When and Why Do Old Adults Outsource Control to the Environment?

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Running Head: Outsourcing Control to the Environment

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Abstract

Old adults' tendency to rely on information present in the environment rather than internal representations has been frequently noted, but is not well understood. The fade-out paradigm provides a useful model situation to study this internal-to-external shift across the life span: Subjects need to transition from an initial, cued task-switching phase to a fade-out phase where only one task remains relevant. Old adults exhibit large response-time "fade-out costs", mainly because they continue to consult the task cues. Here we show that age differences in fade-out costs remain very large even when we insert between the task-switching and the fade-out phase 20 single-task trials without task cues (during which even old adults' performance becomes highly fluent; Exp. 1), but costs in old adults are eliminated when presenting an on-screen instruction to focus on the one remaining task at the transition point between the task-switching and fade-out phase (Exp. 2). Furthermore, old adults, but not young adults also exhibited "fade-in costs" when they were instructed to perform an initial single-task phase that would be followed by the cued task-switching phase (Exp. 3). Combined, these results show that old adults' tendency to over-utilize external support is not a problem of perseverating earlier-relevant control settings. Instead, old adults seem less likely to initiate the necessary reconfiguration process when transitioning from one phase to the next because they use under-specified task models that lack the higher-level distinction between those contexts that do and that do not require external support.

When und Why Do Old Adults Outsource Control to the Environment?

In many real-world situations, people have a choice: They can either rely on automatic retrieval from memory to guide behavior or instead can search the environment for cues about what to do next (e.g., Craik, 1994, Lindenberger & Mayr, 2014). While the first supports fluent behavior, the latter mode of processing leads to slower, more deliberate patterns of action. There is increasing evidence that advancing age brings not only a decrement in basic processing capacities, but also a shift towards a greater reliance on external rather than internal information. Importantly, such an altered mode of processing may be responsible for slower and more disfluent behavior in older adults over and above the effects of basic-level decrements (Touron & Hertzog, 2004).

Currently, not much is known about what exactly triggers this greater reliance on external support in older adults. A better understanding of the relevant boundary conditions is important for distinguishing age differences that are due to basic-level decrements from those that are due to a change in processing-mode. Information about what turns the externally-directed processing mode on and off can also help devising potential countermeasures to older adults' suboptimal over-reliance on external information. Therefore our goal in the current series of experiments was to identify critical conditions for age differences in the tendency to rely on the environment for guidance. We first describe the basic experimental paradigm before discussing potential triggers of shifts between internally-oriented and externally-oriented processing modes.

The Fade-Out Paradigm

An experimental model in which old adults' internal-to-external shift becomes particularly apparent is the "fade-out" variant of the task-switching paradigm (Mayr &

Liebscher, 2001; Spieler, Mayr, & LaGrone, 2006). Participants start out by switching randomly between two different tasks according to task cues presented on the screen (see Figure 1 for sample stimulus displays). From a particular point in time within the block, one of the tasks is "faded out" and is no longer relevant for the remainder of the block. At this point, young adults transition very quickly to the same level of fluent performance they achieve when the same task has been relevant throughout the block. In contrast, old adults exhibit large response-time (RT) costs during this fade-out phase, which persist until the end of the block (i.e., the fade-out cost). These costs arise even though the fade-out point is clearly signaled—the on-screen task cue associated with the no-longer relevant task is covered with a red “strike-out” bar— and subjects receive very detailed instructions about the block structure. Moreover, eye-tracking has revealed that during the fade-out phase old adults overwhelmingly continue to inspect the task cues during the fade-out phase on about 80% of trials compared to about 15% for young adults. This result indicates that the RT costs do in fact reflect a very strong tendency to check the environment prior to responding.

Largely parallel results have been also observed in the noun-pair lookup task (Rogers, Hertzog, & Fisk, 2000; Touron & Hertzog, 2004), a variant of a paired-associates learning paradigm where subjects can transition from externally-oriented processing (i.e., consulting a lookup table) to internally-driven processing (i.e., retrieval of learned word-associations). Old adults take much longer to make this transition, even after they have learned the word pair. We will further discuss this related body of research in the *General Discussion*.

Passive Perseveration versus Lack of Active Configuration

When it comes to identifying reasons for old adults' tendency to rely on external information, one potentially important observation is that in the examples discussed so far, people initially need to rely on external information, but then have the opportunity to transition to a mode of control that relies on internal information. In the fade-out paradigm it is the initial task-selection phase that requires extensive cue processing; in the paired-associate learning paradigm it is the early learning phase where inspection of the word pairs is necessary. In each of these cases, it seems that old adults *perseverate* the initially appropriate strategy of consulting the environment beyond its point of usefulness.

Such perseveratory tendencies in the use of external information may occur as a *passive* aftereffect of having had to rely on such information in the first place. For example, old adults are often thought to have problems with selecting from competing tasks (Mayr, 2001) or when having to rely on episodic memory (Burke & Light, 1981). As a result, when faced with situations that challenge internal representations (such as in the cued task-switching phase of the fade-out paradigm or during the noun-pair lookup task) old adults may become particularly biased towards externally available information rather than relying on potentially faulty, internal information. Because this initial, external bias is more extreme in old than in young adults it takes longer to relax this bias, even when relying on the environment is no longer necessary.

If this type of perseveration hypothesis is correct then it should be possible to reduce fade-out costs simply if old adults experience that internal information is sufficiently robust to solve the task successfully, thereby providing an opportunity for the bias towards external information to relax. In Experiment 1, we test this hypothesis, but find evidence that is consistent with passive perseveration as the mechanism behind old adults' reliance on external information. Therefore in the remaining experiments, we examine an alternative explanation for old adults' overreliance on environmental support, namely that the external-internal transition involves an active configuration process that routinely happens in young adults, but that old adults frequently fail to engage in. In Experiment 2 we find positive evidence that an external prompt to engage in active configuration does in fact reduce the fade-out effect in old adults. In Experiment 3, we pit two possible explanations for why old adults are less likely to engage in active configuration against each other. Specifically, we contrast a perseveration account with the hypothesis that old adults use low-complexity mental models that do not adequately reflect the structure of the task space.

Experiment 1

Our goal for this experiment was to test the idea that in the regular fade-out block it is the initial experience with the cued switching phase that biases the system towards environmentally outsourced control. Such a bias should be reversed in a situation in which participants are able to experience fluent task performance without relying on external information. Our experimental design builds on Experiment 2 in Spieler at al. (2006) where a regular fade-out phase was compared to one in which the task cues were eliminated from the screen during the fade-out phase. Interestingly, in this latter condition old adults' fade-out costs were reduced to the level of young adults, indicating that in principle, old adults are able to perform the fade-out phase without relying on task cues. In the current experiment, we added to this design a condition in which task cues disappeared for the first 20-trial period of the fade-out phase (see Figure 1, display C), but then reappeared for the second 20-trial period (see Figure 1, display B). If the passive perseveration explanation of the fade-out costs is correct then by performing successfully in the absence of task cues, old adults' fade-out costs should remain small, even after the cues return.

