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Why are You Late?: Investigating the Role of Time Management in Time-Based Prospective Memory

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Abstract

Time-based prospective memory tasks (TBPM) are those that are to be performed at a specific future time. Contrary to typical laboratory TBPM tasks (e.g., "hit the "z" key every 5 minutes"), many real-world TBPM tasks require more complex time-management processes. For instance to attend an appointment on time, one must estimate the duration of the drive to the appointment and then utilize this estimate to create and execute a secondary TBPM intention (e.g., "I need to start driving by 1:30 to make my 2:00 appointment on time"). Future under- and overestimates of drive time can lead to inefficient TBPM performance with the former lending to missed appointments and the latter to long stints in the waiting room. Despite the common occurrence of complex TBPM tasks in everyday life, to date, no studies have investigated how components of time management, including time estimation, affect behavior in such complex TBPM tasks. Therefore, the current study aimed to investigate timing biases in both older and younger adults and further to determine how such biases along with additional time management components including planning and plan fidelity influence complex TBPM performance. Results suggest for the first time that younger and older adults do not always utilize similar timing strategies, and as a result, can produce differential timing biases under the exact same environmental conditions. These timing biases, in turn, play a vital role in how efficiently both younger and older adults perform a later TBPM task that requires them to utilize their earlier time estimate.

Keywords

prospective memory; time estimation; time perception; aging; older adults

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Time-based prospective memory (TBPM) tasks include those that must be performed either at a certain time of day (e.g. attend a doctor appointment at 2:00 pm) or after a specific duration has elapsed (e.g. rinse the hair dye out in 10 minutes). Such tasks occur frequently in everyday life, and failure to perform these tasks (e.g. forgetting to take medication at the appropriate time) can have major consequences.

TBPM is typically studied in the laboratory by asking participants to make a time-based response (e.g. push the 'z' key every 5 minutes) while an ongoing task, such as lexical decision, is performed simultaneously. Typically, participants are allowed to check a clock as

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frequently as they would like to assist them in making their time-based responses accurately. Previous findings from the use of this and similar techniques have established that the pattern of clock-checking observed during the TBPM task is predictive of performance. Specifically, those participants who check the clock more frequently as the target time approaches tend to make more accurate TBPM responses than do participants who check the clock less often during the same time period (Einstein, McDaniel, Richardson, Guynn & Cunfer, 1995). While younger adults characteristically increase their clock-checking prior to the target time, older adults are less likely to produce this efficient pattern of clock-checking, and thus, also make less accurate TBPM target responses than do younger adults (Einstein et al. 1995; Park, Herzog, Kidder, Morrell & Mayhorn, 1997).

Though previous work has demonstrated a PM disadvantage for older adults in the commonly used laboratory paradigm, the applicability of previous findings remains limited to a constrained subset of TBPM tasks. Specifically, the simple TBPM tasks typically used require only momentary attentional diversions from an ongoing task for clock-checking and target response production (e.g., hitting a specified computer key). However, these simple TBPM tasks do not capture many of the time management components that are likely required in many other TBPM situations. For instance, consider the oft-used TBPM example of attending a doctor appointment on time. Successful completion of this TBPM task does not simply require one to momentarily pause ongoing activities to make clock-checks and a target response, but instead requires an accurate prediction of the duration of an intervening task (e.g., the drive to the appointment), incorporation of this time estimate into a secondary TBPM intention (i.e., "I think the drive will last 30 minutes, so I need to leave the house by 1:30 to make it to my 2:00 appointment on time."), and finally, successful completion of both the secondary and primary TBPM intentions (e.g. leaving the house at 1:30 and successfully arriving at the appointment at 2:00). In other words, successful performance requires efficient planning and successful plan completion, both of which are considered vital components of efficient time management (Francis-Smythe, 2006). Our lives are filled with these types of complex time-based PM tasks from finishing the dog walk by the time the cookies are done in 15 minutes, to purchasing popcorn before the movie start time, to completing all of the scheduled student meetings prior to the 3:00 pm faculty meeting. Each of these TBPM examples requires time estimates of future tasks, planning, and plan execution. Despite the commonality of these tasks in daily life, to this point, no studies have investigated how it is we successfully perform such tasks.

Time Management and Aging in TBPM

As outlined above, many real-life TBPM tasks require numerous time-management steps including time estimation, planning, and plan performance not required in previous TBPM laboratory paradigms. Thus, for this kind of real-life, complex TBPM task it remains unexplored whether age differences will emerge in PM performance, and at what step (e.g. time estimation, planning, plan fidelity) they arise. In the following section, we consider each time management step in turn, and review relevant previous research to consider how age might influence performance of each step and consequently how PM performance might be affected.

Time Estimation and Planning

It seems clear that time estimates of future events are important determinants of TBPM plans and performance. There has been very limited empirical work aimed at elucidating the role of time estimation in TBPM. One correlational study suggested that the ability to estimate how long a task will take to complete in the future is related to self-reported time management ability (Francis-Smythe & Robertson, 1999). A few other studies have reported that performance on time perception tasks is associated with clock-checking during standard TBPM tasks (Labelle, Graf, Grondin, & Gagne-Roy, 2009; Mioni & Stablum, 2014; Mioni, G., Stablum, McClintock, & Cantagallo 2012). Finally, Waldum and Sahakyan (2013) demonstrated that time estimates of events that occur during an interval both influence clock-checking patterns and can impair the accuracy of time-based prospective memory responses that are to be performed during that interval. Together, these findings suggest that time estimation ability may also influence TBPM plan efficiency and time management in more complex time-based PM situations. To illustrate, consider the doctor appointment scenario. Specifically, suppose that you are working on a paper at home and need to decide when you should stop working on that paper to start the drive to the doctor's office for your 2:00 pm appointment. An accurate future time estimate of the drive can lead to an efficient TBPM plan. Particularly, if you accurately estimate that the drive will take you 30 minutes to complete, you may plan to stop working on your paper and leave the house at 1:30 for your 2:00 appointment. This plan is very efficient because it allows you to work on your paper for the maximum amount of time and still attend your appointment on time.

However, what about when future time estimation is inaccurate? For example if you erroneously underestimate that the drive will only take you 20 minutes, you may plan to work on your paper until 1:40. This plan is inefficient because it does not allow you enough time to complete the drive prior to your appointment time, resulting in a late arrival. Future time overestimates can also lead to inefficient plans. For example, overestimating that the drive will take 50 minutes will likely lead you to begin the drive by 1:10. This plan is inefficient because it leads to a 1:40 arrival time and thus 20 minutes spent in the waiting room that could have been better spent working on your paper at home.

Previous research has demonstrated that people estimate how long tasks will take to complete in the future by considering how long the same or similar tasks have taken to complete in the past (Roy & Christenfeld, 2007). For instance, you may estimate that the drive to an appointment will take approximately 30 minutes because you remember the drive lasted for 30 minutes last time you made it. No future time estimation studies have been conducted with older adults, therefore it is uncertain whether this group relies as heavily on memory for past durations as do younger adults. It is also unclear whether time estimates in each of these groups are biased by the same factors. For instance, though a number of time estimation studies have demonstrated that younger adults utilize memory for events that occupied an interval to estimate its duration (e.g. Block & Zakay, 1997; Waldum & Sahakyan, 2013), we are aware of no such studies that have been conducted with older adults. This is especially surprising given the well-documented decline in episodic memory for older adults.

While work on future time estimation and the role of memory in time estimation is limited, work investigating how time estimates are incorporated into the plans and performance of future tasks is entirely absent. Therefore, it is unclear whether younger and older adults may utilize time estimates differently when planning and performing complex TBPM tasks. For instance, older adults, who report being more conscientious than younger adults, may attempt to compensate for time estimation biases by producing more conservative TBPM plans. In other words, older adults may allot themselves more time for intervening task completion (e.g., the drive) than they need to ensure TBPM accuracy. If this is the case, older adults may be earlier to arrive to their appointment and thus be as accurate, or even more accurate than younger adults in performing the TBPM task on time. However, such a conservative approach would also likely lead to an inefficient use of time (spent waiting in the waiting room) prior to TBPM task performance for older compared to younger adults.

