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Investigations into the locus of language-switching costs in older adult bilinguals*

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Language switching was studied with older adult (age 65 years and older) and young adult (18–24 years) bilinguals in a blocked-language or mixed-language condition. Results revealed small differences in reaction time (RT) between older adults and college-age participants in the blocked condition. However, older adults showed much slower RTs in the mixed condition which involves sustained switching relative to young adults. In Experiment 2, the same design was used except that participants were asked to translate an auditory word. In this condition, older adults showed a slowing effect but to a much lesser degree. Furthermore, comparisons within the mixed condition (transient switching) revealed that switching costs varied across languages and age groups. The results from the picture-naming task are consistent with models that predict deficiencies in task-set shifting in older adults especially when a stimulus activates multiple responses. Furthermore, the results indicate interesting differences in sustained and transient switching depending on the task.

Keywords: bilingualism, aging, cognitive control, language switching

Proficient bilinguals are able to adjust between bilingual and monolingual modes of processing. They can speak only one language with monolinguals and can also serve as interpreters in which they effectively alternate between languages in order to assist two monolinguals in communicating. But does this ability to alternate or switch between languages break down with age? Previous studies have found that older adults find language switching much more difficult than young adults (Gollan & Ferreira, 2009; Hernandez & Kohnert, 1999; Weissberger, Wierenga, Bondi & Gollan, 2012). This increase in language-switching costs in older adults is very similar to the effects that have been observed in the nonverbal task-switching literature with monolinguals (Hahn, Andersen & Kramer, 2004; Olk & Jin, 2011; Terry & Sliwinski, 2012; Wasylyshyn, Verhaeghen & Sliwinski, 2011). Furthermore, researchers have suggested that the locus of these increased costs is due to the exogenous control, the need by participants to assign a task in order to mediate between two competing responses to the same stimulus (Lavric, Mizon & Monsell, 2008; Longman, Lavric & Monsell, 2013; Monsell, Matthews & Miller, 1992; Monsell & Mizon, 2006; Rogers & Monsell, 1995). In Experiment 1, we used a cued picture-naming paradigm in blocked (single-language) and mixed (switching between languages) conditions in older adult and college-age Spanish–English bilinguals. This will serve as a replication of previous studies (Gollan & Ferreira, 2009; Hernandez & Kohnert, 1999). It will also serve as an extension by including additional comparisons between switch and noswitch trials. In Experiment 2, we will also look at language blocked and language switching using a translation paradigm. Translation, like picture naming involves the generation of a response. However, in translation, unlike in picture naming, each stimulus is linked to a unique response and may not be conceptually mediated (for a review see Snodgrass, 1993). The comparison of results from Experiment 1 (blocked–mixed picture naming) and Experiment 2 (blocked–mixed translation) will help to resolve whether increased language-switching costs are due to a generation of a response or to the way in which the response is cued. We first review the literature on task switching in older adults before proceeding to describe work that has investigated language switching with young and older adult bilinguals.

Task switching

Seminal studies exploring the nature of task switching were conducted over 80 years ago (Jersild, 1927) but received little attention in the literature until the 1990s. These initial findings were so robust that they were easily replicated (Allport, Styles & Hsieh, 1994; Hsieh

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& Allport, 1994; Monsell & Mizon, 2006; Rogers & Monsell, 1995; Spector & Biederman, 1976). Although switching costs appeared for both errors and reaction times (RTs), the majority of studies indexed costs in terms of latency. These studies also began to consider the potential theoretical constructs that might account for these switching effects. Allport and colleagues have suggested that task-switching costs occur because of task-set inertia (TSI), the inability to overcome previous task commands. Support for this view has been obtained from a series of studies which have found that costs remain across delays of up to a second between response to one stimulus and presentation of the next stimulus (Allport et al., 1994).

Work by Rogers and Monsell (1995) confirmed and extended the TSI account by indicating the importance of a retrieval cue. Reaction times were collected to a set of letter–number pairs in which the digit was classified as even/odd or the letter was classified as consonant/vowel in college-age participants. Rogers and Monsell did observe a reduction of the cost as the Response Stimulus Interval (RSI) was increased to 600 ms. However, a large asymptotic cost remained even with an RSI of 1200 ms, but only on the first trial of the new task. Rogers and Monsell (1995) amend the TSI account of Allport and colleagues by suggesting that switching can be viewed as a task-set reconfiguration (TSR) process. Specifically, stimuli exogenously (i.e. outside the individual) "prime" certain responses while people endogenously (i.e. internally) choose which response to execute. For example, when presented with a red square, both a red response and square response will be primed. The reconfiguration occurs when a person has to choose either the red response or the square response on a particular trial.

The TSR account makes specific predictions about what the locus of slowing might be during task switching. In this view, switch costs arise when participants have to endogenously choose among multiple responses to a single stimulus. Interestingly, some components of switching costs can be reduced in advance of the stimulus through endogenous control. Hence, under certain conditions giving participants time in advance to know which aspect of the stimulus will be necessary for the choosing the appropriate response can serve to eliminate switching costs. In addition, the relationship between cues and responses is also important. Cues that are less closely linked with a response will result in much less endogenous control and hence in smaller switching costs. Studies have found considerable reduction of switch costs with cues that are strongly linked to a particular response (Jersild, 1927; Spector & Biederman, 1976).