Methods

Participants

Twenty-five younger adults were recruited from the undergraduate student population at Georgia Tech and participated for course credit. Twenty-two older adults were recruited from a pool of community dwelling older adults in the Atlanta metropolitan area and were paid $15 per hour for their participation. The younger adults scored an average of 88.1 (SD = 14.3) on the Wechsler Adult Intelligence Scale (WAIS-III) Digit-Symbol subscale and 48.3 on the WAIS-III Vocabulary subscale (Wechsler, 1997). Older adults averaged 54.6 (SD = 18.1) on the Digit-Symbol and 50.2 (SD = 12.1) on the Vocabulary subscale.

Stimuli

Stimuli were displayed on a white background. The verbal task cues ("color" or "shape") were displayed in the upper left and right corners of the display, separated by 20.6 degrees and both were 14.9 degrees from the centrally presented stimulus, a 2.7 degree by 1.1 degree vertically or horizontally oriented bar that required either a color or orientation judgment from the participants. The bars were displayed in either the color red or blue. During the fade-out phase and the transition trials, the task cue for the no-longer relevant task was presented with a red strikethrough line. For trials where no task cues were displayed, the location of the task cue was replaced by identical 1.5 degree by 1 degree grey patch with black cross hatching.

Design and Procedure

There were two single-task control blocks—one for each task. There were three types of fadeout blocks: (1) In the standard fadeout condition an initial phase with 40 trials of cued task switching was followed by a 40 trial single-task phase with cues present. (2) In the no-cue condition, cues were eliminated during the fadeout phase after three transition trials (trials 41 to 43). (3) In the reappearing cue condition, cues were again removed after a three transition (trials 41 to 43), but reappeared from trial 61 to 80. Each of these fadeout blocks was implemented twice, once for each task as the single task.

At the start of the session, participants were given instructions outlining the tasks that they would perform. Participants then proceeded through several practice blocks designed to familiarize them with the tasks and ensure they understood the design of the fadeout blocks. The order of the practice blocks was held constant to provide all participants experience with the single tasks, then task switching, and then with the 3 types of fadeout blocks. In total, participants then went through 6 mini blocks (2 single task, one task switching and 3 fade-out blocks) of trials. When the fadeout blocks were introduced during the practice phase of the experiment, emphasis was placed on the fact that all three types of fade-out blocks had the same transition to single task performance regardless of the presence of the cues. After completing the practice phase, participants proceeded to the experiment. During the experiment, the blocks were presented in random order. At the start of each block participants were reinstructed by the experimenter on whether they were going to perform a single task or fade-out block. If a fadeout block was next, they were informed of the task that would be relevant during the fade-out phase but they were not told which of the three types of fade-out blocks they would see.

Each trial began with a single plus sign ("+") as a fixation point in the center of the screen for 500 ms, followed by a 50 ms blank screen and the the trial stimulus appeared and remained on the screen until the participant make a response and was followed by a 750 ms intertrial interval before then next trial. Individuals made their color (red or green) and orientation (vertical or horizontal) judgments using the 'z' and '/' key on the keyboard.

Results and Discussion

Responses less than 200 ms and greater than 5,000 ms were eliminated from all analyses (2.2% of the entire distribution). Also, error trials and trials after errors were excluded for response time (RT) analyses. RTs and errors across the main experimental conditions and major block segments are presented in Table 1. Error rates in no way counteracted the pattern of RT results.

The main analyses focused on performance during the single-task phase of the fade-out blocks (Trials 44 – 80; henceforth, the fade-out phase) in comparison with the corresponding trials from single-task blocks. Figure 2 (see also Table 1) shows the relevant fade-out costs as a function of 5-trial segments (with the exception of initial 7-trial segment that follows the 3-trial transition segment) with the corresponding within-subject 95% confidence interval computed on the difference between fadeout and single task for each segment (Loftus & Masson 1994).

There are four important observations to emphasize in these results. First, in the absence of cues during the fadeout phase of the experiment, both young and older adults' performance is similar to single task performance by the third segment of trials. Second, with the presence of cues throughout the fadeout phase, younger adults' but not older adults' performance reaches single task performance by the end of the fadeout phase. These two observations replicate our results from Experiment 3 in Spieler et al. (2006). Third, in blocks in which the task cues reappear on trial 61, both young and older adults exhibit an increase in RT suggesting both groups register the appearance of these cues. Fourth, the cost associated with the reappearance of the task cues is substantial and lasting in older adults while the cost for younger adults appears limited to the 10 trials following the reappearance of the cues.

Consistent with these observations, we obtained in an analysis of variance (ANOVA) with the between-subject factor Age, and the within-subject factor Cue Presence (Fade Cue, Fade No Cue), the critical Age x Cue Presence interaction, $F(1, 45)=24.36$, $MSE=13166$. This reflects the larger influence of cue presence/absence on old adults' performance compared to young adults. Separate analyses showed that old adults were considerably better without task cues, $F(1,21)=35.18$, $MSE=24419$, whereas young adults were not, $F(1,24) = 3.22$, $MSE = 5195$, $p>0.05$. Finally, for fade-out blocks in which the stimulus reappears, the segments after the reappearing cues were considerably more slowed relative to single task controls for old adults than younger adults, $F(1,45) = 12.01$, $MSE=19353$.

In this experiment we tested the hypothesis that old adults' experience of being particularly dependent on external information during the initial task-selection phase produces a prolonged bias towards external information. If this version of a passive perseveration hypothesis were correct, fade-out costs should have been reduced after providing subjects with the experience of successful and fluent internally-based processing during the intermittent no-cue phase. However, once the task cues reappeared, also the RT costs reappeared in full force. This pattern does not support the idea that a bias towards either internal or external information is simply an aftereffect of the control demands that were relevant in the immediate past.

Experiment 2

The results from Experiment 1 are not consistent with the passive perseveration hypothesis. In Experiment 2, we turn to an alternative possibility. Maybe what is missing in old adults is an explicit, self-initiated configuration process (Braver, Paxton, Locke, & Barch, 2009; Craik, 1994) that prepares the system for the next category of events at the fade-out point. Without such explicit configuration there might be a slow adaptation to the new demands, as reflected in the gradually declining fade-out costs, but not the swift return to single-task performance level seen in young adults.

If old adults lack a self-initiated configuration process, we should be able to replace it through one that is exogenously prompted. Therefore, in this experiment we compared three conditions in a group of old adults. Aside from the standard fade-out condition and the single-task control, we added a fade-out-plus-instruction condition. Here, the task-selection and the fade-out phase where separated by a 3.5 second break during which a short written instruction reminded subjects that from now on only one of the two tasks remains relevant. In order to test the pure instruction effect, an unfilled 4-second break was also inserted in the standard fade-out and single-task control conditions. If missing self-instruction is responsible for the finding of large fade-out costs then we should see that these costs are reduced when explicit instruction is provided.

