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Aging and Language Switching in Bilinguals*

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ABSTRACT

Language switching was studied with a group of bilingual older adults (65 and older) and college-age bilinguals using a cued picture naming paradigm in a blocked (English or Spanish), unpredictable mixed (Spanish and English cues change randomly from trial to trial), and a predictable mixed condition (cues alternate between English and Spanish from trial to trial). Results revealed equivalent error rates and small differences in reaction time (RT) between older adults and college-age participants in the blocked condition. However, older adults showed much slower RTs and made significantly more errors in the mixed conditions. The results are consistent with models that predict deficiencies in task set shifting across the life span.

In recent years, researchers have investigated executive processes by exploring the nature of dynamic processing, such as participants' ability to shift in attending from one aspect of a stimulus to another aspect. Results from a series of experiments have found that older adults find task switching particularly difficult compared to college-age adults (Compton & Park, 1998; Hahn et al., 1998; Kray & Lindenberger, 1998; Salthouse, Fristoe, McGuthry, & Hambrick, in press). This is consistent with the notion that older adults show a deficit in executive processing. One particularly interesting way to look at central executive processing in switching tasks is to use bilingual participants. Bilinguals frequently have to switch from one language to another. Language switching costs have been observed in young adult bilinguals (MacNamara, Krauthammer, & Bolgar, 1968; MacNamara & Kushnir, 1971; Soares & Grosjean, 1984), suggesting that this type of switching results in costs in processing time which are very similar to those observed in task switching. However, to our knowledge potential differences in language switching between college-age and older adult bilinguals have not been investigated. The current study will investigate this issue directly. As background we will first review current theories on changes that occur in older adults with regard to task switching before proceeding to the implications of this for bilinguals.

Task Switching

Experiments typically require participants to employ a single set of cognitive operations over and over again. In the real world, however, people typically have to shift dynamically from one task or set of tasks to another. Interest in the mechanisms that are employed to control volun-

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tary shifts of attention have recently undergone a 'revival.' The first study of this nature investigated the time to process whole lists. Participants were required to perform one task or to switch between tasks. Jersild (1927) used a number of tasks, some of which resulted in switching costs and others which did not. However, Jersild was only able to calculate switch costs across entire lists (where participants see all the stimuli on a single sheet of paper).

Almost 50 years later Spector and Biederman (1976) replicated these effects by using the list method and by displaying one stimulus at a time using monolingual participants. They replicated Jersild's finding of a switch benefit between naming antonyms for words and subtracting 3 from two-digit numbers using the list method. Furthermore, they found that this benefit disappeared if participants saw one stimulus at a time. Spector and Biederman also observed switching costs between adding 3 and subtracting 3 from two-digit numbers. However, this switching cost was reduced when participants were given a retrieval cue (e.g., 57 + 3, 22 – 3). Spector and Biederman concluded that switch costs are associated with the extent to which a stimulus has a readily discriminable retrieval cue.

More recently Allport and colleagues (Allport, Styles, & Hsieh, 1994; Hsieh & Allport, 1994) looked at the cost of switching using two different tasks: naming the color of the ink or the word in a Stroop paradigm or naming the value (9,999 → response 9) or the size of a group (9,999 → response 4) of the same digit (9999) with monolingual participants. Allport found larger within-dimension switching than between-dimension switching costs. That is, participants showed more interference when having to switch between naming colors and words on a Stroop task (within-dimension switching) than between naming colors and numerical values (between-dimension switching). In addition, Allport et al. found that the size of the switching cost was larger when participants had previously engaged in the other cognitive operations involved with those stimuli. For example, switching between color naming and value naming resulted in a larger cost when participants had previously switched between word naming and group-size naming. Following this logic it was also observed that switching costs on the word naming and group-size naming was larger when participants had previously switched between color naming and value naming. Finally, Allport et al. presented two items and asked participants to perform the same task on both or to switch from one task to the other. The period between the response to the first stimulus and the presentation of the second stimulus (R-S interval) was extended from 20 to 1,100 ms with very little change in the switch cost. Allport et al. argue that these results are consistent with the view that the switching cost is due to what they call *task set inertia*. In this view, participants are suffering from interference of previously activated task commands. The more an alternative task command is active, the larger the switching cost. Furthermore, increasing the time between these tasks does not result in a reduction in the switching cost. Hence, task set inertia lasts over time (about a minute or so). This also explains why interference effects were larger when people had previously activated a competing task set in an earlier experiment.

Rogers and Monsell (1995) also performed a series of experiments which looked at reaction times (RTs) to a set of letter-number pairs in which the digit was classified as even or odd or the letter was classified as consonant or vowel in monolingual college-age participants. Rogers and Monsell did observe a reduction of switching costs as the R-S interval was increased to 600 ms, but a large asymptotic cost remained even with an R-S interval of 1,200 ms (limited only to the first trial of the new task). Rogers and Monsell argue that when the stimulus cues the switch there are no additional costs encountered. Furthermore, they suggest that their results are not compatible with the task set inertia account of Allport and colleagues. If the latter account were true, participants would be slowed beyond the first trial as the task set inertia dissipated. Note that both a task set inertia and a stimulus-cued switch account predict that switches should be slower than nonswitches. However, the stimulus-cued switch account argues that once the switch has been cued by the stimulus there is no additional switch cost, a point we will return to later in the Results section.

