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Time-based (TB) prospective memory tasks require the estimation of time in passing – known as prospective timing. Prospective timing is said to depend on an attentionally-driven internal clock mechanism, and is thought to be unaffected by memory for interval information (for a review see, Block & Zakay, 1997). A prospective timing task that required a verbal estimate following the entire interval (Experiment 1) and a TB prospective memory task that required production of a target response during the interval (Experiment 2) were used to test an alternative view that memory does influence prospective timing. In both experiments, participants performed an ongoing task for 11.02 minutes while a varying number of songs were played in the background.

Experiment 1 results revealed that participants' time estimates became longer the more songs they remembered from the interval, suggesting that memory for interval information influences prospective time estimates. In Experiment 2, participants who were asked to perform the TB prospective memory task without the aid of an external clock made their target responses earlier as the number of songs increased, indicating that estimates of elapsed time increased as more songs were experienced. For participants who had access to a clock, changes in clock-checking coincided with the occurrence of song boundaries, indicating that participants used both song information and clock information to estimate time. Finally, ongoing task performance and verbal reports in both experiments further substantiate a role for memory in prospective timing.

INVESTING THE "TIME" IN TIME-BASED PROSPECTIVE MEMORY

by

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CHAPTER I

INTRODUCTION

Taking an egg out of the pan before it burns, turning off the tap before the bathtub overflows, attending a meeting at 2:00 pm, removing hair dye after 10 minutes, stopping by the grocery store on the way home to pick up milk, remembering to take medication every morning. What do all these tasks have in common? They are all prospective memory tasks; tasks that one needs to remember to perform at an appropriate point in the future. Prospective memory tasks are ubiquitous in everyday life, and failure to successfully perform such tasks can be detrimental not only in terms of minor annoyances (having to throw out burnt eggs) and increased stress (rushing to get to a meeting), but also can be damaging to ones physical health (forgetting to take daily medication).

A distinction has been made between two different types of prospective memory tasks. The first type is called an event-based (EB) prospective memory task; these tasks require people to perform an action when a specific external cue is present (e.g., remembering to stop at the grocery store to buy milk). The second type is known as a time-based (TB) prospective memory task, and it involves remembering to perform a specified action either after a certain amount of time has passed, or at a specific future time. For instance, remembering to take the cookies out of the oven in 5 minutes, or remembering to go to a doctor's appointment at 2:00 pm would be instances of TB prospective memory.

Although great strides have been made toward understanding the mechanisms of EB prospective memory, there is still a paucity of studies examining the mechanisms of TB prospective memory. The goal of this dissertation, therefore, is to help further the understanding of TB prospective memory by focusing on time estimation processes, which are a unique and central aspect of this type of prospective memory. Although researchers agree that time estimation is imperative in TB prospective memory tasks (e.g., Block & Zakay, 2006, Cockburn, 2006; Graf & Grondin, 2006; Harris & Wilkins, 1982; Jager & Kliegel, 2008; Kvavilashvili & Fisher, 2007; Mantyla & Grazia-Carelli, 2006; Park, Herzog, Kidder, Morrell, & Mayhorn, 1997), there is a lack of integration between research on TB prospective memory and research examining time estimation processes. Therefore, the current research utilizes experimental paradigms from both fields to investigate how time estimation processes contribute to TB prospective memory performance.

Time-Based Prospective Memory (TB prospective memory)

Time-based prospective memory tasks are often very similar to those used to study EB prospective memory. For example, in both TB and EB prospective memory tasks, participants are required to perform some ongoing task, while also remembering to perform a secondary task in the future. In EB prospective memory tasks, the secondary task is to remember to respond to a target cue that was learned prior to the beginning of the task, whereas during TB prospective memory experiments, participants need to remember to perform a prospective memory task at a pre-specified time rather than in response to a pre-specified cue. Typically a clock is provided, and participants are informed that they can check the clock at any time to assist them in performing the TB prospective memory task as close to the target time as possible.

While there are a number of theories regarding EB prospective memory performance, these theories largely have not been extended to TB prospective memory for two reasons. First, all of the current EB prospective memory theories focus on explaining how the external cue(s) embedded within the ongoing task affect performance (e.g., Einstein & McDaniel, 1996; McDaniel & Einstein, 2000; Smith, 2003). However, unlike in EB prospective memory tasks, there are no external cues embedded within TB prospective memory tasks. Instead, participants are required self-initiate clock checks for the TB prospective memory target time. Therefore, theories concerning the external cues of EB prospective memory cannot easily be applied to TB prospective memory performance. Next, numerous researchers have suggested that time estimation mechanisms are likely involved in TB prospective memory performance (e.g., Block & Zakay, 2006, Cockburn, 2006; Graf & Grondin, 2006; Harris & Wilkins, 1982; Jager & Kliegel, 2008; Kvavilashvili, 2007; Mantyla & Grazia-Carelli, 2006; Park et al., 1997) and the current theories of EB prospective memory do not address any such timing mechanism(s).

While theory regarding TB prospective memory is lacking, one recent descriptive model by Block and Zakay (2006) is noteworthy because it is the first TB prospective memory model to draw upon time estimation research. Specifically, Block and Zakay have distinguished between mechanisms thought to underlie two different types of time estimation- retrospective timing and prospective timing- to elucidate the timing components of TB prospective memory performance. The following sections offer a brief overview of these two types of time estimation and describe how Block and Zakay's (2006) TB prospective memory model builds upon research concerning retrospective and prospective time estimation.

Time Estimation Research

Consider the following two requests: "How long did it take you to drive to the grocery store?," versus "When you get to the grocery stores, please call to tell me how long the drive was." While the difference between these two requests may seem negligible to most, to time estimation researchers, the difference between these requests is paramount because the reply to each is thought to not only require different types of time estimation but also entirely separate cognitive timing mechanisms.

For example, to answer the question "How long did it take you to drive to the grocery store?" you need to make what is known as a *retrospective time estimate*; an unexpected time estimate of a past event. Because of the unexpected nature of retrospective estimation, it is thought that people use memory for information that occupied the time interval to help them estimate its duration (e.g., Block & Reed, 1978; Poynter, 1983). According to the memory-based view of retrospective timing, the more retrievable information there is associated with a past interval, the longer the retrospective estimate of that interval will be. For example, according to the memory-based view of retrospective timing, even if two different routes to the grocery store lead to identical objective travel time, the route comprised of more memorable events (e.g., more turns onto different streets) will lead to a longer retrospective estimate than a route that was comprised of fewer memorable events.

While memory for interval information is thought to be important when making retrospective estimates, a very different time estimation process is said to be involved when one is aware that time estimation is required – known as *prospective time estimation*. Prospective timing situations include not only instances where one is aware that a verbal estimate will be required following an interval (i.e., being aware that your friend wants to know the duration of your yet to be made trip to the grocery store), but also include time-based prospective memory situations (i.e., I need to call my friend back in 5 minutes). Such situations are said to involve prospective timing because in each case the individual is aware from the formation of the intention that tracking the passage of time is important for successful task performance. Researchers claim that when people are aware that time estimation is important, they actively attend to the passage of time and make time estimates based on information collected by an internal clock mechanism rather than by using the memory mechanisms associated with retrospective estimation (e.g., Block & Zakay, 1997).

The current dichotomous view of retrospective and prospective timing emerged primarily due to double dissociations observed in experiments that directly compared the two types of estimation. In such experiments, participants perform a task, such as rating a list of words, and then are asked to make either a prospective (expected) or retrospective (unexpected) estimate of the task's total duration. Historically, such experiments have demonstrated that manipulations varying memory for non-temporal information (e.g., the number of context changes or segments experienced during the task) affected retrospective but not prospective estimates, whereas manipulations varying the amount of attention required by the task (e.g., processing difficulty) affected prospective but not retrospective estimates (e.g., Block, 1992; Hicks, Miller, & Kinsbourne, 1976). The interpretation of these double-dissociations has convinced many researchers that retrospective and prospective time estimation do indeed rely on different underlying mechanisms, with prospective time estimation being determined by attentional processes, and retrospective time estimates being driven by memory processes (for a review see Block & Zakay, 1997).

The Link between Prospective Timing and TB Prospective Memory

As Block and Zakay (2006) point out, TB prospective memory tasks take place under prospective timing conditions. As such, Block and Zakay's (2006) model of TB prospective memory is largely an extension of their model of prospective timing, the attentional-gate model (Zakay & Block, 1996). The attentional-gate model centers on the notion that the amount of attention devoted to monitoring time affects how much internal clock information is collected and used during any prospective timing situation. Zakay and Block (1996) argue that the internal clock information that is used to make a prospective time estimate is only collected when a person actively monitors time, and is not collected when attention is devoted to other ongoing tasks. Therefore, the magnitude of a prospective estimate is said to be entirely dependent on how much attention is devoted to monitoring time during an interval, such that the more attention that is devoted to monitoring time during an interval, the longer the time estimate for that interval will be. Block and Zakay (2006) extended the attentional-gate model to TB prospective memory via addition of an intention retrieval component. The addition of this component accounts for the notion that one must not only attend sufficiently to time for the internal clock to signal that the target time has been reached, but must also successfully retrieve the intention that is to be performed at the target time.

Evidence supporting Zakay and Block's (1996) attentional-gate model of prospective timing has emerged from numerous experiments using classic prospective timing paradigms. For instance, researchers commonly find that when attention is divided between prospective timing and an ongoing task, prospective estimates become shorter and ongoing task performance suffers compared to single-task conditions (e.g., Brown, 1997; Brown, 2006; Brown & Merchant, 2007). Furthermore, prospective estimates made under dual-task conditions are typically shorter when the ongoing task is complex compared to when it is simple (e.g., Brown & Boltz, 2002; Block, 1992; Hicks et al., 1976; Zakay & Block, 2004). Together, the dual-task findings suggest that prospective timing is indeed attentionally demanding.

Importance manipulations have also been used to show attentional effects without changing the parameters of the ongoing task. For instance, when participants are instructed that a timing task is more important than an additional ongoing task, performance on the ongoing task decreases and prospective estimates become longer compared to when the ongoing task is emphasized over the timing task (e.g., Kladopoulos, Hemmes, & Brown, 2004; Labelle, Graf, Grondin, & Gagne'-Roy, 2009;

Macar, Coull, & Vidall, 2006; Macar, Grondin, & Casini, 1994; Zakay, 1998). These importance manipulation findings suggest that as participants devote more attentional-resources to monitoring time, fewer resources are available for ongoing task performance.

There is also indirect evidence in the TB prospective memory field to support Block and Zakay's (2006) view that attentionally demanding time estimation processes are at work in TB prospective memory situations. For instance, researchers have observed decreases in ongoing task performance with the addition of a TB prospective memory task – known as 'task interference' or 'costs' (e.g., Hicks, Marsh, Cook, 2005; Marsh, Hicks, & Cook, 2006). While the observation of task interference is often attributed to monitoring for the target event in EB prospective memory studies (e.g., McDaniel & Einstein, 2007a; McDaniel & Einstein, 2007b; Smith, 2003), there is no target event embedded within the stimuli of TB prospective memory tasks for which to monitor. Therefore, it is quite possible that task interference observed in TB prospective memory tasks arise due to the allocation of attention to monitoring time.

In sum, evidence can be found in both the prospective timing and the TB prospective memory literature that is in line with the assertion that an attention-dependent internal clock plays a central role in prospective timing situations. However, there are also a number of reasons to doubt that prospective time estimation relies solely on an attention-dependent internal clock mechanism.

Limitations to the Current Attentional View

Continuous Attention to is not Feasible in Many Timing Situations

Many researchers agree that internal-clock processes are often involved in prospective time estimation, and there is evidence to support this claim. However, some researchers have also argued that people may employ other less costly strategies in real-world prospective timing situations, such as everyday TB prospective memory tasks (e.g., Kvavilashvili & Fisher, 2007; Mantyla & Grazia-Carelli, 2006). For instance, it is unlikely that people choose to continuously monitor time in numerous real-world TB prospective memory situations that include delays of days, weeks, or even months between intention formation and intention completion (e.g., Graf & Grondin, 2006; Kvavilashvili & Fisher, 2007).

Empirical evidence to support the idea that people do not continuously monitor time throughout long delays comes from a diary study conducted by v and Fisher (2007). In this study, participants were asked to record each time they thought about a TB prospective memory intention that was to be performed after a seven day delay. Kvavilashvili and Fisher found that people did not often think about the TB prospective memory intention over this long delay, as they reported only a mean of 8-12 rehearsals over the entire 7 day period. Because people do not often attend to the TB prospective memory intention itself, it can also be inferred that they are also not attending to time in relation to the TB prospective memory intention throughout most of the delay. Therefore, if TB prospective memory performance relied solely on the amount of attention devoted to actively monitoring time from the instantiation of the intention, as

Block and Zakay's (2006) model suggests, these types of intentions would likely never be successfully performed.