Increased switching costs in older adults relative to younger adults have been observed in a number of non-verbal domains (Botwinick, Brinley & Robbin, 1958; Brinley, 1965; Hahn et al., 2004; Olk & Jin, 2011; Panek, Barrett, Sterns & Alexander, 1977; Terry & Sliwinski, 2012; Wasylyshyn et al., 2011; Wickens, Braune & Stokes, 1987). Salthouse, Fristoe, McGuthry & Hambrick (1998) asked participants to perform a single task (e.g., deciding if a single digit is odd or even) for nine trials before switching to another task (e.g., deciding if a single digit is less or more than five). Salthouse found increased switching costs for older adults relative to younger adults. Furthermore, RTs for all groups were slowest on the switch trial (i.e. trial number 10) and then dropped towards baseline on subsequent trials. The interesting part is that older adult response times began to approach those of younger adults as a task was repeated across trials. This suggests that slowing of responses in older adults is much greater in conditions of switching relative to task maintenance. Given the results reviewed here it is clear that older adults show an increase in switching costs relative to younger adults. Finally, it has been argued that switching between tasks results in increased central executive processing which is found to break down in older adults (Albinet, Boucard, Bouquet & Audiffren, 2012; Daigneault & Braun, 1993; Pennington, 1994; Schretlen, Pearlson, Anthony, Aylward, Augustine, Davis & Patrick, 2000).

Despite the consistent experimental findings of increased task-switching costs with older adults, there is still an underlying question about what the locus of this increased cost might be. One likely explanation is that increased switching costs across age groups are due to differences in the endogenous (internally driven) component of switching. Hence, older adults will show increased switching costs relative to younger adults especially when one stimulus has many potential responses, that is, when task-set reconfiguration is necessary (see Rogers & Monsell, 1995). When a single response is easily associated with a stimulus either directly or through the use of a strong cue, the endogenous component of switching should be reduced. Hence, under these conditions switching costs for older adults and college-age participants should be comparable.

Differences in switching costs have also been addressed by investigating the difference between transient switching which occurs trial-by-trial and sustained switching which occurs across an entire set of trials. In one study, with older adults, Jimura and Braver (2010) asked a group of young and older adult monolinguals to switch between a size decision (smaller or larger than a computer monitor) and a type decision (manmade or natural). Two types of switching effects were studied. One involved sustained switching in which comparisons were made between the combined results of a block of trials that involved switching and a block of trials with only one task. The second involved comparisons within the sustained switch blocks between trials in which the task was repeated or when it switched. These smaller switching effects were termed transient effects. The results revealed that older adults relative to young adults differed in both transient and sustained switches. Young adults showed relatively increased activity in the anterior prefrontal cortex for sustained switches relative to older adults. However, older adults showed increased activity for transient switching in the same region of the prefrontal cortex relative to young adults. In addition, older adults showed increased activity to lateral prefrontal and posterior parietal cortex for transient switches. The authors interpret these results as showing that older adults are performing in a more reactive manner relative to the young adults. Specifically, rather than showing increased activity in a block of trials that contains many switches, the older adults showed increased activity differentially to switches within a block of trials. This suggests that older adults are executing switches on a trial-by-trial basis. The present study will help to build on this finding by looking at the nature of both sustained and transient switching in older and younger adult bilinguals

Bilingualism and language switching

In the previous section, the nature of task switching, the increased difficulty that older adults have with it, and the conditions under which older and younger adults might show comparable switching costs were discussed. A parallel set of issues has also emerged in the bilingual literature with regard to language switching (alternation between first and second language). At the behavioral level, classic studies revealed no effect of language switching (Dalrymple-Alford & Aamiry, 1969; Kolers, 1966) while others have found effects of language switching particularly in terms of speed of processing (MacNamara, Krauthammer & Bolgar, 1968; MacNamara & Kushnir, 1971; Meuter, 1993; Soares & Grosjean, 1984; von Studnitz & Green, 1997). This apparent inconsistency in findings may be attributed to a difference in the nature of the experimental task itself. Language-switching costs were found when a response was generated (Hernandez & Kohnert, 1999; Kohnert, Bates & Hernandez, 1999; MacNamara et al., 1968; Meuter & Allport, 1999) but not when the response was present in the stimulus (Caramazza, Yeni-Komshian & Zurif, 1974; Chan, Chau & Hoosain, 1983). In the numeral-naming task used by MacNamara et al. (1968) and Meuter and Allport (1999) and in the cued-picture-naming paradigm described later, each stimulus can have a response in each language. However, in tasks such as reading, the generation of responses is reduced considerably.

The increase in response competition (which should involve an increase in the need for task-set reconfiguration) can be seen in a study by Grainger and Beauvillain (1987). Participants were asked to make lexical decisions to words that were legal letter strings in both languages or in one language only. Results revealed a language-switching cost but only for words that were orthographically legal in both languages. This study very nicely illustrates how language-switching effects (like task-switching effects) arise when the link between a stimulus and a response becomes ambiguous. According to our hypothesis, it is under these conditions that bilingual older adults will show an increase in language-switching costs relative to young adults.

To address some of these questions, Hernandez and Kohnert (1999) investigated the nature of language switching in older adult and young adult Spanish–English bilinguals using a cued picture-naming paradigm. In this paradigm, participants were asked to name a picture in the language of a simultaneously presented auditory cue. The cue was in English (say) or Spanish (diga which is “say” in Spanish). Stimuli were presented in two different conditions. In the blocked condition, participants received separate blocks of English or Spanish stimuli. In the mixed condition, participants switched between languages within the same stimulus set. Comparisons within each group revealed slower reaction times in the mixed than in the blocked conditions. Comparisons across groups revealed large differences in both reaction times and error rates in the mixed conditions but small differences in reaction times and no differences in the number of errors in the blocked (single-language) condition. Of particular interest was the nature of the errors made by older adults. In the mixed condition, older adults made more wrong-language errors than young adults, suggesting that they had an increased difficulty imposing the appropriate task set. Hence, information from both languages was becoming available at the time of response in the mixed condition. In the blocked condition, where only one language was active, young and older adults showed very small differences in reaction times and no differences in errors. This is consistent with the hypothesis that under conditions where multiple responses to the same language are active, older adults show much larger language-switching costs. The results observed in that study also fit in with previous studies with older adults that find difficulties with sustained switching, as seen in studies with monolinguals.