The task set inertia and the stimulus-cued switch account have different predictions about continued costs after the switch has been cued. Although some controversy exists about the mechanisms that are responsible for switch costs, there is converging evidence that these costs do appear. Furthermore, it has been argued that switching between tasks results in increased central executive processing (Hahn et al., 1998). These results carry two important implications. First, switching costs should be larger in populations such as older adults who have difficulty with aspects of executive control. Second, if switching between languages in proficient bilinguals taps these executive processing skills, then the documented language switching costs in younger adult bilinguals should be exacerbated in older adult bilinguals. The current paper will draw parallels between the skilled performance necessary for task switching and language switching. A brief review of these two literatures follows.

Aging and Task Switching

Evidence from recent studies is consistent with the view that switching costs increase in older adults relative to younger adults in a number of domains. These include age-related increases in switching costs when participants have to alternate between two auditory or visual channels (Braune & Wickens, 1985; Panek, Barrett, Sterns, & Alexander, 1977; Wickens, Braune, & Stokes, 1987). In addition, investigators have also observed increased switching costs for older adults on tasks such as addition and subtraction or providing antonyms and synonyms (Botwinick, Brinley, & Robbin, 1958; Brinley, 1965; Schaie, 1958). More recently Salthouse et al. (in press) asked participants to perform one task for nine trials before switching to another task. Participants were shown two digits side by side and asked to decide whether a particular digit was on the right or the left, or to press a digit key that corresponded to the sum or the difference of the two digits. Participants were also shown a single digit and asked to decide whether it was more or less than 5 or asked to decide if it was odd or even. Salthouse et al. found increased switching costs for older adults relative to younger adults. Furthermore, they found that RTs were slowest on the switch trial (i.e., trial number 10) and then dropped towards baseline on subsequent trials. Given the results reviewed, it is clear that older adults show an increase in switching costs relative to younger adults. Furthermore, it is likely that this effect is due to the increased executive processing demands of task switching.

Bilingualism and Language Switching

The nature of switching costs has also been of interest to researchers in the field of bilingual language processing. Surprisingly, the idea that bilinguals might have a switch that mediates between two languages has its genesis not in the bilingual literature but in the neurophysiological literature. Penfield and Roberts (1959) suggested that the functional separation of two languages is carried out by an automatic switch at the neurophysiological level. The aphasia literature had revealed cases of patients who showed difficulties with language mixing. However, some debate existed about the localization of the lesions that lead to language mixing difficulties (for a review see Paradis, 1983, 1995). More recent studies using functional magnetic resonance imaging have found evidence of increased activation in the dorsolateral prefrontal cortex during language switching (Hernandez, Martinez, Wong, Frank, & Buxton, 1998; Paradis, 1995). At the behavioral level, some studies revealed no effect of language switching (Dalrymple-Alford & Aamiry, 1969; Kolers, 1966) whereas others have found effects of language switching particularly in terms of speed of processing (MacNamara et al., 1968; MacNamara & Kushnir, 1971; Soares & Grosjean, 1984). Interestingly, Meuter (1993) observed that *unbalanced* bilinguals (those who were much better in one language than the other) showed more interference when switching from their nondominant to their dominant language. For balanced bilinguals (those who were equally good in both languages), however, there was no asymmetry in the effect. Hence, it appears that there are speed costs that are associated with language switching and these costs are asymmetrical for unbalanced bilinguals. Meuter argues that this is consistent with the task set inertia view discussed earlier. Specifically, performing a nondominant task involves a participant's ability to impose a task set. A weaker task set will require a stronger effort on the part of the participant and will take longer to dissipate. Hence, participants will show larger switching costs from the nondominant task to the dominant task than vice versa.

So far we have reviewed evidence which suggests that older adults show larger switching effects than college-age participants. In addition, we have reviewed evidence consistent with the notion that bilinguals show effects of language costs particularly in terms of processing speed. One of the objectives of the current study is to draw parallels between the skilled performance needed for task switching and that needed for language switching. Increased language switching costs in older adult bilinguals would provide additional evidence that language switching, like task switching, involves an executive component that is sensitive to age differences.

Hernandez (1997) conducted two experiments which looked at the nature of language switching in older adult bilinguals. In Experiment 1, participants were asked to name a visually presented word that either matched or did not match the language of an auditory sentence that preceded it (The man walked down the STREET/CALLE). Younger adults showed no reliable difference in RTs between words that matched and words that did not match the language of the sentence. However, older adults were significantly slower at naming words that did not match the language of the sentence relative to those which did match the language of the sentence. In other words, older adults showed a significant language-switching cost and college-age adults did not. In Experiment 2, participants were asked to name a visually presented target word which was preceded by an auditory sentence context. However, unlike Experiment 1 this target word was preceded by a word which was flashed briefly (200 ms). Participants were instructed to observe the first word and pronounce the second word. The sentence language and the first word were in the same language whereas the target word was in the opposite language. Furthermore, the prime and target could fit or not fit the meaning of the sentence. This was done to increase the cross-language competition, increase the language switching cost, and hence increase differences between age groups. Unlike Experiment 1, there was not an increased language switching cost across age groups in terms of RT. However, older adults showed a switching cost in errors when naming a word that did not fit the sentence context or the sentence language when it was preceded by a word which did fit the context and the language (e.g., the man was walking down the street – NARANJA, where naranja, which is orange in Spanish, is the target word). This was not true for college-age participants. These results suggest that older adults have more difficulty switching languages than college-age controls, especially when there are conflicting stimuli such as in Experiment 2. Furthermore, taken together the two experiments suggest that this cost can appear in terms of errors or in terms of RTs. The current study will explore age differences further by using picture stimuli in a language switching situation.