An additional finding that cannot be adequately explained by the attentional-view of prospective timing is that older adult participants commonly outperform younger adult participants in naturalistic TB prospective memory tasks (for a review see Henry, McCloud, Phillips, & Crawford, 2004). Block and Zakay (2006) depict TB prospective memory as a dual task situation that requires division of attention between monitoring time and performing the ongoing task. Therefore, according to their model, older adults, who are more likely to be impaired in dual task situations than younger adults (e.g., Anderson, Craik, Naveh-Benjamin, 1998; McDowd, & Craik, 1988) should be more impaired than younger adults in both laboratory-based and naturalistic TB prospective memory situations, and this is not the case. Instead, in naturalistic settings, older adults may be able to rely more on duration knowledge, and thus avoid performance decrements associated with more active monitoring of time. Indeed, there is evidence from the field of future time estimation to suggest that people do possess such duration knowledge and can use it to make time estimates.

Duration Memory is used in Future Time Estimates

Researchers investigating future time estimation propose that people often use memory for past event durations to estimate how long a similar task will take to perform in the future. For instance, Boltz, Kupperman, and Dunne (1998) argue that people often rely on memory for event duration in many situations, such as during the planning of the day's scheduled activities. Roy, Christenfeld, and McKenzie (2005) also propose that memory for past durations is integral in planning for the future, and reason that if future time predictions are based on memory for the duration of previously experienced tasks, then biases in predicted estimates should be similar to those observed in past (retrospective) estimates. Indeed Boltz et al. (1998) and Roy and Christenfeld (2007, 2008) have found evidence of a direct relationship between peoples' estimates of how long it took them to perform a task in the past and how long they believe it will take them to perform the same task in the future. If people use event duration memory to plan future tasks, it is also reasonable to think that people can use these same duration memories to estimate how much time has passed in prospective timing situations. For instance, if I know that I need to call a friend back in 45 minutes, and my favorite sitcom just started, I can likely use my duration knowledge that "sitcoms last 30 minutes" to avoid actively monitoring time at least until the sitcom comes to an end.

Memory has not been Ruled out as a Prospective Timing Mechanism

Finally, and perhaps most importantly, the conclusion that prospective estimates are unaffected by memory for interval information may be unwarranted based on the current evidence. For example, Block and Zakay (1997) performed a meta-analysis using 20 experiments that directly compared prospective and retrospective time estimates. This meta-analysis was conducted to provide further support for the notion that different processes underlie prospective and retrospective time estimation. Block and Zakay did find evidence that certain variables affect either only retrospective (e.g., duration length and stimulus complexity) or only prospective estimates (e.g., processing difficulty). However, this meta-analysis should be viewed with caution because some of the variables that have been found to be the most important in retrospective time estimation, such as number of contextual changes, segments, and expertise were not included due either to a limited or complete lack of experiments that have manipulated these variables in the prospective paradigm.

The fact that very few experiments have investigated a number of important memory factors in prospective timing may be in part due to the overwhelming, and somewhat unjustified, acceptance of separate mechanisms by time estimation researchers. Unfortunately, this separate mechanism perspective has become so strong that some researchers have even become convinced that using any memory manipulation in a prospective timing experiment would be futile. For example, Bailey and Areni (2006a) showed that under retrospective timing conditions participants judged an interval during which they heard 8 short songs to have lasted significantly longer than an interval of equivalent objective duration during which they heard 4 longer songs. While Bailey and Areni explain that their findings support a memory-based explanation of retrospective time estimation known as the segmentation-change model (Poynter, 1983), they also justify not including a prospective timing condition by saying that

> …background music will only have this effect under certain conditions. There is considerable evidence that the segmentation-change model applies mainly when individuals are distracted from monitoring the passage of time during the target interval. (p. 438)

While Bailey and Areni (2006a) are correct in stating that some memory manipulations have failed to produce significant effects in prospective timing paradigms, what they may have failed to consider is that the memory manipulation they used in their experiment was unlike those that have previously led to null results. Specifically, many prospective timing tasks require participants to study lists of words or perform other novel processing tasks during the interval that is to be estimated (e.g., Block, 1992; Hicks et al., 1976; Predebon, 1995; Zakay, 1998). In such instances, participants likely do not have any relevant duration knowledge that they can use to avoid monitoring time, and thus have no choice but to rely on the internal clock mechanism described by Zakay and Block's (1997) attentional-gate model of prospective timing. However, it is likely that if participants experience events for which they already possess duration knowledge, such as pop songs playing during the prospective timing experiment, that they can use their memory for these events to estimate the passage of time. Experiment 1 was designed to test this hypothesis.

CHAPTER II

EXPERIMENT 1 METHODS

In Experiment 1, all participants first performed a baseline lexical decision task without any timing requirement, and then performed a second lexical decision task under prospective timing conditions. Some participants performed these two lexical decision tasks while popular songs played in the background, whereas others performed it in silence. While the number of background songs varied between participants, the objective duration of the interval was held constant across conditions.

If people use memory and duration knowledge to make prospective time estimates, participants who hear background songs should be able to use their knowledge of how long pop songs typically last along with their memory of the number of songs played to make their prospective estimate. Such a strategy would be evidenced by participants who remember more songs judging the interval as having been longer than those who remember fewer songs. For instance, if people apply knowledge that pop songs generally last 3-4 minutes, those who hear four songs should estimate the duration to have been about 12-16 minutes, whereas those that hear only two songs should make a much shorter estimate of 6-8 minutes.

In addition to time estimates, we will also investigate lexical decision performance. The attentional view predicts that as prospective estimates increase, ongoing task performance will decrease. This prediction is based on the assumption that longer prospective estimates require greater attention to time, leaving less attentional resources available for ongoing task performance. Therefore, examination of lexical decision performance will allow us to determine if differences in attentional allocation can explain any variation in prospective estimates observed across conditions. Additionally, we will analyze verbal reports of time estimation strategies to establish whether self-reports converge with strategies suggested by the time estimation findings. Finally, we will consider participants' preference for and familiarity with the background songs to determine if either of these factors might contribute to the estimation findings.

Method

Participants

The participants were 160 UNCG undergraduates who participated for course credit. They were tested in groups of up to six. Participants were recruited through an online scheduling system, and upon arrival, were randomly assigned to one of five between-subjects background conditions (silence vs. metronome vs. 2-songs vs. 3-songs vs. 4-songs). All participants in each background condition completed two lexical decision task *sessions* (baseline vs. prospective timing). Therefore, this study employed a 2x5 mixed-factorial design.

Materials

Lexical decision task. Stimuli were 266 words (mean frequency, 146 per million; Kucera & Francis, 1967) and 266 pronounceable nonwords. Nonwords were drawn from the ARC nonword database (Rastle & Coltheart, 2002).

The pool of 532 items (words and nonwords) was randomly divided into three lists; one short practice list of eight items and two experimental lists of 262 items each (Lists: practice, A, and B). Each experimental list contained 131 words and 131 nonwords; the practice list was comprised of four words and four nonwords. One half of participants were presented List A during the baseline lexical decision task and List B during the subsequent prospective timing lexical decision task. The order of the lists was reversed for the remaining participants. Finally, presentation order of each item within each list was randomized for each participant.

Background tracks. Seven different background tracks were created for use during the baseline and prospective timing sessions. Six of these background tracks were comprised of popular songs by top 40 artists, and the final track was a recording of a metronome. Eighteen popular songs were chosen to create the six different song tracks. Two of these song tracks were comprised of two songs each (tracks 2a & 2b), two tracks consisted of three songs (tracks 3a & 3b), and two tracks were comprised of four songs each (tracks 4a & 4b). Each track was included unique songs. In other words, each of the eighteen songs used in the study was placed onto only one of the six different tracks. The baseline and prospective timing sessions were each 11.02 minutes in duration. Therefore, the songs chosen for inclusion on each background track were selected so that the songs, played back-to-back, would also play for a total of 11.02 minutes. Thus, the 2-song tracks consisted of songs of the longest duration (M = 5.53, SD = 0.34), the 3-song tracks included songs shorter in duration (M = 3.80, SD = 0.44) and the 4-song tracks were comprised of the shortest songs in duration (M = 2.78, SD = 0.40).

In addition to controlling for total duration of each track, the average beats per minute (bpm) of the songs included on each track was also controlled. Previous studies using repetitive click presentations (e.g., Penton-Voak, Edwards, Percival, & Wearden, 1996; Treisman, Faulkner, Naish, & Brogan, 1990; Wearden, Edwards, Fakhri, & Percival, 1998; Wearden, Philpott, & Win, 1999) have shown that participants exposed to click trains make longer prospective estimates than do participants not exposed to clicks. The clicks are thought to increase prospective estimates by increasing arousal and subsequently the rate at which the internal clock "ticks." Because songs have an inherent "beat," it was important that the average bpm across the 2-, 3-, and 4-song conditions remained constant, otherwise any differences in estimates could be attributed to differences in bpm rather than differences in the number of songs played. Therefore, to control for tempo, each song selected for use in the experiment deviated no more than five bpm from any other selected song. A variety of resources and technology, including an online DJ database (http://www.djbpmstudio.com), tempo calculation software: Mixmeister BPM Analyzer (Mixmeister, LLC., 2010) and Taptempo (AudioX, LLC., 2009), and a metronome were used to ensure that all songs included in the experiment fell within a range of 126-131 bpm. Finally, an ANOVA confirmed that the average bpm of the songs included in the 2-song condition (M = 129.0, SD = 2.33), 3-song condition (M = 129.6, SD = 1.79) and 4-song condition (M = 129.1, SD = 1.34) did not differ, $F<1$. Finally, a metronome ticking at the mean song bpm (129) was recorded for use in the final background track condition.

Post-experiment verbal report materials. A number of additional materials were created for use following completion of the prospective timing session. These materials consisted of three separate printed forms. The first form included a time estimation measure, while the remaining two forms asked participants to report their time estimation strategy, and to answer a number of questions regarding the songs played during the prospective timing session.

Time-estimation sheet. This sheet contained the sentence: "I think that the time estimation segment of the experiment lasted for ______minutes and _______seconds." Participants were asked to fill in both blanks to indicate their estimate.

Time-estimation strategy report sheet. This sheet contained the sentence "In the blank space below please describe, in as much detail as you can, the thinking that led to you to decide on the time estimate you wrote on the sheet of paper I just collected from you."

Song questionnaire. This sheet contained three questions that inquired about the songs played during the prospective timing segment. The first questions asked participants to report the number of songs they remembered hearing during the time estimation segment of the experiment ('time estimation segment' was the colloquial term used during the experiment to describe the prospective timing session). The second question asked participants to report how many of the songs played during the time estimation segment they were familiar with, or in other words, how many of the songs they had heard prior to the experiment. The third question asked participants to rate on a scale from 1-7 how much they liked or disliked the songs played during the time estimation segment. A rating of 1 represented “like very much” and 7 represented “dislike very much.”

Procedure

Upon arrival, participants were informed that they would be participating in an experiment designed to determine how quickly they could process visually presented items, and were given instructions regarding the lexical decision task. Participants were told to determine as quickly as possible if each letter string presented on the screen was an English word, or was not an English word. They were informed that each time a word appeared on the screen they should press the “P” button on the keyboard, and whenever a nonword letter string appeared, they should press the “Q” key.

Following the lexical decision instructions, each participant completed an 8-item lexical decision practice session, followed by two experimental lexical decision task sessions. Each lexical decision trial was fixed at 2.524 seconds so that both the number of trials and the total duration of each lexical decision task remained constant for each participant. Each stimulus item was presented on the computer screen either for a maximum of 2500 milliseconds or until a word/nonword response was recorded. If a response occurred prior to the 2500 millisecond time limit, the stimulus item disappeared and an ‘xxx’ display replaced the item on the screen for some variable amount of time until the total 2500 millisecond duration elapsed. Finally, a blank screen was displayed for 24 milliseconds during the screen transition that occurred prior to the presentation of each new stimulus item. Therefore, the baseline and prospective timing lexical decision task sessions each lasted 11.02 minutes.

Following completion of the practice session, all participants performed the baseline lexical decision task. Their only responsibility during this baseline task was to make word/nonword decisions as quickly and accurately as possible. This task was performed either in silence, or while a metronome, two, three or four songs played in the background. Prior to the start of the baseline session, participants in the metronome and song conditions were informed that we would be observing how environmental factors might affect their visual processing ability. This warning was included to lessen any reactivity effects potentially associated with experience of a background track.

Following the baseline lexical decision task, all participants performed a second lexical decision task of equal duration under prospective timing conditions. The background conditions present during the prospective timing task were the same as those experienced during the baseline task. For instance, participants who performed the baseline task in silence also performed the prospective timing task in silence. Similarly, participants hearing the two songs of track 2a play during the baseline task heard the two songs of track 2b during the prospective timing task. The 'a' and 'b' tracks of each song condition were assigned equally often to play during the baseline and prospective timing task sessions.

Prior to the start of the prospective timing session, participants were told that they were about to perform the "time estimation segment" of the experiment. They were informed that this segment would not only require word/nonword decisions, but would also require a time estimate following its completion. Specifically, participants were informed that they would later be asked to estimate, in minutes and seconds, the entire duration of the time estimation segment. The experimenter clearly specified that the later estimate should only include time that passed from when they began the next session to when the last item disappeared from the screen to end the session. Finally, all participants were asked to put watches and cell phones out of sight.

