitive primitive of attentional inhibition, specifically the ability to *resist interference.*

Cognitive Development: Resisting Interference

The ability to *resist interference* is part of a family of inhibitory processes (as opposed to a unitary con-struct) which form the core of several contemporary theories of cognitive development (e.g., see Dempster & Brainerd, 1995; Harnishfeger, 1995). Harnishfeger defines the cognitive concept of interference as a "central processing by-product that disrupts efficient processing" (1995, p. 180). Interference results from the cognitive competition among multiple stimuli, processes or responses. Empirical measures of this interference include decrements in speed of access (comprehension), speed of response (production), and dual-task processing. Interference disrupts efficient processing because it produces bottlenecks during which selection procedures must isolate the processes that will be executed, and the response that will be produced. In the current study, the dual-language (mixed) picture-naming task involves a highly competitive response condition. This mixed condition requires the participants to resist both within- and cross-language lexical competitors as they are alternately cued to name pictures in either Spanish or English. Interference would result in both increased errors and a general slowing across response times in the dual-language (mixed) condition relative to the single-language (blocked) production condition.

The ability to resist interference (that is, to maintain processing efficiency on a given task despite a highly competitive context) improves over childhood (Brainerd & Reyna, 1989; see also Harnishfeger, 1995). The concepts of resistance to interference and inhibition play a critical role in limited-resource models of developmental changes in children's cognitive processing (e.g., Case, 1985). These theoretical models postulate that the limited pool of cognitive resources available for the execution of mental operations and for the storage of information does not increase with age. The improvements in cognitive performance seen across development (e.g., as in memory span performance) are instead due to increases in the efficiency with which these processes are executed (Harnishfeger, 1995). That is, these limited-resource models propose that increases in processing speed or efficiency are the causal agents of improvements in cognitive functioning across development, given stable mental capacity. Children's relative inhibitory inefficiency is thus seen as "a pattern of immature cognition that is characterized by susceptibility to interference" (Harnishfeger, 1995, p. 178; cf. Brainerd & Dempster, 1993; cf. Dempster, 1993).

Thus, in addition to profiling the lexical-semantic production skills in both Spanish (L1) and English (L2) across age and years of language experience in early sequential bilinguals, a secondary purpose of the current study was to explore the effects of basic-level cognitive processing (specifically the ability to *resist interference)* on lexical-semantic production in developing bilinguals. The present research applied a cued picture-naming paradigm in low- and high-response competition con-ditions. In the low-response competition condition (language blocked), participants were auditorily cued to name a series of pictures depicting common objects in either Spanish *or* English. In the high-competition response condition (language mixed) participants were cued to name a series of pictures depicting common objects *alternating* between Spanish and English on every second stimulus presentation.

The following research hypotheses were formulated within a general interactive-activation account of language, extending the bilingual specific view of wholistic language processing to early sequential bilinguals. Given the lack of information in basic-level language processing in children who are developing two language systems, coupled with the diverse findings in the bilingual adult literature, it would be premature to directly test competing hypotheses related to theoretical models of lexical representation. As such, the current study is considered exploratory, with predictions formulated within an interactive framework of cognitive-linguistic processing in bilinguals, based on empirical findings in the cognitive development and adult bilingual processing literatures. With respect to the forementioned experimental paradigm we anticipate that:

1. Error rates for picture-naming and response latencies for accurately named items would be reduced across age in both languages, indicating an overall effect of development. This is consistent with empirical findings of naming in the monolingual literature (e.g., see German, 1994 for review).
2. This overall improved fluency across age in lexical-semantic production (as measured by increased accuracy and faster responses) would be more marked in English than in Spanish, reflecting the influence of the formal educational environment and changing patterns of relative use across the two languages (consistent with Mägiste, 1992).
3. The youngest participants (5-7 years) would be faster and more accurate in their responses in Spanish and the adolescents and young adults would be faster and more accurate in their responses in English. We anticipated that the cross-over point would be either in the 8-10- or 11-13-year-old groups. These predictions were based on the relative amount of use of each language as a function of the shifting primary spheres of influence (i.e., home or school) across the age levels tested.
4. Errors in the mixed condition would be greater than in the blocked condition for the youngest participants, as a result of the interference imposed by the mixed condition. We anticipated that accuracy would be maintained in the older two groups (14-16-year-olds and College age) as a function of increased ability to resist lexical interference across development.
5. Response times for accurately named items would be slower for all age groups in the mixed relative to the blocked condition. It was unclear how the nature of the performance trade-offs would change as a function of age (and developing cognitive processing resources) or as a function of increasing language proficiency.