In addition to switching costs, bilinguals also show effects of language dominance. A number of studies in our laboratory and other laboratories have shown that early Spanish-English bilinguals who receive the majority of their education in the US become dominant in English (Altarriba, 1991, 1992; Hernandez, Bates, & Avila, 1996; Kohnert, Hernandez, & Bates, 1998). Hence, we expect this population to show faster and more accurate performance in English than in Spanish. However, it is also important to note that these participants are early bilinguals who are highly fluent in both languages.

The current experiment will use a cued picture naming paradigm to investigate the nature of language switching in college-age and older adult Spanish-English bilinguals. In this paradigm, participants are asked to name a picture in the language of a simultaneously presented auditory cue. The cue is in English (*say*) or Spanish (*diga*, which is *say* in Spanish). In the blocked condition, participants receive separate blocks of English or Spanish stimuli. In the mixed condition, participants switch between languages within the same stimulus set. There were two mixed conditions: predictable mixed in which the language of the cue alternated predictably between Spanish and English and unpredictable mixed in which the language of the cue varied between Spanish and English in a random fashion.

Our hypothesis is that the increased processing demands of the mixed-language condition will lead to a disproportionate slowing of RT in older adults or a disproportionate increase in error rates, or both, relative to college-age participants. We anticipate that differences between age groups in the blocked condition will be much smaller. Of particular interest are the differences between the predictable mixed and the unpredictable mixed conditions in older adults who are known to have difficulty with switching. Our task shares some aspects of switching tasks since participants are asked to alternate between two sets. However, it is also unique because each picture activates a verbal output in each language. To test the difference in our paradigm relative to other paradigms we used two mixed designs. In the unpredictable mixed condition, participants do not know what language has to be prepared for each trial. Hence, the unpredictable mixed condition requires participants to attend to the cue (since it varies randomly) more than the predictable mixed condition. The predictable mixed condition, on the other hand, results in a consistent pattern of switching and requires participants to switch more often but requires little attention to the cue. Using these two conditions will allow us to evaluate whether RT costs are larger when participants have to attend to the cue or when they have to switch languages.

Previous studies have found that switch trials result in an increase in RTs relative to nonswitch trials (Salthouse et al., in press). If language switching and task switching share similar cognitive operations we should observe slower RTs in the predictable mixed relative to the unpredictable mixed condition. However, we leave open the possibility that language switching differs from task switching and that attention to the cue and not the number of switches will dictate the increased RT. To further disambiguate the locus of the switch costs we will look at trial by trial analyses of the unpredictable mixed condition in order to see whether RTs are slowed for switch versus nonswitch trials. This comparison will allow us to distinguish between a task set inertia and a stimulus-cued account of switching. The task set inertia account of Allport and colleagues (Allport et al., 1994; Hsieh & Allport, 1994) would predict that switching costs will continue beyond the first trial whereas the stimulus-cued completion hypothesis of Rogers and Monsell (1995) would predict that switching costs will not. We will look at one and two trials beyond the switch to see which account is consistent with our data. In addition, we will be able to look at whether switching costs are larger from the nondominant (Spanish) to the dominant language (English) as predicted by Meuter (1993). It will be important to consider whether our results support this aspect of the task set inertia account of switching. Finally, an analysis of errors will be performed to look at within-language errors versus cross-language errors. An increase in both types of errors in the mixed condition for older adults relative to the college-age controls will suggest that the increased demands of switching result in general processing difficulty for older adults. An increase in cross-language errors only will suggest that older adults are experiencing more difficulties with switching languages. We predict that in both mixed conditions there will be difficulty with maintaining the correct language instruction in mind. This difficulty will be larger for older adults who have more difficulty with central executive processing.

METHOD

Participants

A total of 64 Spanish-English bilingual adults participated in this study. The college-age participants were 32 right-handed individuals recruited through the participant pool in the Department of Psychology at the University of California, San Diego. The mean age of the group was 21 (*SD* = 2.34). The older adult bilinguals consisted of a group of 32 right-handed individuals from the San Diego area. The mean age of the group at testing was 70.79 (*SD* = 7.22) and the average education was 12.31 (*SD* = 4.42). All of the older adult participants scored above the cutoff for dementia on the administration of the Mini-Mental Status Examination (26 correct items or higher). In terms of language proficiency, all participants rated themselves as more fluent in English than Spanish and all had learned both languages before the age of 8. Both young and older adults reported using both languages in their daily lives. The results from the Boston Naming Test (BNT) reflect the similarity in fluency levels across languages in both groups. The BNT (Kaplan, Goodglass, & Weintraub, 1983) was administered twice (once in Spanish and once in English to each participant) in order to determine whether there were differences in confrontation naming of objects across groups. The scores from the BNT were entered into a 2 (age) x 2 (language) mixed ANOVA. The results revealed a main effect of language, more pictures were named correctly in English (46.33) than in Spanish (33.10), $F = 74.48$, $p < 0.001$, $MSE = 4665.67$. The mean score for the college-age group was 46.72 in English and 31.53 in Spanish. The mean score for the older adult group was 45.94 in English and 34.66 in Spanish. There was no effect of age and no interaction between age and number of items identified in each language. The finding of low scores on the BNT in English reflects cultural and linguistic differences in Spanish and should not be regarded as evidence of neurological impairment. We have collected data using this measure from over 100 young healthy college-age bilinguals. The sample mean score for the 100 participants was 46.66 (*SD* = 6.64) in English and 32 (*SD* = 8.83) in Spanish (Kohnert et al., 1998).