Following the prospective timing session, participants were asked to complete the time estimation sheet. Subsequently they were asked to describe the basis for their estimate on the timing strategy report sheet, and finally those participants in the song conditions were asked to complete the song questionnaire. Each form was completed separately and was collected by the experimenter prior to distribution of each subsequent form.

CHAPTER III

EXPERIMENT 1 RESULTS AND DISCUSSION

Results

Song Memory

The primary question of interest is whether memory for the number of songs played during the lexical decision task affects the prospective time estimates of that task. Therefore, we first we examined if participants who heard fewer songs in fact remembered fewer songs than those who heard more songs. Indeed, a strong positive correlation indicates that the number of songs participants remembered hearing increased as the number of songs played increased $r(94) = 0.89$, $p < .001$. Although the number of songs played and the number of songs remembered were highly correlated, memory for the number of songs played during the prospective timing session was not perfect. In fact, participants' memory became more inaccurate as the number of songs played increased (see Table 1).

Table 1. Proportion of participants reporting each number of remembered songs by Background Condition in Experiment 1.

Background Condition	Remembered 1	Remembered 2	Remembered 3	Remembered 4	Remembered 5
2 songs played	3%	94%	3%	0	0
3 songs played	0	6%	91%	3%	0
4 songs played	0	3%	16%	78%	3%

Because our hypothesis concerns participants' use of remembered events to make prospective time estimates, it was more appropriate to investigate time estimates based on participant memory for the number of songs played, rather than the objective number of songs played. Initial analyses confirmed that while the pattern of estimation findings is unaffected if the number of songs played is used as a variable rather than the number of songs remembered, the latter leads to stronger differences in estimates between the three song conditions.

Duration Estimates

Duration estimates were converted to relative time estimation error scores by subtracting 11.02 from each participant's estimate. Negative relative error scores represent underestimation of the interval while positive error scores represent overestimation. A score of zero represents perfect accuracy. The results are shown in Figure 1.

First, we compared estimates between the silence and metronome conditions. The metronome played at the mean tempo of the song tracks (129 bpm), and it is possible that this particular tempo may have altered the rate of the internal clock. For instance, if as suggested by a number of previous studies (e.g., Penton-Voak et al.,1996; Treisman et al., 1990; Wearden et al., 1998; Wearden et al., 1999), the presence of a metronome increases the internal clock rate via an increase in arousal, we would expect to see longer estimates in the metronome than in the silence condition. Alternatively, if the metronome tempo led to slowing of the internal clock, we should see shorter estimates in the metronome condition than in the silence condition. This analysis revealed that estimates made in silence and metronome conditions were not significantly different from each other, t < 1 (see Figure 1). Overall, this finding suggests that the mean bpm used in both the metronome and song conditions likely did not affect the rate of an internal-clock mechanism. Because estimates did not differ between the silence and metronome conditions, we collapsed across these two conditions in the subsequent analysis. Together these two conditions are referred to as the *no-song condition*.

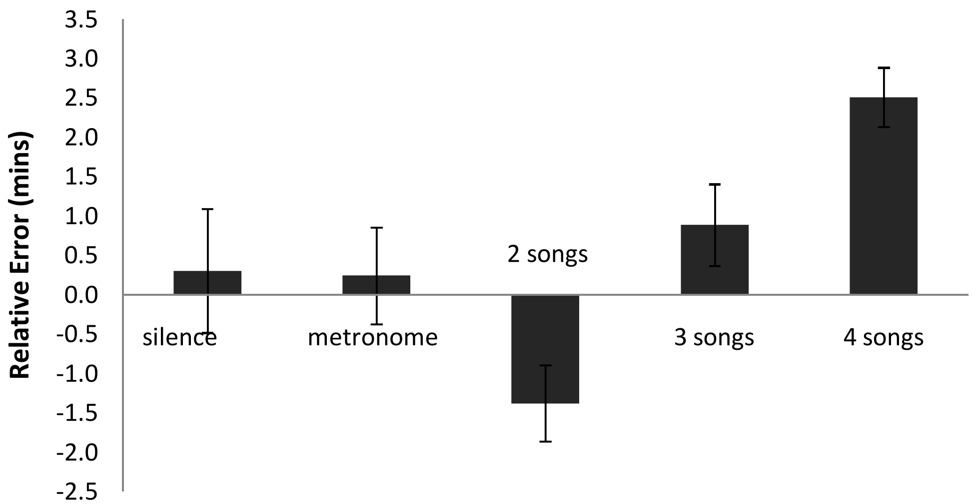
An ANOVA was conducted on relative error scores using participants' *remembered background* (no-song vs. two songs vs. three songs vs. four songs). Only one participant recalled one song, and one additional participant recalled five songs; these two participants were not included in this analysis. The ANOVA revealed a significant main effect of remembered background, $F(3, 154) = 7.15$, $MSe = 10.679$, $p < .001$, $\eta^2 =.122$ (See Figure 1). Follow-up tests were conducted to further investigate this background effect. First, estimates made in the song and no-song conditions were compared. Participants in the no-song condition ($M = 0.29$, $SD = 3.96$) made estimates that were significantly longer than those by participants who remembered two song, $t(95) = 2.14$, $p < .05$, and significantly shorter than those made by participants who remembered four songs, $t(88) = 2.74$, $p < .01$. Estimates made in the three song, and no-song conditions did not differ, $t < 1$.

More importantly, follow-up tests comparing estimates across the three song conditions revealed that estimates in each song condition were significantly different from one another. Specifically, participants who remembered four songs made significantly longer estimates than those who remembered either two songs, $t(57) = 6.08$,

$p < .001$, or three songs, $t(59) = 2.37$, $p < .05$. In turn, participants who remembered three songs made longer estimates than those who remembered only two songs, $t(66) = 3.19$, $p < .01$. Thus, the more songs participants remembered having played during the task, the longer their estimates tended to be.

Next, relative error scores in each background condition were compared to zero to determine if significant under- or overestimation was present. Results revealed that in neither the silence nor metronome conditions did estimates deviate significantly from zero (both *t's* < 1), indicating that there was not a bias toward over- or underestimation of the interval in either of the no-song conditions. However, in the song conditions, participants who remembered hearing two songs significantly underestimated the duration of the interval, $t(32) = 2.85$, $p < .01$, and participants who remembered four songs significantly overestimated the duration of the interval, $t(25) = 6.66$, $p < .001$. Participants who remembered three songs also showed a non-significant trend toward overestimation $t(34) = 1.72$, $p = .09$. In sum, while no systematic over- or underestimation of the interval was observed when participants experienced either silence or a metronome, participants did show a systematic trend to move from under- to over-estimation of the interval as the number of songs remembered from that interval increased.

Figure 1. Relative time estimation error by Remembered Background in Experiment 1. Error bars represent SE.

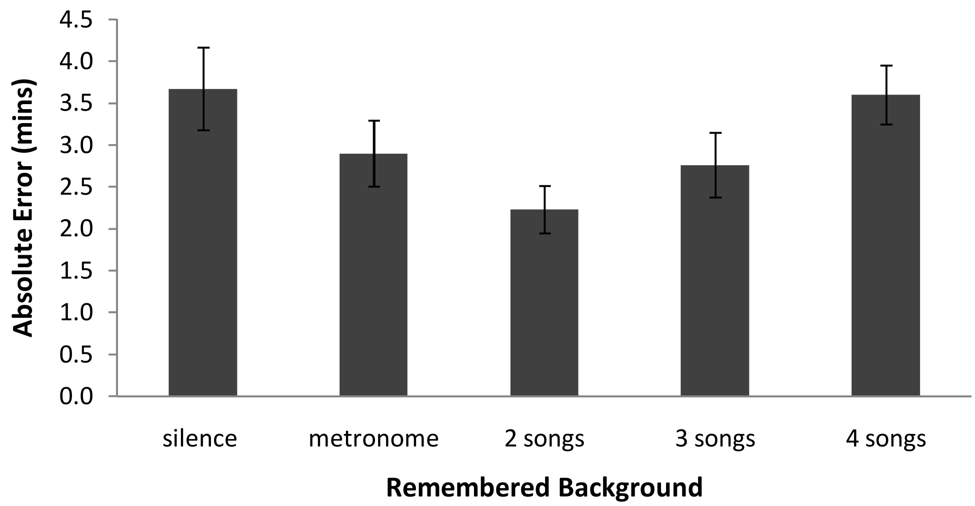


Absolute Time Estimation Error

One may note from the previous analysis that participants in the silence and metronome conditions look to have made more accurate prospective estimates than participants in the song groups. However, this may not be the case because relative error is a metric for overall bias, and therefore averages across over- and underestimation errors. We can obtain a much more accurate measure of overall error by calculating absolute error, which is a measure of the overall error observed regardless of direction. Absolute error scores were calculated by subtracting each participant's duration estimate from 11.02, and then taking the absolute value of this score. The closer the absolute error score is to zero, the more accurate the participant's estimate. The results are summarized in Figure 2.

Once again we first compared absolute error in the silence and metronome conditions. Because absolute error did not differ significantly between these groups, $t(62) = 1.22$, $p = .23$, we again combined these two conditions into a single *no-song condition*. An ANOVA was then conducted on the absolute error scores using *remembered background* (no-songs vs. two songs vs. three songs vs. four songs). This analysis revealed a marginally significant main effect of background, $F(3,154) = 2.45$, $p = .07$. Follow-up tests indicate that estimates from participants in the no-song condition ($M = 3.28$, $SD = 2.54$) were associated with significantly more absolute error than those made by participants who remembered two songs, $t(95) = 2.16$, $p < .05$. Additionally, estimates made by participants who remembered four songs were associated with significantly more absolute error than estimates made by participants who remembered three songs, $t(62) = 2.15$, $p < .05$. None of the remaining comparisons produced significant differences in absolute error (no songs vs. 3 songs, $t(97)=1.01$, $p = .31$; no-songs vs. 4 songs, $t<1$). In sum, while participant in the silence and metronome conditions do not show a tendency to over- or underestimate, consideration of absolute error reveals that estimates in these two groups were not more accurate overall than estimates made in the song conditions.

Figure 2. Absolute time estimation error by Remembered Background in Experiment 1. Error bars represent SE.



To this point, we have presented strong estimation evidence to suggest that participants who hear songs play during an ongoing task use memory of those songs to make their prospective time estimates. These estimation findings contradict the attentional-view of prospective timing which assumes that people do not use memory to make prospective estimates, but instead rely on temporal information that is collected by an internal clock when one attends to the passage of time. According to the attentional account of prospective timing, increased allocation of attentional resources to monitoring time serves not only to increase the amount of information collected by the internal clock, but also detracts from the resources available for ongoing task performance. Therefore, according to this view, increases in prospective time estimates should be accompanied by decreases in ongoing task performance (e.g., Kladopoulos et al., 2004; Labelle et al., 2009; Macar et al., 1994; Macar et al., 2006; Zakay, 1998). In the current experiment, prospective estimates became significantly longer with each additional remembered background song. A purely attentional view of these increasing estimates, therefore, would require the assumption that as the number of remembered songs increases, the amount of attention paid to monitoring time also increases. Such an explanation would be supported by declines in ongoing task performance with increases in the number of background songs remembered. However, if ongoing task performance does not differ across song conditions, it would further suggest that memory for songs rather than an attentionally-driven internal clock mechanism is the primary influence on duration estimates in these conditions. In the following section we analyze both lexical decision accuracy and reaction time to determine if ongoing task performance differed across background conditions.

Ongoing Task Performance

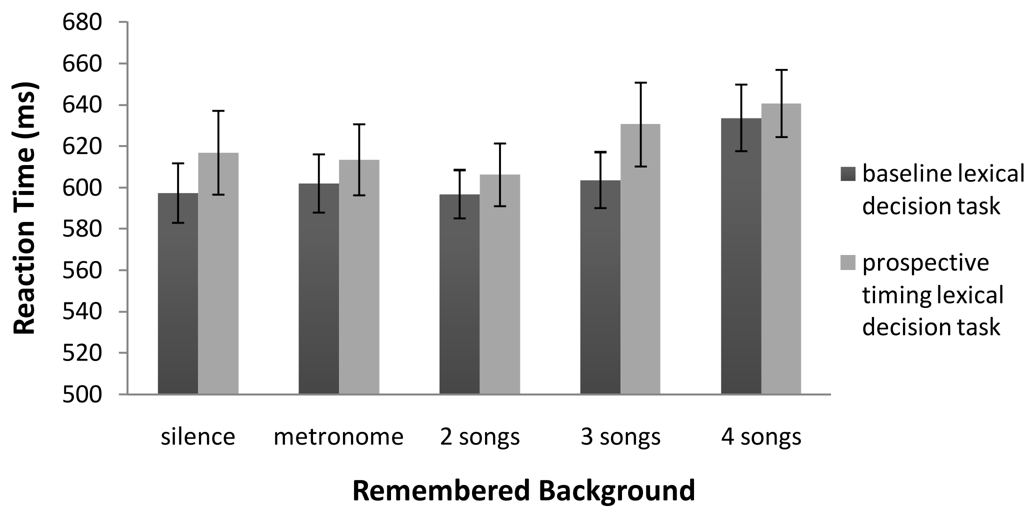
Lexical decision accuracy. A mixed-factorial ANOVA conducted on the proportion of correct lexical decision responses using *session* (baseline vs. prospective timing) and *remembered background* (silence vs. metronome vs. two songs vs. three songs vs. four songs) as factors revealed neither significant main effects of session ($F < 1$) (baseline, $M = 0.95$, $SD = 0.04$; prospective timing, $M = .95$, $SD = .06$), nor of background, $F < 1$, nor an interaction, $F(4, 153) = 1.32$, $p = .27$. These findings suggest that participants' ability to perform the task was not affected by which background condition was present and that the addition of the prospective timing task did not adversely affect participants' ability to perform the lexical decision task accurately in any of the background conditions. Lexical decision accuracy is normally very high, and is often unaffected by the addition of a secondary task (e.g., Hicks et al. 2005; Marsh, Hicks, Cook, Hansen, & Pallo, 2003; Smith, 2003). Reaction times are a more sensitive measure, and therefore, are commonly analyzed to determine if the addition of a secondary task causes significant task interference (e.g., Einstein et al., 2005; Hicks et al., 2005; Marsh et al., 2003; Marsh et al., 2006; Smith, 2003; Smith, Hunt, McVay, & McConnell, 2007).