Method

Subjects

A total of 100 individuals participated in the current study, 20 at each of the following age levels: 5-7 years; 8-10 years; 11-13 years; 14-16 years and young adults (18-22 years). All participants were from Spanish-speaking families (caregivers reported Spanish to be their primary or sole language) and began the systematic learning of English as a second language in school in the U.S., between 4 and 6 years of age. All participants resided in the U.S., however, and exposure to English prior to beginning formal education (e.g., via television, older siblings, community professionals etc.) was present. Both child and young adult participants lived in large cities in Southern California, were from working-class socioeconomic backgrounds, and were of Mexican-American descent.

Parents of the 5–16-year-old children completed a language and developmental screening questionnaire and participated in a brief interview to clarify their responses. Children with a history of language, developmental, learning, behavioral delays/disorders, or suspected neurological deficits as indicated by parental report or poor academic performance were excluded from the study. The experimental results of 12 children were excluded from subsequent analyses due to parental concerns with reading or verbal language skills, attentional abilities or academic performance (even though none of these children had received services related to these areas). In addition, all children passed a pure-tone hearing screening at 25 dB HL (ANSI, 1989) at 1000, 2000, and 4000 Hz. Children were compensated $5.00 for their participation. The young adult participants (n = 20) were recruited from UCSB and were given course credit or paid $5.00 for their participation. These students completed health and language history questionnaires. General exclusion criteria included left-handedness, a history of speech, language, or hearing deficits, and proficiency or prolonged exposure to languages other than those tested. Table 1 provides a summary of participant information for each age group.

Materials and Experimental Design

The experiment included a total of 100 test trials in three conditions: Blocked-Spanish, Blocked-English, and Mixed-Spanish & English. A trial consisted of naming a picture presented on a computer screen in the language indicated by a simultaneous auditory cue. Pictures were randomized across conditions and participants saw each picture only one time. The Spanish blocked and English blocked trials were counterbalanced, but always preceded the mixed condition. Each blocked condition consisted of 25 items and 5 practice trials. Participants were cued to name the picture in English ("say") or Spanish ("diga") in these single-language conditions. The mixed condition consisted of 50 trials preceded by 10 practice pictures. Participants were cued to name the pictured items in Spanish or English (with "say" or "diga"), alternating languages on every third trial.

A total of 100 black line-drawn test pictures (as well as an additional practice set) of common nouns were used (Abbate & LaChapelle, 1979; Snodgrass & Vanderwart, 1980). Examples of pictured stimuli are "shoe", "key", "hand", "moon", "bed" and "cat". These pictures were chosen as the best candidates based on a previous series of picture-naming studies done on Spanish-English bilinguals in our research center (i.e., pictures were accurately named in both languages by >85% of subjects) (Hernandez & Kohnert, 1999). All pictures were optically scanned, edited, and presented as black-on-white line drawings appearing on a 12.1-inch monitor placed approximately 12 inches in front of each subject. The microphone was connected to a Carnegie Mellon University button box to record the timing of responses. The picture stimuli were presented on a Macintosh 3400c Powerbook computer using the PsyScope experimental shell from Carnegie Mellon University (Cohen, MacWhinney, Flatt, & Provost, 1993). The auditory cues ("say" for English trials, "diga" for Spanish trials) were recorded by a fluent male speaker into a Sony Digital Audio Tape recorder in a soundproof booth. The auditory cues were then digitized at 16-bit, 22k sampling rate using the SoundEdit 16 software package.

Procedures

All children (n = 80) were tested individually in their homes. The young adults (n = 20) were tested individually in the bilingual psycholinguistic laboratory at UCSB. Participants were fitted with a microphone and bilateral earphones set and seated in front of the computer screen. They were instructed to name the pictured items as quickly as possible in the language indicated by the simultaneous auditory prompt (e.g., "say" or "diga"). The volume of the auditory cue was adjusted to a comfortable loudness for each participant. The trial presentations were examiner paced with short breaks between each of the blocked and mixed conditions. A trained research assistant was present throughout each session to record production errors, hesitations, as well as the occasional failure of the microphone to detect accurately named items. Error responses were eliminated from the RT analyses. Each session was also tape-recorded for independent verification of the accuracy scoring.