Apparatus

The picture stimuli were presented on a Macintosh Quadra 660AV 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.

Design and Materials

A total of 180 black line-drawn test pictures (as well as an additional practice set) of common nouns was selected from the Snodgrass & Vanderwart (1980) standardized set and the Pictures Please articulation supplement (Abbate, 1984). All pictures were optically scanned, edited, and presented as white-on-black line drawings.

The 180 pictured test stimuli were arranged in 8 different lists and combined into four different test conditions: (a) blocked Spanish, (b) blocked English, (c) unpredictable mixed condition, and (d) predictable mixed condition. No practice or test pictures were repeated within or across conditions for any participant. Pictures were rotated so that each picture appeared in each condition across participants. Furthermore, conditions were counterbalanced such that a quarter of the participants received each of the following orders: (a) blocked Spanish, blocked English, unpredictable mixed, predictable mixed; (b) blocked English, blocked Spanish, unpredictable mixed, predictable mixed; (c) predictable mixed, unpredictable mixed, blocked English, blocked Spanish; and (d) predictable mixed, unpredictable mixed, blocked Spanish, blocked English. Across participants each of the conditions appeared as either the first, second, third, or fourth experimental block.

The language blocked conditions consisted of 30 test items preceded by 15 practice trials. All auditory prompts were in a single language (i.e., diga in blocked Spanish, say in blocked English). Each of the two language mixed conditions consisted of 60 test items preceded by 30 practice trials, with equal numbers of Spanish and English targets. In the predictable mixed condition, the auditory cues alternated in a consistent pattern between the languages with each picture presentation (i.e., Spanish-English-Spanish-English). This required participants to switch languages in a regular manner to name the pictured stimuli in the target language. In the unpredictable mixed condition, however, the occurrence of language switches could not be predicted. Language cues were randomized throughout the set, so that participants could not anticipate the response language (e.g., Spanish-Spanish-Spanish-English-English-Spanish-English).

Procedure

The experiments were self-paced. Each stimulus presentation commenced with a button press from the participant. Then the auditory cue (the word say or diga) was presented simultaneously with the picture stimulus. Pictures were presented on a 12-in. (30-cm) monitor placed approximately 18 in.

(45 cm) in front of each participant. Participants were given 3 s to respond. Once a response was recorded or the 3 s had elapsed the experiment advanced to the next trial. Errors were monitored by an experimenter who sat next to the participant during the entire testing session. The BNT was administered in each language to each participant (counterbalanced for order of presentation) after the experiment so that it would not influence speed or accuracy of naming in the experiment.

Data Analysis

Response times (in milliseconds) were recorded for accurately named items and entered into subsequent analyses. A response was counted as correct if (a) it was produced without audible hesitation in the target language and (b) 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 (a) cross-language errors (e.g., a picture named in English that was cued in Spanish), (b) within-language errors including superordinate names (e.g., *bird* instead of *duck* or *clothes* instead of *shirt*), (c) no responses in which participants did not respond at all, and (d) other errors including audible hesitations (such as *uh*, *um* or *ra-rabbit*) causing a false trigger of the voice key.

RESULTS

Tables 1 and 2 show the mean response latencies and percentage of errors for each group, respectively. First, note that latencies increased in both groups from blocked to unpredictable mixed with a further increase from the unpredictable to the predictable mixed condition. Second, there were fewer errors and smaller RTs in English relative to Spanish (i.e., English naming skills were stronger than Spanish in both measures). Finally, the difference between college-age and older adults in error rates and RT was smallest in the blocked design (66 ms), larger in the unpredictable mixed (219 ms), and largest in the predictable mixed condition (332 ms).

These observations were confirmed by a 2 (age) × 2 (language) × 3 (condition) mixed factors ANOVA for both RT and percentage of errors. The results from RTs revealed a main effect of age, $F(1, 62) = 13.02$, $p < 0.001$, MSE = 31,2068.86; condition, $F(2, 124) = 66.83$, $p < 0.001$, MSE = 38,100.03; language, $F(1, 62) = 4.90$, $p < 0.001$, MSE = 3,3649.76; and an age by condition interaction, $F(2, 124) = 14.95$, $p < 0.001$, MSE = 38,100.03. No other interactions reached significance. Planned comparisons on the age by condition interaction revealed that

Table 1. Reaction Times and Percentage of Errors for the Cued Picture Naming Experiment.

Auditory language	*n*	Condition	Mean reaction time (*SD*)	Mean percentage of errors (*SD*)
		College-age participants		
English	32	Blocked	1,071 (238)	9 (6)
		Unpredictable mixed	1,202 (265)	12 (7)
		Predictable mixed	1,262 (296)	11 (10)
Spanish	32	Blocked	1,176 (265)	27 (13)
		Unpredictable mixed	1,262 (313)	26 (13)
		Predictable mixed	1,272 (320)	28 (14)
		Older adult participants		
English	32	Blocked	1,162 (166)	12 (9)
		Unpredictable mixed	1,448 (375)	22 (17)
		Predictable mixed	1,594 (317)	22 (16)
Spanish	32	Blocked	1,217 (146)	22 (15)
		Unpredictable mixed	1,454 (197)	30 (17)
		Predictable mixed	1,605 (336)	35 (21)

Table 2. Percentage of Errors for Different Types of Errors for the Cued Picture Naming Experiment.