Lexical decision reaction time. During lexical decision tasks, nonword reaction times are typically longer and more variable than are word reaction times (e.g., Marsh et al., 2003; Hicks et al. 2005; Piercey, 2008). Furthermore, increases in reaction times to words that occur with the addition of a secondary task are often not accompanied by increases in response times to nonwords (e.g., Cohen, Jaudas, & Gollwitzer, 2008; Smith et al., 2007; Smith, 2010). Smith (2010) has argued that because reaction times costs are not equivalent for words and nonwords, analyses conducted collapsing across both words and nonwords is inappropriate. Indeed, a number of researchers agree that additional processing of nonlexical information is required on nonword trials (see Grainger & Jacobs, 1996), and therefore choose to limit reaction time analyses to word responses (e.g., Hicks et al., 2005; Marsh et al., 2003; Smith et al., 2007; Smith, 2010). We therefore limit our reaction time analyses to accurate word responses (2.5% of total word responses removed). Additionally, reaction time was trimmed so that any accurate responses more than 2.5 standard deviations from a participant's grand mean response time were eliminated (additional 2.98%) (e.g., Einstein, et al. 2005; Ratcliff, 1979).

A mixed-factorial ANOVA was conducted on reaction time to lexical decision task words using *session* (baseline vs. prospective timing) and *remembered background* (silence vs. metronome vs. two songs vs. three songs vs. four songs). The results are summarized in Figure 3. This analysis produced a significant main effect of session, $F(1, 153) = 11.63$, $MSe = 1476.18$, $p = .001$, $\acute{\eta}^2 = .071$. Overall, participants responded significantly slower during the prospective timing session ($M = 620.97$, $SD = 101.76$) than during the baseline session ($M = 605.67$, $SD = 78.23$). However, more importantly, neither the main effect of remembered background nor the interaction were significant (both *F*'s <1). These findings indicate that reaction times did not differ significantly by background condition and that the slowing observed from the baseline to the prospective timing task occurred equally across all background conditions.

According to the attentional view of prospective timing, increases in prospective time estimates should be accompanied by decreases in task performance (e.g., Labelle et al., 2009; Zakay, 1998). Contrary to this prediction, in the current study, lexical decision task accuracy and reaction time patterns were constant across all conditions, irrespective of observed prospective estimate. This finding further suggests that memory better accounts for the prospective estimates observed in song conditions than does an attentionally-driven internal clock.

Figure 3. Lexical decision reaction time by Remembered Background in Experiment 1. Error bars represent SE.



Verbal Reports of Estimation Strategy

Thus far, time estimates in the song conditions are consistent with a memory-based explanation, and ongoing task performance results are inconsistent with an attentionally-demanding internal clock explanation. Verbally reported estimation strategies can provide further converging evidence of memory-based strategies in the song conditions. Particularly, self-reported estimation strategies can reveal whether participants in the song conditions consciously used song-memory to make their estimates. If this is the case, we should see that a majority of participants who heard songs play in the background reported using those songs to estimate time. Further, we will investigate whether non-song strategies are reported more often in the no-song condition (i.e. the silence and metronome condition) compared to when background songs are available.

First, in the song conditions, a chi-square was used to determine if the proportion of participants who reported using songs to estimate time (94%) differed significantly from the proportion of participants who reported other strategies including: *attempting to count stimuli or seconds* (4%), *using knowledge of experiment length* (1%) or simply *using a feeling to guess* (1%). The results of this analysis confirmed that of participants who heard songs play in the background, a significantly higher proportion reported using the songs to make their estimate than all other strategies combined, $\chi^2(1, N = 96) = 73.50$, $p < .001$.

While strategy reports made in the silence condition were more variable than those made in the song conditions, they had some overlap with strategies reported in the song conditions (see Table 2). Separate chi-squares were conducted on the proportion of participants using each of these strategies across the song and no-song conditions. Results of these analyses revealed that strategies including, *using a feeling to guess*, $\chi^2(1, N = 160) = 23.21$, $p < .001$, *using knowledge of the experiment duration*, $\chi^2(1, N = 160) = 11.11$, $p = .001$, and *counting seconds or the number of stimuli*, $\chi^2(1, N = 160) = 25.05$, $p < .001$, were more commonly used in the no-song condition than in the song conditions. Overall, these findings suggest that participants who have background songs available are less likely to use any of the strategies reported in the no-song condition.

Together, the time estimation strategy reports support the use of memory to estimate time prospectively. Participants who heard background songs reported using these songs to make their estimates far more often than they reported any other strategy.

Furthermore, compared to the no-song condition, participants who heard songs were much less likely to report the use of any non-song strategy, indicating that the tendency to use songs is very strong when they are available.

Table 2. Proportion of participants reporting each time estimation strategy in Experiment 1.

Song Strategies	**Song Conditions** **N=96**	**No-Song Condition** **N=64**
Used Songs	87%	-
Used Songs plus an additional strategy	7%	-
Sang song of known duration in head	-	3%
Total	**94%**	**3%**
Non-song Strategies		
Made estimate based on a "feeling"	1%	25%
Counted seconds or stimuli	4%	27%
Used knowledge of experiment duration	1%	14%
Compared feeling to that of task with known duration	-	9%
Made estimate based on physical symptoms (i.e. fatigue, eye strain)	-	11%
Kept track of every time is felt like certain amount of time (e.g., 1 min.) had elapsed	-	11%
Total	**6%**	**97%**

Questionnaire Responses

Finally, we consider the possibility that certain subjective characteristics of the songs used in the current experiment may have influenced the estimation findings. For instance, previous research in marketing has examined how background music liking and familiarity influences perceived shopping experiences and other customer service situations that require waiting (i.e. waiting rooms and holding on phone calls). These studies have reported that both song liking (e.g., Cameron, Baker, Peterson, & Braunsberger, 2003; Lopez & Malhorta, 1991) and song familiarity (e.g., Bailey & Areni, 2006b; Yalch & Spangenberg, 2000) can affect duration estimates. Therefore, we conducted a regression analysis to determine if either liking or familiarity may have influenced estimates beyond song memory. One participant did not report how many songs he was familiar with, and therefore is not included in the analysis.

Liking of the songs was measured using a scale of 1-7, where 1 represented "like very much" and 7 represented "dislike very much," Overall, participants' mean liking was 2.72 (*SD* = 1.21). Familiarity scores for each participant were calculated by dividing the number of songs they reported being familiar with by the number of songs they remembered hearing. The mean proportion of remembered songs participants reported begin familiar with was 0.63 (*SD* = .33).

A multiple linear regression analysis was conducted to determine if scores on the self-report measures may have influenced time estimates. Number of remembered songs, song liking, and song familiarity were regressed on relative time estimation error scores. Together, these three predictors explained a significant proportion of variance in relative estimation error, $R^2 = .26$, $F(3, 91) = 10.87$, $p < .001$. However, as can be seen in Table 3, the number of remembered songs was the only significant predictor ($\beta = .49$, $t(93) = 5.39$ $p < .001$). In sum, even after considering self-reported song liking and familiarity, number of remembered songs remains the only factor that explains a significant amount of variance in prospective time estimates when songs are played in the background.

Table 3. Summary of multiple linear regression analysis predicting relative time estimation error in Experiment 1.

	All Song conditions		
Variable	*B*	*SE B*	β
# Remembered Songs	1.800	.334	.491**
Liking	-.111	.256	-.043
Familiarity	.612	.928	.066

Note: All factor entered simultaneously

** p < .001

Discussion

The results of Experiment 1 demonstrate that contrary to the attentional view of prospective timing, prospective estimates are strongly influenced by memory for interval information. Participants' memory of the number of songs played during a lexical decision task was directly related to the magnitude of prospective time estimates. Specifically, the more songs participants remembered, the longer their estimates became. If anything, the attentional-view of prospective timing may have predicted the exact opposite, namely, shorter estimates for participants who remembered hearing more songs. For instance, according to the attentional-view of prospective timing, the less attention that is devoted to monitoring time throughout an interval, the shorter the time estimate for that interval will be. As such, one might expect that participants who remembered hearing more songs may have had more attention drawn away from the timing task than did participants who remembered only two songs, or for those that heard no songs at all. On the contrary, in the current study, remembering four songs led not to shorter estimates, but to longer estimates than those made either by people that remembered only two songs or who heard no songs at all. Furthermore, compared to the baseline condition, reaction times slowed to an equal extent across all background conditions with the addition of the prospective timing task. Such equivalent slowing across background conditions further suggests that differential song memory rather than differential internal clock involvement underlie the estimates observed in the song conditions.

As evidenced not only by the prospective estimates themselves, but also by strategy reports, participants who heard songs play in the background used these songs to make their prospective estimates. The strong tendency to use songs to estimate the passage of time in the current experiment suggests that people may rely heavily on such memory-based strategies in many everyday prospective timing situations, such a TB prospective memory. Therefore, the aim of Experiment 2 is to determine if the findings of Experiment 1 can be extended to TB prospective memory.

CHAPTER IV

EXPERIMENT 2 METHODS

Experiment 2 was designed to determine if the prospective timing estimates observed in Experiment 1 would extend to a TB prospective memory task. In this experiment, participants were told to press the 'Z' key on the keyboard after 10 minutes of a lexical decision task had elapsed. As in Experiment 1, background condition was varied between participants. Therefore, some participants performed the lexical decision task in silence while others heard either two or four songs play in the background. Additionally, we varied how accessible a clock was during the TB prospective memory task. Participants in a low-consequence clock condition had unlimited access to a clock throughout the ongoing task, while participants in a high-consequence clock condition were told they would incur a penalty every time they checked the clock. Finally, participants in the no-clock condition had no access to a clock. While previous TB prospective memory research has always allowed unlimited clock checks (but see Labelle et al., 2009), by including the high-consequence and no-clock groups we could extend the findings to different types of TB prospective memory situations, which do not offer unlimited clock information (e.g., you take your 30 minute lunch break outside, but forgot your watch).

In Experiment 1, the more songs that participants remembered, the more time they thought had elapsed during the lexical decision task. If participants use the same memory-based estimation strategy that was evident in Experiment 1, we should see similar timing biases emerge in the target responses of a TB prospective memory task. Namely, relative to participants in the 4-song condition, participants in the 2-song condition should judge that less time has elapsed during the interval and thus wait longer to make their target response.

As in Experiment 1, we will consider a variety of dependent measures in addition to target responses to determine if participants who hear songs use those songs to estimate the passage of time. Two measures commonly investigated in prospective memory research – ongoing task performance and clock-checking – can help to elucidate the timing mechanisms employed during the TB prospective memory task. For instance, because the attentional-view of prospective timing assumes that earlier target responses occur due to the increased allocation of attention to monitoring time, ongoing task performance can indicate whether differences in attentional allocation can account for any variation in target response times across conditions. Furthermore, participants decisions about when to check the clock during the course of the experiment can indicate whether or not they are using the songs to help them track the passage of time. If participants estimate the length of each song based on prior duration knowledge, they may make clock-checks at song boundaries to determine the accuracy of their song-length estimates. We would expect that the likelihood of clock-checking would increase at song boundaries with the use of such a strategy.

Method

Participants

The participants were 384 UNCG undergraduates who participated for course credit. They were tested in groups of up to six. Participants were recruited through an online scheduling system, and upon arrival, were randomly assigned to one of the 12 between-subjects conditions. *Session* (baseline vs. no-clock vs. low-consequence clock vs. high-consequence clock) and *background* (silence vs. 2-songs vs. 4-songs) were both manipulated between subjects.

Materials

The materials were identical to those used in Experiment 1, with a few minor exceptions. First, neither the three song nor the metronome conditions were included in Experiment 2. The results of Experiment 1 showed that the metronome condition was not different from the silence condition, and therefore the metronome condition was not included Experiment 2. Also, because the strongest estimation biases appeared when participants reported remembering two or four songs, the three song condition was also omitted.