Our preceding work (Exp. 1 and Spieler et al., 2006) has suggested that a hallmark of the fade-out effect is that it is much larger on blocks during which task cues are present then when they are not. As a secondary question in this experiment, we wanted to examine if the moderating effects on fade-out costs could be achieved even through a trial-by-trial manipulation of cue presence (i.e., displays B and C in Figure 1). Thus, we should expect particularly large fade-out costs on cue-present trials, and this cue effect should be reduced after external instruction.

In this experiment, we only tested old adults. For young adults, regular fade-out costs are typically so small that there is not sufficient room for further reduction through an externally prompted configuration process.

Method

Participants

We tested 18 older adults with a mean age of 71.9 (SD=5.7) who were recruited through newspaper ads from the Eugene/Springfield area and reimbursed with $20 for their participation. The average WAIS-III Digit Symbol score was 56.2 (SD=17.8); the average Vocabulary score was 52.4 (SD=11.7).

Stimuli

Stimuli were displayed against a black background within a white frame (11.5 degrees visual angle wide and 13.7 degrees high). As task cues the words "Color" was shown in the upper left corner and "Shape" was shown in the lower right corner. Each word was about 1.1 degrees wide and 5 degrees in height. A thin white frame (1 pixel) surrounded each task label that thickened (8 pixels) for the label corresponding to the currently relevant task. During the fade-out phase and the transition trials, the task cue for the no-longer relevant task was presented with a red strikethrough line. The task stimulus was presented centrally, 2.8 degrees from the bottom of the frame. The direct distance between task labels and stimulus was 9.1 cm. The stimulus was a square or a circle that was shown in either red or green and of about 1.7 degrees width and height.

Design and Procedure

Three basic task conditions were implemented: The standard fade-out condition, a fade-out-plus-instruction condition, and a single-task control condition. As in Experiment 1, in the fade-out condition task cues varied initially randomly between the two tasks on a trial-by-trial basis. After 30 trials followed a 3.5 second unfilled break during which the screen turned black and from trial 31 onwards, a line was drawn through one of the two task labels indicating that this task would be no longer relevant for the remaining 30 trials. The fade-out-plus-instruction condition was identical to the fade-out condition, only that during the 4 second break after trial 30 the following instruction appeared on the screen: "Please remember: Only the COLOR [SHAPE] task will remain relevant". Finally, the *single-task control condition* was identical to the standard fade-out condition (including the 3 second unfilled break) only that the same task that was relevant during the fade-out phase was also the only relevant task during the initial 30-trial phase. For all conditions, trials 31 to 33 served as a "transition phase" during which subjects had an opportunity to adapt to the changed task demands and task cues were present on each of these trials. Otherwise, cue presence was manipulated on a trial-by-trial basis during the fade-out phase or the corresponding trials (34-63) of the single-task control condition.

Each of these three conditions was implemented twice, once for each task as the single task. To familiarize subjects with the tasks and the task-switching situation, subjects started with two 63-trial single-task blocks and a 63-trial task-switching block. In addition, each individual test block was not only preceded by detailed instructions, but also by a 14-trial "instruction" block that resembled the structure of the following test block in a compressed manner (initial phase: 5 trials, transition phase: 3 trials, fade-out phase: 6 trials). The sequence of the six test blocks was counterbalanced across subjects.

Each trial began with a 500 ms period during which only the stimulus frame was present. Then the task cue was presented for 100 ms followed by the stimulus. Cue and stimulus remained on the screen until the response was entered. The two tasks required subjects to respond to either the color (red or blue) or the form (vertical or horizontal) of the stimulus and participants made their responses using the / and z key of the keyboard.

Results and Discussion

Again, responses less than 200 ms and greater than 5,000 ms were eliminated from all analyses (.5% of the entire distribution). Also, error trials and trials after errors were excluded for RT analyses. RTs and errors across the main experimental conditions and major block segments are presented in Table 1. Error rates in the critical conditions were low and did not counteract RT results.

Our main analyses focused on the fade-out phase and to what degree fade-out costs were affected by the instruction manipulation. Figure 3 shows fade-out costs after the transition phase, from trial 33 onwards in terms of six 5-trial segments for the the no-instruction and the instruction condition. The average RT for the single-task control condition averaged across trials 34-63 was 654 ms (SD=210). As evident, in the no-instruction condition we obtained a substantial fade-out cost (M=220 ms, SD=285), $F(1,17)=23.61, p<.001$, MSE=227636.0, which declined somewhat across the 30 trial phase, $F(5, 85)=7.34$, $p<.001$, MSe=21631.29, but remained significant in each segment (see confidence intervals in Figure 3). More importantly, the instruction delivered at the transition point reduced these costs by an average of 164 ms (SD=132), $F(1,17)=26.26$, $p<.001$, MSE=113208.28, an effect that was significant for nearly every individual segment (see confidence intervals in Figure 3).

In this experiment we also wanted to check to what degree even a trial-by-trial cue manipulation modulated the over-reliance on external information. Responses were generally slower when the cue was present than when the cue was absent across all conditions: single-task control=35 ms (SD=84), no-instruction fade-out=94 ms (SD=114), instruction fade-out=21 ms (SD=63). The difference between the cue effect in the control and no-instruction fade-out condition was in the expected condition, but failed to reach significance, $F(1,17)=2.44$, $p<.12$, MSE=24481.21. However the difference in the cue-effect between the instruction/fade-out condition and no-instruction fade-out condition was significant, $F(1,17)=3.50$, $p<.05$, MSE=32044.73. Overall, the effect of the trial-by-trial cue-present/cue-absent manipulation was not quite as striking as for the blocked manipulation (see Exp. 1 and Spieler et al., 2006). However, the overall pattern of results was in the expected direction. It is particularly noteworthy that explicit instructions reduced susceptibility to the cue manipulation. This is consistent with the view that the bottom-up cue effects in the standard fade-out condition result from a failure of old adults to update their internal control setting at the appropriate part of the fade-out block.

Experiment 3

As the preceding experiment demonstrated, a brief external instruction is sufficient to induce reconfiguration and substantially reduce fade-out costs, including the bottom-up modulation of these costs though the presence/absence of task cues. Thus, the key to understanding fade-out costs may be found on a relatively high level of representation, one that is sensitive to verbal instructions. Arguably, young adults spontaneously generate the necessary self-instruction, whereas in old adults the same top-down control setting needs to be provided externally.

But why would old adults be less likely to self-initiate a reconfiguration process? One possibility is, again a version of the perseveration hypothesis. High-level control setting adopted during the initial task-selection phase may perseverate in old adults, possibly as a result of an inhibitory deficit (e.g., Hasher, Stoltzfus, Zacks, & Rypma, 1991). There is, however an interesting alternative possibility. Perhaps, what keeps old adults from initiating the necessary change is not so much the *preceding* experience with the initial task-selection stage. Rather the difficulties may arise from the fact that old adults do not fully represent the hierarchical nature of the task space relevant for a fade-out block (Duncan, Emslie, Williams, Johnson, & Freer, 1996). Figure 4 illustrates this idea. The internal task model that is necessary to fully capture the distinction between the task-selection phase and the fade-out phase needs two levels: the level of tasks (color/shape) and the level that defines which constellation of tasks is relevant at a given point in time. Only participants who represent a fade-out block in this manner (i.e., most young adults, see Figure 4) can be expected to self-initiate the critical transition between task phases. Participants can perform a fade-out block without errors even with a “flat task model” that only includes the task-selection demands (i.e., most old adults, see Figure 4). With such a task model participants would perform in the fade-out phase "as if" they were still in the task-selection phase, namely by remaining attentive to cues for information about the currently relevant task.