The current study is designed to replicate and extend our previous findings. First of all, the locus of mixed-language costs will be more actively investigated by comparing a translation task to a picture-naming task. A group of older adult (65+ years) and young adult (18–24 years) bilinguals will be given the cued picture-naming paradigm (Experiment 1) and an auditory translation task (Experiment 2) in the blocked (single-language) and the mixed condition. Second, unlike Hernandez and Kohnert (1999), we controlled the number of switches and kept task alternation to every other trial (as opposed to the

Table 1. *Summary of task demands for Experiment 1 and 2.*

Task	Picture-naming Experiment 1	Translation Experiment 2
Verbal encoding	No	Yes
Semantically mediated	Yes	Yes
Response generation	Yes	Yes
Potential responses in both languages	Yes	Yes
Verbal responses	Yes	Yes
Response latency	Faster	Slower
Need for control in the blocked condition	Less	More
Age difference of sustained switching effect	Larger	Smaller
Size of transient switching effect	Smaller	Larger

alternation on every trial used in our previous study). This will allow us to look at effects of sustained switching when comparing the blocked and mixed condition. At the same time, comparisons between switch trials (in which the previous stimulus was named in the opposite language) and no-switch trials (in which the previous stimulus was named in the same language) within the mixed condition allows us to investigate the nature of transient switching. Furthermore, the use of picture naming and translation may offer additional insight into the locus of language-switching costs, a point we will return to below. Table 1 shows the similarities and differences between these two tasks.

We predict that older adults will show a significant cost in terms of errors, reaction times or both relative to young bilinguals in the mixed but not in the blocked condition for picture naming. One question that is left is at which level this cost arises. One possibility is that the cost in the mixed condition during picture naming results from increased competition in the retrieval or the production or both of a language appropriate response. Hence, in choosing a comparison task for picture naming we were careful to use one that involved retrieval and production of language appropriate responses. To this end we chose an auditory word translation task, one that is similar to picture naming in some key aspects. For example, both picture naming and translation involve imposing a task and involve the generation of a response (i.e. the stimulus does not contain the response). Both also involve access to semantic information (for further discussion see Kroll & De Groot, 1997). However, there are also some important differences. Translation is slower than picture naming, especially in languages that are spoken fluently. Snodgrass (1993) has proposed that this is due to the difference in the speed of encoding and production of responses in translation. Whereas picture naming involves the production of a response, translation involves the encoding of words in one language and production of words in the other. Given previous findings we predict that picture naming will be faster than translation across conditions.

There is another key aspect in which translation and picture naming will differ. Specifically, we hypothesize that picture naming and translation will differ in the extent to which a language-specific response is cued. The picture-naming task we use involves an auditory cue that serves to indicate the language of response. Translation, on the other hand, does not involve a separate cue. Rather the subject uses endogenous control in order to produce the translation of a word. As such translation tends to involve activation of a word and its translation in both single-language and dual-language conditions. Thus, there should be a relatively low additional cost for sustained switching. However, in picture naming the difference between mixed and blocked conditions becomes stark. Specifically, picture naming in a mixed condition involves additional competition over and above that seen in the blocked condition. Interestingly, this difference should lead to overall slowing of translation. The main question is how this might affect the nature of switching in older adults relative to young adults.

Earlier we reviewed evidence from Rogers and Monsell (1995) suggesting that it is the "endogenous" selection among multiple responses to one stimulus which leads to increased switching costs. That is, older adults find it harder to perform tasks that involve the selection of one response relative to another. We hypothesize that this selection process will break down in older adults. If our hypothesis is correct, the dramatic slowing for older adults observed in processing mixed lists for picture naming should be diminished in the auditory translation experiment. However, overall translation should continue to be slower than picture naming across both populations (see Snodgrass 1993). One interesting question is how young and older adults will differ in sustained switching in both conditions. While the precise direction of this difference in each task is hard to predict, it is likely that picture naming and translation will show different patterns of switch and noswitch differences. Specifically, it is likely that greater differences in sustained switching across groups will be seen in the translation task. The increased switching and increase in cueing of both a word and translation is likely to affect older adults who are particularly reactive and not as proactive as young adults. Finally, the current study will be testing participants that are native Spanish speakers but have been educated in English, which leads to them being dominant in the latter language. Hence, we should see a proficiency effect such that picture naming is faster in English than in Spanish and translating is faster from Spanish to English than from English to Spanish (De Groot, Dannenburg & Van Hell, 1994; De Groot & Hoeks, 1995; Heredia, 1997; Kroll & Stewart, 1994; Sholl, Sankaranarayanan & Kroll, 1995; Snodgrass, 1993).