Auditory language	*n*	Condition	Within language	Cross language	No Response	Other
		College-age participants				
English	32	Blocked	5 (4)	0 (1)	3 (3)	3 (3)
		Unpredictable mixed	4 (4)	3 (3)	4 (3)	1 (3)
		Predictable mixed	4 (4)	2 (3)	5 (7)	0 (0)
Spanish	32	Blocked	5 (4)	0 (1)	17 (9)	5 (4)
		Unpredictable mixed	4 (5)	1 (3)	17 (11)	5 (10)
		Predictable mixed	5 (6)	2 (3)	17 (13)	4 (6)
		Older adult participants				
English	32	Blocked	4 (5)	3 (10)	12 (11)	4 (2)
		Unpredictable mixed	5 (5)	7 (11)	13 (9)	1 (4)
		Predictable mixed	6 (5)	12 (12)	18 (13)	8 (3)
Spanish	32	Blocked	6 (4)	0 (0)	5 (6)	15 (8)
		Unpredictable mixed	4 (4)	8 (9)	7 (8)	15 (10)
		Predictable mixed	4 (3)	9 (10)	7 (7)	22 (10)

older adults were significantly slower than younger adults in the unpredictable mixed condition, $F(1, 62) = 40.65$, $p < 0.001$, $MSE = 38{,}100.03$, and in the predictable mixed condition, $F(1, 62) = 92.58$, $p < 0.001$, $MSE = 38{,}100.03$. In the blocked condition, differences did not reach significance although the effects were in the expected direction with older adults being slower, $F(1, 62) = 3.66$, $p < 0.060$, $MSE = 38{,}100.03$. In addition, planned comparisons were run between the two mixed conditions and between the unpredictable mixed and the blocked condition in each group. The result revealed that the blocked condition was significantly faster than the unpredictable mixed condition in the college-age group, $F(1, 62) = 9.80$, $p < 0.003$, $MSE = 38{,}100.03$, and in the older adult group, $F(1, 62) = 57.21$, $p < 0.001$, $MSE = 38{,}100.03$. However, the predictable mixed condition was slower than the unpredictable mixed condition but only in the older adult group, $F(1, 62) = 18.64$, $p < 0.001$, $MSE = 38{,}100.03$. In summary, older adults showed slower RTs than younger adults. These differences were much larger in the two mixed designs. Furthermore, older adults showed increased slowing in the predictable mixed condition relative to the unpredictable mixed condition. However, younger adults showed no differences in their RTs to the two mixed conditions. These results are consistent with the view that older adults show increased slowing of RT as the number of language switches in a set of stimuli is increased.

The results from percentage of errors revealed a main effect of age, $F(1, 62) = 5.35$, $p < 0.024$, $MSE = 523.58$; condition, $F(2, 124) = 14.32$, $p < 0.001$, $MSE = 109.78$; language, $F(1, 62) = 62.56$, $p < 0.001$, $MSE = 33{,}649.76$; and an age by condition interaction, $F(2, 124) = 14.95$, $p < 0.001$, $MSE = 279.69$. No other interactions reached significance. Planned comparisons on the age by condition interaction revealed that older adults made significantly more errors than younger adults in the unpredictable mixed condition, $F(1, 62) = 14.28$, $p < 0.001$, $MSE = 109.78$, and in the predictable mixed condition, $F(1, 62) = 24.77$, $p < 0.001$, $MSE = 109.78$, but not in the blocked condition. Additional planned comparisons revealed significant differences between the blocked condition and the unpredictable mixed condition, $F(1, 62) = 23.09$, $p < 0.001$, $MSE = 109.78$, but only in the older adult group. The results for percentage correct paralleled those of naming speed. However, in this case there was no additional increase in errors between the unpredictable and the predictable mixed condition. Taken together the RT and the error data suggest that older adults find language switching more difficult than younger adults.

The age by condition interaction for percentage errors and RT can be seen in Figure 1.

Further breakdown of the conditions in the unpredictable mixed condition can be seen in Table 3. The data reveal that participants showed the slowest RT at the switch followed by faster RTs on the first and second trial after the switch. The increase in speed was larger in English than in Spanish and larger in older adults than in college-age adults. These results were confirmed by two, 2 (age) × 2 (language) × 3 (switch position), mixed factors ANOVA for RT and percentage of errors. For the ANOVA on RT, there was a main effect of age, $F(1, 62) = 8.62$, $p < 0.005$, $MSE = 30,6812.01$; language, $F(1, 62) = 9.91$, $p < 0.003$, $MSE = 56,779.47$; and switch position, $F(1, 62) = 29.16$, $p < 0.000$, $MSE = 36,034.58$. There were also age by switch position, $F(2, 124) = 4.63$, $p < 0.012$, $MSE = 36,034.58$, and language by switch position, $F(2, 124) = 6.70$, $p < 0.002$, $MSE = 25,407.62$, interactions. For the ANOVA on percentage of errors, there was a main effect of age, $F(1, 62) = 5.54$, $p < 0.022$, $MSE = 848.37$, and language, $F(1, 62) = 21.85$, $p < 0.000$, $MSE = 517.13$. Hence, it appears that there is an additional savings for at least two trials after the switch. These results are consistent with the task set inertia proposal of Allport and colleagues, a point we will take up later in the Discussion section. The results from the age by switch position interaction for RT can be seen in Figure 2.

