Performance monitoring and decision-making: psychophysiological and developmental analyses
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8. Developmental changes in task switching: Examining the role of retroactive adjustment

Abstract

The hypothesis was tested that developmental changes in task switch performance result from changes in retroactive response adjustment, that is, the facilitating or interfering effect of the previously acquired stimulus-response (S-R) association. Three age groups (7-8 year-olds, 10-12-year-olds, and 20-25-year-olds) performed a 2-choice reaction time (RT) task in which spatially compatible or incompatible responses were required. Switching tasks was associated with an RT cost. These costs were larger when responses were repeated than when responses were alternated. The response repetition costs were much larger for younger children, but became less prominent when the interval between the previous response and the upcoming stimulus increased. In contrast, age differences in switch costs were absent when responses were alternated. These findings suggest that young children retroactively adjust responses for the same task more strongly than older groups, which interferes with their ability to switch to currently intended actions. These results implicate that not only preparatory control processes, but also retroactive memory traces are sensitive to developmental change.

8.1. Introduction

The ability to control cognitive processes for the regulation of behavior becomes more efficient during childhood, as can be seen by age-related changes identified across a variety of control and executive function tasks (Diamond, 2002; Nelson, 1995; Nelson, & Luciana, 2001; Stuss, 1992; Welsh, 2002). This developmental change has often been interpreted in terms of increased capacity for behavioral inhibition and mental flexibility, suggesting that the ability to shift back and forth between multiple tasks and to monitor cues from the environment in order to adjust subsequent performance increases during childhood (Crone, Ridderinkhof, Worm, Somsen & Van der Molen, 2003; Pennington, 1994; Welsh, 2002).

The task switch paradigm has been proposed to provide a valuable tool for dissociating distinct developmental trajectories of cognitive flexibility and control. In this paradigm (Allport, Styles & Hsieh, 1994; Meiran, 1996; 2000; Rogers & Monsell, 1995), participants rapidly switch between two or more reaction-time (RT) tasks that are typically performed to the same set of stimuli (e.g., switching between color discriminations or shape discriminations). The task to be performed can be determined by a pre-specified paradigm in which participants switch on every nth trial (Rogers & Monsell, 1995) or by randomly presenting a task-cue indicating which task to perform on the subsequent trial (Meiran, 1996). Switching between tasks is usually associated with a sizeable decrement in performance. As would be expected following the assumed age-changes in flexibility and control, several developmental studies reported that switch costs decrease as children grow older (Cepeda, Kramer, & De Sather, 2001; Huizinga & Van der Molen, 2003; Span, 2002).
However, several researchers have reported that increasing preparation time for the next upcoming stimulus did not reduce children's switch costs. For instance, in a life-span study, Cepeda et al. (2001) manipulated the response-cue interval (RCI) and the cue-target interval (CTI) to examine if age-related differences in task switch performance could be explained by age-related changes in 'passive' previous-task dissipation or 'active' upcoming-task preparation. That is, during the RCI, the participant has not yet been informed about the upcoming task, and thus cannot use the RCI for task-set preparation. Nonetheless, extending RCI yields a reduction in switch costs, a reduction attributed to the dissipation of the task set associated with the previous trial (Meiran, 1996, 2000). The CTI is presumed to reflect the time in which endogenous process of task reconfiguration can be carried out in anticipation of the stimulus, during which new processing algorithms are loaded in working memory and during which the processing algorithm that is no longer appropriate can be actively suppressed. Cepeda et al.'s life-span results showed that the benefit of increasing the CTI was similar for all age groups. In contrast, increasing the RCI resulted in a decrease in switch costs for young adults, but failed to reduce switch costs for children. These results were interpreted to suggest that younger children experience more interference from the previous task set, suggesting less efficient task dissipation, whereas preparatory functions may have reached mature levels relatively early in childhood.