Experiment 1: Picture naming in a mixed and blocked condition

Method

Participants

A total of 40 Spanish–English bilingual adults participated in this study. The college-age participants were 20 right-handed individuals recruited through the subject pool in the department of psychology at the University of California, Santa Barbara. The mean age of the group was 21 ($SD = 2.34$). The older adult bilinguals consisted of a group of 20 right-handed individuals from the San Diego and Los Angeles area. The mean age of group at testing was 74.39 (*SD* of 5.22) and the average education was 12.31 (*SD* of 4.42). All of the older adult participants scored above the cutoff for dementia on the administration of the Mini-Mental State Examination (26 correct items or higher). In terms of language proficiency, all participants rated themselves as more fluent in English than in Spanish and all had learned both languages before the age of eight. Both young and older adults reported using both languages in their daily lives. The Boston Naming Test (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) $\times$ 2 (language) mixed ANOVA. The results revealed a main effect of language – more pictures named correctly in English (46.33) than in Spanish (33.10) ($F = 74.48$, $p < .001$, $MSE = 4665.67$) only. There was no effect of age and no interaction between age and number of items identified in each language. The mean score was 46.72 in English and 31.53 in Spanish for the college-age group and 45.94 in English and 34.66 in Spanish for the older adult group. These scores are consistent with those observed in other studies in our laboratory with Spanish–English bilinguals (Kohnert, Hernandez & Bates, 1998).

Apparatus

The picture stimuli were presented on a Macintosh computer using the PsyScope experimental shell from Carnegie Mellon University (Cohen, MacWhinney, Flatt & Provost, 1993). This work was completed on a Starmax 5000 using the Macintosh operating system. 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

The experiment included a total of 100 test trials in three conditions: Blocked-Spanish, Blocked-English, and Mixed-Spanish and 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 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 five 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, 1984; Snodgrass & Vanderwart, 1980). These pictures were chosen as the best candidates based on a previous series of picture-naming studies done on Spanish–English bilinguals (i.e., pictures were accurately named in both languages by $>85\%$ of subjects) (Hernandez & Kohnert, 1999; Kohnert et al., 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.

Procedure

Older adults ($n = 20$) were tested individually in their homes. The young adults ($n = 20$) were tested individually in the language and cognitive processing 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.

Table 2. *Reaction times and percent errors for Experiment 1 (picture naming).*

Auditory language	n	Condition	Mean Reaction Time (*SD*)	Mean Percent Errors (*SD*)
		Young adult participants		
English	20	Blocked	982 (165)	4 (4)
		Mixed	1114 (139)	12 (7)
		Mixed–Blocked	+132	+8
Spanish	20	Blocked	1115 (187)	27 (13)
		Mixed	1197 (144)	28 (14)
		Mixed–Blocked	+82	+1
		Older adult participants		
English	20	Blocked	1035 (185)	12 (9)
		Mixed	1450 (217)	22 (17)
		Mixed–Blocked	+415	+10
Spanish	20	Blocked	1162 (168)	22 (15)
		Mixed	1424 (170)	35 (21)
		Mixed–Blocked	+262	+13

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 (i) NO RESPONSES within the pre-set four-second response window; (ii) audible hesitations (such as uh, um or ra-rabbit) causing a false trigger of the voice key; (iii) WITHIN LANGUAGE errors such as superordinate names (e.g., bird instead of duck or clothes instead of shirt); and (iv) CROSS-LANGUAGE errors such as a picture cued in one language but named in the other (e.g., cued diga to name casa but produced house). Correct responses that failed to trigger the timing devise were less than three percent of the total.

The data from both dependent variables (percent correct and reaction time) 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 subject variables.

Results and discussion

Table 2 shows the mean response latencies and percent errors for each age group, respectively. The table highlights a number of interesting findings. First, note that there was a very small increase in RT in the older adult group relative to the young adult group in the blocked condition. Second, note that there was a dramatic increase in reaction time for older adults in the mixed condition (257 ms) relative to the young adult group. Third, note that there is not as much of a difference between English and Spanish in the mixed conditions for either of the groups. Fourth, error rates revealed a difference between mixed and blocked conditions across age groups. Finally, there were fewer errors and smaller RTs in English relative to Spanish (i.e. English naming skills stronger than Spanish in both measures) across age groups.

These observations were confirmed by a 2 (age) × 2 (language) × 2 (condition) mixed-factors ANOVA for both reaction time and percent errors. The results from reaction time revealed a main effect of age ($F(1,38) = 15.90$, $p < .001$, $MSE = 67399.10$), condition ($F(1,38) = 89.38$, $p < .001$, $MSE = 23344.48$), language ($F(1,38) = 11.99$, $p < .001$, $MSE = 20259.99$), an age by condition interaction ($F(1,38) = 25.24$, $p < .001$, $MSE = 23344.48$), and a condition by language interaction ($F(1,38) = 13.38$, $p < .034$, $MSE = 14545.39$). No other interactions reached significance. Planned comparisons on the age by condition interaction revealed that older adults were significantly slower than younger adults ($F(1,38) = 152.92$, $p < .001$, $MSE = 20801.13$) in the mixed condition. In the blocked condition, differences did not reach significance although the effects were in the expected direction with older adults being slower than younger adults by 50 ms. These results are consistent with the view that older adults are showing increased slowing of reaction time in the mixed condition relative to the young adult group.