Session was also manipulated between subjects rather than within subjects as in Experiment 1. This change was made to avoid any carry-over effects that may have resulted from participants' experience with the initial baseline lexical decision task in Experiment 1. Particularly, the between-subjects design allows us not only to determine if timing biases will emerge when participants have no previous experience with the lexical decision task and background conditions, but also eliminates practice effects that may have diminished the slowing in lexical decision reaction time that was observed in the prospective timing session of Experiment 1. Therefore, in Experiment 2, all participants completed either a baseline session or a session which was performed under TB prospective memory instructions. In addition to recording lexical decision responses and reaction times, in the TB prospective memory conditions we also recorded the target ‘Z’ key responses. Additionally, for participants in the two TB prospective memory clock conditions, a “clock key” was created by covering the “T” key with a picture of a clock. Pressing this designated “clock key” displayed the elapsed duration of the lexical decision task at the bottom of the computer screen for 1 second. Finally, an additional 8-item practice session was created for use in the two clock conditions.

Procedure

As in Experiment 1, upon arrival, all participants were informed that they would be performing a task designed to test their visual processing abilities. They were then given instructions regarding the lexical decision task, and performed an eight item lexical decision practice session. Following the practice session, all participants performed an 11.02 minute lexical decision task while zero, two, or four songs played in the background. Prior to the experiment, all participants in the baseline condition were informed that they should perform the lexical decision task as quickly and accurately as possible. Participants in the TB prospective memory conditions were asked to remove watches and/or cell phones out of sight, and were informed that in addition to performing the lexical decision task as quickly and accurately as possible, they should also remember to press the ‘Z’ key on the keyboard after exactly 10 minutes had elapsed. Participants in the *no-clock* condition were simply told that they should press the 'Z' key when they estimated that 10 minutes had elapsed. Participants in the *high* and *low consequence clock* conditions were informed that to aid them in pressing the 'Z' key as close to the 10 minute mark as possible, that they could choose to view the exact amount of elapsed time by pressing the "clock" key at any point during the task. All participants in the two clock conditions then performed an additional eight item lexical decision practice session during which they were asked to press the 'Z' key after 15 seconds had elapsed. They were encouraged to practice using the clock key to help them perform this task on time. Following this practice session, participants were informed that the same clock would be available during the rest of the experiment. While participants in the low-consequence clock condition were told that frequent clock-checking may interfere with performance on the word decision task, they were not given specific ramifications for checking the clock. Participants in the high-consequence clock condition, on the other hand, were told that each clock check would result in an additional two minutes of the lexical decision task being added onto the end of the task. This clock-checking consequence was not actually enforced.

Following completion of the lexical decision task, participants in the two clock conditions were given a strategy sheet which asked them to describe, in a much detail as possible, how they decided when to check the clock and when to make their 'Z' response. Participants in the no-clock condition were simply asked to describe how they decided when to make their 'Z' response. Finally, all participants who heard songs play in the background were asked to fill out the same song questionnaire used in Experiment 1.

CHAPTER V

EXPERIMENT 2 RESULTS AND DISCUSSION

Results

Unlike in Experiment 1, we used the number of songs played rather than the number remembered to conduct the analyses in Experiment 2. In the current experiment, all participants needed to estimate when 10 minutes had elapsed during the experiment, rather than making a verbal estimate of the *entire duration* of the lexical decision task as in Experiment 1. Therefore, in the current experiment, song information was likely only important to participants until a response was made during the task, making retrospective memory for total number of songs irrelevant for this experiment.

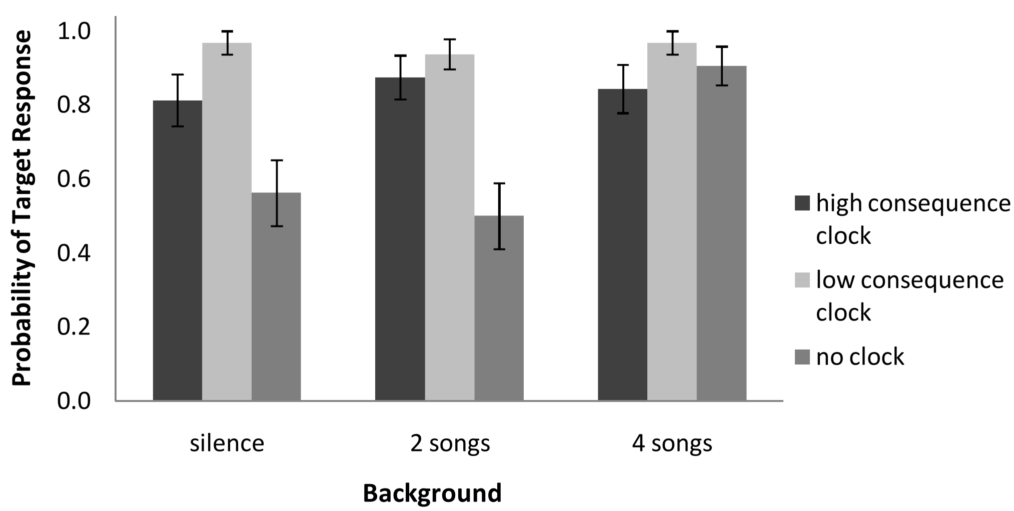
Probability of Making a Target Response

If participants estimate that more time has elapsed the more songs they hear, then participants in the *2-song* condition should wait significantly longer to make their target response than those in the *4-song* condition. In fact, it is possible that participants who hear only two songs may underestimate the passage of time to such a degree that they will be less likely to ever make a target response during the lexical decision task than participants who hear four songs. For instance, if participants estimate that songs last about four minutes, they may plan to wait until the third song begins to make their 10 minute target response. While such a strategy would lead to production of a target response in the 4-song condition, in the 2-song condition, participants waiting for a third song would never make a target response during the task.

To determine if background influenced the probability of target response production, we first assigned each participant a zero if they never made a target response during the lexical decision task, or a one if a target response was made. A pure factorial ANOVA was then conducted on the probability of responding using *TB prospective memory condition* (low-consequence clock vs. high-consequence clock vs. no-clock) and *background* (silence vs. 2-songs vs. 4-songs). The results are summarized in Figure 4. This analysis produced a significant main effect of TB prospective memory condition $F(2, 279) = 17.80$, $MSe = 0.125$, $p < .001$, $\eta^2 = .113$, such that the probability of target response production was significantly lower in the no-clock condition ($M = .66$, $SD = .48$) compared to the low-consequence condition ($M = .96$, $SD = .20$), $t(190) = 5.71$, $p < .001$, or the high-consequence condition ($M = .84$, $SD = .37$), $t(190) = 3.06$, $p < .01$. The low-consequence and high-consequence groups also differed significantly, $t(190) = 2.70$, $p < .01$. A significant main effect of background also emerged ($F(2, 279) = 4.35$, $p < .05$, $\eta^2 = .030$) indicating a significantly greater probability of a target response in the 4-song condition ($M = .91$, $SD = .29$) than in the silence condition ($M = .78$, $SD = .42$), $t(190) = 2.41$, $p < .05$, or in the 2-song condition ($M = .77$, $SD = .42$), $t(190) = 2.58$, $p < .05$. No differences emerged between the 2-song and silence conditions $t < 1$. Finally, a significant interaction qualified these two main effects, $F(4,279) = 4.10$, $p < .01$, $\eta^2 = .055$.

To further investigate this interaction, a separate ANOVA was conducted in each of the three TB prospective memory conditions using *background* (silence vs. 2-songs vs. 4-songs) as the factor. These analyses revealed that background produced no effect in either the high- or low-consequence clock conditions (both *F*'s <1), but that background had a large effect in the no-clock condition, $F(2, 93) = 7.66$, $MSe = 0.200$, $p < .001$, $\eta^2 = .141$ (see Figure 4). There was a significantly higher probability of a target response in the 4-song condition ($M = .91$, $SD = .30$) compared to the 2-song ($M = .50$, $SD = .51$), $t(62) = 3.91$, $p < .001$, and silence conditions ($M = .56$, $SD = .51$), $t(62) = 3.33$, $p < .01$. The silence and the 2-song conditions did not differ from each other, $t < 1$.

Figure 4. Probability of target response production by TB Prospective Memory Condition and Background in Experiment 2. Error bars represent SE.



To summarize, when a clock was available for use, there was no difference in the probability of making a target response across background conditions. However, when no clock was available, participants were far more likely to make a target response in the 4-

song condition than in the silence or 2-song conditions. In fact, in the no-clock condition approximately 50% of the participants in both the silence and 2-song conditions never made a target response because they judged that 10 minutes had not yet elapsed when the task ended, despite the task being 11.02 minutes in duration. In contrast, only 9% of people who heard four songs in the no-clock condition failed to make a target response during the task, indicating that a large majority of participants in this condition judged that at least 10 minutes had elapsed during the task. These results suggest that participants in the 4-song condition estimated that more time had elapsed during the lexical decision task than did participants in the 2-song condition. However, because the current analysis only considers whether or not participants responded at *any* point during the lexical decision task, it does not allow us to conclude that participants in any one condition waited significantly longer to respond than did participants in any other condition. To draw such conclusions, in the next section we analyze target response times.

Target Response Time

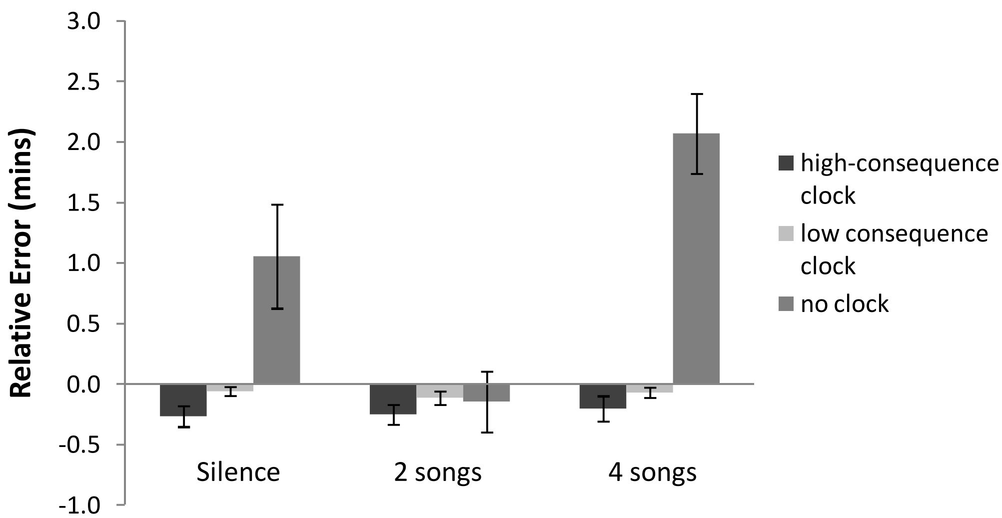
Some participants in each TB prospective memory condition failed to make a target response during the lexical decision task, and as mentioned in the previous section, this number approximated 50% for participants who heard zero or two songs in the no-clock condition. In other words, we had missing response time values for all those participants who greatly underestimated the duration of the task and never made any target response during the experiment. Therefore, instead of analyzing only the available target response times, we opted to replace the missing values. We concluded that the participants who never made a target response underestimated the duration of the task by at least 1.02 minutes because the target response time was supposed to be made at 10 minutes, and the entire session lasted for 11.02 minutes. Therefore, missing values were replaced by assigning each participant who failed to make a target response a response time of 11.03 minutes (which is 1 second later than the end of the experimental session). However, the actual response times may have been much later than the replacement value of 11.03 had the task continued until a response was recorded. Therefore, the estimated target response times produced by this analysis will provide a very conservative approximation of underestimation and likely will not capture the true degree of underestimation that was present.

Relative target response error scores were computed by subtracting each participant's target response time from 10. Negative relative estimate scores represent responses made too late (after the 10 minute mark) while positive scores represent responses made too early (prior to the 10 minute mark), and a score of zero represents perfect target response accuracy. An ANOVA conducted on relative error scores using *TB prospective memory condition* (high-consequence clock vs. low-consequence clock vs. no-clock) and *background* (silence vs. 2-songs vs. 4-songs) revealed a significant main effect of TB prospective memory condition, $F(2, 279) = 31.24$, $MSe = 1.387$, $p < .001$, $\acute{\eta}^2 = .183$. Follow-up tests indicated that target response times observed in the no-clock condition ($M = 0.10$, $SD = 2.14$) were made significantly earlier than those made in both the low-consequence clock condition ($M = -0.08$, $SD = 0.26$), $t(190) = 4.90$, $p < .001$, and the high-consequence clock condition ($M = -0.24$, $SD = 0.51$), $t(190) = 5.50$, p

$< .001$; responses in the high-consequence condition were also significantly later than those in the low-consequence condition $t(190) = 2.68$, $p < .01$. A significant main effect of background was also observed, $F(2, 279) = 10.27$, $p < .001$, $\acute{\eta}^2 = .068$. This effect was driven by significantly later response times in the 2-song condition ($M = - 0.17$, SD = 0.88) than in the silence condition ($M = 0.25$, $SD = 1.54$), $t(190)=2.29$, $p<.05$, or 4-song condition ($M = 0.60$, $SD = 1.54$), $t(190) = 4.25$, $p < .001$; no difference emerged between the silence and 4-song conditions, $t(190) = 1.59$, $p = .11$. Finally, a significant TB prospective memory task by background interaction was also observed, $F(4,279) = 9.05$, $p < .001$, $\acute{\eta}^2 =.115$.