Data Analysis

Response times (in milliseconds) were analyzed only for those items that were accurately named. A response was counted as correct if it was produced without audible hesitation in the target language and if it corresponded to either the dominant name of the picture or was an appropriate synonym/dialectal variation of the item (e.g., in Spanish, "cabello" and "pelo" were both correct responses for the target "hair"; in English "plane" was accepted for "airplane"). Items scored as incorrect and therefore eliminated from subsequent response time analysis included (1) "no responses" within the pre-set four-second response window; (2) audible hesitations (such as "uh", "um" or "ra-rabbit") causing a false trigger of the voice key ; (3) translation errors (e.g., a picture named in English that was cued in Spanish and (4) "within-language" errors such as superordinate names (e.g., "bird" instead of "duck" or "clothes" instead of "shirt"). Correct responses which failed to trigger the timing device were less than three percent of the total.

The data from both dependent variables (percent correct and reaction times) were entered into separate mixed analyses of variance using group age as the between-subjects variable, and language (Spanish or English) and condition (Blocked or Mixed) as the within-subjects variables. Separate analyses were done within each group to look at the effect of target language and condition on RTs and error rates. In order to further explore the effects of language and context across development, pairwise comparisons (using Bonferroni correction with $p < .05$) were done between sequential age groups. All analyses were done using the JMP statistical software package (JMP, SAS Institute, 1996).

Results

There were two primary purposes of the current study. The first was to investigate developmental changes in basic-level lexical-semantic encoding skills in both L1 and L2 in early sequential bilinguals (during language-blocked picture naming). The second was to explore the effects of cognitive resource control (specifically the ability to resist internal linguistic interference) on lexical production as a function of age and language fluency in these normally developing bilinguals (during language-mixed picture naming). Results relevant to these two purposes are presented first looking *between* age groups, and then *within* the respective age groups. All pairwise comparisons reported were done using the Bonferroni correction ($p < .05$) to control for Type I errors.

Overall Age Effects for Language and Condition

Accuracy

In the correct naming of pictured objects, gains were made in both languages across age with overall increases greater in English (mean gain from oldest to youngest = 67%) than in Spanish (mean gain from oldest to youngest = 27%). The error rate in the youngest group was high (e.g., 40% in the Spanish blocked condition), despite the fact that these items depict relatively common objects. This error rate decreased substantially across age (e.g., to a low of 4% in English in the College age group). The high error rate in the youngest participants was likely due, at least in part, to the time pressure imposed in this speeded-response experimental paradigm.

Accuracy scores were entered into a 5 (group) × 2 (language) × 2 (condition) ANOVA. Results of the analysis are summarized in Table 2. There were main effects of group and condition as well as three significant interactions: group × language, group × condition and condition × language. The effect of language on accuracy, collapsed across conditions, is shown in Figure 1. A number of pairwise comparisons revealed that:

Spanish accuracy at 5-7 < [8-10 = 11-13] < 14-16 < College age
English accuracy at 5-7 < 8-10 < 11-13 < 14-16 < College age.

In Spanish, small numerical differences in accuracy between the middle groups were not reliable. In English, the between-group differences for all chronological pairwise comparisons were reliable.

The group × condition interaction effect on accuracy, collapsed across languages, is also shown in Figure 1. Between-group comparisons revealed significant differences between the youngest two groups (5-7 < 8-10) and the oldest two groups (14-16 < College) in the blocked condition. A comparison of blocked accuracy between the middle three groups showed no reliable differences. In the mixed condition, however, all between-group pairwise comparisons were significant, such that accuracy at 5-7 < 8-10 < 11-13 < 14-16 < College = 18.10. In summary, the gains made in accuracy in the single-language (blocked) condition reached a plateau in the middle childhood years. In contrast, improvements made in naming accuracy in the alternating-language (mixed) response condition continued incrementally across the age groups studied.

Response Times

Response Times were entered into a 5 (group) × 2 (language) × 2 (condition) ANOVA. The results are summarized in Table 2. There were main effects of group (reflecting a significant decrease in reaction times as a function of age), condition (reflecting slower RTs in the mixed condition) and language. In addition to these main effects, there were three significant interactions: group × condition, group × language and condition × language.

The language by group interaction reflects a cross-over similar to the one reported above for accuracy. (See Figure 2.) Overall gains were significantly greater in English (mean gain from oldest to youngest group = 367 ms) than in Spanish (mean gain = 198 ms), and the pattern changes over age groups from Spanish dominance (faster responses in Spanish) to English dominance (faster responses in English -- see below for between-language comparisons within each age level). Between-group comparisons revealed that:

Spanish RT at 5-7 > [8-10 =11-13] > 14-16 > College
English RT at 5-7 > [8-10 =11-13] > 14-16 > College

That is, for both Spanish and English, significant differences in RT were found between the two youngest groups, between the 11-13- and 14-16-year-old groups and again between the two oldest groups. There were no significant differences between the 8-10-year-old and 11-13-year-old groups in either language. Overall, there was an increase in the speed of naming across age in Spanish and English. These results paralleled the previously noted findings of improved accuracy in both languages across development.