Plan Fidelity

While future time estimation may influence plan efficiency, a plan can only lead to efficient time management if it is carried out successfully. In other words, even if an accurate time estimate is produced and incorporated into an efficient plan, TBPM can still fail if the plan is not executed appropriately. Failure to execute a plan may arise for a number of reasons. First, a plan may not be followed simply because it is forgotten. If the intention to leave the house at a specific time is not maintained, it cannot be carried out. Older adults' retrospective memory decrements have been well-documented, thus, older adults may experience a complex TBPM disadvantage if they are less able to recall their PM plan than are younger adults.

Another reason for failing to follow a plan could be poor time monitoring. For example, even if the intention to leave the house by 1:30 is maintained, this target time may be missed simply because the clock is not monitored until it is already 1:45. Clock-checking has already been established as a key predictor of accurate TBPM target response production (e.g. Einstein et al. 1995, Maylor, Smith, Della Sala, & Logie, 2002), and it likely also plays a vital role in successfully following self-generated TBPM plans. Furthermore, older adults are less likely to monitor the clock efficiently during TBPM tasks (e.g., Einstein et al. 1995, Park et al., 1997). Therefore, like in the typical laboratory paradigm, they may experience a complex TBPM disadvantage due to reduced clock-monitoring (i.e., they may more often fail to follow their TBPM plan more often because they monitor the clock less efficiently).

Finally, failure to follow a plan may occur even in the case of a successfully maintained intention and sufficient clock-monitoring, if an inhibitory type of failure occurs. For instance, even if the plan to leave the house at 1:30 is maintained and a clock-check at 1:30 indicates that it is the appropriate time to leave, the plan may not be carried out if other goals such as answering one more email are prioritized above following the original TBPM plan. Indeed, Kliegel, McDaniel, and Einstein (2000) found that plan fidelity and inhibitory ability predicted participants' scores on a complex task that required participants to self-initiate six task changes in six minutes. The authors highlight the particularly interesting role of inhibitory ability and explain that inhibition may be key in the ability to stop performing one task and begin another at the appropriate time.

Overall, there is research to suggest that both planning and plan fidelity are integral components of complex TBPM tasks. Furthermore, there is reason to suspect that age differences in time estimation, clock-checking and inhibition may influence performance of the different steps of complex TBPM performance. To investigate the roles of different components of time management on complex TBPM, we designed a novel experimental paradigm that better reflects time management requirements of many everyday TBPM tasks than do the simplistic TBPM laboratory paradigms used to this point. Given that one component of time management we are particularly interested in is how previous time estimation biases influence later TBPM performance (e.g., how does underestimating the duration of your last drive to the doctor influence your ability to arrive at your next appointment on time?), it was necessary to include two task phases in the current experiment. The first phase comprised a timing phase during which participants estimated the duration of a trivia task. The subsequent phase was a TBPM task phase during which the previous trivia duration was relevant for TBPM planning and performance (See Figure 1).

During the trivia timing phase, we utilized a background manipulation that has previously been shown to bias time estimates. Specifically, Waldum and Sahakyan (2013) demonstrated that as the number of background songs participants remembered having heard while performing a task increased, the longer the estimates for that task became despite the objective duration being fixed across background condition. In fact, younger adults who remembered only two songs were biased toward significant underestimation of the task, whereas those who remembered hearing four songs were biased toward significant overestimation of the very same task. Therefore, use of a background manipulation during the trivia timing phase should ensure that some participants overestimate the trivia duration and that others underestimate the trivia duration. Consequently, we will be able to investigate how each type of bias influences performance during the later TBPM task phase.

Though Waldum and Sahakyan's (2013) findings suggest that the background manipulation should be effective in biasing younger adults' trivia time estimates, no prior studies, of which we are aware, have investigated the influence of environmental cues on older adults' time estimates. This gap in the literature makes it unclear whether older adults, like younger adults, will utilize background information to inform their time estimates. On the one hand, it may be the case that older adults rely on memory for background songs during time estimation to the same extent as do younger adults. On the other hand, some research suggests that older adults may avoid using such a memory-based time estimation strategy. Specifically, a number of studies have demonstrated that older adults are reluctant to use the same memory-based strategies utilized by younger adults in a variety of tasks (e.g., Frank, Touron, & Herzog, 2012; Touron & Hertzog, 2004; Rawson & Touron, 2009) and that this reluctance seems to be related to older adults' under confidence in their ability to effectively employ the memory-based strategy (e.g., Touron & Herzog, 2004). Therefore, inclusion of the background manipulation during the trivia timing phase allows us to investigate the additional under-researched question: Do the same factors influence timing biases in both younger and older adults? If older adults tend to avoid a memory-based time estimation strategy, it would be the first evidence to suggest that time estimation strategies may differ across the life span. Further, and importantly for present purposes, this age-related difference might prove to be especially relevant for performance of important everyday goals such as TBPM.

Paradigm Overview

Because the two-phase paradigm that we designed to investigate the above research questions is novel and somewhat complex, we provide an overview here. Phase 1 consisted of a time estimation task. During this task, both older and younger adults performed an 11.02 minute trivia task during which either zero (silence), two, or four pop songs played in the background. Participants were informed prior to performing the trivia task that they would be asked to estimate, in minutes and seconds, the duration of the entire trivia task upon its completion. The main reason for including this timing phase was to have participants associate a time estimate with the trivia task. This time estimate is then considered with regard to TBPM performance during Phase 2, allowing us to determine how time estimates of past events influence TBPM. A secondary goal of Phase 1 was to investigate how the presence of duration relevant information (i.e. the background songs) influences time estimates of older and younger adults. We expected to replicate Waldum and Sahakyan's (2013) findings that younger adults utilize the background songs to make their estimates, and in doing so move from underestimation to overestimation as the number of background songs played increases. Of interest was whether older adults might also utilize the songs to inform their time estimates.

Phase 2 of the experiment represented the complex TBPM phase. During this phase, participants were given a 20 minute TBPM task. They were further informed that they would perform two tasks prior to making their 20 minute TBPM response. First, they could work on a jigsaw for any amount of time they wished. Once they stopped working on the jigsaw puzzle they would be required to repeat the trivia task they performed in Phase 1 in its entirety before they could make their 20 minute TBPM response. In other words, participants were told that they would need to decide how long they could initially work on the puzzle while still leaving enough time to complete the entire trivia task prior to 20 minutes so that they could make their TBPM response on time. Participants were told that they would earn points for their work on the puzzle and for the accuracy of their TBPM response; accordingly they were encouraged to keep in mind that their goal was to maximize the use of their time as efficiently as possible. Participants were also shown how to check a clock on the computer and were told that it would be available throughout this phase of the experiment. Finally, participants were asked to write down a plan for TBPM performance and then to begin the TBPM task. This paradigm allowed us to assess how factors including Phase 1 time estimation biases, age, inhibitory ability, and clock-checking influence TBPM plans and performance.

Method

Design and Participants

The experiment was a 2 × 3 factorial design with age (younger vs. older) and trivia timing phase background (silence vs. 2 songs vs. 4 songs) varied between subjects. Participants included 36 younger adults (M_{age}=21.61 years, SD_{age} = 3.19, Range = 18-36) and 34 older adults (M_{age} = 72.79, SD_{age} =7.06, Range = 60-87). Participants were randomly assigned to a background condition, resulting in 12 younger adults in each background condition, and 11 older adults in each of the 2-song and 4-song background conditions and 12 older adults in the silence condition. Given the novelty of our study relative to previously published work, the selected sample size was determined primarily using the only published finding for which conditions were similar to those in Phase 1 of the current study: the time estimation findings for younger adults reported in Waldum and Sahakyan (2013). The difference in time estimates between the two and four song conditions (the same song conditions we used in the current study) in younger adults was very large in that study (d=1.62), and power analyses indicated that 11 people per condition would provide 95% power to detect a similarly large effect in the current study. This sample size will also allow us to detect a moderate (d=.60) to large (d=.80) age by background (2 vs. 4 song) interaction effect with 70% and 90% power respectively. Einstein et al. (1995) and Park et al. (1997) also reported large age-related TBPM accuracy and clock-checking effects (ranging from d=.80 to d=1.47). Power analyses reveal that the 70 participant sample utilized in this study is more than adequate to detect similarly large effects with 90% to 99% power.