Likewise, Huizinga and Van der Molen (2003) manipulated preparation interval (CTI) at three levels and found that increasing the time for active preparation did not reduce age-related differences in switch costs. The finding that age differences in switch costs cannot be reduced by increasing preparation time is somewhat surprising, because from a developmental perspective it would be expected that the intentional or preparatory component of task control can be predominantly attributed to an executive mechanism (for example the Supervisory Attention System; Shallice & Burgess, 1993), and this process would be expected to develop relatively late (Van der Molen, 2000, Welsh, 2002).

The literature on sequential effects may be particularly relevant for assessing switching ability in children. Sequential effects are changes in response speed due to the sequence of preceding stimuli. Previous research has shown that the stimulus presentation rate determines the pattern of sequential effects. When the response-stimulus interval (RSI) is short, individuals benefit from stimulus repetition, referred to as 'automatic facilitation'. This process may reflect the influence of residual memory traces remaining from the previous stimulus-response cycle on the processing of the next stimulus. Studies with short RSIs typically show that children favour response repetitions over alternations (automatic facilitation), and the magnitude of this repetition effect decreases with age. In contrast, when the RSI is long, individuals benefit from alternation, referred to as 'subjective expectancy' (Soetens, Boer, & Hueting, 1985). These expectancy processes appear to increase from childhood to adulthood (Kerr, Blanchard, & Miller, 1980; Kerr, Davidson, Nelson, & Haley, 1982).

The application of this interpretation to explain developmental changes in task switching is demonstrated by a study of Kerr et al. (1982). They had children and adults switch between stimulus rules that required either a left or right hand responses. To examine stimulus and response contributions, they repeated or alternated both stimulus and response characteristics (e.g., both a '1' and a '2' required a left hand response, '3' and '4' required
a right hand response). Kerr et al. found that children responded much slower to a new stimulus requesting the same response (e.g. '2' followed by '1') than to a same stimulus requesting the same response (e.g., '2' followed by '2') or to a new stimulus requesting a different response (e.g., '2' followed by '3'). These age-related RT costs decreased when RSI increased. These results were interpreted to suggest that benefits from receiving the same stimulus twice in a row resulted from faster stimulus encoding and recognition, and employing the rule that pairs the stimulus with its appropriate response more quickly. Following this assumption, the required adjustment of previously acquired stimulus-response (S-R) associations when switching between tasks may be stronger in young children, and consequently, these acquired S-R associations may account for the larger switch costs when children need to adjust the acquired S-R association for the new task.

The strength of the previous S-R association has been described in the task-switch literature as 'residual switch costs'. It is well known that extending the interval between the response on one trial and the stimulus of the next trial (RSI) results in a gradual decrease in switch costs (e.g., Rogers & Monsell, 1995), but even when given ample time to prepare, switching cost is usually not eliminated. For example, it has been observed that prolonging the preparation interval from 150 to 600 ms results in a reduction in switch costs, but when the interval is extended to 1200 ms no further reduction in switch cost is observed (De Jong, 2000; Rogers & Monsell, 1995; Meiran, 1996).

Residual switch costs are presumed to consist of two components. The first is called 'exogenously triggered task-set reconfiguration' or 'stimulus-cued task-set completion' (cf. Rogers & Monsell, 1995). This component refers to the notion that activation of the task set is completed only after presentation of the target stimulus. This notion is comparable to the utilisation behavior displayed by frontal-lobe patients (e.g., Lhermitte, 1983; Shallice, Burgess, Schon, & Baxter, 1989). That is, a stimulus immediately activates its typical task set (such as combing one's hair when given a comb), regardless of whether or not this task set is in accordance with current intentions or instructions.