How can we test this idea against the hypothesis that fade-out costs are caused by the perseveration of control settings? If the perseveration hypothesis is correct then it is of course critical that the fade-out phase comes *after* the task-selection phase. However, for the hierarchical complexity of the task structure it should not matter if the fade-out phase comes after or whether it comes *before* the task-selection phase (i.e., a "fade-in" phase).

To test the perseveration and the task-model hypothesis against each other we included in this final experiment aside from the standard fade-out condition also a fade-in condition in which subjects were instructed to initially work only on one of the two tasks (i.e., with the irrelevant task cue "marked out") and then to transition into a task-selection phase at a clearly marked transition point. If the task-model hypothesis is correct then we should find “fade-in costs” during the initial single-task phase, which directly follows instruction of the block structure but precedes the task-selection phase.

Method

Participants

We tested 18 older adults with a mean age of 73.1 (SD=6.2) were recruited through newspaper ads from the Eugene/Springfield area and 18 University of Oregon undergraduate students with a mean age of 20.4 (SD=1.7). Older adults received $20 as compensation for their efforts; young adults received course credit. Old adults had an average WAIS-III Digit Symbol score of 55.4 (SD=15.9) and an average vocabulary score of 54.4 (SD=14.9).

Stimuli, Design, and Procedure

We used the same tasks and stimuli as in Experiment 2. We also included the same type of fade-out and single-task control blocks as in that experiment; albeit without the 3.5 second break after trial 30. In addition, we also presented fade-in blocks with an initial, 30-trial single-task phase, three transition trials, and then 30 cued task-selection trials. Again, each condition was presented twice, once for each of the two tasks during the single-task portions of the block. The sequence of these six different blocks was counterbalanced across subjects. Also, subjects were presented with the same sequence of practice blocks and the 14-trial, compressed "instruction" blocks prior to each test block, as in Experiment 2.

Results and Discussion

As in the preceding experiments, responses less than 200 ms and greater than 5,000 ms were eliminated from all analyses (.7% of the entire distribution for old adults and .2% for young adults). Also, error trials and trials after errors were excluded for RT analyses. RTs and errors across the main experimental conditions and major block segments are presented in Table 1.

For the main analyses, we looked at RTs either before the transition phase (for fade-in blocks) and after the transition phase (for fade-out blocks) compared to the corresponding phases of the single-task control blocks. Figure 5 shows the resulting fade-in and fade-out costs as a function of 5-trial segments.

As evident from the figure (see also Table 1), age differences were large both in fade-in costs (Young=49 ms, SD=63, Old=221 ms, SD=149) and in fade-out costs (Young=41 ms, SD=60, Old=187 ms, SD=137). In an ANOVA with the between-subject factor age, experimental (i.e., fade-in and fade-out combined) versus single-task control, fade-in vs. fade-out, and quintiles, the theoretically critical age x experimental/control interaction was highly reliable, $F(1,34)=36.11$, $MSE=37577.07$, $p<.01$. In order to test whether fade-out costs differ in size from fade-in costs we need to examine to what degree this interaction is further modulated through the fade-in/fade-out factor. The corresponding three-way interaction was far from reliable, $F(1,34)=.23$, suggesting an approximately equivalent pattern of costs before and after the task-selection phase. This result is inconsistent with the preservation interpretation of the fade-out pattern but it is consistent with the hypothesis that old adults operate with a restricted task model that lacks a clear distinction between the task-selection and the single-task parts of either the fade-in or the fade-out block.

There is, however one aspect of the pattern of fade-in costs that is curious in light of this hypothesis: Both young and old adults showed a marked increase of these costs in the 6th quintile, just prior to the transition, which is probably due to the fact that participants were slowing down in preparation for the impending, mid-block change in rules. The fact that not only young adults, but also old adults shows this pattern seems difficult to reconcile with the claim that old adults do not adequately distinguish between the two phases. How could they prepare for something that is not an explicit part of their task model? It is, however possible that in old adults, this preparatory effect was mainly due to a subgroup of participants who actually did operate on the basis of more complete task models. To test this idea, we conducted a median split on the basis of fade-in costs (based on block quintiles 1-5, but excluding the final, sixth quintile). For young adults, the low fade-in cost group (cost=17 ms, SD=51) showed a final-quintile increase of 104 ms (SD=142) and the high fade-in cost group (cost=73 ms, SD=63) showed an increase of 114 ms (SD=120). For old adults the corresponding values for the low fade-in cost group (cost=92 ms, SD=77) was 172 ms (SD=92 ms), but it was actually negative, namely -20 ms (SD=176) for the high fade-in cost group. Thus, in old adults only the low fade-in cost group showed a marked preparatory increase in RTs, whereas the high-cost group showed no preparatory effect. The corresponding interaction between age and high/low fade-in cost groups was reliable, $F(1,32)=6.55$, $MSE=48252.50$, $p<.02$. This pattern is consistent with the idea that high fade-in costs result from a task model that does not reflect the distinction between block phases.

As in Experiment 2, we had also manipulated the presence of task cues on a trial-by-trial basis. Overall, cues led to a larger increase in RTs for old than for young adults, $F(1,34)=5.98$, $p<.05$, $MSE=8998.63$, and this effect was larger for either of the two experimental conditions (fade-in or fade-out) than for the single-task control condition, $F(1,34)=5.88$, $p<.05$, $MSE=2118.02$. However, this age x cue x experimental/control interaction was further modulated by the fade-in/fade-out factor, $F(1,34)=6.10$, $p<.05$, $MSE=1311.45$. In old adults, the effect of cue presence (109 ms, SD=94) in the fade-out condition costs was larger than for young adults (14 ms, SD=52). Generally, the cue-effect was much more modest for fade-in costs (old=38 ms, SD=108, young=28 ms, SD=64). Closer inspection of the results revealed that it was not so much that old adults in the fade-in condition were not affected by cue presence, (old=100 ms, SD=130, young=47, SD=62), but rather that old adults showed a rather marked effect of cue presence already in the corresponding single-task baseline trials (old=62 ms, SD=118, young=20 ms, SD=41). Thus, while trial-by-trial cue effects for the fade-out condition fully replicate the previous results, the situation is slightly more complicated for the fade-in condition. The relatively large cue effects in the control condition may indicate that old adults had greater difficulty differentiating between single-task control and the fade-in conditions.

In terms of errors, young adults showed overall slightly higher error rates than old adults, $F(1,34)=18.52$, $p<.001$, $MSE=.01$. There also was a main effect of experimental (fade-in and fade-out combined) versus control (corresponding single-task) conditions, $F(1,34)=4.52$, $p<.05$, $MSE=.01$, but no further reliable interactions (see Table 1).