The results from percent errors revealed a main effect of age ($F(1,38) = 20.76$, $p < .001$, $MSE = 239.49$),

Table 3. *Reaction times and percent errors as a function of switching in the mixed condition for Experiment 1 (picture naming).*

Language	n	Condition	Mean Reaction Time (*SD*)	Mean Percent Errors (*SD*)
		Younger adult participants		
English	20	NoSwitch	1069 (134)	4 (6)
		Switch	1152 (156)	10 (6)
		Switch–NoSwitch	+83	+6
Spanish	20	NoSwitch	1149 (181)	20 (16)
		Switch	1241 (154)	15 (12)
		Switch–NoSwitch	+92	–5
		Older adult participants		
English	20	NoSwitch	1407 (231)	22 (22)
		Switch	1481 (233)	21 (17)
		Switch–NoSwitch	+74	–1
Spanish	20	NoSwitch	1380 (197)	28 (19)
		Switch	1475 (228)	33 (18)
		Switch–NoSwitch	+95	+5

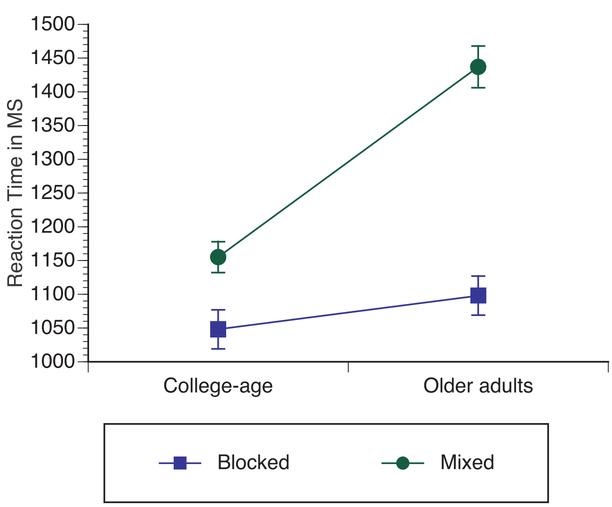

Figure 1. (Colour online) Age by condition interaction for reaction time in Experiment 1 (picture naming).

condition (F(1,38) = 15.38, $p < .001$, MSE = 108.18), and a main effect of language (F(1,56) = 25.61, $p < .001$, MSE = 127.93). No interactions reached significance. The age by condition interaction for reaction time can be seen in Figure 1.

In addition to exploring the differences between mixed and blocked conditions, we also subdivided the mixed condition into switch and noswitch trials. This further breakdown of the mixed condition can be seen in Table 3. The data reveal that both older and young adults showed slower reaction times on switch trials than on noswitch trials. Furthermore, participants performed better (faster and more accurate) on English trials than on Spanish trials.

These results were confirmed by two separate, 2 (age) × 2 (language) × 2 (switch) mixed factors ANOVA for reaction times and percent errors. For the ANOVA on reaction time, there was a main effect of age (F(1,38) = 33.36, $p < .001$, MSE = 99810.45) and condition (F(1,38) = 16.39, $p < .001$, MSE = 15033.20). For the ANOVA on percent errors, there was a main effect of age (F(1,38) = 14.06, $p < .001$, MSE = 534.00), language (F(1,38) = 24.91, $p < .001$, MSE = 194.63), and an age × language × switch interaction (F(1,62) = 4.63, $p < .038$, MSE = 85.15). For percent errors, there was a slight shift in errors with younger adult bilinguals showing an improvement from switch to noswitch condition for accuracy in English and a decrease in accuracy in Spanish. Older adults, however, showed no change in accuracy in English but a slight INCREASE in accuracy in Spanish.

The results from both reaction times and percent errors revealed a number of interesting findings. Older adults showed slower reaction times and made more errors compared to college controls. However, age interacted with condition in both analyses. Older adults were only marginally slower than young bilinguals in the blocked condition. The largest slowdown was found in the mixed condition where older adults were 272 ms slower than the younger group. The results from percentage of errors did not reveal an increase in the mixed condition for older adults. Finally, our results from analyses of reaction times in the mixed condition for transient switching revealed that switch trials were faster than noswitch trials in both groups. Error rates, on the other hand, revealed some effects of language and switching condition that differed slightly across groups.

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So far our results are consistent with findings from previous studies. Namely, language processing in the mixed condition is disproportionately slowed in older adults relative to college-age adults. However, there were very slight differences when comparing older adults to young adults for transient switching in errors but not for reaction time. Hence, the effect of aging is very large for sustained switching when comparing the mixed and blocked conditions and only present for errors for transient switching within the mixed condition. Experiment 2 was designed to further investigate the nature of this mixed/blocked processing cost in older adults. Specifically, it is hypothesized that processing of mixed language lists will result in very small (if any) differences between age groups due to the fact that each word is strongly linked to its translation.

Experiment 2: Translation in a mixed and blocked condition

Method

Participants

A total of 40 Spanish–English bilingual adults participated in this study. The college-age participants were 20 right-handed individuals recruited through the subject pool in the department of psychology at the University of California, Santa Barbara. The mean age of the group was 21 ($SD = 2.34$). The older adult bilinguals consisted of a group of 20 right-handed individuals from the San Diego area. The mean age of group at testing was 72 (*SD* of 6.67) and the average education was 13.31 (*SD* of 2.46). All of the older adult participants scored above the cutoff for dementia on the administration of the Mini-Mental State 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 eight. Both young and older adults reported using both languages in their daily lives. The Boston Naming Test (BNT) (Kaplan et al., 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) × 2 (language) mixed ANOVA. The results revealed a main effect of language – more pictures named correctly in English (46.33) than in Spanish (33.10) ($F = 69.73$, $p < .001$, $MSE = 4891.78$) only. There was no effect of age and no interaction between age and number of items identified in each language. The mean score was 44.31 in English and 33.96 in Spanish for the college-age group and 45.53 in English and 26.29 in Spanish for the older adult group.