Further breakdown of error types can be seen in Figure 3. First, there were no differences between age groups for within language errors. Second, older adults showed a dramatic increase in the number of cross-language errors in the mixed conditions relative to college-age participants. These observations were confirmed by a 2 (age) × 2 (language) × 3 (condition) mixed factor ANOVA which compared performance for the two groups on within-language and cross-language errors separately. The results for within-language errors revealed an interaction of language by condition only. Age did not appear as a main effect or interact with any of the other variables used. The results from the ANOVA with cross-language errors revealed a main effect of age, $F(1, 62) = 19.87$, $p < 0.000$, $MSE = 11.09$; condition, $F(2, 124) = 33.76$, $p < 0.000$, $MSE = 2.76$; and a group by condition interac-

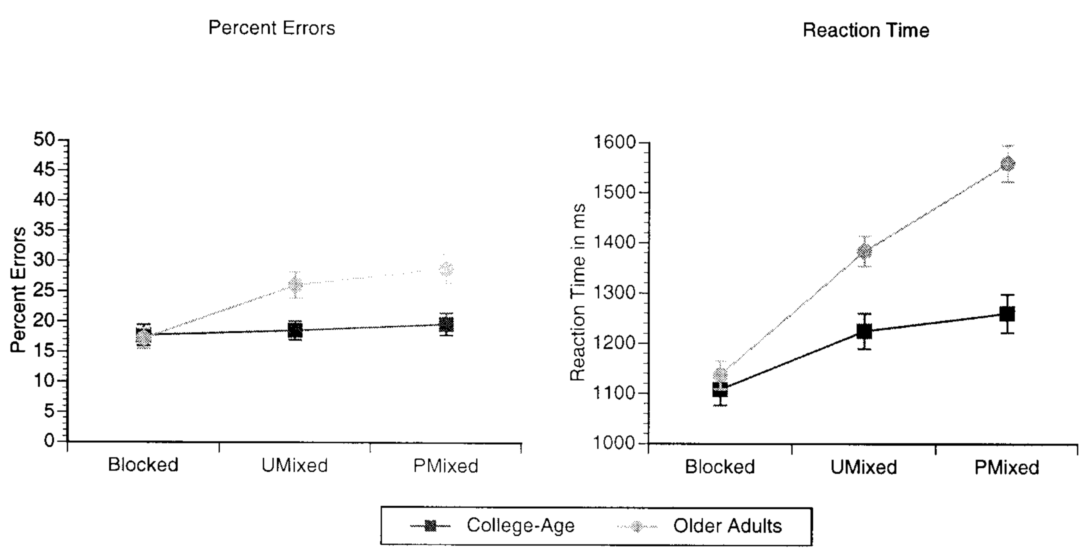

Fig. 1. Age by condition interaction for percentage of errors and reaction time. UMixed = unpredictable mixed; Pmixed = predictable mixed.

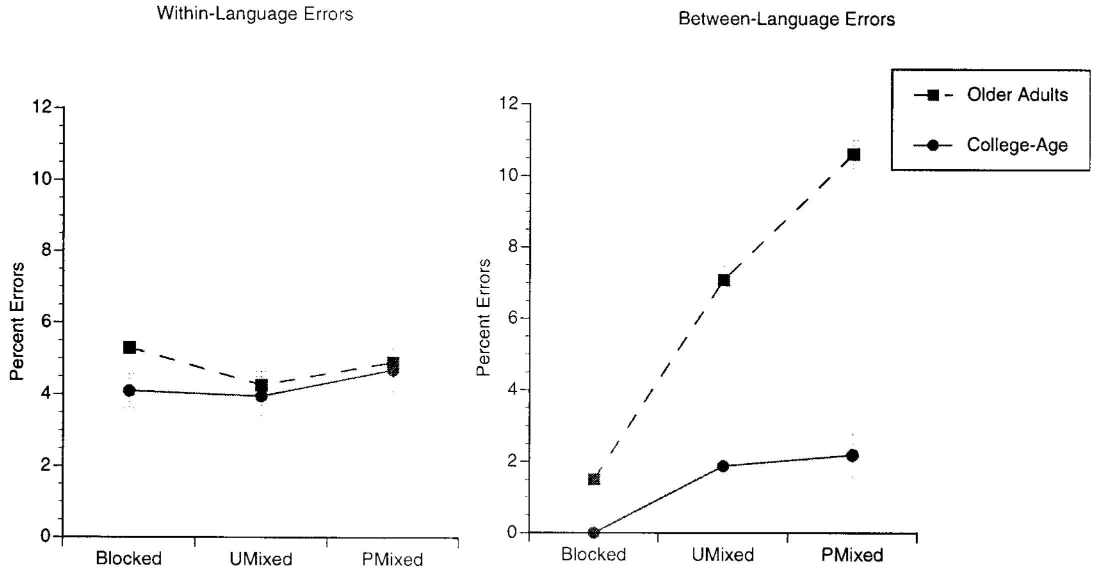

Fig. 2. Age by condition interaction for within and cross language errors. UMixed = unpredictable mixed; Pmixed = predictable mixed.

tion, $F(2, 124) = 12.53$, $p < 0.000$, $MSE = 2.76$. Pairwise comparisons were conducted on the age by condition interaction to see which error types showed a significant increase across groups. This revealed a significant difference between older and younger adults for cross-language errors in the unpredictable mixed condition, $F(1, 62) = 28.31$, $p < 0.001$, $MSE = 2.76$, and the predictable mixed condition, $F(1, 62) = 74.15$, $p < 0.001$, $MSE = 2.76$. In addition, the

Table 3. Reaction Times and Percentage of Errors for Trial by Trial Analyses of the Unpredictable Mixed Condition.