General Discussion

Older adults often show a greater tendency than young adults to rely on information available in the environment, even when they seem perfectly capable of performing fluently and accurately on the basis of internal representations. In the current work, we tried to arrive at a better understanding of why, and under which circumstances, older adults over-utilize environmental support. With our results we were able to rule out one, theoretically highly plausible category of explanations, namely that such over-reliance on external representations is the result of a perseveratory tendency in old adults. Instead, our results strongly favor a novel hypothesis, namely that older adults seem to operate on the basis of internal representations of the task space that do not clearly specify when reliance on environmental support is necessary and when it is not. In the remainder of this section, we will discuss the theoretical implications and open issues regarding these new results as well as how they may elucidate related phenomena from other experimental paradigms (e.g., Touron & Hertzog, 2004)

Differences in Perseveration or Task Models?

As an indicator of reliance on external information we looked at the so-called fade-out cost that arises when subjects need to transition from a cued task-switching phase to a single-task phase, but with the external task cues remaining present on the screen. The structure of this situation lends itself to a perseveration explanation of the age differences in fade-out cost. Older adults may have a harder time returning to the efficient single-task mode because the initially established routine of inspecting the task cues has greater persistence for them than it has for young adults. Such greater persistence could be the result of an inhibitory deficit (Hasher et al., 1991). It could also be a simple consequence of the fact that for old adult the initial task-selection phase is more difficult and affords a particularly strong bias towards externally-oriented routines, which in turn makes them more difficult to get rid off, when no longer relevant (Gilbert & Shallice, 2002). Combined, our results speak against this general category of perseveratory explanations.

The first two critical results in this regard came from experiments in which we inserted different types of events between the cued task-switching and the fade-out phase. In Experiment 1, we found that fade-out costs are *not* reduced by providing participants the experience of fluent and successful behavior, namely by inserting a phase in which cues were removed from the screen. Once the task cues reappeared, also the fade-out costs fully re-emerged in full force. We interpret this as indicating that old adults' fade-out costs do not result from a particularly strong bias towards external information as a result of the initial difficult, cued task-switching phase. If such a bias were responsible for the fade-out costs then the cue-absent phase (where old adults show virtually no costs) should have provided ample opportunity for “de-biasing”. More generally, given that the intermittent no-cue phase temporarily separates the initial task-selection from the fade-out phase, but does not reduce fade-out costs, this result is at least difficult to reconcile with any simple perseveration explanation.

In Experiment 2 we found that inserting a visually presented verbal instruction between the task-selection and the fade-out phase eliminated nearly all of the fade-out costs in old adults. Apparently, the verbal instruction triggered an explicit reconfiguration process that routinely seems to take place in a self-initiated manner in young adults, but that requires external prompting in old adults. There is a well-established body of research in the memory literature, which suggests that older adults are less likely to self-initiate processing (e.g., Craik, 1994). For example, older adults are less likely to spontaneously restructure items in ways that improve memory and they are less likely to spontaneously engage in efficient memory encoding strategies (Anderson et al., 2000). More recently, this general idea has also been applied in the domain of action selection. In particular, Braver and colleagues have argued for a cognitive and neural-level dissociation between proactive (i.e., self-initiated) and reactive control (Braver, 2012). They have also provided evidence of particular age-related deficits in proactive control, and that these could be reversed through instructions and strategy training (Braver et al., 2009). In the context of the fade-out paradigm, the act of self-instructing a focus on the one, remaining task can be viewed as an act of proactive control that needs to take place at the right point in time and in the absence of explicit, external prompts.

In the final experiment, we tested competing hypotheses about why old adults might have problems with adequately timed self instruction. As mentioned, the structure of the fade-out paradigm can easily inspire a perseveration explanation. Specifically, the fact that a control setting (i.e., to perform cued task switching) is already highly activated at the transition point may make it particularly difficult to replace it through a new one. However, another possibility is that old adults do not adequately distinguish between the two different phases of the block, but rather approach the *entire* episode simply as one uniform "task-switching block". Consistent with this hypothesis we found that old adults exhibited costs even when the single-task phase occurred *before* the cued task-switching phase. Thus, the mere instruction of a complex two-phase structure leads to inefficient processing for the single-task blocks. Clearly then, the “flat” task model that lacks the adequate higher-level distinction between the different phases of upcoming block rather than perseveration is responsible for old adults' unusual pattern of performance in the fade-in/fade-out situation.

Age Differences in Capacity or Strategy?

Proactive self-instructions do not occur in a vacuum. Rather, they need to be triggered based on adequate internal models about the structure of the task space. At least in the present situation, old adults’ problems with proactive control seem to be linked to an incomplete, internal model. It is important to stress that the incomplete task model explanation is not the same as saying that old adults simply did not understand the instructions for each block. In fact, we know that old adults are able to perform with high degree of accuracy when no task cues are present—which would be impossible without a principal understanding of the task demands. Rather, what seems to be missing is a "compilation" of the verbally instructed task model into an "executable" representation. This interpretation may appear somewhat post-hoc and tailored towards accommodating our findings. However, the literature provides important precedence for such a view. Duncan et al. (1996) found that people often miss to act upon the instruction of performing a rule change that was contingent on an arbitrary external event, even though they were able to verbalize the instruction. These omissions, which Duncan et al. referred to as "goal neglect" were particularly prevalent when (a) the overall task model that specified the rules was complex (Duncan et al., 2008) and (b) subjects had relatively low fluid intelligence (Duncan et al., 1996). Duncan and colleagues suggested the fluid intelligence represents the capacity to represent the currently relevant task space both reliably and flexibly. Aspects in the task model that are not reliably represented are easily missed and may lead to goal neglect.

The pattern of age differences in fade-in/fade-out costs is clearly consistent with the idea that old adults do not adequately represent complex, hierarchically organized task models (see also Eppinger, Walter, Heekeren, & Li, 2013). Furthermore, there is ample evidence that fluid intelligence or working memory capacity are reduced with age. Thus, it is certainly possible that old adults' fade-in/fade-out costs simply reflect the same type of capacity limitation that according to Duncan et al. produces goal neglect in young adults. It will be necessary to assesses the relationship between fluid intelligence or working memory capacity on the one hand and fade-in/fade-out costs on the other to directly test this hypothesis in future work. For example, in this case we should see that young adults with low fluid intelligence behave similarly to old adults (e.g., Schmitt, Ferdinand, & Kray, 2014).

Beyond capacity limitations, there may be other reasons that lead people to endorse simplified task models in particular circumstances. The simplified task model that old adults seem to have endorsed encompasses the cued task-switching phase--which is the more complex of the two phases of the critical experimental blocks. This raises the possibility that old adults endorse a satisficing (Simon, 1972), rather an optimizing strategy of making sure they get the most difficult aspects right, but worry less about being optimally tuned towards fluent behavior for the easier parts of the overall situation (see also Strayer & Kramer, 1994). This interpretation is also generally compatible with results indicating that even in simple choice response-time tasks, old adults favor higher response thresholds, which in turn leads to higher accuracy at the cost of longer RTs. Starns and Ratcliff (2010) have recently proposed that this type of threshold setting could be explained by assuming that old adults operate with the motivation to avoid errors (at almost all costs), whereas young adults focus on increasing the rate of reward per time unit. Applied to our situation, it seems reasonable to assume that a system that is mainly geared towards avoiding errors pays less attention to the distinction between the task-switching and the single-task phase than on adequately representing the most difficult aspects of the task.