The group by condition interaction effect on RT, collapsed across languages, is shown in Figure 2. This interaction reflects an overall improvement in the mixed-response condition from the youngest to the oldest age participants. Between-group comparisons revealed significant differences between the youngest two groups (RT at 5-7 > 8-10) and the oldest two groups (RT at 14-16 years old > College) in the blocked condition. A comparison of blocked RTs for the 8-10-year-old and 11-13-year-old groups again showed no reliable differences. In the mixed condition, however, the difference between these two groups reached significance in the opposite direction of that predicted by a simple linear developmental model. Pairwise comparisons revealed that the 11-13-year-old group was significantly *slower* than the younger (8-10-year-old) group ($F[1, 38] = 11.75$, $p = .0006$). Other significant pairwise comparisons in the mixed condition were such that RT at 5-7 > 8-10; 11-13-year-olds were slower than 14-16-year-olds, and RT at 14-16 > College. In other words, there were nonmonotonic effects on the RT variable in the mixed condition, indicating a significant slowing of responses in the 11-13-year-old group. A possible interpretation of this U-shaped effect will be discussed later.

Finally, the condition by language interaction reflects larger effects of condition within English. However, as the planned comparisons presented below will indicate, the advantages of blocked processing and the disadvantages of mixed processing underwent some interesting changes with development.

Within-Group Effects of Language and Condition

When we looked across the five age groups there was no overall language × condition × group interaction for either the accuracy or RT variable. However, there were multiple two-way interactions which warranted further statistical attention within each group (Table 2). For example, age interacted separately with each of the language and condition factors (for both the accuracy and RT measures). In order to sort out the complex patterns indicated by these multiple interactions, separate 2 (language) × 2 (condition) ANOVAs were done within each group for the accuracy and response time variables. Table 3 shows the mean percent correct for each group, separated by language and condition. Table 4 shows the mean RT for each group separately for language and condition. Significant effects of language within each age level tested are indicated for the blocked and mixed processing conditions. Results of the speed and accuracy analyses for the middle three age groups were most complex and are, therefore, also presented separately.

In the accuracy analysis for the 8-10-year-old group, there was a main effect of condition (F[1, 17] = 24.77, $p < .0001$) and a significant condition × language interaction ($F[1, 17] = 7.46$, $p = .0063$). For RT there was also a main effect of condition ($F[1, 17] = 104$, $p < .0001$) and a condition × language interaction ($F[1, 17] = 4.5$, $p = .034$). Because there was no main effect of language for this age group in either of the analyses of variance, we might infer that these children are completely balanced bilinguals. However, the two significant interactions reflect a much more complex pattern (see Tables 3 and 4), which we explored with pairwise comparisons.

If we look at these interactions from the point of view of language dominance, we find that accuracy scores were significantly higher for Spanish (78%) than English (70%) in the blocked condition; there was a slight advantage for English (66%) over Spanish (62%) in the mixed condition, but this numerical difference was not significant. Hence these 8-10-year-olds seem to be *more accurate at naming in Spanish*, but the difference is only evident under the less taxing blocked condition. However, a rather different pattern emerges from the reaction time analysis: 8-10-year-old children were significantly faster in English (1125 ms) than Spanish (1198 ms); there was a slight advantage for Spanish (1362 ms) over English (1376 ms) in the mixed condition, but this difference did not reach significance. Hence the RT analyses suggest that 8-10-year-olds are *more efficient at naming in English*, but this difference is also evident only under the less taxing blocked condition. In other words, the global impression of balanced bilingualism that emerges from Figures 1 and 2 is belied by more detailed analyses within this age group.

Some additional information is gleaned if we look at the same interactions from the point of view of processing costs (operationalized as the difference between blocked and mixed conditions). In the accuracy analyses, these 8-10-year-olds showed a significant (16%) difference between mixed and blocked conditions in Spanish, but no reliable difference (4%) between mixed and blocked in English. In the reaction time analyses, 8-10-year-olds showed a large difference (164 ms) between mixed and blocked in Spanish, but the difference was even larger (251 ms) in English. These results suggest that developmental changes are underway in these “balancing” bilinguals: greater accuracy in Spanish may be slowly giving way to greater efficiency in English.