Design, materials, and procedure

The setup of Experiment 2 was very similar to the one used in Experiment 1. For each of the 100 pictures from Experiment 1, a set of translation equivalents were recorded which corresponded to the dominant name of each picture in Spanish and English. These words were obtained from a picture-norming experiment conducted in our laboratory. These words were recorded and digitized using 16 bit sound sampled at 44 kHz. The design and procedure were identical to Experiment 1 except that participants were presented with auditory words and asked to translate them into the other language. Again, like Experiment 1 the words were either in one language only (blocked) or alternated between languages on every third trial. This again allowed us to compare blocked and mixed conditions as well as switch and noswitch trials within the mixed condition.

Results and discussion

Table 4 shows the mean response latencies and percent errors for each age group, respectively. First, note that both groups were faster and more accurate at translating from Spanish to English than vice versa. Second, notice that across both groups responses in the blocked condition were faster than in the mixed condition (albeit with no additional cost when translating from English to Spanish for young adults in the mixed condition). Finally, unlike Experiment 1 there was no increase in RT in the older adult group relative to the young adult group for translation.

These observations were confirmed by a 2 (age) × 2 (language) × 2 (condition) mixed-factors ANOVA for both reaction time and percent errors. The results from reaction times revealed a main effect of language ($F(1,38) = 23.43$, $p < .001$, $MSE = 8153.52$) and condition ($F(1,38) = 5.31$, $p < .027$, $MSE = 18975.28$). Although the age by condition interaction did not reach significance it was in the expected direction ($F(1,38) = 3.05$, $p < .089$, $MSE = 19718$) with older adults showing a larger slowdown in the mixed condition. However, the difference across groups in the mixed condition was 45 ms compared to 272 ms in Experiment 1. No other interactions reached significance. There was an effect of direction of translation much like in studies reviewed earlier (Spanish to English being faster). The condition effect across age groups for reaction time can be seen in Figure 2.

The results from percent errors revealed a main effect of language ($F(2,57) = 41.02$, $p < .001$, $MSE = 85.16$) and a three-way age by condition by language interaction ($F(2,57) = 41.02$, $p < .001$, $MSE = 85.16$). This interaction was due to differences in the error pattern in the English-to-Spanish condition across group and condition. Specifically, younger adults showed more errors in the blocked than in the mixed condition (17% vs. 13 %) whereas older adults showed the reversed pattern (14%

Table 4. *Reaction times and percent errors for Experiment 2 (translation).*

Auditory/Response language	n	Condition	Mean Reaction Time (*SD*)	Mean Percent Errors (*SD*)
		Young adult participants		
Spanish/English	20	Blocked	1321 (117)	6 (7)
		Mixed	1374 (112)	7 (6)
		Mixed–Blocked	+53	+1
English/Spanish	20	Blocked	1425 (128)	17 (12)
		Mixed	1419 (106)	13 (9)
		Mixed–Blocked	–6	–4
		Older adult participants		
Spanish/English	20	Blocked	1299 (277)	7 (7)
		Mixed	1423 (177)	6 (6)
		Mixed–Blocked	+124	+1
English/Spanish	20	Blocked	1384 (323)	14 (15)
		Mixed	1461 (221)	19 (14)
		Mixed–Blocked	+77	+5

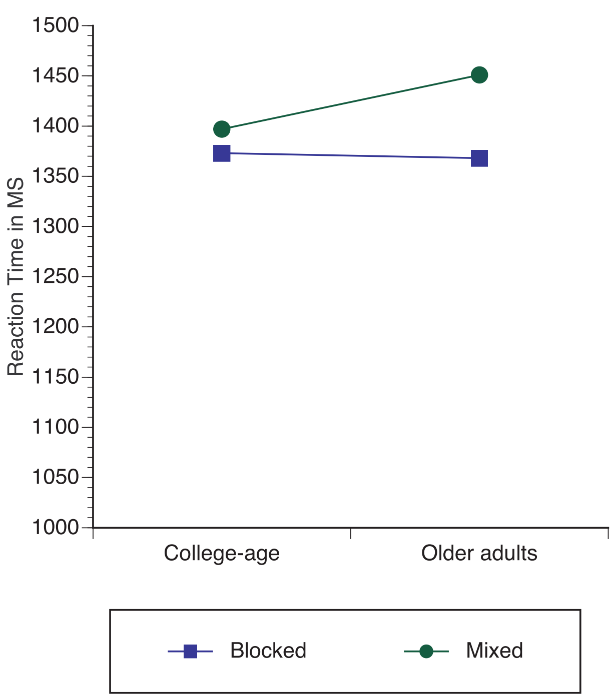

Figure 2. (Colour online) Effects of condition across age groups in Experiment 2 (translation).

vs. 19%). In the Spanish-to-English translation condition both groups showed similar patterns of performance.

The effect of alternating between languages, within the mixed condition can be seen in Table 5. The data revealed a complex but interesting pattern of results. Young adults were significantly faster than older adults for noswitch trials when translating from Spanish to English. Furthermore, older adults were slower at responding for switch trials when translating from English to Spanish. These results were confirmed by two, 2 (age) × 2 (language) × 2 (switch) mixed factors ANOVA for reaction time and percent errors. For the ANOVA on reaction time, there was a marginally significant main effect of language ($F(1,38) = 4.07$, $p < .051$, $MSE = 8321.87$) and an age by language by switch interaction ($F(1,38) = 6.38$, $p < .016$, $MSE = 8411.65$) which can be seen in Figure 3. A set of post-hoc comparisons were used to compare RTs between younger and older adults across all 4 conditions used in the experiment (i.e. switch and noswitch by direction of translation). These comparisons revealed that younger adults were significantly faster than older adults on noswitch trials ($F(1,38) = 6.87$, $p < .013$, $MSE = 8411.65$) but not on switch trials when translating from Spanish to English. When translating from English to Spanish older adults were significantly slower in the switch condition ($F(1,38) = 10.73$, $p < .005$, $MSE = 8411.65$) but not in the noswitch condition. Note, that these effects are in the 70 ms range and are hence about a quarter of the size of the 272 ms slowdown observed in Experiment 1.