This satisficing explanation is not necessarily an exclusive alternative to the limited-capacity explanation. However, if there are strategic settings that intervene between limited capacity on the one hand and the kind of behavior we observed then the relationship could these two could be relatively loose (see Lindenberger & Mayr, 2014). For example, it is possible that a gradual, age-related increase of occasional experiences with behavioral errors due to capacity limitations could lead to a generalized, play-it-safe strategy. Further, the degree to which such strategies are adopted may also depend on non-cognitive factors, such as different styles of coping with age-related changes (Freund & Baltes, 2002). Clearly, it will require additional work with larger sample sizes and assessment of adequate covariates to disentangle these different potential factors. Despite the remaining uncertainties, the current results suggest new directions in exploring the reasons behind old adults' over-reliance on environmental support.

Relationship to Old Adults' Retrieval Reluctance

Finally, it is important to discuss our results vis-à-vis related findings using the earlier-mentioned noun-pair lookup paradigm (Rogers et al., 2000; Touron & Hertzog, 2004). Here subjects need to perform a paired associate learning task with a limited set of word pairs by relying either on a memory-retrieval strategy or by looking up the correct word pairs on the upper half of the screen. Young adults quickly transition from the cumbersome lookup to the fast memory strategy, whereas old adults seem to remain stuck in the lookup strategy. This age difference is relatively robust, but as with the fade-out cost it largely disappears when the lookup table is removed from the screen (Touron & Hertzog, 2004). Also, even without the lookup table, old adults perform with high accuracy, indicating that—as in the fade-out paradigm—there are no easily apparent competence reasons for the resistance towards the more fluent, memory-based strategy.

There are differences between the Hertzog/Touron paradigm and the fade-out/fade-in paradigm. For example, only the fade-in/fade-out paradigm has the clear separation between a task-switching and a single-task phase that lends itself to a hierarchically organized task model. In the noun-pair lookup paradigm the distinction between a phase where it is clearly beneficial to utilize the environment and a phase where it is clearly beneficial to use memory is much more gradual and ambiguous. Nevertheless, at its core similar issues may be responsible for the observed age differences. In particular, it is possible that if the transition to retrieval in young adults is the result of a relatively early, top-down initiated self-instruction ("from now on, I can trust my memory"). In contrast, in old adults this self-instruction may happen much later or not at all. As in the fade-in/fade-out paradigm this missing self-instruction may be based on an incomplete task model that either does not recognize the distinction between the two modes of processing in the first place, or that lacks a clear criterion about when to make the transition. Clearly, to obtain a better understanding of the nature of the age differences in each of these two different paradigms future research needs to explore the relationship between them.

Conclusion

Our results clarify that old adults' costly over-reliance on externally presented cues in task-switching situations is not the result of perseveration of earlier established control settings. Rather, the most straightforward interpretation of our result is that older adults operate with impoverished task models and therefore fail to initiate the self-instructions that would be required for the level of behavioral fluency seen in young adults. One of the next important questions is to what degree the simplified task models are a direct result of limited internal representational capacity or may (also) reflect a strategic adaptation to gradual, life-span changes in resources and goals.

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Table 1. Young and old adults' average RTs and error probabilities (SD) for all major conditions and block segments in Experiments 1 to 3. Theoretically critical conditions are printed in bold.

	Young Adults		Old Adults	
	RT	Errors	RT	Errors
Exp. 1				
Single task (1-40)	375 (75)	.03 (.02)	649 (176)	.04 (.05)
No-Switch (1-40)	907 (126)	.04 (.03)	1426 (245)	.04 (.06)
Switch (1-40)	1099 (177)	.06 (.05)	1772 (335)	.07 (.10)
Single task control (44-60)	**368 (75)**	**.03 (.03)**	**564 (134)**	**.04 (.07)**
Fade-out with cue (44-60)	**413 (185)**	**.02 (.04)**	**975 (304)**	**.04 (.10)**
Fade-out w/o cue (44-60)	**371 (90)**	**.02 (.04)**	**680 (164)**	**.03 (.06)**
Fade-out reapp. cue (44-60)	**373 (84)**	**.02 (.02)**	**668 (143)**	**.06 (.14)**
Single task control (61-80)	**348 (69)**	**.03 (.02)**	**550 (122)**	**.05 (.11)**
Fade-out with cue (61-80)	**383 (99)**	**.02 (.03)**	**803 (275)**	**.03 (.06)**
Fade-out w/o cue (61-80)	**353 (56)**	**.04 (.05)**	**553 (96)**	**.03 (.05)**
Fade-out reapp. cue (61-80)	**409 (115)**	**.02 (.02)**	**899 (290)**	**.07 (.13)**
Exp. 2				
Single task (1-30)			675 (194)	.01 (.01)
No-switch (1-30)			1554 (332)	.02 (.02)
Switch (1-30)			1888 (412)	.04 (.02)
Single task w/o instruction (34-64)			**655 (210)**	**.01 (.01)**
Fade-out w/o instruction (34-64)			**875 (250)**	**.02 (.02)**
Fade-out with instruction (34-64)			**711 (178)**	**.01 (.01)**
Exp. 3: Fade-in				
Single-task (1-30)	**458 (76)**	**.02 (.02)**	**677 (185)**	**.01 (.01)**
Fade-in (1-30)	**507 (87)**	**.03 (.02)**	**898 (272)**	**.01 (.01)**
No-switch (34-64)	862 (132)	.04 (.03)	1436 (342)	.02 (.03)
Switch (34-64)	1081 (229)	.06 (.06)	1763 (430)	.04 (.04)
Exp. 3: Fade-out				
No-switch (1-30)	833 (160)	.04 (.03)	1286 (322)	.01 (.02)
Switch (1-30)	1045 (225)	.08 (.06)	1736 (423)	.04 (.04)
Single-task (34-64)	**449 (64)**	**.03 (.02)**	**639 (181)**	**.01 (.01)**
Fade-out (34-64)	**490 (83)**	**.03 (.02)**	**826 (247)**	**.02 (.01)**

Captions

Figure 1. Sample displays used in Experiments 2 and 3. Experiment 1 displays were similar, only that vertically or horizontally aligned rectangles were used instead of squares versus circles as response-relevant stimuli and that grey patches were used as placeholders instead of the cues on cue-absent trials (display type C). Display type A was used for cued task-switching or corresponding single-task block segments (i.e., Exp. 1: trials 1-40; Exp. 2: trials 1-30; Exp. 3, fade-in blocks: trials 31-63; Exp. 3. Fade-out blocks: trials 1-30). Display types B and C were used during fade-out or fade-in segments or corresponding single-task control segments (i.e., Exp. 1: display type B for transition trials 41-43, display type C for trials 44-60 and display type B for trials 61-80; Exp. 2: display type B for transition trials 31-33 and display types B and C randomly intermixed for trials 34-63; Exp. 3, fade-in blocks: display types B and C randomly intermixed for trials 1-30; Exp. 3. Fade-out blocks: display type B for transition trials 31-33 and display types B and C randomly intermixed for trials 34-63). Note, that stimuli were always ambiguous, that is contained response-relevant values for both task dimension. Stimulus displays are not drawn to scale.