The second component of residual switch costs has been labelled 'retroactive response-set adjustment' by Meiran (2000; Meiran & Gottler, 2001) and refers to post-response (retroactive) modulations of the strength of the association between a particular response and a particular task when responses are bivalent (i.e., when both tasks involve the same responses). Let us denote $S[A,L]$ for the strength of the association between task A and the left-hand response; $S[A,R]$ for the strength of the association between task A and the right-hand response; $S[B,L]$ for the strength of the association between task B and the left-hand response; and $S[B,R]$ for the strength of the association between task B and the right-hand response. Let us assume (for the sake of argument) that $S[A,L], S[A,R], S[B,L], \text{and } S[B,R]$ add up to 1.0, and that each has a starting value of 0.25. Consider a sequence of trials where trial N-1 involved task A and a participant pressed the left key to indicate his/her response to task A. Pressing the left key is presumed to result in strengthening of $S[A,L]$ to, say, 0.4, and in reducing $S[B,L]$ to, say, 0.1. Since the right-hand key was not pressed on trial N-1, $S[A,R]$ and $S[B,R]$ remain unaltered at 0.25. Switching to task B on trial N would result in relatively difficult selection of the left-hand compared to the right-hand response, because $S[B,L]$ is weaker (0.1) than $S[B,R]$ (0.25). A repetition of task A on trial N would, by contrast, facilitate selection of the left-hand compared to right-hand response, because
S[A,L] is already stronger (0.4) than S[A,R] (0.25). This pattern explains why response repetitions are typically associated with greater task-switch costs than response alternations (Kray & Lindenberger, 2000; Meiran, 1996; Meiran & Gottler, 2001; Rogers & Monsell, 1995).

The hypothesis stating that age-changes in task switch performance may be explained by differences in retroactive response adjustment is supported by the observation that in developmental task switch studies (Cepeda et al., 2001; Huizinga & Van der Molen, 2003, Span, 2002), age differences in the remaining (residual) switch costs were quite large even at extended intervals between the task to be performed and the completion of the previous task. In these studies, age-related improvement in performance on switch trials may therefore be caused by changes in the control of 'residual switch costs'. Following this assumption, we predict that the interference from the response recoding on the alternative task at Trial N-1 is larger for younger children, resulting in a larger contribution of retroactive response adjustment.

In this study, we examined age effects on switch costs for response repetitions and for response alternations. Three age groups responded to targets presented on the left or right side of the computer screen. Target properties (e.g., green circle or a red triangle) indicated that a compatible (left side, left key) or incompatible (left side, right key) response should be given. Participants performed these tasks repeatedly or switched from one task to the other. The main dependent variable was the extra time required to alternate between tasks, as compared to the repetition of the same task (Switch cost RT = task alternation RT – task repetition RT).

Age differences in response adjustment were examined by comparing the time required to perform a task switch when the response differed from the response on trial N-1 (task alternation, response alternation) with the time needed to complete a task switch on which the response on trial N and trials N-1 were the same (task alternation, response repetition). The Response-Stimulus Interval (RSI) was manipulated at three levels (50 ms, 500 ms and 1250 ms). The target itself designated the new task, excluding the influence of advanced preparation (see also Van Asselen & Ridderinkhof, 2000). Switch costs should be larger in younger compared to older children for response repetition trials but not for response alternation trials (Kerr et al., 1982; Soetens & Hueting, 1992). Manipulation of RSI should replicate the effects reported by Cepeda et al. (2001), showing that participants benefit more from increased dissipation time with age. Following Kerr et al. (1982), longer RSIs should result in a decrease in age-differences in response repetition switch costs.

Finally, we examined age differences in cognitive control by complementing the switching paradigm (Meiran, 1996) with the measurement of a non-switch baseline (Kray & Lindenberger, 2000). The goal was to assess cognitive control components that were specifically related to the switch situation and control components related to the dual-task situation in general. In homogeneous task blocks, participants performed either the compatible S-R task or the incompatible S-R task. Costs of mixing were determined by computing the differences in reaction times between task repetitions in the heterogeneous task and task repetitions in the homogeneous task and were termed mixing costs (Los, 1996). We predicted that mixing costs are more pronounced for compatible than incompatible S-R relations, as reflected by an underadditive interaction between block heterogeneity...
and S-R compatibility (Los, 1996; Stoffels, 1996) but based on previous work (Span, 2002) we expected these effects to be similar for all age groups.

8.2. Method

8.2.1. Participants
Three age groups participated in the study, 22 younger children between 7 and 8 years of age (M = 8.0, SD = .50, 10 female), 23 older children between 10 and 11 years of age (M = 11.2, SD = .49, 11 female), and 21 university students aged between 20 and 25 years (M = 22.8, SD = .47, 14 female).