For percent errors, there was a main effect of language ($F(1,38) = 42.31$, $p < .000$, $MSE = 89.42$) and an age by language interaction ($F(1,38) = 4.35$, $p < .044$, $MSE = 89.42$). Participants were more accurate when translating from Spanish to English than vice versa. This effect varied slightly over age with older adults making more errors than young adults when translating from English to Spanish ($F(1,38) = 8.05$, $p < .010$, $MSE = 89.42$).

The results from Experiment 2 revealed a different effect than that observed in Experiment 1. Namely, older adults were not significantly slowed in the mixed condition relative to young adults (note that the effect was in the

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Table 5. *Reaction times and percent errors as a function of switching in the mixed condition for Experiment 2 (translation).*

Auditory/Response language	n	Condition	Mean Reaction Time (*SD*)	Mean Percent Errors (*SD*)
		Younger adult participants		
Spanish/English	20	NoSwitch	1340 (126)	5 (6)
		Switch	1407 (119)	8 (8)
		Switch–NoSwitch	+67	+3
English/Spanish	20	NoSwitch	1415 (120)	11 (8)
		Switch	1424 (151)	16 (14)
		Switch–NoSwitch	+9	+5
		Older adult participants		
Spanish/English	20	NoSwitch	1435 (189)	18 (20)
		Switch	1410 (219)	19 (13)
		Switch–NoSwitch	–25	+1
English/Spanish	20	NoSwitch	1429 (242)	4 (8)
		Switch	1492 (235)	8 (8)
		Switch–NoSwitch	+63	+4

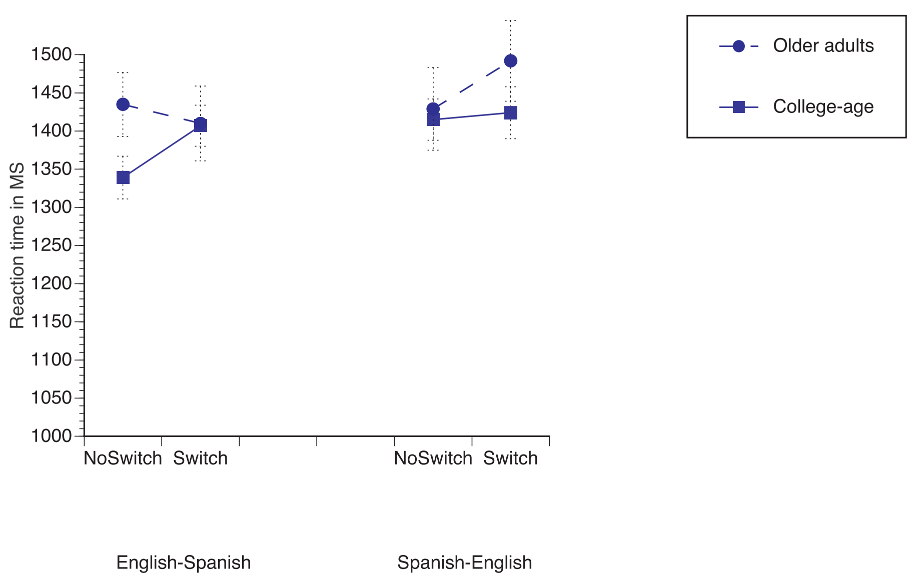

Figure 3. (Colour online) Age by language by switch interaction in Experiment 2 (translation).

right direction). In addition, the mixed condition revealed some differences between older and younger adults, which varied across condition, and language.

General discussion

The current studies were designed to explore the locus of potential response decrement in language-mixed relative to single language processing conditions in proficient bilinguals as a function of age and experimental task. In Experiment 1 (picture naming), both groups of bilinguals were faster and more accurate in English than in Spanish. However, older adults showed a significant slowdown relative to young adults in Experiment 1. This slowdown was particularly large in the mixed condition where older adults showed a 272 ms slowdown relative to young adults. In the blocked design, older adults were roughly 50 ms slower than young adults. Although the latter effect was not significant it was in the expected direction. Hence, it appears that older adults have particular difficulty with switching in the mixed condition in terms of reaction time costs, a replication of previous studies (Hernandez & Kohnert, 1999). Unlike Hernandez and Kohnert, however, our effects were restricted to reaction time costs. Older adults showed an increased number of errors relative to the young adult group in both the blocked and the

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mixed condition, suggesting that picture naming may have been more difficult for the older age group in this experiment. Finally, the current design also revealed no difference between switch and noswitch trials within the mixed design across groups, an extension of our previous study.