In the accuracy analysis, there were no reliable effects of language for the 11-13-year-old children (i.e., Spanish = English). There was a reliable effect of condition on naming accuracy ($F[1, 17] = 5.582$, $p = .0182$), with more errors in the mixed than blocked condition, although here the magnitude of this effect was smaller than it was in the younger age groups. The mean difference in errors between the two conditions was just 4% (mixed 27% > blocked 23%). There were main effects of language ($F[1, 17] = 4.2265$, $p = 0.04$) and condition ($F[1, 17] = 216.43$, $p < .0001$) on the response speed variable. In comparing the mean responses across languages within each condition, however, the differences between Spanish and English were not reliable (e.g., $p = .289$ for blocked-language difference; $p = .067$ for mixed Spanish-English difference). There was an overall slowing of responses in the mixed condition, and the magnitude of this difference in RT across conditions was much greater than it was in the younger age groups. There were no significant interactions. Hence these 11-13-year-olds appear to be completely balanced across their two languages (in contrast with the complex pattern we uncovered for the 8-10-year-olds). However, the surprising developmental increase in reaction times that we observed for these preadolescents suggests that they are struggling to protect themselves against error, a point that we will take up again later on.

For the 14-16-year-old group there was a reliable difference in accuracy between the two languages ($F[1, 17] = 78.89$, $p < .0001$), with more items correctly named in English than in Spanish. There was, however, no effect of condition on naming accuracy in this 14-16-year-old age group (mean = 79.2 in blocked vs. 79.4 in mixed). That is, these adolescents were able to maintain equivalent levels of naming accuracy across both the low (i.e., blocked single language) and the high (i.e., mixed alternating language) processing conditions. The RT analysis resulted in main effects of language ($F[1, 17] = 26.37$, $p < .0001$) and condition ($F[1, 17] = 69.42$, $p < .0001$), and a language × condition interaction ($F[1, 17] = 11.02$, $p = .0009$). Cell means for the interaction are available in Table 4.

Pairwise comparisons were conducted to explore this interaction in more detail. As Table 4 shows, the interaction reflects a much larger difference between blocked and mixed conditions when participants had to name the pictures in English (214 ms) than in Spanish (92 ms). Conversely, the interaction also shows that the advantage of English over Spanish in the RT data is substantially larger in the blocked condition (155 ms) than it is in the mixed (33 ms). The fastest reaction times by far were observed in the English blocked condition (999 ms) and the slowest were observed in the Spanish mixed condition (1246 ms). Hence these adolescents seem to have completed a transition into English dominance, evident in their naming accuracy and naming speed in the blocked condition. However, the speed advantage for naming in English is minimized in the mixed condition, due perhaps to continuing interference from the early-acquired Spanish names for the same pictures.

Summary and Discussion

The present study was designed to investigate developmental change in the lexical-semantic production skills of early sequential bilinguals, in Spanish (L1) and in English (L2), and to explore the effects of basic-level cognitive processing (specifically the ability to resist interference) on word production as a skill system (including both accuracy and reaction times). A low-competition (blocked single language) vs. high-competition (mixed alternating languages) cued picture-naming paradigm was used. For all study participants, Spanish was the primary home language with formal experience in English beginning at school age.

Development

Across the 5-20-year age range studied here, we observed an increase in picture-naming accuracy, accompanied by an increase in fluency (i.e., decreased latencies to name pictures) in both English and Spanish. Our finding for accuracy is consistent with previous studies with both monolingual English-speaking children (e.g., see German, 1994 for review) and bilingual Swedish-German children (Mägiste, 1992), but we have added new information about developmental changes in processing efficiency. The task and stimuli used in the current study emphasized lexical-semantic *processing* by measuring access to names of pictures depicting very common nouns (as opposed to emphasizing *experience*, typically assessed by measuring how many low-frequency or total words are known in each language). To assure that our results would reflect processing dynamics rather than knowledge of picture names, we used items that are usually within the vocabulary of monolingual English- and Spanish-speaking children by 3-4 years of age. Nevertheless, the error rates observed with these pictures were very high in the youngest (5-7-year-old) age group. This result is likely to be driven by the speeded nature of the experimental task, although substantial differences in knowledge related to the pictured items across age cannot be ruled out.

We want to underscore that gains were made in both Spanish and English across the period studied, and there were no absolute performance decrements in L1 as a function of improving skills in L2. This improved performance across age was, however, greater in English than in Spanish on both dependent variables measured, reflecting a developmental cross-over from Spanish to English dominance -- which brings us to the next point.