Figure 2. Fade-out costs in Experiment 1 as a function of fade-out conditions for young and old adults. Error bars reflect 95% within-subject confidence intervals testing for each segment separately fade-out costs against the single-task baseline condition.

Figure 3. Fade-out costs for the instruction and the no-instruction condition. Only old adults were tested in this experiment. Error bars reflect 95% within-subject confidence intervals testing for each segment separately the no-instruct condition against the

instruction condition and the instruction condition against the single-task baseline condition.

Figure 4. Idealized structure of young and old adults' hierarchical task models for fade-out blocks. Note, that the complexity of the task models is not affected by whether or not the cued switching phase comes first (as in fade-out blocks) or last (as in fade-in blocks).

Figure 5. Fade-in and fade-out costs for young and old adults. Error bars reflect 95% between-subject confidence intervals testing for each segment separately the age difference in fade-in/fade-out costs.

Figure 1

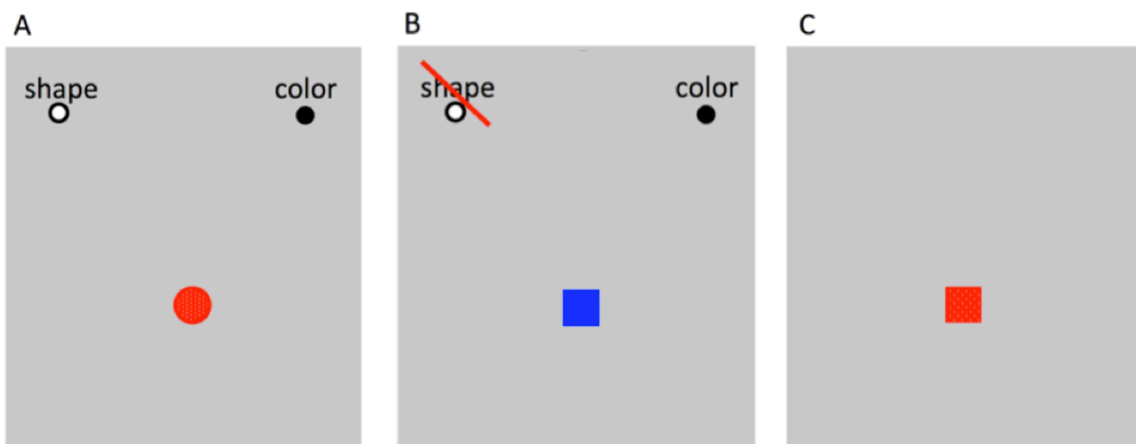


Figure 2

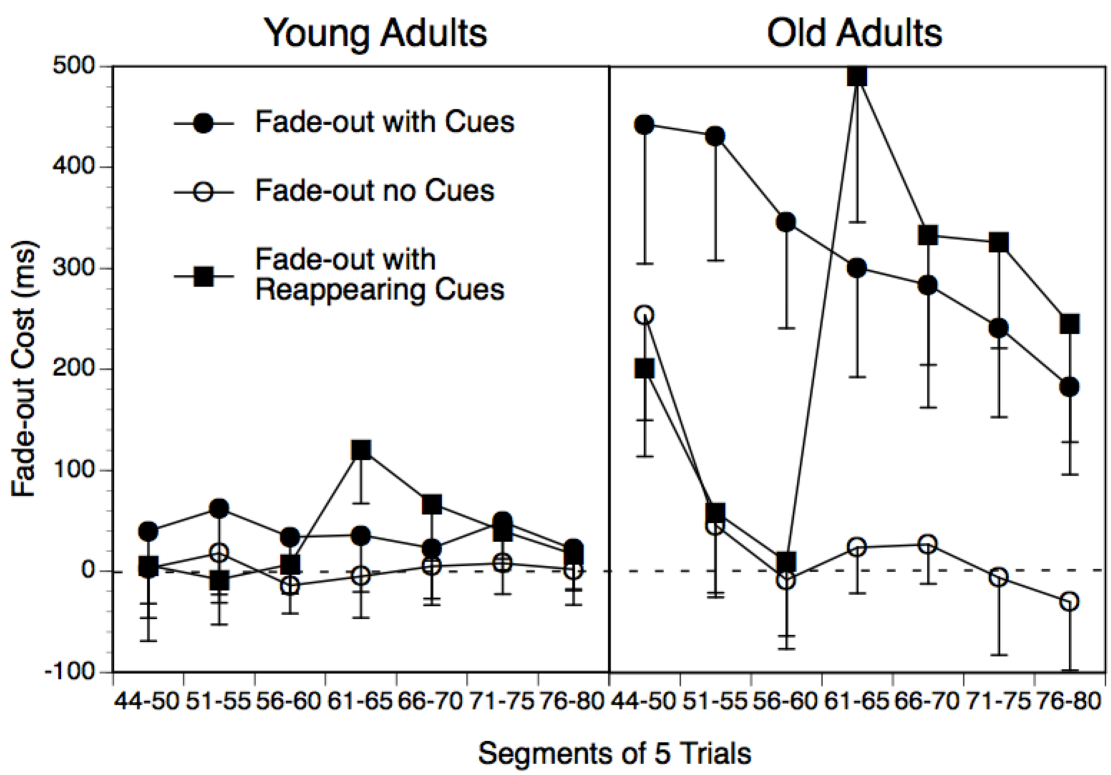

Young Adults
Old Adults
Fade-out with Cues
Fade-out no Cues
Fade-out with Reappearing Cues
Fade-out Cost (ms)
500
400
300
200
100
0
-100
44-50
51-55
56-60
61-65
66-70
71-75
76-80
Segments of 5 Trials