Experiment 2 was designed to further clarify the nature of the slowdown in the mixed condition in older adults by using a translation task. The motivation behind using translation was to find a task with at least the same level of difficulty as picture naming which also required generation of a response. Despite the similarities across tasks, there were also important differences. Specifically, translation always involves the link between a word and its lexical equivalent in the other language. Because both language labels are activated on each trial, there is less of an additional cost that is encountered when switching languages in terms of sustained switching. In terms of language dominance we observed results that are consistent with our previous study and with the literature on translation. Namely, translating into English was faster than translating into Spanish across both young and older adults (consistent with our participants greater skill in English relative to Spanish). As predicted, there was only a marginally significant age effect when comparing blocked and mixed conditions across groups. Finally, comparison of switch and noswitch trials in the mixed condition did reveal some differences across age for transient switching. Specifically, younger adults were faster than older adults at translating from Spanish to English for noswitch trials (but not for switch trials) and older adults were slower at translating from English to Spanish for switch trials (but not for noswitch trials). The difference in the asymmetry of the effect suggests that there are some slight differences in the ability to allocate attention during transient switching, a point we will return to below.

The results are, for the most part, consistent with a task-set reconfiguration process (Monsell & Mizon, 2006; Rogers & Monsell, 1995). According to this view, switching costs are due to increases in the amount of endogenous control needed when a stimulus exogenously primes multiple responses. For bilinguals, pictures can potentially activate items from both languages. The use of a cue provides a way to select a response in the appropriate language especially in the mixed condition. However, translation involves a different type of control since each word serves to cue the translation. Hence, participants are not faced with having to link two competing responses even though translation equivalents are active in a translation task. The current results qualify previous studies by indicating the component of language switching responsible for the breakdown observed in older adults. Specifically, it appears that the slowing is due only in part to language switching and to the generation of a word. More significantly it appears that the ability to choose between items from each language when these items compete at the response level shows the largest breakdown in older adults.

This hypothesis is further qualified by the comparison of performance on the switch and noswitch trails in the mixed condition for both experiments. In Experiment 1, there was no difference across groups when comparing switch and noswitch trials. That is, older adults found the mixed condition difficult. There was a significant cost regardless of whether they were responding to switch or no switch trials. This is very similar to what Hernandez and Kohnert (1999) found. The costs of switching in cued picture naming diminished significantly but only on the first to the second trial after the switch. Subsequent studies that have used a picture-naming paradigm have also found significant differences between the mixed and blocked condition in language-switching paradigms (Gollan & Ferreira, 2009; Weissberger et al., 2012). We suggest that this increased cost is due to a generalized difficulty with sustained switching in the mixed condition.

Whereas the comparison between mixed and blocked conditions did not yield a large mixing cost in Experiment 2, the comparison between switch and noswitch trials revealed interesting differences between older adults and young adults. Here we found that young adults were faster than older adults for noswitch trials when translating from Spanish to English with no difference between the groups for switch trials. When translating from English to Spanish, older adults showed slower reaction times for switch trials with no difference between the groups for noswitch trials.

What might account for the different patterns of switch and noswitch effects observed? One factor that might account for these differences has to do with the attentional allocation across translation and picture-naming tasks. In picture naming, both languages become active when encountering each stimulus in a mixed condition. The costs that are observed are due to sustained switching and hence older adults do not benefit from noswitch trials and do not show additional processing costs for switch trials relative to young adults. In short, the mixed condition is sufficiently difficult that there is no additional benefit or cost for either group in transient switching. In the translation task, however, the task involves the activation of the other language item on every trial. For our study participants, translating from Spanish (the weaker language) to English (the stronger language) is easier than translating from English to Spanish (Heredia, 1997). Older adults showed no facilitation in the easier condition (i.e. Spanish to English) for noswitch trials and showed significant slowing for switch trials in the more difficult condition. We suggest that older adults are experiencing more difficulty with transient switching. In the easy condition (i.e. Spanish to English), residual interference from the previous condition continues onto the noswitch trial but only for older adults. In the more difficult condition, increased task-set interference results in slowing for switch trials but only for older adults. In short, older adults are showing more interference on both switch and noswitch trials relative to young adults. This is consistent with previous studies that have found a more reactive form of switching for older adults relative to young adults (Jimura & Braver, 2010).

These results are interesting in light of recent developments in the aging and task-switching literature. Work by Weissberger et al. (2012) looked at the presence of language-switching and non-verbal switching tasks in a group of bilingual younger and older adults. Older adults showed slower reaction times when switching between tasks or languages than when naming items in a single language or performing a single task. However, the magnitude of the switching effects was much larger for the non-verbal switching task than for the language-switching task. This suggests that not all switching tasks require the same amount of executive function and hence will not show the same magnitude of slowdown in older adults. In this respect, the use of a translation task represents to a certain degree less of a task-set reconfiguration than picture naming in the context of language switching. That is, the translation task tends to activate both items but does not lead to response competition. Thus, our findings fit in nicely in showing a continuum in the cost associated with switching on older adult bilinguals that is dependent on the type and amount of executive function needed. Finally, Weissberger et al. (2012) also observed interesting changes in the direction of switch and non-switch trials in the non-verbal task when comparing older adult and young adult bilinguals. These differences in transient switching are similar to the ones we found in the current study and to those found by Jimura and Braver (2010). Future studies are needed to further explore the differences across these tasks and to pinpoint more precisely the locus of language-switching effects as a function of age in bilinguals.

In summary, the current study is consistent with the view that older adults show increased switching costs relative to young adults in tasks that require language switching. However, this cost varies across tasks. The largest effect observed was for sustained switching in picture naming where the stimulus activates lexical candidates in both languages. In translation, where the stimulus has a unique response these costs are considerably reduced. Hence, the cost is most likely due not directly to the imposition of a task-set. Rather it is most likely due to having to endogenously choose between competing alternatives. In this respect, the results from the translation task are consistent with studies that have found older adults to be more reactive than younger adults. Future studies should continue to look at the continuum of control tasks to observe under what conditions older and younger adult bilinguals differ in their ability to switch between languages.

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