Younger adults were Washington University in St. Louis undergraduates who participated either for course credit or for monetary compensation. Older adults were recruited via the Washington University older adult participant pool and were provided monetary compensation. Older adults (M = .89, SD = .07) scored significantly higher on the Shipley vocabulary test than did younger adults (M =.85, SD =.08), $t(68) = 2.02$, $p<.05$. Older adults (M = 15.76, SD = 2.92) also reported having had significantly more years of education than did younger adults (M = 14.69, SD = 1.14), $t(68) = 2.04$, $p<.05$. Finally, younger adults ($M_{\text{number of incongruent items named in 45 seconds}}$ = 55.16, SD = 11.62) performed the Stroop task significantly better than did older adults ($M_{\text{number of incongruent items named in 45 seconds}}$ = 38.56, SD = 8.51), $t(67) = 6.71$, $p < .001$ (one younger adult is missing from the Stroop data because of experimenter error).

Materials

Trivia Task—The trivia task included 55 general knowledge trivia questions (e.g. "The smallest of the great lakes is….). Four alternative answers were presented beneath each question [e.g., a.) Lake Ontario, b.) Lake Erie, c.) Lake Superior, d.) Lake Huron]. Each trivia question trial was fixed at 12022 milliseconds (ms) so that both the number of trials and the total duration of the trivia task totaled 11.02 minutes for each participant. Each trial consisted of a question display followed immediately by a feedback display. Each question display was presented on the computer screen either for a maximum of 10 secs or until a response was recorded. If a response occurred within the 10 sec time limit, the question disappeared and an 'xxx' display was presented for some variable amount of time until the total 10 sec duration elapsed. A feedback displaying the correct answer option presented in bold font was then presented for 2 secs. Finally, a blank screen was displayed for 22 ms prior to each new question.

Background tracks—To ensure equivalent song familiarity for older and younger adults, we utilized the same 2-song and 4-song tracks used in Waldum and Sahakyan (2013) that were comprised of popular current songs, and we also created four additional tracks using older songs from the 1950′-70's. Therefore, four of the background tracks were comprised of recent popular songs by top 40 artists (e.g. “Boom, Boom, Pow” by the Black Eyed Peas), while the remaining four tracks were comprised of older popular songs (e.g., “Jimmy Mack” by the Vandellas). Overall, four of the song tracks were comprised of two songs each, and four tracks were comprised of four songs each. Participants assigned to the song background conditions were equally likely to hear the current song or older song track. Because the trivia task duration was held constant at 11.02 mins, songs included on the 2-song tracks were longer in duration ($M = 5.52$, $SD = 0.45$) than those of the 4-song tracks ($M = 2.76$, $SD = 0.37$). The average tempo of each song was also controlled using the same measures used in Waldum and Sahakyan. The tempo of each song differed no more than 7 bpm from the grand mean tempo of 127 bpm.

Time-estimation form—This form contained the sentence: “I think that the last task I completed lasted for ______minutes and _______seconds.”

Planning form—This form contained the sentence: “Please describe in the space below your plan for earning points during the next phase of the experiment.”

Jigsaw Puzzle—The jigsaw puzzle was a 100- piece commercially available puzzle depicting an outer space scene.

Post-experimental questionnaire—A computerized questionnaire contained questions that inquired about the songs played during the trivia timing phase and a jigsaw puzzle performed during the TBPM task phase. The first question asked participants to report the number of songs they remembered hearing the first time they performed the trivia task. The next question assessed participants' familiarity with the songs by asking them to report how many of the songs they had heard prior to the experiment. The third question asked participants to indicate whether they used the number of songs that played during the trivia task to help them make their original trivia time estimate. They were told to indicate their answer to this question by pressing the keyboard key associated with the answers a.) yes, b.) no, or c.) not sure. The next question asked participants to rate how much they liked or disliked the song track by using a scale from 1-5, where a rating of 1 represented “like very much” and 5 represented “dislike very much.” Finally, participants were asked to use a 1-5 scale to indicate how much they enjoyed the jigsaw puzzle and the trivia task and to rate the difficulty of the puzzle and trivia task using a scale from 1-5, where a rating of 1 represented “very low liking or difficulty” and 5 represented “very high liking or difficulty.”

Procedure

Trivia Timing Phase—After completing the psychometric measures (Shipley vocabulary, Stroop), participants were informed that they would be performing a multiple choice, general knowledge, trivia task. They were informed that four answers labeled a, b, c, and d would be simultaneously presented on the screen with each trivia question. Participants were told to press the corresponding key on the keyboard to indicate their answer for each question. Participants were also told that they would only have a certain amount of time to answer each question before they would automatically receive the correct answer feedback. Participants were encouraged to make their response in the given time, and to simply guess if they were unsure of the correct response.

Following a 4-question practice set, participants were informed that in addition to performing the trivia task that they would also be required to estimate the entire duration of the trivia task upon its completion. It was made clear that the duration estimate should include all time that elapsed from presentation of the first question to disappearance of the very last question. Background music presentation began simultaneously with presentation of the first question for those in the song conditions; those in the silence condition did not experience any background songs. Upon completion of the trivia task, participants were asked to complete the time estimation form.

TBPM Phase—Following collection of the time estimation form, participants were told that we would now be moving on to the next phase of the experiment during which they would work on a jigsaw puzzle and then repeat the exact same trivia task that they had just performed; it was emphasized that the trivia task would take them exactly the same amount of time to complete as it did earlier. Participants were told that they would earn points based on how efficiently they could use their time to perform these two tasks. Participants were informed that they would earn the most points by pushing the ENTER key as close to 20:00 as possible and were also directed to the clock key, which they were told they could push at any time to see how much time has elapsed. Participants were also told that they could earn extra points by connecting puzzle pieces. The following two rules were also emphasized. 1. You will work on the puzzle first, but once you switch to the trivia task, you cannot return to the puzzle. You should push the SPACE BAR when you want to start working on the trivia task. 2. You must repeat the entire trivia task before you can make your ENTER response. Therefore, you should attempt to finish the trivia by the time the clock reads 20:00 so that you can make your ENTER response on time. If the clock does not yet read 20:00 when you finish trivia, you should wait to push ENTER until the clock does read 20:00. If 20:00 has already elapsed when trivia is finished, push ENTER as soon as possible.

Participants were asked to explain the task goals and rules to the experimenter to ensure understanding. Finally, participants were asked to complete the planning form. After the planning form was collected, participants pushed the ‘s’ key on the keyboard to start the clock and began work on the puzzle. Participants initiated work on the trivia task on their own by pushing the SPACE BAR. Participants then completed the entire trivia task before hitting the ENTER key which ended the task. Following TBPM task completion, participants were asked to write down their original plan as close as possible to the way they had originally written it to assess plan memory. Finally, participants were asked to complete the post-experiment questionnaire.

Results

Given the discrete questions of interest associated with each task phase, we have presented the results associated with each phase separately. First, we present the results of Phase 1, the time estimation phase. Here we are primarily interested in whether both older and younger adults utilize memory for environmental information to the same degree to make time estimates.

Phase 1: Trivia Timing

Song Familiarity—A song familiarity score was calculated for each participant[1] by dividing the number of songs each participant reported being familiar with on the post-experiment questionnaire by the number of background songs played. A between-subjects ANOVA using age group (younger vs. older) and song era (current vs. oldies) was conducted on these familiarity scores. The main effect of age group was not significant $F(1,41) = 1.09$, $p = .30$, indicating that overall song familiarity did not differ between younger (M=.66, SD = .39) and older adults (M=.47, SD = 71). The main effect of song era approached significance, $F(1,41) = 3.52$, p=.07, suggesting that both older and younger adults were somewhat more familiar with the oldies (M=.73, SD = .67) than the current songs (M = .41, SD = .42). Finally, the age group by song era interaction was not significant, $F(1,40) = 1.69$, p=.20. These analyses indicate that there were no obvious differences in song familiarity between the two age groups, regardless of song era[2]. Further, additional analyses that included song era (current vs. oldies) revealed no effects on participants' time estimates; consequently, we collapsed across song era in all remaining analyses.