Children were recruited by contacting schools. These participants were selected with the help of their teacher and their primary caregiver signed a consent letter for participation. All children had average or above average intelligence (based on teachers report). The students were recruited through flyers and received credit points for their participation. All participants reported to be in good health and had normal or corrected-to-normal vision.

8.2.2. Stimuli and Apparatus
Stimuli were approximately 8 mm wide and 8 mm high, displayed in red or green on a white background, presented in random order and equiprobably, 3 cm to the left or right of a black vertical fixation line (6 cm in length) on a 17-inch computer monitor. Participants viewed the monitor from a distance of 60-75 cm, resulting in a between-stimulus horizontal visual angle of 1° to 1.15°. The left key 'z' was operated with the left index finger in response to stimuli presented to the left of the fixation line in compatible conditions and to stimuli presented to the right of fixation in incompatible conditions. The right key '/' was operated with the right index finger for stimuli presented right of fixation in compatible conditions and for stimuli presented left of fixation in incompatible conditions.

Participants were instructed to respond to two types of stimuli, that could be a circle or a triangle presented in red or green. The two stimuli differed in both shape and color to facilitate discrimination. The first type of stimulus required a spatially compatible response, and the second stimulus required a spatially incompatible response. The assignment of shapes and colors to compatible and incompatible stimuli was counterbalanced between participants and kept fixed across the experiment.

8.2.3. Procedure
First, a practice block was presented of 50 trials in which the participants responded to compatible trials with 500 ms RSIs. The experimental task consisted of 20 blocks of 105 trials. The first five trials of each block were considered 'warming-up' trials and were excluded from analysis. RT was recorded as the time between stimulus onset and pressing of the response keys. The stimulus was response terminated and the response initiated the RSI. RSIs were fixed at 50, 500 or 1250 ms. No error corrections were possible.

Participants completed five types of tasks: four pure blocks of compatible trials with RSIs of 500 ms, four pure blocks of incompatible trials with RSIs of 500 ms, four switch blocks with RSIs of 50 ms, four switch blocks with RSIs of 500 ms and four switch blocks
with RSIs of 1250 ms.

All participants were tested individually in a quiet laboratory or classroom. They performed the five types of tasks in counterbalanced order. Including instructions and breaks, participants spent approximately one hour in the laboratory or classroom.

8.3. Results

8.3.1. Switch costs

Trials with RTs of less than 100 ms, error trials, and trials immediately following an error were excluded from RT analysis. Prior to analysis, RTs were transformed to their natural logarithm to reduce the influences of differences between age groups in baseline performance (Meiran, 1996).

Response Latencies. The first set of ANOVAs focused on switching within the separate switch blocks. The factor 'Task Switch' examined the difference in RT on task switch trials in comparison to trials on which the same task was performed as on the previous trial. Similarly, the factor 'Response Switch' examined the difference in RT between trials on which the response alternated relative to the preceding trial compared to trials on which the same response was repeated. The difference in RT on compatible S-R trials and incompatible S-R trials was examined by the factor Task 'S-R Compatibility'. Finally, the factor 'RSI' referred to the differences in RT when trials were presented within blocks of 50 ms RSI, 500 ms RSI and 1250 ms RSI. These factors were submitted to repeated-measures ANOVA with Age Group (4) as a between-subjects variable, and Task Switch (2), Response Switch (2), S-R Compatibility (2), and RSI (3) as within-subjects variables.

The ANOVA revealed main effects of Age Group, $F(2, 63) = 60.47, p < .001$, and Task Switch, $F(1, 63) = 445.65, p < .001$. These main effects were qualified by two-way interactions between Age Group and Task Switch, $F(2, 63) = 8.86, p < .001$, Task Switch and Response Switch, $F(1, 63) = 105.14, p < .001$, and a three-way interaction between Age Group, Task Switch, and Response Switch, $F(2, 63) = 4.98, p < .01$, which is plotted in Figure 8.1. As can be seen in the Figure, switch costs were larger for response repetition trials (217 ms on average) than for response alternation trials (79 ms). Most importantly, this effect is more pronounced for younger children (346 ms vs. 126 ms) than for older children (104 ms vs. 61 ms), and young adults (101 ms vs. 49 ms). Separate post hoc ANOVAs revealed that switch costs remained significantly different between the three age groups for response repetition trials, as was seen by an interaction between Age Group and Task Switch, $F(2, 63) = 8.04, p < .001$. In contrast, for response alternation trials this interaction failed to reach significance, $F(2, 63) = 2.67, p = .08$.