L1/L2 Proficiency

The combined findings of within- and between-group cross-language comparisons revealed a shift in relative language dominance from L1 to L2 (as indexed by response times and percent accuracy in picture naming) over the years studied. The youngest children in the study were Spanish dominant (i.e., faster and more accurate in Spanish than in English). At the time of testing they had, on average, 1.5 years of formal experience with English. The next two age groups in this study (8-10-year-olds and 11-13-year-olds) were more balanced in their lexical fluency, although with interesting exceptions as a function of language, response context (mixed vs. blocked) and dependent variable (accuracy vs. reaction time). Hence this period of middle childhood should be viewed not as a static phase of language balance, but as a transition point in a shifting developmental landscape.

Specifically, the 8-10-year-old group (who had on average 4.3 years of formal experience with English at the time of testing) showed a speed advantage for naming in English in the blocked condition, although they were able to name significantly more items in Spanish. With the increased cognitive demands associated with the mixed condition, however, this pattern reversed so that English was at a relative advantage for accuracy, but now at a disadvantage for speeded access. This pattern of results reflects the instability of this age group’s dual-language system, in terms of relative Spanish-English dominance. That is, they are balancing their cross-linguistic performance with different strengths emerging depending on which skills are measured. Clearly this group illustrates that bilingualism is not necessarily a steady state, particularly during development. In contrast, the 11-13-year-old group, with an average of 6.8 years of formal English experience, showed no reliable differences between their languages in terms of speed or response accuracy when results for the blocked and mixed conditions were analyzed separately. Hence their responses appear to reflect a true balancing point on this measure of lexical-semantic production. Even here, however, the cross-linguistic interaction with cognitive skills is not quite so simple. For example, with the increased demands to resist internal linguistic interference in the mixed condition (relative to single-language processing), there was a trend for accuracy to be more affected in Spanish (7% errors vs. 3% errors in English), indicating its relative advantage in the blocked naming. By contrast, the older adolescents (14-16-year-olds) and young adult groups, now with an average of 10.6 and 14.5 years of formal experience in English, respectively, were clearly stronger in English than in Spanish on this measure of lexical fluency.

In summary, on this measure of lexical-semantic production the youngest participants were more proficient in L1 (Spanish) and the oldest groups were more proficient in L2 (English). During the middle childhood years (11-13) there was a relative balancing of performance across the languages both in terms of naming accuracy and in the speed of responses. However, the balance is eventually lost in adolescence and young adulthood, as spheres of influence shift from home to school and the majority (English-speaking) culture. These results are consistent with previous research indicating a shift in relative language dominance from L1 to L2 (e.g., see Kohnert, Hernandez, & Bates, 1998). The present study adds to the literature by isolating language cross-over points with a large-scale experimental study with children, using a relatively dynamic processing- (vs knowledge-) dependent measure. It also focuses on a very basic level of linguistic processing – the retrieval, encoding, and production of common words in both languages – as well as the cognitive-linguistic skill interplay (discussed in the following section). Although, in the current study, performance in L2 did overtake that of L1, this did not happen until there had been approximately 10 years of formal experience in English. Proficiency in L2, relative to L1 performance even on this very basic-level linguistic skill did not occur until after 4.3 years of English experience for fluent access (production speed) and until 6.8 years for naming accuracy.

Mixed vs. Blocked Processing: Performance Trade-offs and the Cost of Interference

In the high- (mixed) versus low- (blocked) response competition condition used in the current study, we found significant performance decrements on naming accuracy and/or response speed within each group. There was clearly a processing cost associated with resisting linguistic interference and achieving efficient naming when participants were cued to alternate between their languages on every third trial. Although all age groups (including adults) displayed a decrement in efficiency in the mixed condition in the RT data relative to the blocked condition, the pattern across age was one of overall improvement in the ability to resist linguistic interference in achieving and maintaining naming accuracy. This finding is consistent with current models of cognitive development (e.g., Dempster 1993; Harnishfeger, 1995).