To further investigate the TB prospective memory task by background interaction, three separate ANOVAs were conducted on the relative target response error scores in each of the TB prospective memory conditions using *background* (silence vs. 2-songs vs. 4-songs). There was no indication of a background effect in either of the clock conditions (both F's<1), but a large effect of background emerged in the no-clock condition, $F(2,93) = 10.26$, $MSe = 3.824$, $p < .001$, $\acute{\eta}^2 = .181$ (see Figure 5). Participants in no-clock condition waited significantly longer to make their target response if they heard two songs play in the background ($M = -0.14$, $SD = 1.43$) than if they heard four songs ($M = 2.07$, $SD = 1.87$), $t(62) = 5.32$, $p < .001$, or if they performed the task in silence ($M = 1.06$, $SD = 2.44$), $t(62) = 2.41$, $p < .05$; responses in the 4-song condition were marginally earlier than those in the silence condition $t(62) = 1.86$, $p = .07$. Together these results suggest that while background does not seem to affect final target response times when participants can rely on an external clock during the task, when no clock is available, response times mirror the estimation biases observed in Experiment 1. Specifically, participants estimate that more time is passing when they hear four songs play in the background than when they hear two songs, which leads to significantly earlier response times in the 4-song than in the 2-song condition. [1]

Figure 5. Relative target response error by TB Prospective Memory Condition and Background in Experiment 2. Error bars represent SE.



Replacement of missing values is helpful in allowing us to determine simply if participants who heard two songs waited longer to make their target response relative to those who heard four songs. However, because the true extent of underestimation is unknown, calculation of over- and underestimation biases, or absolute accuracy based on the estimated target response times is not appropriate.

[1]The pattern of response time results remains the same if only participants who made a response are included. In other words, even if only actual response times are included in the analysis, only in the no-clock condition do participants wait significantly longer to respond in the 2-song condition than in the silence or 4-song conditions. Therefore, the pattern of target response times reported above is not driven by the replacement of missing data points.

The results of the target response analyses clearly demonstrate that background influences both if and when target responses occur when participants do not have access to a clock. However, it is also clear from these analyses that neither the probability of making a target response, nor the target response times themselves is influenced by background when a clock is accessible. Despite the lack of background effects in the clock conditions, it is still possible that participants in these conditions utilize background information to help them estimate the passage of time prior to making a target response. Particularly, it is quite possible that participants use their knowledge of song duration to help them estimate the passage of time *between* clock-checks. If this is the case, rather than random clock-checking across the experiment, we would expect to observe systematic increases in the likelihood of clock-checking at song boundaries.

Decisions to Check the Clock across Temporal Intervals

Next, we examined the probability of clock-checking across different temporal intervals of the experiment to determine if the presence of background songs systematically influenced when participants checked the clock. We are primarily interested in whether the probability of clock-checking increased at song boundaries in the song conditions compared to the same time points in the silence condition. Systematic increases in the likelihood of checking at song boundaries would imply that participants are utilizing both prior knowledge of song duration and external clock information to track time. We chose to analyze probability of clock-checking rather than number of clock checks because clock-checking was much more frequent in the low-consequence (M = 13.70, SD = 12.00) than in the high-consequence condition (M = 3.91, SD = 5.03),

$t(190) = 7.37$, $p < .001$. Therefore, rather than examining how often participants checked the clock at different time points throughout the experiment, we elected to examine whether or not they checked the clock.[2]

To determine if song boundaries coincide with significant increases in the probability of clock-checking, we compared the probability of clock-checking at critical song boundaries with the probability of clock-checking during the remaining intervals. To do this, we first divided the experiment into five temporal intervals. Minutes 1-4 are designated as *Block 1*, minute 5 represents *Critical Boundary 1*, minutes 6-7 are designated as *Block 2*, minute 8 represents *Critical Boundary 2*, and finally minutes 9-11 are designated as *Block 3*. Each participant was then assigned a score of zero or one for each of these temporal intervals. A score of one was assigned whenever at least one clock check was made, and a score of zero was assigned if no clock check was made. Therefore, probability of clock checking was defined as the number of participants who made a least one clock check during any interval.

A mixed factorial ANOVA was then conducted on the probability of clock-checking using *temporal interval* (Block 1 vs. Critical Boundary 1 vs. Block 2 vs. Critical Boundary 2 vs. Block 3) as the within-subjects factor, and *background* (silence vs. 2-songs vs. 4-songs), and *consequence condition* (high vs. low) as the between-subjects factors. While this analysis did not reveal a significant main effect of background, $F<1$, there was a significant main effect of consequence condition, [$F(1,186)=128.22$,

[2] While we report only clock-checking analyses based on probability of clock-checking, it should be noted that analyses using number of clock checks produces a very similar pattern of findings. The only notable difference is that the number of clock checks increases significantly in both the 2- and 4-song conditions from Block 2 to Critical Boundary 2.

MSe=.279, *p*<.001, η^2 =.408], indicating a significantly higher probability of clock-checking in the low-consequence condition than in the high-consequence condition. A significant main effect of temporal interval was also observed, $F(4,744) = 28.02$, *MSe*=.092, *p*<.001, η^2 =.131. However, this main effect was qualified by significant interactions with both consequence condition, $F(4,744) = 6.78$, *p*<.001, η^2=.035 and more importantly with background, $F(8,744)=2.15$, $p < .05$, η^2=.023. Finally, the 3-way interaction was not significant, *F*<1.

Our primary interest lies in the temporal interval by background interaction (see Figure 6, bottom panel). Follow-up tests confirmed that this interaction was driven by changes in clock-checking that differed according to the experience of song boundaries. For instance, participants in both the 2-song and 4-song conditions experienced a song boundary during Critical Boundary 1, whereas participants in the silence condition obviously did not. Accordingly, the probability of making a clock-check increased significantly from Block 1 to Critical Boundary 1 in both the 2-song condition, $t(63)=3.85$, *p*<.001, and 4-song condition, $t(63)=3.13$, *p*<.01, but did not in the silence condition, $t(63)=1.17$, *p*=.25. Additionally, only participants in the 4-song condition experienced a song boundary during Critical Boundary 2, and indeed, a significant increase in clock-checking probability from Block 2 to Critical Boundary 2 appeared in the 4-song condition only, $t(63)=3.15$, *p*<.01, (in 2-song, $t(63)=1.52$, *p*=.13; in silence, $t<1$). Likely as a result of the close temporal proximity of Critical Boundary 2 with the target time, the probability of clock-checking remained equally high from Critical

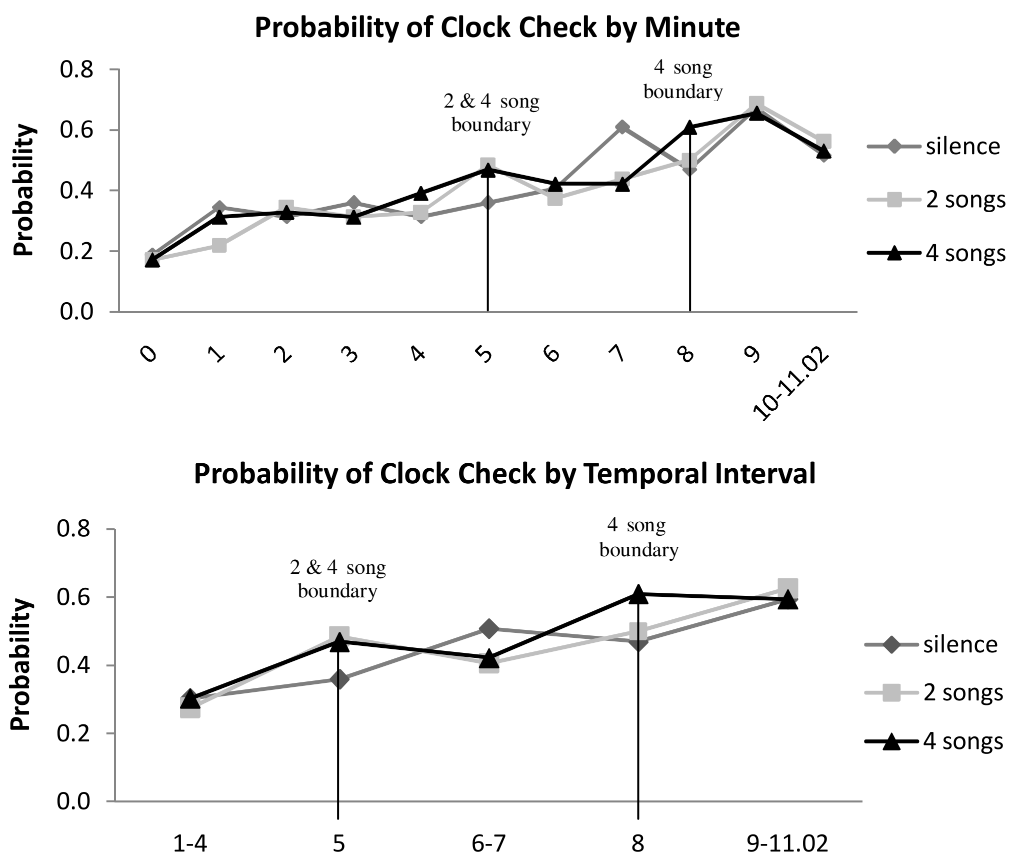
Boundary 2 to Block 3 in the 4-song condition ($t<1$), and increased significantly in both the 2-song [$t(127)=2.13$, $p<.05$] ,and silence conditions, $t(127)=2.30$, $p<.05$.

Finally, Block 2 was not associated with a song boundary in any condition, and the probability of checking actually decreased numerically but not significantly from Critical Boundary 2 to Block 2 in both the 2-song [$t(63)=1.22$, $p=.23$], and 4-song conditions, $t<1$. Conversely, the probability of checking increased during this time period in the silence group $t(63)=2.58$, $p<.05$.

The consequence condition by block interaction was driven by a significant increase in the probability of checking from Block 2 to Critical Boundary 2 in the low consequence clock condition [$t(95)=4.47$, $p<.001$] that was not present in the high consequence condition, $t<1$. Increases in checking are commonly observed as the target response time approaches (e.g., Ceci & Bronfenbrenner, 1985; Mantyla, Carelli, & Forman, 2007). Therefore, because Critical Boundary 2 is in relatively close temporal proximity to the target time, the increase in the probability of clock-checking from Block 2 to Critical Boundary 2 in the low consequence condition is not surprising. The probability of checking likely did not increase to the same extent in the high-consequence condition simply because of the greater resistance to clock-checking in this group.

In summary, the probability of clock-checking increased systematically with the occurrence of song boundaries in both song conditions. However, such increases were not evident at matched time-points in the silence condition. Together, these findings suggest that even when a clock is available, people use duration knowledge associated with salient environmental information to help them estimate the passage of time during an ongoing activity. This memory-based estimation, in turn, helps participants decide when to perform clock checks.

Figure 6. Probability of a clock check during each Minute (top panel) and Temporal Interval (bottom panel) by Background Condition in Experiment 2.



Ongoing Task Performance

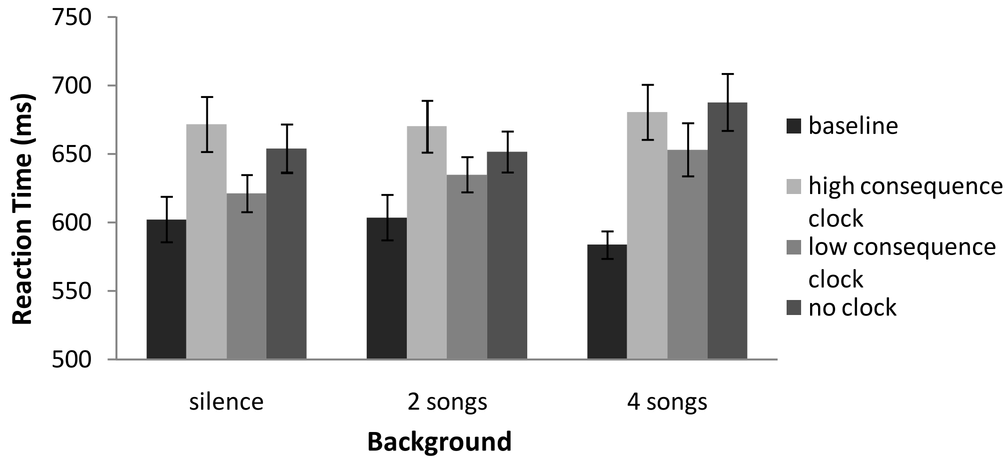
Both the target response time and clock-checking data strongly suggest that participants used background songs to estimate time in the current TB prospective memory task. These findings contradict the recent model of TB prospective memory that builds upon the attentional-model of prospective timing (Block & Zakay, 2006). This model claims that participants make their TB prospective memory target response only once an adequate amount of temporal information has been collected by an internal clock mechanism. As in the traditional model of prospective timing (Zakay & Block, 1996), the internal-clock mechanism of this TB prospective memory model is said to be attentionally-dependent. In other words, more information is collected by this internal clock as attention to time increases. At the same time, increased attention to time detracts from the resources available for ongoing task performance, and it suffers (e.g., Brown, 1997; Brown & Merchant, 2007; Kladopoulos et al., 2004; Labelle et al., 2009; Macar et al., 1994; Macar et al., 2006; Zakay, 1998;). A purely attentional explanation of the current findings, therefore, would require the assumption that participants paid more attention to time in conditions where earlier target response times were observed. This increased attention would lead to the faster accumulation of time information by the internal clock, and thus earlier target response times. This explanation would be corroborated by decreased ongoing task performance in conditions associated with earlier response times. However, if task performance is not associated with target response times, it would further suggest that an attentionally-driven internal clock mechanism alone cannot account for the current findings. In the following section we will analyze both lexical decision accuracy and reaction time to determine if task performance differed across conditions.