The main effect of RSI, $F(2, 126) = 60.95, p < .001$, interacted with Age Group, $F(4, 126) = 3.90, p < .01$, Response Switch, $F(2, 126) = 9.67, p < .001$, and Task Switch x Response Switch, $F(2, 126) = 11.78, p < .001$, and was included in the Age Group x Task Switch x Response Switch interaction, $F(4, 126) = 3.20, p < .05$. The latter interaction is plotted in Figure 8.2. A separate post hoc ANOVA, for response repetition trials only, showed that the age-related task switch costs for response repetitions (plotted in Figure 8.1) increased with shorter RSI intervals, as was seen by the interaction between Age Group, Task Switch and RSI, $F(4, 126) = 5.41, p < .01$. In contrast, there was no significant Age Group x Task Switch x RSI interaction for response alternations.
Figure 8.1. Effects of response repetition versus response alternations on RT differences in task switching for each age group.

Figure 8.2. Age-related differences in sensitivity to Response-Stimulus Intervals (RSI) for response repetitions and response alternations as measured by the difference in RT when switching tasks versus repeating tasks.

Finally, S-R Compatibility interacted with Task Switch, $F(1, 63) = 45.85, p < .001$. This interaction revealed that switch costs were larger when participants switched to the compatible S-R rule (164 ms) compared to when they switched to the incompatible S-R rule (133 ms). There was also a four-way interaction between S-R Compatibility, Task Switch,
Response Switch and RSI, F (2, 126) = 12.54, p < .001, but this interaction was unexpected, and not further investigated. Most importantly, S-R Compatibility did not interact with Age Group.

**Errors.** Square roots of choice error percentages were submitted to a 3 (Age Group) x 2 (S-R Compatibility) x 2 (Task Switch) x 2 (Response Switch) x 3 (RSI) ANOVA. In general, the mean number of errors was low (8%). There was a main effect of Task Switch, F (1, 63) = 164.19, p < .001, showing that participants made more errors when switching between tasks (10.0%) compared to task repetitions (4.3%). This effect was modulated by a number of factors. The error % for these effects are presented in Table 8.1.

First, there were two-way interactions between Task Switch and S-R Compatibility, F (1, 63) = 47.05, p < .001, between Task Switch and RSI, F (2, 126) = 15.87, p < .001, and a three-way interaction between Task Switch, S-R Compatibility and RSI, F (2, 126) = 4.74, p < .01. This interaction shows that accuracy on task switch trials compared to task repetition trials was decreased more for compatible S-R trials than for incompatible S-R trials. This difference in accuracy costs was more pronounced for longer RSIs.

Second, there was a two-way interaction between Task Switch and Response Switch, F (1, 63) = 157.49, p < .001, and this interaction was included in a three-way interaction between Task Switch, Response Switch, and S-R Compatibility, F (1, 63) = 19.89, p < .001. This last interaction shows that the task-switch costs for accuracy were larger when responses alternated, compared to when responses were the same, and these differences were larger for compatible S-R trials than for incompatible S-R trials. Most important, age groups did not differ in accuracy, F (2, 64) = .24, p = .79, and there were no interactions including the factor Age Group.