Auditory language	*n*	Condition	Mean reaction time (*SD*)	Mean percent age of errors (*SD*)
		College-age participants		
English	32	Switch	1,270 (290)	13 (11)
		Switch +1	1,144 (268)	10 (10)
		Switch + 2	1,071 (282)	12 (19)
Spanish	32	Switch	1,276 (318)	24 (12)
		Switch +1	1,257 (343)	28 (23)
		Switch + 2	1,252 (378)	23 (22)
		Older adult participants		
English	32	Switch	1,510 (178)	26 (20)
		Switch +1	1,330 (214)	28 (18)
		Switch + 2	1,214 (219)	20 (28)
Spanish	32	Switch	1,488 (206)	29 (18)
		Switch +1	1,443 (303)	30 (23)
		Switch + 2	1,281 (339)	31 (24)

predictable mixed condition was significantly different from the unpredictable mixed condition, $F(1, 62) = 13.10$, $p < 0.001$, $MSE = 2.76$, which was significantly different from the blocked condition, $F(1, 62) = 30.95$, $p < 0.001$, $MSE = 2.76$. There were no differences between groups for cross-language errors in the blocked condition and no difference across error types for college-age participants.

The results from both RTs and percentage of errors revealed a number of interesting findings. Older adults showed slower RTs and made more errors compared to college controls. However, age interacted with condition in both analyses. In the blocked condition, older adults and college controls were not significantly different in terms of percentage of error and only marginally different for RT. Older adults showed slower RTs and made more errors in the predictable and unpredictable mixed conditions. Planned comparisons revealed elevated RTs but no increase in errors for older adults in the predictable mixed condition relative to the unpredictable mixed condition. College controls did not reveal any difference between the two mixed conditions. In addition, older adults showed a larger amount of slowing on switch trials compared with college controls in the unpredictable mixed condition. Finally, more information was revealed from the analysis of error types. Of particular interest was the fact that older adults showed an increase in the number of cross-language errors as RTs slowed down in the mixed conditions. The number of within-language errors did not increase significantly. Thus, older adult bilinguals found the constant switching between languages to be particularly difficult. Furthermore, it appeared that they had a particular difficulty in switching from the language cued on the previous trial to the language cued on the current trial, as indexed by the increase in cross-language errors for older adults relative to the college-age participants in the mixed-language conditions. The larger slowing effect in the older adults for switch trials relative to nonswitch trials in the unpredictable mixed is also consistent with a difficulty in switching languages.

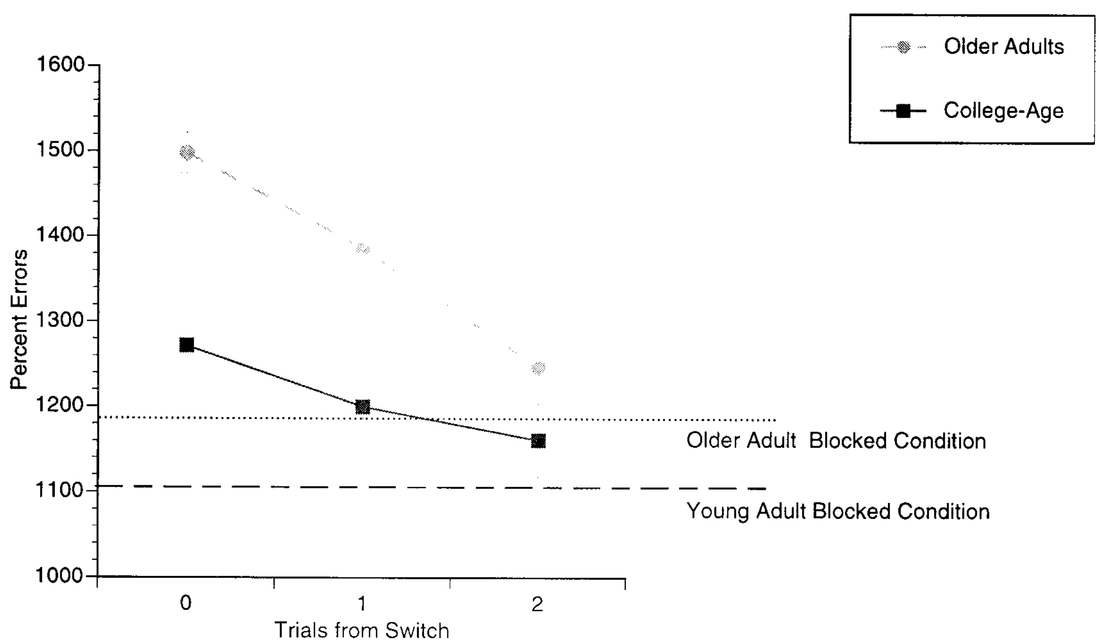

Fig. 3. Age by trials from switch interaction for reaction time.