Lexical decision accuracy. An ANOVA conducted on proportion of correct lexical decision responses using *session* (baseline vs. no-clock vs. high-consequence clock vs. low-consequence clock) and *background* (silence vs. 2-songs vs. 4-songs) as factors revealed a significant main effect of session, $F(3, 372) = 6.72$, $MSe = 0.001$, $p <$ $.001$, $\eta^2 = .051$. Follow-up comparisons confirmed that participants in the baseline condition ($M = .96$, $SD = .03$) were significantly more accurate than those in the high-consequence clock condition ($M = .93$, $SD = .04$), $t(190) = 4.52$, $p < .001$, those in the low-consequence clock condition($M = .94$, $SD = .04$), $t(190) = 3.69$, $p < .001$, and those in the no-clock condition ($M = .94$, $SD = .04$), $t(190) = 3.40$, $p < .01$. No significant differences between the three TB prospective memory conditions emerged (all *t's* < 1). Neither the main effect of background ($F < 1$), nor the background by session interaction were significant, $F(6, 372) = 1.26$, $p = .28$. In sum, participants' lexical decision accuracy decreased with the addition of the TB prospective memory task compared to a baseline condition. However, equivalent decreases were observed regardless of background condition, and regardless of whether or not participants had access to an external clock. Next, we consider lexical decision reaction time, which may better capture differences across conditions because it is a more sensitive measure of task interference (e.g., Einstein et al., 2005; Hicks et al., 2005; Marsh et al., 2003; Smith et al., 2007; Smith, 2003).

Lexical decision reaction time. As recommended by a number of researchers (e.g., Hicks et al., 2005; Marsh et al., 2003; Smith et al., 2007; Smith, 2010) , we included only accurate word responses in this analysis (2.29% of total word responses removed for inaccuracy). Additionally, all reaction times at least 2.5 standard deviations from a participant's grand mean response time were eliminated (additional 3.02%) (e.g., Einstein, et al., 2005, Ratcliff, 1976). An ANOVA conducted on reaction times using *session* (baseline vs. no-clock vs. low-consequence vs. high-consequence) and *background* (silence vs. 2-songs vs. 4-songs) revealed a significant main effect of session, $F(3, 383) = 12.38$, $MSe = 9363.389$, $p < .001$, $\eta^2 = .091$ (see Figure 7 below) . Follow-up tests confirmed that reaction times in the baseline condition ($M = 596.64$, $SD = 83.03$) were significantly faster than those in the low-consequence condition ($M = 636.43$, $SD = 87.98$), $t(190) = 3.22$, $p < .01$, in the high-consequence condition ($M = 674.12$, $SD = 110.51$), $t(190) = 5.49$, $p < .001$, and in the no-clock condition ($M = 664.50$, $SD = 101.85$), $t(190) = 5.06$, $p < .001$. Furthermore, the low-consequence condition was significantly faster than both the high-consequence condition, $t(190) = 2.61$, $p < .05$, and the no-clock condition , $t(190) = 2.04$, $p < .05$. Reaction times did not differ significantly between the high-consequence and no-clock conditions, $t < 1$. Neither the main effect of background nor the session by background interaction was significant (both F's < 1). [3]

[3] These results are nearly identical if trials on which a clock check is made are removed. Furthermore, limiting reaction time analyses to trials completed prior to the target response also does not alter the pattern of results. This indicates that even if analyses are limited to trials during which time estimation is important (i.e. before a target response is produced), there is no indication that target response times are associated with lexical decision performance.

Figure 7. Lexical decision reaction time by Session and Background in Experiment 2. Error bars represent SE



These results reveal not only that that there were reaction time costs to the ongoing task with the addition of a concurrent prospective memory timing task, but also that the requirements of this timing task led to differential costs. Specifically, more self-reliant timing tasks (i.e. no-clock and high-consequence clock conditions) led to greater reaction time costs than the same task performed with a readily available clock (i.e. the low-consequence clock condition). We observed neither a main effect of background, nor any higher order interactions involving background. The lack of background effects suggests than an attentional-clock mechanism alone cannot account for the target response times observed in the current experiment. Further discussion of the reaction time results is deferred until the General Discussion section.

Verbal Reports of Estimation Strategy

Next we examined verbal strategy reports to determine if they provide converging evidence of the song-use indicated to this point by both the target response and clock-checking results. If participants consciously used songs to estimate the passage of time, we should see that a majority of participants who heard songs reported using those songs to estimate time. However, it may also be the case that participants who had access to a clock relied less on song information to track time than did those who had no clock. Therefore, we will also compare strategy reports between the low-consequence clock, high-consequence clock, and no-clock conditions. Finally, we will investigate whether non-song strategies are reported more often when the task must be performed in silence compared to when background songs are available.

First, in the song groups, a chi-square was used to determine if the proportion of participants who reported using songs to track time (81%) differed significantly from the proportion of participants who did not report using songs, and instead reported strategies such as: *attempting to count stimuli or seconds* (3%), *using a "feeling" of elapsed time to decide when to check and/or make target response* (11%) *initially checking the clock based on a feeling, and then counting as the 10-minute mark neared* (2%), and *just checking the clock randomly* (3%). The results of this analysis confirmed that of participants who heard songs play in the background, a significantly higher proportion reported using the songs to track time than all other strategies combined, $\chi^2(1, N = 192) = 75.00$, $p < .001$.

Next, additional chi-squares were conducted to determine if the proportion of participants who reported using songs differed between the three TB prospective memory conditions. Indeed, the proportion of participants reporting song-use in the no-clock condition (95%) was significantly greater than in the high-consequence clock condition

(84%), $\chi^2(1, N = 128) = 4.20$, $p < .05$, which in turn was significantly greater than in the low-consequence condition (64%), $\chi^2(1, N = 128) = 6.90$, $p < .01$. However, it is important to note that even in the two clock conditions, the proportion of participants who reported using songs to help them estimate time (74%) was greater than the proportion of participants who reporting all other strategies combined (26%), $\chi^2(1, N = 96) = 30.02$, $p < .001$.

While strategy reports made in the silence condition were more variable than those made in the song conditions, they had some overlap with strategies reported in the song conditions (see Table 4). However, a chi-square confirmed that use of all the overlapping strategies combined was greater in the no-song condition than in the song condition, $\chi^2(1, N = 288) = 142.51$, $p < .001$.

Overall, the strategy reports support participant song-use to estimate the passage of time during the TB prospective memory task. It is clear that participants who had songs available very often reported using these songs to track time throughout the experiment. However, it is also apparent that reliance on song information decreased as clock information became more accessible in the high-consequence and low-consequence clock conditions respectively.

Table 4. Proportion of participants reporting each time estimation strategy in Experiment 2.

	Song Conditions				Silence Condition
Song Strategies	High Consequence N=64	Low Consequence N=64	No-clock N=64	Total N=192	Total N=96
Use song info only to check and/or make target response	59%	28%	88%	**58%**	-
Use songs & simultaneous counting	5%	6%	6%	**6%**	-
Use songs for initial checks, then counted when close to 10	8%	6%	-	**5%**	-
Use songs for initial checks, then checked more often when close to 10	12%	24%	-	**12%**	-
Sang song of known duration in head	-	-	-	**-**	1%
Total	**84%**	**64%**	**94%**	**81%**	**1%**
Non-song Strategies					
Use "feeling" of elapsed time to check clock and/or make target response	9%	23%	3%	**11%**	51%
Counted seconds or stimuli	5%	2%	3%	**3%**	16%
No real strategy, just checked clock randomly	2%	6%	-	**3%**	5%
Use "feeling" for initial checks, then count when close to 10	-	5%	-	**2%**	21%
Compared to feeling of a 10 minute everyday task	-	-	-		6%
Total	**16%**	**36%**	**6%**	**19%**	**99%**

Questionnaire Responses

Finally, because previous studies have reported that factors such as background song liking and familiarity can influence time perception (e.g., Bailey & Areni, 2006b; Cameron et al., 2001; Lopez & Malhorta, 1991; Yalch & Spangenberg, 2000), we examined whether either of these factors may have influenced target responses times in the current experiment. One participant did not report how many songs he was familiar with, and therefore is not included in the subsequent analyses.

Across all participants, the mean liking rating was 2.63 (SD = 1.28), and participants reported being familiar with about one half (*M* = .55, *SD* = .32) of the songs they remembered hearing. To determine if either of these self-report measures may have influenced target responses times, we conducted separate linear regressions on target response times in each of the three TB prospective memory conditions using song condition (2 songs vs. 4 songs), song liking, and song familiarity. Together, these three predictors explained a significant proportion of variance in target response times in the no-clock condition, $R^2 = .32$, $F(3, 60) = 9.27$, $p < .001$. However, as can be seen in Table 5, only background was a significant predictor of target response time in this condition ($\beta = -.56$, $t(62) = 5.24$ $p < .001$). These same three predictors did not explain a significant amount of variance in target response times in either the low-consequence clock ($R^2 = .05$, $F < 1$) or the high-consequence clock conditions ($R^2 = .01$, $F < 1$).

Table 5. Summary of multiple linear regression analyses predicting relative target response times in Experiment 2.

	High-Consequence Clock			**Low-Consequence Clock**			**No Clock**		
Variable	*B*	*SE B*	β	*B*	*SB*	β	*B*	*SB*	β
Song Condition	-.026	.067	-.051	-.012	.037	-.043	-1.112	.212	-.563**
Liking	.027	.062	.066	-.024	.032	-.106	-.017	.167	-.011
Familiarity	.017	.277	.010	-.197	.129	-.213	.322	.645	.056

Note: Song Condition dummy coded with 2-songs serving as the reference group

all factors entered simultaneously

**p<.001

Discussion

Experiment 2 was conducted to determine if memory-based time estimation strategies would influence behavior during a TB prospective memory task. When participants were required to press a target key at a pre-specified point during the experiment without the aid of a clock, their target responses revealed systematic time estimation biases. Namely, participants made target responses significantly earlier when they heard four songs compared to when they heard two songs, suggesting that estimates of elapsed time increased as more songs were played in the background. While background had a large effect on target responses when no clock was available, this factor did not produce any effects on target responses when participants had access to a clock. The lack of a background effect in the clock groups could indicate that rather than relying fully on the memory-based strategy that led to response biases in the no-clock condition, participants use available clock information to avoid such biases. Indeed, while 95 of the 128 participants in the two clock conditions reported using songs to help them estimate time, only six of these participants never made a clock-check. Therefore, it is clear that when participants use environmental duration information to estimate time, they also prefer to utilize an available external clock to supplement this information.

Participants' decisions of when to check the clock also point to song-use in the clock conditions. Particularly, the probability of clock-checking increased systematically at song boundaries in the song conditions, but did not increase at matched time-points in the silence condition. This pattern suggests that participants used song boundaries as cues to check the clock. Such a strategy likely helped to supplement the duration information provided by the background songs. For instance, a clock-check following a song would allow participants to determine if an estimate based on prior song knowledge was accurate.

Despite having obtained a variety of evidence to suggest that participants relied heavily on song information to track the passage of time during the TB prospective memory task, we nonetheless analyzed lexical decision task performance to determine if any differences in target response times could be explained by the attentional-view of prospective timing. According to the attentional-view, earlier target response times should have been associated with greater costs on the lexical decision task because earlier responses occur when more attention is drawn away from the ongoing task to instead monitor time. Contrary to this prediction, no association between the ongoing task performance and target response times were observed. For example, despite large differences in target response times across background conditions in the no-clock condition, both lexical decision accuracy and reaction times were equivalent across background conditions in the no-clock condition. Additionally, task performance was equivalent across the high-consequence and no-clock conditions despite significant differences in target response times between these two groups. Because no clear link between target response times and task performance was observed in the current experiment, it is unclear how an attentional-clock explanation alone could account for the current results.