<table>
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<td>7.6 (.014)</td>
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<td>8.4 (.011)</td>
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<td>Incompatible</td>
<td>3.5 (.005)</td>
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*Table 8.1: Means and standard errors of error percentages.*

**8.3.2. Mixing Costs**

**Response Latencies.** The second set of ANOVAs focused on age-specific effects on general mixing costs (task repetitions in pure blocks versus task repetitions in switch blocks). Task repetitions in the pure blocks and in the switch blocks with 500 ms RSI were examined with the factor 'Block Type'. Task repetitions could occur for compatible S-R trials and for incompatible S-R trials, referred to as 'S-R Compatibility'. Task repetitions could occur for response repetitions and response alternations, referred to as 'Response Switch'. The 3 (Age Group) x 2 (Block Type) x 2 (S-R Compatibility) x 2 (Response Switch) ANOVA revealed
a main effect of Age Group, $F(2, 63) = 76.91, p < .001$, showing that RTs from young adults ($M = 336, SD = 13.5$) were faster than those of older children ($M = 440, SD = 14.3$), and older children responded faster than younger children ($M = 561, SD = 14.7$). There were also main effects of Block Type, $F(1, 63) = 283.37, p < .001$, S-R Compatibility, $F(1, 63) = 102.14, p < .001$, and Response Switch, $F(1, 63) = 46.82, p < .001$. There were two-way interactions between Block Type and S-R Compatibility, $F(1, 63) = 51.76, p < .001$ and between Block Type and Response Switch, $F(1, 63) = 29.06, p < .001$. Finally, there was a three-way interaction between Block Type, S-R Compatibility and Response Switch, $F(1, 63) = 119.11, p < .001$. This last interaction is plotted in Figure 8.3. As can be seen in the Figure, responses were slower for mixed blocks than for pure blocks, and for incompatible than for compatible responses. However, the difference in response time to incompatible and compatible trials disappeared in mixed blocks when responses were alternated, whereas this was not observed when responses were repeated. Most importantly, there were no interactions including the factor Age Group.

**Errors.** Square roots of choice error percentages were submitted to a $3 \times 2 \times 2 \times 2$ ANOVA. This analysis resulted in only an effect of Block Type, showing that participants made more errors in the switch blocks (9.6%) than in the pure blocks (6.5%), $F(1, 63) = 11.55, p < .001$. There were no other main effects or interactions.

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**Figure 8.3.** RT effects of mixing tasks for response repetitions and response alternations.

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**8.4. Discussion**

Previous studies have reported a pronounced reduction in switch costs during childhood, which could not be accounted for by changes in preparation processes. The literature on sequential effects suggests that children may acquire stronger S-R associations which bene-
fits them in case responses to the same trial type need to be rapidly repeated but results in costs when S-R associations are alternated (Kerr et al., 1982; Soetens & Hueting, 1992). This study examined if 'retroactive response adjustment' (Meiran, 2000) could account for age-changes in RT costs when switching between tasks.

The switch pattern of adults was consistent with the observation that switch costs differ as a function of response repetition/alternation. Rogers and Monsell (1995) previously reported a highly significant interaction between response repetition and task switching for young adults. That is, a benefit was observed of repeating the same response in non-switch trials, but a cost of repeating the same response in switch trials. This interaction was also observed by Meiran (1996; 2000) and Kray and Lindenberger (2000), and was interpreted in Meiran's processing model (2000) in terms of response readiness initiated by the previous response.

Similar as in previous developmental studies (Cepeda et al., 2001; Huizinga & Van der Molen, 2003; Span, 2002), switch costs were much larger for the younger age group than for the older age groups. Most importantly, we found that the switch costs were much larger for younger children when responses were repeated, but disappeared when responses were alternated. This pattern suggests that the age-related variance in residual costs is due to stronger adjustment of the response set in younger children.

Consistent with Cepeda et al. (2001), switch costs were largest when RSI was short (50 ms) but decreased when RSI was prolonged (500 ms or 1250 ms). Interestingly, Kerr et al. (1980; 1982) and Soetens and Hueting (1992) previously suggested that when trials are rapidly succeeding, individuals cannot form expectancies about the upcoming stimulus. Instead, stimuli are processed rather automatically, and automatic processing was found to benefit children more than adults. For example, in a single task, children were found to benefit more from response repetitions when RSIs are short (Smulders et al., in preparation; Soetens, & Hueting, 1992), and the greater benefit from response repetition diminished with longer RSIs (500 ms). Therefore, greater automatic facilitation during short response-stimulus intervals (Soetens, et al., 1985) is thought to result from a temporary shortcut in central processing stages. Children's response alternations therefore result in much slower response times than response repetitions at short RSIs. The larger switch costs for younger children at shorter RSI may be similar in this respect.