Trivia Task Performance—Next, trivia task performance was analyzed to determine if age differences were present either in trivia accuracy or reaction time. Age-related decline in trivia performance could suggest that older adults' attentional resources are more taxed by the trivia task than younger adults. Consequently, older adults may have more difficulty simultaneously performing the trivia task and tracking time for the later time estimate potentially leading to age differences in later time estimate accuracy or strategy use. To determine if age-related effects emerged on trivia task performance, factorial ANOVAs were conducted separately on trivia task accuracy and reaction time using age group (younger vs. older) and background (silence vs. 2 songs vs. 4 songs) as between subjects factors. See Table 1 for results. The accuracy analysis did not reveal significant main effects of age group, $F < 1$, or background, $F(2,64) = 1.07$, $p = .35$. The interaction was also not significant, $F < 1$. The reaction time ANOVA revealed a significant main effect of age group. Overall, older adults answered the trivia questions more slowly than did younger adults, $F(1,64) = 11.17$, $MSe = 566670.76$, $p = .001$, $\eta_p^2 = .149$. There was neither a main effect of background, $F(2,64) = 2.35$, p=.10 nor a background by age group interaction, $F < 1$.

Trivia Time Estimates—A between-subjects ANOVA was conducted on time estimates using background (silence vs. 2 songs vs. 4 songs)[3] and age group (younger vs. older). The results are summarized in Figure 2. There was no main effect of age group, $F(1,64) = 1.78$, p=.19, or background, $F(2,64) = 2.84$, $p = .07$, however, a significant age group by

[1]One younger adult participant was not included in either the song familiarity or strategy analyses because the post-experimental questionnaire was not completed due to a computer error

[2]The same analysis conducted instead on song liking ratings revealed no main effects of song era or age group and no interaction (all F's <1), indicating no difference in the degree to which either age group liked the background songs.

[3]The number of songs played rather than the number remembered was used in the current analysis because song memory ranged from 2-6 in the older adult group, and 2-5 in the younger adult group. There were very few observations in the 3-,5-, and 6-song memory categories making them inappropriate for use in an ANOVA.

background interaction was observed, $F(2, 64) = 3.34$, $MSe = 11.17$ $p = .04$, $\eta_p^2 = .091$ Analysis of simple main effects indicated that while there was no effect of background in the older adult group, $F<1$, background did have a significant effect in the younger adult group, $F(2, 64) = 5.68$, $p < .01$. Pairwise comparisons confirmed that younger adults estimated the task to have lasted significantly longer when four songs played in the background ($M =$ 13.27, $SD = 1.31$) than when only two songs were played ($M = 8.67$, $SD = 2.29$) ($p =.001$). Estimates in the silence condition ($M =10.96$, $SD= 3.35$) did not differ significantly from those made in either the 2-song ($p=.10$) or 4-song ($p=.10$) conditions.

Next, time estimates in each age group were compared to 11.02 (the objective trivia duration) to determine if significant under- or overestimation was present. Results revealed that older adults' estimates ($M = 9.87$, $SD = 4.01$) were trending toward significant underestimation, $t(33)= 1.67$, $p=.10$. The removal of two older adult outliers who made estimates that were more than 2.5 standard deviations above the mean results in significant underestimation in this group ($M=9.24$, $SD = 3.19$), $t(31)=3.15$, $p=.004$, $d =.56$.[4] This finding is in line with previous studies that have demonstrated that older adults tend to underestimate the passage of time during attentionally demanding tasks (e.g. Craik & Hay, 1999; Bherer, Desjardins, & Fortin, 2007).

While older adults' demonstrated numerical underestimation in all the background conditions, younger adults' estimation biases differed according to background. Therefore, we conducted separate one-way t-tests for each background condition to examine timing biases in this group. Results of these analyses revealed that younger adults in the 2-song condition significantly underestimated the trivia duration, $t(11) = 3.54$, $p=.005$, $d =1.02$ while those in the 4-song condition significantly overestimated the trivia duration t(11) = 5.97, $p < .001$, $d=1.72$. In the silence condition, younger adults showed no significant bias, $t<1$.

Strategy reports—Eighty-seven percent of younger adults responded in the affirmative when asked whether they had used the background songs to make their time estimate. Significantly fewer older adults (36%) reported that they had used the songs to estimate time, $\chi^2(1, N = 45) = 12.24$, $p < .001$. Analysis of the retrospective song memory question included in the post-experimental questionnaire provides converging evidence that older adults did not rely on song memory to make their time estimates. Particularly, younger adults' memory for the number of songs played during the trivia timing phase was highly accurate and differed significantly between the 2-song ($M=2.08$, $SD=.29$) and 4-song ($M=4.0$, $SD=.45$) conditions, $t(21)=12.32$, $p<.001$. Furthermore, the number of songs remembered retrospectively was significantly correlated with trivia time estimates, $r(23)=.75$, $p<.001$. The number of songs older adults' reported having heard during the trivia timing phase, on the other hand, did not differ between the 2-song ($M=3.55$, $SD=1.64$) and 4-song ($M=3.80$, $SD=.92$) conditions, $t<1$. Retrospective song memory also did not correlate with trivia time estimates in this group, $r(21)=-.27$, $p=.23$, suggesting that the poorer song memory in the older adult group did not lead to the null time estimation effect between the

[4]Power analysis indicated that a sample of 160 older adults would be required for .95 power to detect significant time underestimation with the $d=.29$ effect size that emerges if the two outliers remain in the sample.

2- and 4-song background conditions. Rather, it seems that older adults simply did not rely on the same song memory strategy utilized by younger adults.

Overall, the time estimation and strategy report results suggest that older and younger adults largely relied on different time estimation strategies when background songs were present. That is, time estimates increased as the number of songs increased for younger adults, but not for older adults. Additionally, the majority of younger but not older adults specifically reported using background songs to inform their time estimates. Finally, the tendency for older adults to underestimate across background conditions is in line with those of previous studies that have reported older adult underestimation in attentionally-demanding task conditions (e.g., Craik & Hay, 1999, Bherer, 2007).

While the background manipulation did not uniformly influence older adults' estimates, there were older adults in each background condition who underestimated the trivia duration and those who overestimated the trivia duration. Therefore, in the following TBPM task phase results section, we can investigate how previous biased time estimates, along with other factors including planning and plan fidelity influence time management efficiency in a TBPM scenario.

Phase 2: Complex TBPM

In the TBPM task phase, participants performed a TBPM task that required them to interpolate completion of the trivia task prior to PM target response production. The trivia task used in this segment of the experiment was exactly the same task used in Phase 1. Therefore, if participants rely on memory for previous duration to perform complex TBPM tasks, participants overall TBPM efficiency should be influenced by time estimation biases of the Phase 1 trivia task. Analysis of plan reports will also allow us to determine the degree to which participants relied on their previous trivia time estimate in their TBPM phase plan, and also assess how factors such as age, inhibitory ability, and clock-checking influence plan fidelity.

Puzzle Performance—Overall, the amount of time older (M=10.00 mins, SD = 4.45) and younger adults (M=8.71 mins, SD= 3.45) chose to work on the puzzle did not differ significantly, $t(67) = 1.35$, p=.18. However, younger adults connected more puzzle pieces (M=44.97, SD = 23.97) than did older adults (M=21.82, SD = 14.50), $t(67) = 4.85$, p< .001.

Trivia Task Performance—The experiment was terminated for one older adult who continued to work on the puzzle for 35 minutes. This participant did not complete the trivia or TBPM portions of the experiment and thus is not included in any of the following analyses associated with performance of the TBPM phase. Factorial ANOVAs were conducted separately on trivia task accuracy and reaction time using age group (younger vs. older) and Phase 1 time estimation bias type for the first trivia task (overestimate vs. underestimate) as between subjects factors[5]. The accuracy analysis did not reveal significant

[5]Bias Type was included as a factor instead of background as in Phase 1, because background was irrelevant during Phase 2 (i.e. there was no music played during trivia task performance in Phase 2).

main effects of age group $F(1,65)=3.76$, $p=.06$ or bias type, $F<1$ (see Table 1 for means). The interaction was also not significant, $F<1$.

The reaction time ANOVA revealed that in general older adults responded more slowly than younger adults, $F(1,65) = 24.54$, $MSe = 726173.92$, $p < .001$, $\eta_p^2 = .274$. There was no main effect of bias type, $F<1$, but there was a significant age group × bias type interaction $F(1,65)= 4.77$, $MSe = 726173.92$, $p =.03$, $\eta_p^2 = .068$. Simple main effects revealed that this interaction occurred as a result of significantly faster reaction times for younger adults who underestimated compared to older adults who underestimated ($p < .001$). The difference in reaction time was not significant for younger and older adults who overestimated ($p=.08$). This interaction effect was not anticipated. However, it could be that younger adults who underestimated realized during Phase 2 that they would be late finishing the trivia task and thus would also fail to make their TBPM response on time. The faster responses in this group, therefore, may have been an attempt to increase performance on the trivia task to offset the poorer performance that they expected to have on the time-based task. Older adults, on the other hand, may not have had the capacity to increase their response rates to the same extent. This explanation is clearly speculative and given that there is no clear implication for an age-related response time difference in the underestimation group versus the overestimation group, we will not discuss this finding further.