Figure 3

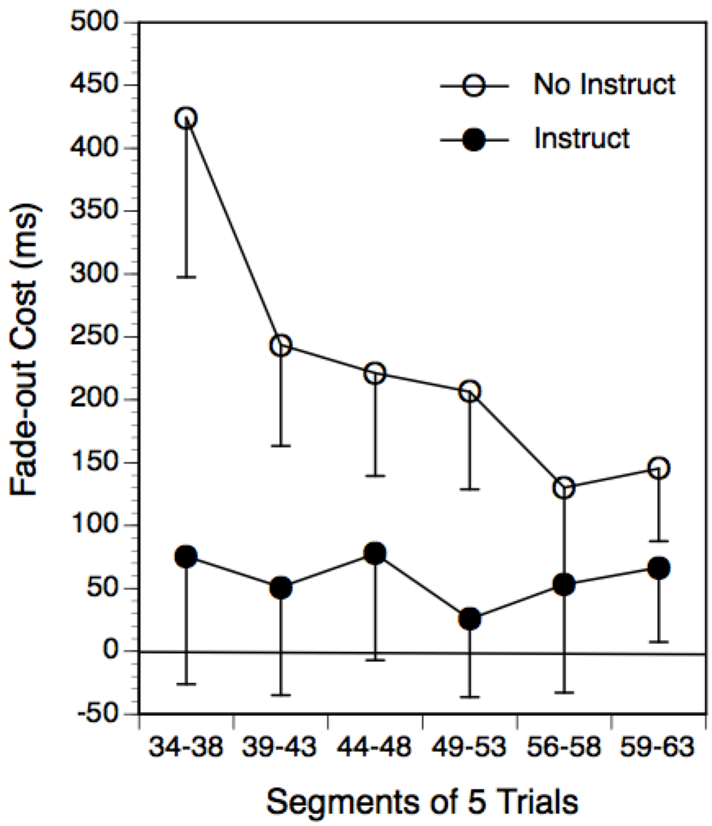

No Instruct
Instruct
Fade-out Cost (ms)
500
450
400
350
300
250
200
150
100
50
0
-50
34-38
39-43
44-48
49-53
56-58
59-63
Segments of 5 Trials

Figure 4

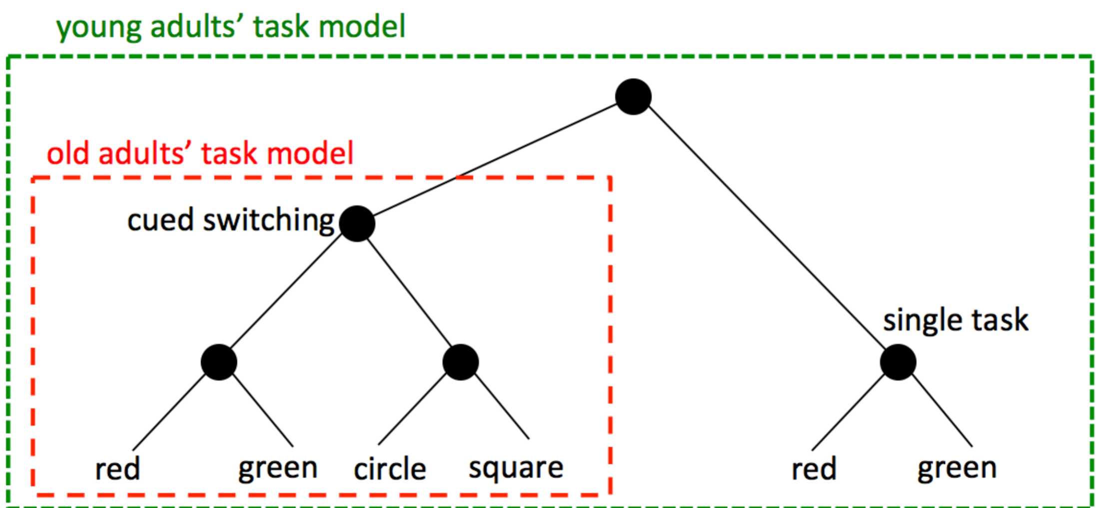
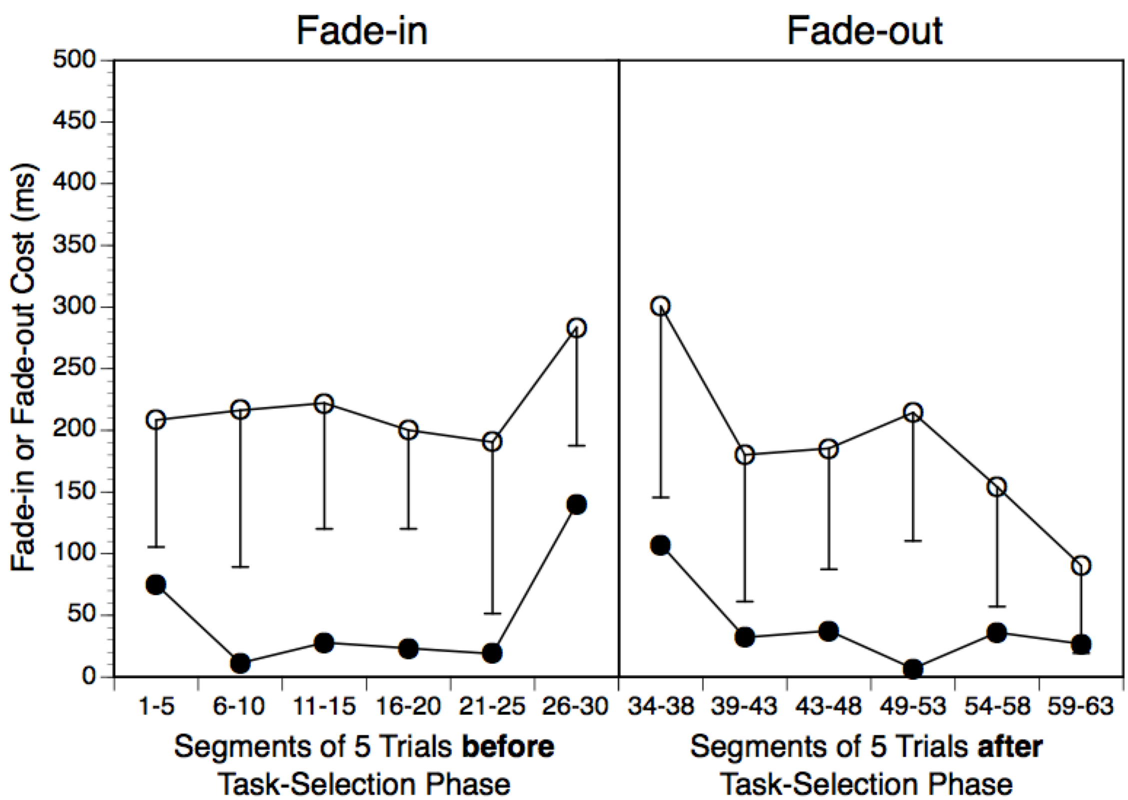

young adults' task model
old adults' task model
cued switching
single task
red
green
circle
square
red
green

Figure 5



Fade-in
Fade-out
Fade-in or Fade-out Cost (ms)
500
450
400
350
300
250
200
150
100
50
0
1-5
6-10
11-15
16-20
21-25
26-30
34-38
39-43
43-48
49-53
54-58
59-63
Segments of 5 Trials **before** Task-Selection Phase
Segments of 5 Trials **after** Task-Selection Phase

Dear Rob,

thank you for these final useful comments. We followed all of them, except for the suggestion to use a linear trend analysis for Experiment 2. The effect is of course highly reliable. However, we worry that it will seem inconsistent that we analyze within-block trends only in Experiment 2 and we really don't want to go into these details for the other two experiments. We do believe that the within-subject confidence intervals for each segment provide sufficient information about the development of costs.

Thank you for accompanying us through this process!

Best,

Ulrich