More specifically, the older adolescents (14-16 years old) and young adults (18-20 years old) were better at resisting linguistic interference in the competitive response condition than the younger age groups. Although their response latencies were higher in the mixed- relative to the blocked-language condition, they were able to maintain high levels of accuracy across conditions (with .2% and 4% difference in the number of errors across conditions for the respective groups). In contrast, performance trade-offs in the development of this cognitive skill can be clearly seen in the combined speed and accuracy responses of the 11-13-year-old group. This group began to close the gap in response accuracy across conditions (with only a 5% increase in error rates in the mixed condition compared to a 10% increase in the 8-10-year-old group); hence the magnitude of performance decrement in naming accuracy in the mixed condition was reduced in the 11-13-year-old group relative to the younger participants. However, the cost for this maintained naming accuracy was a disproportionate slowing on the response speed variable: the mean RT at 11-13 was 70 ms *greater* than RT at 8-10 years of age, and 216 ms greater than at 14-16 years. In other words, the combined RT and percent correct measures indicate a clear speed-accuracy trade-off in the 11-13-year-old group. By contrast, the two youngest groups in the study (5-7- & 8-10-year-olds) split the processing cost of the mixed condition equally across the response variables; that is, they showed reliable decreases in both naming accuracy and response speed in the mixed relative to the blocked condition. Hence the youngest children appear to sacrifice accuracy for some gain in speed. Comparing the 8-10-year-old and 11-13-year-old groups, we suggest that the overall pattern of development in the competitive (mixed) processing condition was to pay a high cost in speed in order to maintain baseline levels of accuracy. The desired pattern of efficient processing was achieved in the current study by 14-16 years of age.

In addition to splitting the cost in the mixed condition across the speed and accuracy variables as noted above, splitting the cost differentially across languages was another possibility in these developing bilinguals. The differential performance across languages and conditions in the 8-10-year-old group (as discussed in the previous section) may reflect developing cognitive skills interacting with developing bilingualism. Again, this may further indicate that the cross-language balancing point of these young sequential bilinguals is indeed fragile when the system is taxed. In summary, balancing linguistic performance across processing conditions appears to be a complex phenomenon which may interact both with development and language proficiency.

Conclusions

The present study profiled basic lexical-semantic encoding skills in both the L1 and L2 of early sequential Spanish-English bilinguals who were developing language normally. Our choice of materials for this experimental task emphasized processing abilities over more experience-dependent vocabulary knowledge. Results indicated a clear cross-over from L1 to L2 proficiency across the ages studied, albeit without an absolute decrement in L1 (i.e., this is not a case of language loss). These results provide further evidence against the widespread belief that a bilingual's *first* language (L1) remains her *best* language. This kind of language reversal (L2 > L1) has been demonstrated in other studies; our results suggest that such effects are reflected in a very basic level of processing efficiency as well as in the breadth of knowledge previously documented. The developmental shift in dominance that we have documented here cautions against overly simple assumptions about critical periods in the development of one's "mother tongue."

In addition, by varying the production conditions we were able to explore the interplay of age and the cognitive ability to resist interference. The high-competition (mixed) condition interacted with both development and the relative level of cross-linguistic proficiency (degree of balance). Results indicated that both basic-level language processing skills (i.e., picture naming in L1 and L2) and the ability to resist linguistic interference improved across development. Findings also provided an indication of what the pattern of cognitive resistance looks like in terms of performance trade-offs as a function of age.

In addition to the theoretical significance of such research, there are very practical reasons for linking basic-level linguistic processing and basic-level cognitive development into a profile of normal first- and second-language performance. Language minority children are the fastest growing segment of our school-age population. According to the 1990 census, nearly 6.3 million children between the ages of 5-17 (i.e., one of every seven children of school age in the U.S.) spoke a language other than English at home. Between 1980 and 1990, the population of language minority children of school age increased by 41.2%, while the total U.S. school enrollment declined by 4%. If current immigration and birth trends continue, shortly after the turn of the century a majority of school-age children in the U.S. will likely be early learners of English as a *second* language. From an educational perspective, our ability to serve these children is hampered by a general lack of understanding of normal early sequential bilingualism, coupled with a critical lack of research into the developmental profile of basic-level skills that underlie the metalinguistic performance emphasized in the educational system. From a clinical perspective, a better understanding of the interplay between language skills and cognitive resources in early bilinguals should make it easier to identify a breakdown in the developmental process when it occurs. The pattern of normal bilingual performance in the current study should be viewed as preliminary, however, as bilingual proficiency is variable across individuals, languages, across linguistic subsystems, and over time (e.g., Grosjean, 1994; Miller, 1988).

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Table 1. Summary of Participants in each Age Group

Group	**Female/Male**	**Age**	**Age at First Formal English Experience**	**Yrs of Formal English experience**
5–7 y.o.	9 F / 11 M	6.6 (.61)	5.1 (.48)	1.5
8–10 y.o.	8 F / 12 M	9.4 (.87)	5.1 (.52)	4.3
11–13 y.o.	10 F / 10 M	12.2 (.95)	5.3 (.47)	6.8
14–16 y.o.	13 F/ 7 M	15.8 (.94)	5.2 (.98)	10.6
College	17 F / 3 M	19.2 (1.7)	4.7 (.65)	14.5

Gender, mean age (and standard deviation) at testing, the average age of beginning formal experience with English in the U.S. school system, and the total number of years of English at the time of testing are shown for each group. All participants acquired Spanish as a first language (from birth) in the home.