Although the concept of automatic facilitation has only been applied to single-task conditions, it bears resemblance to the reactive adjustment component in Meiran's model (2000). That is, the prevalent interpretation of automatic facilitation is in terms of residual memory traces from processing the previous trial (Soetens et al., 1985). Following this interpretation, switching to a different task with the same response may be especially difficult for young children, because the binding of memory traces with the previous task is stronger (Meiran, 2000), and this binding may diminish when the time between the previously acquired binding and the upcoming trial increases (Soetens & Hueting, 1992).

Note that both interpretations of acquired S-R associations, sequential effects and retroactive response-set adjustment, are elegantly captured by a recent application of event-coding theory to task switching (Waszak, Hommel, & Allport, 2003). In this model, stimuli and responses acquire associations with the specific tasks in which they occur, that is, these features are bound together into an episodic 'event file'. When the stimulus on the
present trial was recently associated with another task and with another response, this stimulus may trigger retrieval of the associated episodic event and, hence, activation of a competing task set, thus provoking switch costs. Thus, children may experience larger interference from the competing task when the required response was previously associated with the other task.

Additionally, we found that in general, responses were slower to incompatible compared to compatible trials. This finding has previously been interpreted as the time needed to inhibit the pre-potent response (compatible response) prior to execution of the incompatible response (Kornblum, Hasbroucq, & Osmanet, 1990). When switching between tasks, switch costs were smaller for the incompatible task than for the compatible task. This pattern of results has also been reported by others (Allport et al., 1994; De Jong, 1995; Monsell, Yeung, & Azuma, 2000; Stoffels, 1996), and has been interpreted to suggest that suppression of a strongly competing task set can carry over to a later trial, making it more difficult to activate the previously competing task set on a switch trial (Allport et al., 1994). This finding was not different for children and adults, indicating that age changes in retroactive response adjustment could not be explained by differential sensitivity to S-R compatibility. Children and adults did not differ in sensitivity to S-R compatibility, suggesting that in the current paradigm children did not have more difficulty inhibiting the pre-potent response tendency to the compatible response (see also Van den Wildenberg & Van der Molen, 2003).

A final aim of this study was to examine the performance decrement associated with the fact that trials of two tasks were intermixed. Mixing costs refer to the difference between no-switch trials within a switch block and blocks in which participants perform a single task and do not switch tasks. We found that participants responded slower in the mixed situation compared to the pure blocks. When responses were repeated, this decrement was similar for compatible and incompatible S-R trials. When responses were alternated, this decrement was larger for compatible S-R trials than for incompatible S-R trials. The latter finding is consistent with previous studies (Allport et al., 1994; Los, 1996; Stoffels, 1996) and reflects that mixing costs are larger for the fast, and possibly automatic level of processing than for the slow, control demanding level. Most important, mixing costs did not differentiate between age groups, suggesting that age-changes in specific task switch performance cannot be attributed to age-changes in the ability to remember task context. This finding is consistent with findings reported by Span (2002), who found that children show greater switch costs but do not differ in mixing costs. Cepeda et al. (2001) observed that not only switch costs but also mixing costs were larger in children, but they referred to mixing costs as the difference between repetitions in pure blocks and switch trials in switch blocks, so the difference in selected trials can possibly account for the differences in findings.

Taken together, it has been suggested that age changes in task switching may result from age changes in flexibility and endogenous control processes (Cepeda et al., 2001; Luciana & Nelson, 1998; Welsh, 2002). This study, however, showed that developmental changes in task switch costs can be largely explained by the experience of greater involuntary retrieval of S-R associations, which interferes with children's ability to switch to currently intended actions (Kerr et al., 1982; Soetens & Hueting, 1992).