Complex TBPM Efficiency—Because participants were required to complete the trivia task before they could make their TBPM response, it was necessary for participants to determine how much time they could initially work on the puzzle while still leaving enough time to complete the trivia task by 20:00. If participants utilized their earlier time estimate of the trivia task to determine when to stop work on the puzzle and begin the trivia task, these time estimates should influence TBPM efficiency in predictable ways. Specifically, participants who originally underestimated the trivia task duration should spend too much time on the puzzle, thereby not allowing themselves enough time to repeat the trivia task prior to the 20:00 target time and negating the possibility for an on-time TBPM response (see Figure 3, top panel). By contrast, those who overestimated the trivia task should switch from the puzzle to the trivia task before it is necessary. As a result, they should finish the trivia task well before the 20 minute target time, allowing for very accurate TBPM responses. However, these accurate TBPM responses will come at the expense of time that could have been spent working on the puzzle (see Figure 3, bottom panel).

Because efficient performance during the complex TBPM phase involved both maximizing the amount of time spent on the puzzle and accurate performance of the 20 minute TBPM target response, participants who finished the trivia task closest to the 20:00 target time managed their time most efficiently (i.e. finishing the trivia task very close to 20:00 allowed for maximum puzzle time and the least amount of waiting time between the end of trivia and the TBPM target time). To assess whether Phase 1 time estimation bias influenced TBPM performance in the predicted directions for older and younger adults, we first conducted a factorial ANOVA on trivia completion time using age group (older vs. younger) and Phase 1 trivia estimate bias type (underestimation vs. overestimation) as between-subjects factors. The number of participants who underestimated was similar across the older (n=22) and younger (n=19) groups. Overestimation also occurred at a similar rate for older (n=11) and younger (n= 17) adults. The results are presented in Figure 4. This analysis revealed a significant main effect of trivia estimate bias type, as those who overestimated the trivia task duration finished the trivia task significantly earlier (*M*= 17.73, *SD* = 3.72) than those who underestimated (*M*= 22.14, *SD* = 3.08), $F(1, 65) = 25.50$, $MSe = 11.32$, $p < .001$, $\eta_p^2 = .282$. Neither the main effect of age group, $F(1,65) = 1.06$, $p=.31$ nor the interaction $F(1,65) = 1.00$, $p = .32$ was significant.

Overall, it is clear that time estimation biases affect TBPM task efficiency, with overestimation of an intervening task leading to relatively inefficient use of time prior to TBPM production (i.e., more time spent waiting rather than working on the puzzle), but the opportunity for accurate target responses. Underestimation, on the other hand, is associated with increased productivity in the time prior to TBPM production (i.e. more time spent on the puzzle), but disallows for accuracy on the TBPM task itself[6]. Furthermore, the lack of age effects suggest that bias affects efficiency similarly for both older and younger adults.

TBPM Planning—The TBPM task results clearly suggest that participants relied on their earlier time estimates to perform the TBPM task. That is, those who previously underestimated the duration of the trivia task failed to allow enough time to complete this same task prior to the TBPM target time. Those who overestimated the trivia duration, on the other hand, terminated work on the puzzle task earlier than necessary, allowing too much time to complete the trivia task. Analyzing participants' plans allows us to determine whether participants primarily utilized their earlier time estimates online during the task, or rather, applied these time estimates during plan creation. If participants utilized their original time estimate during the planning phase, there should be a strong relationship between the original trivia time estimates participants made after their first experience with the trivia task, and the amount of time participants allocated for trivia performance in their plan. Overall, 62 of the 70 participants did indicate a time at which they planned to switch from the puzzle to the trivia task and correlational analysis revealed a significant positive correlation, $r(62)= .77$, $p < .001$, between participants' original trivia time estimate and time allocated for trivia in participants' plans. In other words, participants tended to allocate more time to perform the trivia task (i.e. planned to switch from the puzzle to the trivia task earlier) the longer their original trivia estimate was (this correlation did not differ between younger $r(36)=.79$ and older $r(27)=.77$ adults.). Note that indication of a specific time to switch from the puzzle to the trivia task represents the generation of a secondary TBPM intention by participants. Complex TBPM tasks often require the creation of secondary PM intentions for performance, ranging from TBPM intentions, event-based PM intentions (e.g., I will switch after I connect 25 puzzle pieces), or intentions that do not fit any specific PM category (e.g. I will switch when it "feels" right). The wide array of secondary PM intentions that can be created highlights the complexity of many TBPM tasks. To clearly distinguish participants' self-generated secondary intentions with the primary TBPM task of responding at 20 minutes, for ease of exposition, we will refer to the secondary TBPM

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[6]TBPM target time response accuracy results were in line with that expected based on the TBPM efficiency results. Participants who overestimated the trivia task duration responded significantly earlier and closer to the 20 minute target time (*M*=20.52, *SD* = 2.51) than did those who underestimated (*M*=22.67, *SD* = 2.43), $t(67) = 3.75$, $p<.001$.

intention created by participants in their plans as “planned switch time” for the remainder of the paper.

Though robust, the correlation indicated that the amount of time participants planned to allocate for trivia task performance did not match their earlier time estimates perfectly. A plan conservatism score was computed for each participant to assess whether there were age difference in how closely participants planned switch time matched their original time estimate. This score was computed by subtracting the amount of time allotted for trivia performance specified in each participant's plan from their original trivia time estimate. Positive scores represent extra time allocated for trivia performance in the TBPM plan compared to the original estimate, negative scores indicate less time specified in plan compared to the original estimate, and scores of zero indicate plans in which the time allotted for the trivia completion matched the earlier trivia time estimate. Results did not reveal any difference in plan conservatism scores between younger ($M = 0.91$ mins, $SD = 1.97$) and older adults ($M = 1.20$ mins, $SD = 2.78$), $t < 1$. Participants in both age groups tended to allocate more time for trivia task performance in their plans than their earlier estimate would dictate. To illustrate, one participant wrote, “I think the trivia took 8 minutes, but I better play it safe and give myself 9 minutes just in case I was wrong. So, I will switch from the puzzle to the trivia when the clock reads 11:00.” Though strategies were generally conservative (i.e., participants allowed some extra time in their plans to offset potential underestimation of the trivia duration), some participants did allocate less time for trivia completion in their plan than would be required by their earlier estimate. Upon inquiry, these participants often noted that they thought they may have overestimated the duration of the trivia task initially.

Overall, the relationship between original trivia time estimates and time allocated for trivia in participants' plans suggests that participants did rely on their earlier estimates during the TBPM planning phase. Additionally, older and younger adults did not differ in the amount of extra time they allotted for trivia in their TBPM plans.

Plan Fidelity—The majority of participants indicated a specific time in their plans at which they would stop working on the puzzle and begin the trivia task. The following analyses were conducted to determine how closely participants followed their original plans (i.e. did participants start working on the trivia when they planned to?). The results of correlational analyses revealed that the time participants indicated they would switch from the puzzle to the trivia in their plan was strongly related to the time they actually switched from the puzzle to the trivia during TBPM performance, $r = .842$, $p < .001$. What's more, this relationship was strong for both older ($r = .710$, $p < .001$) and younger adults ($r = .933$, $p < .001$).

To further investigate plan fidelity, we calculated both an absolute and relative plan fidelity score for each participant. First, the absolute plan fidelity scores indicate fidelity regardless of whether participants switched prior to or after their original planned time. This score was computed by taking the absolute value of the difference between the time each participant planned to switch from the puzzle to the trivia and the time that they actually switched from the puzzle to the trivia during performance. Scores of zero indicate absolute plan fidelity (e.g. planned to switch at 10 minutes and did switch at 10 minutes), while scores increasing from zero indicate weaker plan fidelity (i.e. greater differences between planned and actual switch times). A one-way ANOVA on the absolute plan fidelity scores indicated that younger adults had numerically greater plan fidelity (M= .84 mins, SD = 1.04) than did older adults (M =1.59 mins, SD = 2.15), however this difference was not significant, $F(1,58) = 3.19$, p=.08.