Table 2. Between-Group Analysis of Variance

		F ratio	
Source	df	Accuracy	RT
Group	4	338.29***	144.35***
Language	1	.419	13.94**
Condition	1	52.54**	459.89***
Group × Language	4	49.52***	12.47***
Group × Condition	4	6.25**	16.49***
Language × Condition	1	7.64*	7.09*
Group x Language × Condition	4	1.37	2.27

Results of the 5 (group) x 2 (language) x 2 (condition) ANOVA for both accuracy and response time are shown. The number of subjects per group = 20. *p < .01, **p < .001, and ***p < .0001.

Table 3. Accuracy Scores

Age Group	*Spanish Blocked*	*English Blocked*	*Spanish Mixed*	*English Mixed*
5–7	60%	38%	46%	30%
8–10	78%	70%	62%	66%
11–13	79%	75%	72%	72%
14–16	71%	87%	71%	87%
College	87%	96%	82%	92%

Mean group percent accuracy scores for picture naming are presented for each language and condition. Standard deviations for each cell ranged from 7–9%. Significant within-group language differences are indicated ($p < .05$). There was also a significant language × condition interaction for the 8–10-year-old group with Spanish affected more than English in the mixed condition.

Table 4. <u>Response Times</u>

Age Group	*Spanish Blocked*	*English Blocked*	*Spanish Mixed*	*English Mixed*
			*	*
5–7	1307	1360	1473	1603
	(104)	(133)	(118)	(144)
	*	*		
8–10	1198	1125	1362	1376
	(86)	(90)	(95)	(93)
11–13	1148	1117	1470	1415
	(91)	(95)	(96)	(95)
	*	*		
14–16	1154	999	1246	1213
	(85)	(78)	(86)	(78)
	*	*	*	*
College	1109	983	1193	1111
	(76)	(82)	(78)	(74)

Mean group response times (and standard deviations) are presented for each language and condition. Significant within-group language differences are indicated within each condition ($p < .05$). In addition, all comparisons between the blocked and mixed conditions within each language were significant. There were language x condition interactions in the mixed condition for the 8–10-year-old and 14–16-year-old groups indicating a bigger advantage for English in the blocked condition for both groups.

Figure 1. Mean accuracy scores for each age group are shown for language (Spanish vs. English) and condition (blocked vs. mixed).

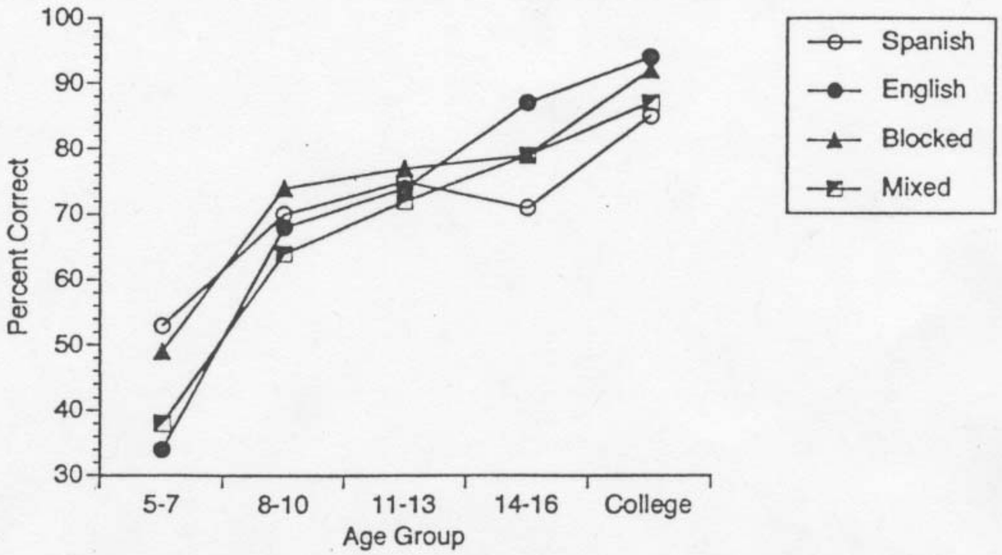

Figure 2. Mean response times for each age group are shown for language (Spanish vs. English) and condition (blocked vs. mixed).