DISCUSSION

The results from the current study revealed a set of interesting findings for the aging and bilingualism literature. Older adults showed small differences in RT and no differences in the number of errors in the blocked (single-language) condition relative to college-age controls. When older adults named pictures in the mixed condition, however, error rates and RTs increased significantly. This was not the case for the young adult group. Particularly striking was the difference between groups in RTs in the predictable mixed (332 ms) and the unpredictable mixed (219 ms) compared to the blocked conditions (66 ms). Thus, it appears that older adults have a particularly difficult time switching to the cued language in the mixed conditions. Older adult bilinguals are able to access lexical items during a picture naming task when responses are required in a single language (i.e., English or Spanish). However, the older adult's ability to alternate between languages in response to an auditory cue is impaired compared to the younger adult group. This slowdown is even larger when older adults are asked to switch continuously.

This difference between age groups can be seen clearly in the RTs, errors, and types of errors in the mixed conditions. The predictable mixed condition had a greater number of switches than the unpredictable mixed condition. Hence, it was likely that the number of switches resulted in a slowdown in RT and not attention to the cue per se. The difficulty with switching was further confirmed on trial by trial analyses of the unpredictable mixed condition. Interestingly, it appears that older adults "recover" from a switch more quickly than younger adults. That is, older adults show a larger reduction in RT on the first trial after the switch than younger adults. This faster recovery has also been observed in switching experiments performed by Salthouse et al. (in press). However, it is most likely due to the fact that older adults showed a larger cost on language switch trials relative to college-age participants. Thus older adults may in fact have more "room" to recover than younger adults, a point we will return to in the next paragraph. Despite some caveats, our data are consistent with the view that switching is more difficult for older adults.

The results from the predictable and unpredictable mixed conditions bring up two important points that warrant further consideration in future studies. First of all, it is important to note that the comparison between predictable and unpredictable mixed conditions could be refined even further. As mentioned in the introduction, it was not clear whether the number of switches would dictate costs or whether attention to the cue would increase costs. Our results suggest strongly that it is the frequency of switching that dictates processing demands and not the cost of attending to the cue itself. Future studies could investigate this issue more precisely in one of two ways. One method would be to design predictable mixed and unpredictable mixed conditions that were equated on the number of switches. This design would allow one to more carefully look at what component (if any) of switch costs are due to attending to the cue. A second method which has been employed by Salthouse et al. (in press) is to employ long runs of stimuli in which there is only one switch (i.e., four in one language followed by four in the other language). This would allow a more accurate characterization of the costs of switching. Furthermore, it would allow one to look at the "rise and fall" of switch costs across both groups and thereby clarify whether the switch cost is larger, but also whether the recovery from the switch is also larger in older adults. Equating for the number of switches in the two mixed conditions and using longer runs of stimuli with fewer switches will allow a more accurate understanding of the nature of language switch costs. Studies along these lines are currently being planned in our laboratory.

Earlier we presented two competing hypotheses. According to the task set inertia account switching costs are caused by activation of previous task demands which conflict with the current task demands. This task set inertia should lead to switching costs for a few trials beyond the first switch. According to the stimulus-cued completion hypothesis, the stimulus can act as a cue for the switch. On a switch there is an increased cost since the stimulus is cuing the switch. However, on the next trial there should be no additional switch cost. Our data revealed switching costs beyond the first trial. As we stated earlier, the task set inertia account suggests that costs should continue beyond the first trial. This is precisely what was found for both older and younger adults. However, we also found some incompatibilities with the task set inertia account. We found that switching costs persisted when switching from the dominant language (English) to the nondominant language (Spanish) across two additional trials. In English, these switching costs dropped off more quickly. Hence, for our paradigm the task set inertia hypothesis cannot account for this aspect of our data. This may have to do with the type of bilinguals or the paradigm that was used. Future studies should look at differences in paradigms and populations in order to further understand these inconsistencies.

The difference between language switching costs in English versus Spanish brings up an additional point. Are the costs of switching dictated by the fluency in each language? Results from percentage correct, the BNT, and self-report indicate that our bilinguals are indeed better in English than in Spanish. The lack of a language by switch condition interaction in our results suggests that switching costs are not larger in the less dominant language. To further clarify this on an individual basis we did a post hoc correlation between participants' scores on the BNT and the size of the switching cost (blocked minus predictable mixed). There was no correlation between these two measures. Hence, there is no indication that for our group of bilinguals there is a larger language switching effect in the less fluent language. As mentioned in the introduction, it is important to point out that participants in the current study are all early bilinguals who have acquired their second language before the age of eight. One language is stronger than the other. However, we leave open the possibility that participants who show a much more asymmetric profile of fluency will show more interference in one of their languages. Future studies should investigate this issue more by looking at whether fluency correlates with language switching costs in highly asymmetric bilinguals.

Our findings are consistent with the breakdown in central executive processing with age as evidenced by the increased switching costs and task set inertia across groups. Despite the similarities between task-switching data and our language-switching data, there are some clear differences as well. In the case of language switching we are using object naming, a task which has been practiced across the life span. Hence, some aspects of this task are more naturalistic compared to the nonverbal tasks that have been used such as switching between vowel/consonant judgments of letters. This cross-language switch paradigm also lends itself to a more detailed analysis of error type. The interference that results from an increase in switching in our task leads to an increase in cross-language errors. In addition, we have found differences between our task and other tasks. This suggests that much can be gained when the errors can be qualified, which is possible in our verbal switching paradigm.

To summarize, the current study found that language switching is particularly difficult for older adult bilinguals. This difficulty results in an increase in RT and in errors. Analyses of errors revealed that older adults made more cross-language errors in the mixed conditions compared to younger adults. The findings are consistent for the most part with the view that older adults have difficulty with task set inertia. That is, they suffer from an increased proactive interference from previous task commands.

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