Next, relative fidelity scores (which were computed as described above without taking the absolute value) were compared across age group to determine if younger and older adults differed in whether they were early or late in switching to the trivia task according to their original plan. Here, negative scores are associated with participants who switched prior to the time they originally planned and positive scores associated with participants who switched later than they originally planned. Again, the results of this analysis revealed no age difference with older adults (M = -.89, SD= 2.53) and younger adults, (M = -.54, SD=1.23), t<1, showing an equal tendency to switch earlier than the time they had planned.

While there were no effects of age on plan fidelity, it is possible that factors such as inhibitory ability and clock-checking might influence plan fidelity within each age group. The following analyses were conducted to investigate how these factors may have influenced plan fidelity.

Inhibition—Kliegel et al. (2000) reported evidence to suggest that inhibitory ability may be related to the ability to switch from one task to another at an appropriate time. Therefore, we investigated whether inhibition (measured using the same task as in Kliegel et al.) may have influenced plan fidelity in the current study. There was no relationship between Stroop score (number of incongruent colors named in 45 sec) and the absolute plan fidelity scores, r =-.08, p=.54. Neither older (r =-.10, p =.65) nor younger (r = .27, p =.12) adults inhibition scores were associated with plan fidelity.[7]

Clock-Checking—Clock-checking is often analyzed in TBPM experiments because those who check the clock frequently tend to be more accurate in making their TBPM response than those who check less frequently (e.g. Einstein et al. 1995). In the current experiment, we chose to analyze clock-checking only prior to the switch from the puzzle to the trivia task to determine if clock-checking influenced plan fidelity. We chose not to analyze clock-checking during the trivia task of the TBPM phase, because participants could not perform the TBPM action until the entire trivia task was completed. Therefore, clock-checking during the trivia task was irrelevant in the current paradigm.[8] An independent samples t-test on the total number of clock-checks participants made prior to starting the trivia task indicated that younger adults (M = 4.78, SD = 2.58) checked the clock significantly more often than did older adults (M = 3.21, SD = 2.22), $t(67) = 2.69$, $p < .01$. Given that younger adults spent numerically less time working on the puzzle than did older

[7]The difference between the number of congruent and incongruent Stroop items named also does not correlate with plan fidelity in either older (r=-.03, p=.87) or younger adults (r=-.007, p=.97).

[8]Clock-checking during performance of an intervening task, such as a drive, would be relevant in many real-life situations where it is possible to speed up or slow down ongoing task performance. However, because the trivia duration was set in the current experiment, clock-checking during the trivia task is less relevant here.

adults, it is clear that younger adults simply had a higher rate of clock checking than did older adults. Younger adults also showed evidence of more frequent clock-checking in the minute prior to starting the trivia task (M = 1.47, SD = 0.97) compared to older adults (M = 1.00, SD =0.56), $t(67) = 2.45$, $p < .02$ indicating that age differences in clock-checking remained even in the time-period just proximal to when participants planned to switch from the puzzle to the trivia task.

Previous studies have established that increased clock-checking in the time period just proximal to a TBPM target time is associated with increased TBPM response accuracy (Einstein et al., 1995; Maylor et al., 2002), and that differences in clock-checking behavior between older and younger adults can help to explain age-related differences in TBPM accuracy (e.g., Park et al. 1997). To determine if clock-checking is also related to plan fidelity in younger and older adults, we conducted a simple linear regression on absolute plan fidelity scores using age group, number of checks made one minute prior to starting the trivia task, and the age × clock-check interaction. The three predictor variables were simultaneously regressed on absolute plan fidelity scores. The results are summarized in Table 2. The model explained a significant proportion of variance in plan fidelity scores, R^2 = .16, $F(3,56) = 3.67$, $p < .02$, with the number of clock-checks made in the final minute prior to starting trivia being the only significant predictor (β =-.702, $t(56) = 2.17$ $p < .04$). The results of this analysis indicate that increased clock-checking prior to performing a planned response increases plan fidelity for both older and younger adults.

Discussion

Older and younger adults completed a novel two-phase experiment that was designed to investigate for the first time how components of time management including time estimation, planning and plan fidelity influence performance of complex TBPM tasks patterned after those that that we often experience in everyday life. The two phases of the experiment included an initial trivia timing phase during which participants were asked to estimate the duration of an 11.02 minute trivia task, and a subsequent TBPM task phase during which participants were required to interpolate completion of the previously estimated trivia task between working on a jigsaw puzzle and performing a 20-minute TBPM target response. The constraint that the TBPM target response could not be performed until trivia task completion is similar to many real-life TBPM scenarios which require completion of an intervening task(s) (e.g., a drive, buying popcorn, student meetings) prior to TBPM performance (e.g., attending a doctor appointment, taking your seat at the movies, attending the faculty meeting). Participants' primary goal was to finish the trivia task prior to the 20 minute mark, so that they could make their 20 minute target response on time. However, participants were also incentivized to spend any additional time they had prior to beginning the trivia task connecting puzzle pieces. As a result, overall task efficiency increased as participant trivia completion time neared the 20 minute target time.

There was a strong effect of time estimation bias on TBPM task efficiency, such that participants who previously underestimated the trivia task duration during the trivia timing phase did not allocate enough time to complete the trivia task prior to the target time, preventing them from making their TBPM response on time. By contrast, those who had previously overestimated the trivia duration allocated more time for performance of the trivia task than was necessary, and consequently experienced waiting time between trivia completion and the TBPM target time. Overall, the results suggest that timing biases associated with previous performance of a task lead to negative consequences, and notably, there were no age-related differences in the detrimental effects of over- and underestimation on TBPM task efficiency. Analysis of participants' TBPM plans indicated that both older and younger adults incorporated their previous time estimates into their TBPM performance plans and that plan fidelity was equivalent in both age groups. While age differences were notably absent in the complex TBPM phase of the experiment, age differences did emerge in the trivia timing phase, where background conditions had a distinct effect on time estimates for younger but not for older adults.

In the introduction, we outlined the numerous steps to the performance of complex TBPM tasks (i.e., time estimation, planning, and plan fidelity) and also indicated reasons to expect that age-related differences might emerge at each of these distinct steps. Below, we will address these components of complex TBPM separately.

Time Estimation

The primary determinant of complex TBPM task performance in the current study was time estimation bias, making clear that estimation of future tasks is a vital component of complex TBPM. The results of the trivia timing phase are also illuminating because they provide the first evidence in the literature that younger and older adults do not always utilize similar timing strategies, and as a result, can produce differential timing biases under the exact same environmental conditions. For younger adults the more background songs that were played during the trivia task, the longer time estimates became (as in Waldum & Sahakyan, 2013); consequently, younger adults significantly underestimated the trivia duration when only two background songs were played, and significantly overestimated the duration of the trivia task when four background songs played. In sharp contrast, older adults' time estimates were not influenced by the number of background songs played. Indeed, the vast majority of older adults specifically reported not using the songs to help them estimate time.

It is uncertain why older adults chose not to rely on the songs to inform their impending time estimate. Song familiarity was similar across both age groups, thus it is likely not the case that older adults' chose not to use the songs simply because they were unfamiliar. More likely perhaps is that compared to older adults, younger adults had greater confidence in their ability to divide attention between performance of the trivia task and tracking the duration relevant songs present in the background. Indeed, a number of older adults in the current study volunteered that they had avoided attending to the songs so that they could perform the trivia task to the best of their ability without being distracted. This information from older adults suggests that similar to previous metacognition research (e.g., Frank, Touron, & Herzog, 2012; Touron & Hertzog, 2004; Rawson & Touron, 2009), older adults may avoid using memory-based strategies in time estimation because they are under-confident in their ability to successfully employ such a strategy.

If not memory for background songs, then what information did older adults use to make their time estimates? Older adults tended to underestimate the trivia duration regardless of background condition. This finding is in line with the attentional view of prospective timing that assumes an internal clock collects temporal information when attention is directed to tracking time during an interval. According to this view, prospective time estimation is attentionally demanding, therefore, some have suggested that older adults' tendency to underestimate is a consequence of their reduced attentional capabilities (e.g. Bherer, 2007). Indeed, in the current study, older adults responded more slowly to the trivia questions during the trivia timing phase than did younger adults. Therefore, underestimation may have emerged for older adults because their time estimation resources were usurped by the demanding trivia task. Overall, the time estimation results suggest possible use of an internal clock for timing by older adults.

It remains to be seen whether the present age-related difference in timing strategy would also emerge in scenarios that provide different types of duration-relevant information (e.g., daily tasks and/or events that are associated with common durations), or in scenarios where duration-relevant information is presented in the focus on attention rather than in the background. For instance, previous research has demonstrated that during duration training procedures, younger adults learn to associate progress on an ongoing task with the trained durations. Once duration-task progress associations are learned, participants often use ongoing task progress to inform later time estimates of the same or similar ongoing tasks (e.g., Wohldmann, Healy, & Bourne, 2010; 2012). Perhaps if older adults were required to process the duration relevant information as part of the ongoing task, they might be more likely to utilize memory for this information to make prospective estimates.

Time Estimation Influences in Complex TBPM

The differential effect of background on time estimates and self-reported time estimation strategy across younger and older adults is important because it suggests that factors such as the presence of environmental information may influence time estimation differently across the life span, and thus may play an integral role in age-related patterns of performance on time-related tasks such as TBPM. To illustrate, in the current study, older adults tended to underestimate the duration of the trivia task regardless of background condition, overall leading them to spend more time on the puzzle (M=9.99, SD = 4.44 vs. M= 8.71, SD = 3.45 for younger adults), but be late to make their TBPM target response (M= 22.22, SD = 3.27) during the TBPM phase. Younger adults' trivia duration estimates, on the other hand, were influenced by background condition, such that they tended to underestimate in the 2-song condition and overestimate in the 4-song condition. As a result, during the TBPM phase, younger adults looked much like older adults when they had heard 2 songs (e.g., spent more time on the puzzle (M=10.72, SD = 3.21) and made late TBPM responses (M =22.48, SD = 2.16), but looked very different when they had heard 4-songs (spent less time on the puzzle (M=6.49, SD=2.22) and made very accurate TBPM responses (M=20.07, SD = 0.17). These findings suggest that age-related differences in time estimation strategies and their resulting biases may play an important role in determining when and if age-related TBPM performance differences emerge.

TBPM Planning and Plan Fidelity

Age differences were almost entirely absent from the planning and plan fidelity results, as older adults showed very similar patterns of performance on these aspects of the TBPM phase compared to younger adults. Participant plans, by and large centered on a time to switch from the jigsaw puzzle to the trivia task. We consider this participant-generated switch time a secondary TBPM task that was completed in service to the primary 20-minute TBPM task assigned to participants. We note that while 62 of the 70 participants self-generated a secondary TBPM intention, 8 other participants created plans that included a secondary event-based PM intention (e.g., “I will switch from the puzzle to the trivia task after I connect 20 puzzle pieces”), or a secondary intention that fit neither a time-based or event-based definition (e.g., “I'll switch when it feels right”). From our perspective, the fact that participants create secondary PM tasks in their plans reinforces and illustrates the complexity of TBPM tasks that are performed in everyday life, and highlights the need to look at the study of TBPM tasks through a broader lens than we have before.

For those participants who did generate a switch time in their plans, older adults and younger adults were similar in terms of how conservative their strategies were and were equivalent in terms of plan fidelity (how close in real time they followed their planned switch times). We had initially anticipated that older adults might suffer in terms of plan fidelity for a number of reasons including an increased likelihood of forgetting their prior plan, reduced clock-checking rates, and reduced inhibition. There are a number of potential reasons that age-related plan-fidelity effects did not emerge, however. Forgetting likely did not contribute to plan fidelity in the current study because all but one older adult remembered their initial plan retrospectively. Though plan memory did not contribute in the current paradigm, it is likely that a more complex paradigm like that of Kliegel et al. (2000), which required six different task changes, might tax older adults memory to a greater extent and thus lead to forgetting of certain plan components and thus reduced plan fidelity. Likewise, while Kliegel et al. (2000) reported a role of inhibition in their 6-task change paradigm, we observed no effect of inhibition with our single-task change paradigm. Again, increased task complexity may be required to tax older adults' resources to an extent that inhibitory-related declines would be observed. Another potential reason that we observed no role of inhibitory ability is that the jigsaw puzzle was very difficult to complete in the amount of time participants allotted for it. Therefore, it may be the case that it is easier to disengage from a task that is far from completion than it is to stop working on tasks that can be completed within the defined experimental time, like those used in Kliegel et al. (2000).[9] Finally, future studies might benefit from expanding beyond the single simple measure of inhibition used here. A combination of inhibition measures might better capture the role inhibition may play in complex TBPM.

Finally, converging with previous research, there was a difference in clock-checking between younger and older adults, with older adults' checking the clock less both overall and in the vital one minute time period proximal to participants' planned switch time.

[9]The 6-elements used in Kliegel et al. (2000) is designed so that so that all six tasks cannot be completed in the designated time. However, participants can choose to complete some of the tasks within the time period, even though this is not the optimal strategy.

Additionally, clock-checking was predictive of overall plan fidelity such that greater clock checking by both younger and older adults was associated with increased plan fidelity. Though we did observe a reduced rate of clock-checking in older adults, and a numerical decline in absolute plan fidelity for older adults, it appears that older adults' reduction in clock-checking was not drastic enough to significantly reduce plan fidelity in older compared to younger adults. Greater declines in older adults' clock-checking may emerge in tasks that are more cognitively demanding. The jigsaw puzzle used in the current experiment, for example allowed participants to work at their own pace and to easily pause working on the puzzle to make clock checks. A task that is experimenter paced and/or one that is negatively impacted by attentional diversions for clock-checking may incite larger age-related clock-checking differences and thus significant differences in plan fidelity between older and younger adults.

In conclusion, creation of the novel paradigm utilized in the current study allowed us to investigate for the first time how components of time management, including time estimation, planning and plan fidelity influence complex TBPM task performance in younger and older adults. The results of the current study suggest that the age-related decline reported with the use of more simplistic TBPM paradigms may not extend to a number of the time management dependent TBPM tasks we perform on a daily basis. The results of the current study also highlight a particularly important role for time estimation in complex TBPM tasks and suggest that differences in time estimation strategies across younger and older adults can have an important influence on the pattern of age-related performance observed in time-related tasks like TBPM.

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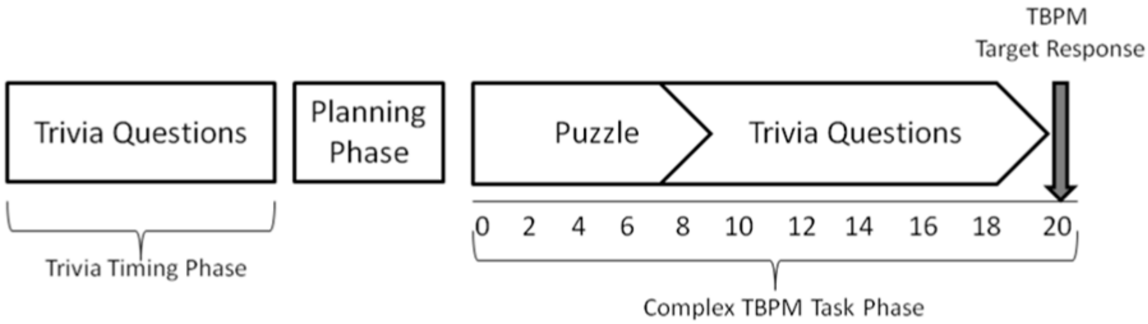

Figure 1. Experimental paradigm

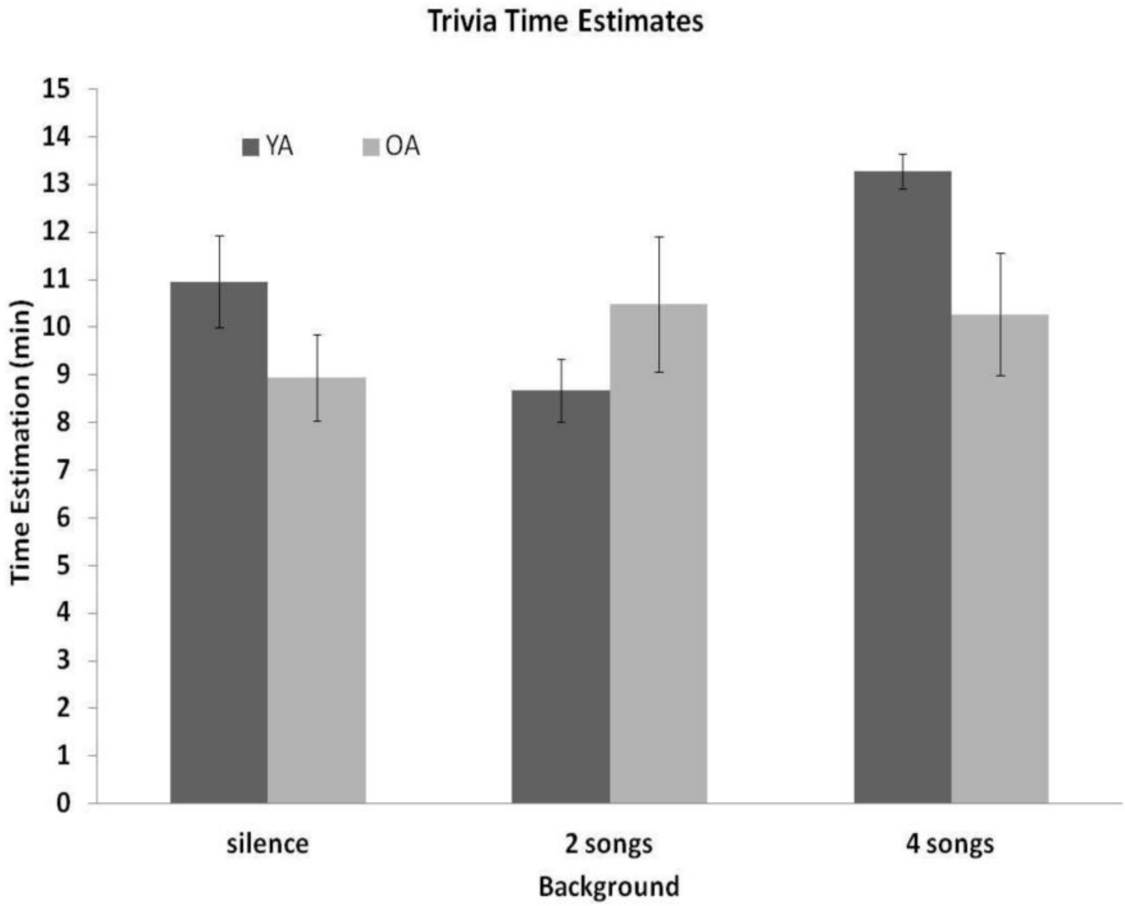

Figure 2.

Trivia task time estimates (mins) by background condition and age group. Error bars represent ±*SE* of the mean. Objective trivia duration was 11.02 mins in all conditions.

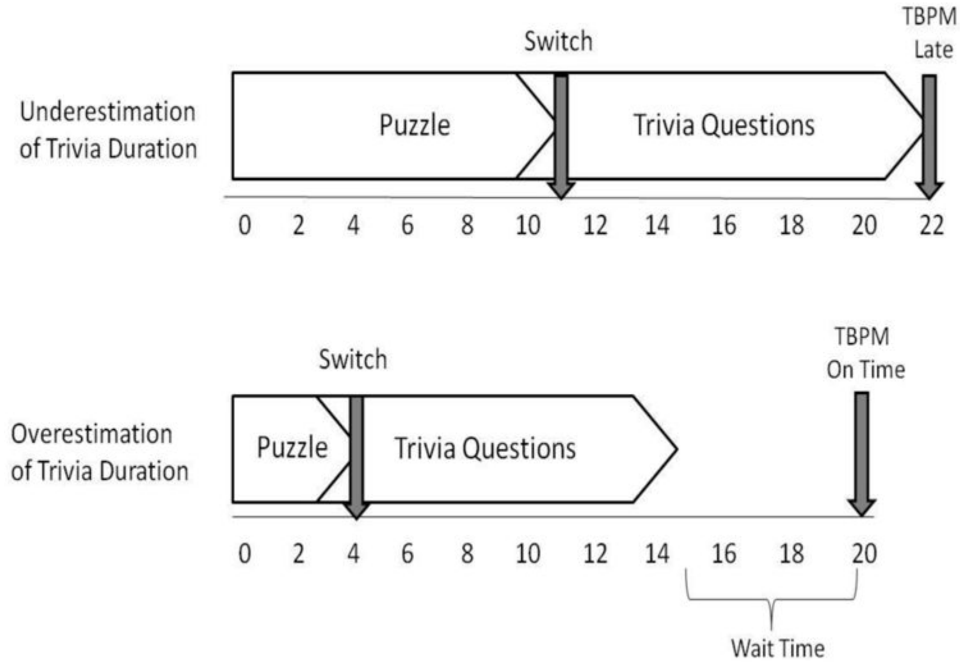

Figure 3.
TBPM task phase predictions based on trivia timing phase time estimation bias. Underestimation (top panel), Overestimation (bottom panel).

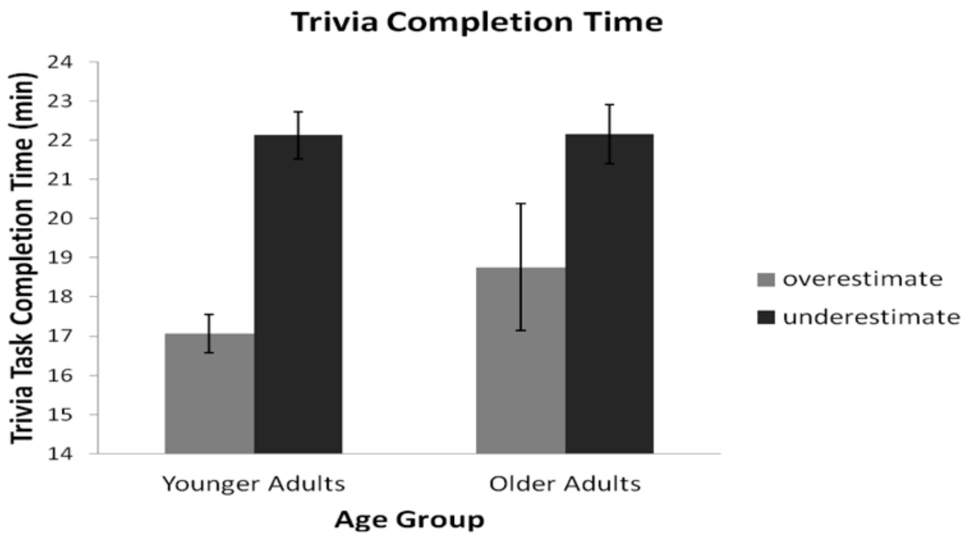

Figure 4.

Trivia completion time (mins) by trivia phase estimation bias, and age group. Error bars represent ±*SE* of the mean. Peak efficiency completion time was 20 mins in all conditions.

Table 1

Average trivia task accuracy and reaction time for older and younger adults. Standard deviations reported in parentheses.

	First Trivia Attempt			
	Accuracy		**Reaction Time**	
First Trivia Background	**YA**	**OA**	**YA**	**OA**
Silence	.52 (.10)	.51 (.16)	5153 (849)	5921 (661)
2 songs	.57 (.11)	.57 (.15)	4839 (844)	5483 (710)
4 songs	.50 (.10)	.61 (.10)	5412 (640)	5806 (783)
Total	.53 (.10)	.55 (.15)	5135 (797)	5742 (721)
Bias Type	***Second Trivia Attempt***			
Overestimated	.86 (.08)	.84 (.14)	2693 (543)	4207 (1073)
Underestimated	.89 (.09)	.82 (.12)	3179 (782)	3766 (890)
Total	.88 (.06)	.82 (.13)	2922 (701)	4060 (1024)

1 OA participant removed for failing to switch from puzzle to trivia task.

Table 2

Summary of multiple linear regression analysis predicting plan fidelity scores.

Variable	*B*	*SE B*	β
Age	-1.56	.883	-.478
# clock checks 1 min prior to trivia start	-1.37	.630	-.702 *
Age × # clock-checks 1 min prior to trivia start	.921	.684	.595

Note: All factors entered simultaneously

* $p < .05$