While target response times were not associated with ongoing task performance, it is interesting to note that reaction time costs were greater in the high-consequence and no-clock conditions compared to the low-consequence condition. This finding suggests that time estimation became more costly as a clock became less accessible.

CHAPTER VI

GENERAL DISCUSSION

"Attentional models are needed to explain prospective judgments, and memory-models are needed to explain retrospective judgments (Block & Zakay, 1997, p. 184)." The time estimation literature is rife with statements that prospective timing is completely dependent on attention to temporal information and is unaffected by memory for interval information. In fact, the strength of this view seems to be increasing with the appearance of yet more categorical conclusions in recent years.

> The prospective findings support models emphasizing attentional resources……the retrospective findings support models emphasizing memory changes. Alternative theories do not fit with the meta-analytic findings and are rejected (Block, Hancock, & Zakay, 2010). (p. 330)

Such conclusions have not only had great influences in the field of time estimation, but have also recently been extended to the field of TB prospective memory tasks, which are said to represent many of the everyday tasks that require prospective timing (Block & Zakay, 2006). Block and Zakay's (2006) model builds upon previous prospective timing models, and therefore assumes that an attentionally-driven internal clock, rather than memory, underlies the time estimation component of TB prospective memory.

Despite the conclusion that memory for interval information is irrelevant in prospective timing situations, the current results indicate that memory does influence timing not only in a traditional prospective timing task that requires a verbal estimate following an interval (Experiment 1), but also in a TB prospective memory task that involves production of a target response at a pre-specified time during an interval (Experiment 2). In both experiments, participants performed a lexical decision task while a varying number of songs were played in the background. Participants' prospective time estimates increased as the number of background songs increased. In Experiment 1, this was evidenced by a direct relationship between memory for interval information and verbal time estimates -- namely, participants' estimates became longer the more songs they remembered from the interval. Similarly, in Experiment 2, participants who had no access to a clock made their target responses earlier as the number of songs increased, indicating that estimates of elapsed time increased as more songs were experienced. The experience of songs also influenced behavior of participants who had access to a clock in Experiment 2. Particularly, changes in clock-checking coincided with the occurrence of song boundaries, indicating that these participants used song information in addition to clock information to help them estimate the passage of time. Further evidence that participants used memory to estimate time came from the verbal reports of time estimation strategy collected in both experiments. Participants who heard songs overwhelmingly reported using these songs to make their verbal estimates in Experiment1, and to determine when to check the clock and when to perform the target response in Experiment 2. Finally, the attentional-view predicts that ongoing task performance should decrease as prospective estimates increase because increased estimates require greater allocation of attention to monitoring time. Contrary to this prediction, there was no evidence of a relationship between ongoing task performance and prospective time estimates in either experiment, further suggesting that processes beyond that of an attentionally-dependent internal clock influenced time estimates in the current study.

Why did these two experiments produce strong memory effects while a number of previous prospective timing studies have failed to do so? We believe that the answer to this question lies in the experimental conditions used in the current studies, which were unlike any previously employed in prospective timing. Previous prospective timing studies have commonly required participants to perform tasks such as rating lists of words (e.g., Block, 1992) studying geometric shapes (e.g., Predebon, 1995), performing tone identification (e.g., Zakay, 1998), performing card-sorting tasks (e.g., Hicks et al., 1976), performing random number generation (e.g., Brown, 2006), etc. While a number of different ongoing tasks have been used, they all have one thing in common –they likely do not provide duration relevant information because participants have little, if any, previous experience with such tasks. Admittedly, the ongoing lexical decision task used in the current study was no more familiar to participants than any of the above mentioned tasks. However, unlike previous prospective timing studies, in our experiment participants not only experienced a novel ongoing task, but were also provided with duration-relevant information that was peripheral to the lexical decision task. Specifically, the provision of background songs in the current experiments served to provide duration-relevant information that is typically absent from prospective timing tasks, but that is normally available as we perform prospective timing tasks in everyday life. Relative to the lexical decision task, participants came into the experiment with knowledge about how long songs typically last. Unsurprisingly then, it was this established duration knowledge that participants utilized to estimate time.

A representative strategy from one Experiment 1 participant makes plain how participants utilized the background songs to estimate time. This participant explained that, "Songs typically last 3-4 minutes, and I listened to four songs. I multiplied four [songs] by three [minutes] to get 12 minutes and I added 30 seconds for any songs that may have been over 3 minutes."

Like the song duration knowledge that was used to estimate time in these experiments, we have duration knowledge for an innumerable number of events. The results of the current study suggest that our memory for events that occur during an interval, along with the duration knowledge we have associated with such events, plays an important role in prospective timing.

While the results of Experiment 1 indicate that people use memory for duration relevant information to make prospective time estimates, the results of Experiment 2 suggest that reliance on such information is mediated by the availability of clock information. Therefore, the results of Experiment 2 have important implications for two distinct types of TB prospective memory tasks, namely (1) when no meaningful clock information is available, and (2) when clock information is available and meaningful. First, let us consider the TB prospective memory situation that has been overlooked in the literature - the situation in which a TB prospective memory task must be performed in the absence of any meaningful clock information. In the current experiment, this situation was represented by the no-clock condition, in which participants were required to make a 10 minute target response without the aid of an external clock. In this condition, we found that participants' target responses were significantly affected by the number of songs played in the background of the ongoing lexical decision task. Participants who heard four songs estimated that more time had elapsed and thus made their target responses significantly earlier than participants who heard only two songs. In fact, 50% of participants who heard two songs failed entirely to make a target response, indicating just how harmful underestimating the passage of time can be in terms of successful TB prospective memory performance. Together, these target response results suggest that biases observed in traditional prospective timing paradigms (Experiment 1), also greatly affect TB prospective memory performance when no clock information is available.

Despite the fact that virtually all previous TB prospective memory experiments have provided unlimited access to an accurate clock (but see Labelle et al., 2009), there are many TB prospective memory situations in real-life that are akin to the no-clock condition. These situations include all of those during which a clock is simply not available (you forgot your watch), the clock information obtained in not meaningful (you do not know what time you put the cookies in the oven, so a clock reading 2:53 is irrelevant), or a clock is available but is not monitored (you are so sure you can grade five more papers before walking to class that you do not bother to monitor the clock while grading). The present results suggest that in any of these situations, people may be able to use duration knowledge and memory to help them estimate the passage of time, and that the biases associated with such a strategy affect when or if a target response is successfully performed.

The results of Experiment 2 also provide new insight into the TB prospective memory situations where clock information is available and meaningful. First, while background had a large effect on target responses in the no clock condition, this factor did not produce any effects on target responses either in the high- or low-consequence clock conditions. This may be surprising given that like participants in the no-clock condition, a majority of participants in the two clock conditions also reported using the songs to help them estimate time. The lack of a background effect in the clock groups, therefore, suggests that participants who used the songs in the clock conditions were able to avoid estimation biases by supplementing their song-use with clock information. For example, if a person estimates that the first song played was 3 minutes and a clock-check reveals that 6 minutes have elapsed, one is likely to abandon a memory-based strategy and instead begin relying on the external and/or internal clocks to make an accurate TB prospective memory response. Indeed, the increased probability of clock-checking observed at song boundaries supports the notion that when an external clock and duration relevant events are available, people use these two sources of information in concert to estimate the passage of time.

In addition to differential background effects across the clock and no-clock conditions, greater reaction time costs in the no-clock and high-consequence clock conditions compared to the low-consequence clock condition further suggest that different timing mechanisms are involved when a clock is more versus less available. Similar reaction time results were observed by Labelle et al. (2009), who found that participants performed an ongoing category decision task more slowly when asked to make 30, 60, and 90 second target responses without the aid of a clock compared to those who performed the same task with a clock readily available. Labelle et al., like most time estimation researchers, embrace the attentional-view of prospective timing and therefore explained that faster reaction times occurred in the clock condition because the availability of an external clock allowed participants to avoid using an attention-demanding internal clock. Like all ongoing tasks used in previous prospective timing studies, the category decision task used in Labelle et al.'s study was most likely novel to participants and thus was not associated with any previous duration knowledge. Because participants could not utilize established duration knowledge to estimate time, they likely had no choice but to rely heavily on both the internal and external clock mechanisms. Therefore, it is quite possible that differences in reliance on an internal-clock did underlie the reaction time effects observed in Labelle et al.'s study.

One could attempt to use Labelle et al.'s (2009) reasoning to account for the similar reaction time pattern that emerged across the clock and no-clock condition of Experiment 2. Specifically, one could argue that smaller reaction time costs emerged in the no-clock and high-consequence clock conditions because these conditions required participants to rely much more heavily on an attention-dependent internal clock than in the low-consequence clock condition. However, consideration of the target response results in concert with the reaction time results make clear that an internal-clock mechanism alone cannot adequately account for the current findings. According to the attentional-view of prospective timing, the magnitude of prospective estimates is determined by the amount of attention that is allocated to monitoring time during an interval. Moreover, because fewer attentional resources are available for ongoing task performance as time is monitored to a greater extent, ongoing task performance should decrease as prospective estimates increase. A number of instances contrary to this prediction were observed across both experiments. For instance, despite large differences in verbal prospective estimates (Experiment1) and target response times (Experiment 2-no-clock condition) across background conditions, no differences in reaction time costs were observed. Furthermore, despite differences in target response times observed between the no-clock and high-consequence clock conditions of Experiment 2, there was no difference in reaction time costs between these two groups. In sum, if reaction time is an indicator of internal clock use, and the internal clock drives prospective estimates, we should have seen differences in reaction times across any groups that differed in target responses (Experiment 2) or verbal prospective estimates (Experiment 1), and this was not the case. Therefore, it is unclear how a purely attentional explanation could account for the current findings.

While inconsistencies between the reaction time and target response results suggest that an internal clock mechanism alone cannot account for the current findings, such inconsistencies certainly do not rule out involvement of an internal-clock mechanism all together. In fact, participants in the silent background conditions were not provided with a clear memory-based strategy, and therefore may very well have relied on an internal-clock mechanism to make their estimates. The question that remains unanswered then is, if participants in the silence conditions used an internal-clock and participants who heard songs relied on a memory-based strategy, why are equivalent reaction times observed between these background conditions? There are a number of potential answers to this question. First, it is possible that an attentionally-dependent internal clock was used to an equal extent across background conditions, leading to equivalent reaction time results, but that participants provided with song information choose to use memory rather than available internal clock information to make their time estimates. Alternatively, it may be that participants in the song conditions used only song information to help them estimate the passage of time, but that the use of this memory-based estimation strategy was just as costly as the internal clock use of participants in the no-song conditions.

While it is unclear what mechanism(s) led to the reaction time costs in the current study, it is likely that costs can be avoided all together by using memory-based estimation strategies that allow for the association of a single salient event with accurate and informative duration information. Such strategies may be likened to the creation of salient, focal event-based prospective memory targets that automatically cue the need for the performance of a task at a specific time. For example, at the beginning of one of your favorite sitcoms you may remember that you need to call a friend in 30 minutes. In this situation, you may likely use the duration knowledge stored in memory that "TV sitcoms are 30 minutes long," to establish the end of the TV show as an EB prospective memory cue to perform the TB prospective memory task. Such a strategy would likely allow you to avoid costly time monitoring all together.

Preliminary evidence of such a cost-free strategy is present in the results of Marsh et al. (2006), who found that participants told that a target response window would not occur until the third phase of the experiment only began to monitor the clock and show reaction time costs relative to a control group once the third phase began. Participants not provided with this information, however, both checked the clock and showed significant reaction time costs from the beginning of the experiment until the intention was completed in phase 3. It seems, therefore, that participants in Marsh et al.'s study were able to associate the need to begin monitoring time with a very specific and salient cue - the start of phase 3. In the current study however, participants may have been unable to establish such a specific cue because they did not know the exact duration of each song. Therefore, they may have needed to track additional information during the task, such as number of choruses, versus, or may have employed use of the internal clock in addition to the song information. Overall, it seems that more specific duration knowledge associated with a single salient event is required to establish a cost-free, memory-based time estimation strategy. Indeed, prior prospective memory research has shown that costs to an ongoing task are only completely eliminated when a single, salient, focal event-based cue is established (Einstein et al., 2005; Hicks et al., 2005; Marsh et al., 2003; Marsh et al., 2006; but see Smith et al., 2007).

In conclusion, the results of the current studies represent the first empirical demonstration that memory for interval information plays a vital role in prospective timing. A role for memory likely emerged for the first time in this study because it is also the first to examine prospective timing under conditions that allowed for and even encouraged participants to use memory-based time estimation. The background songs that played during the ongoing task provided the same type of duration-relevant information that is normally available as we perform everyday prospective timing tasks, and the similar influence of songs on prospective time estimates across two distinct timing situations (i.e. a traditional prospective timing task and a TB prospective memory task) suggests that when duration-relevant information is available, people use memory for such information to estimate time prospectively.

The current experiments were designed expressly to test memory factors in prospective timing, and while the present results clearly point to an important role of memory in prospective timing, they cannot address the extent to which an attentionally-driven internal clock mechanism may also have been involved. An abundance of prior research confirms that attentional mechanisms influence prospective time estimates, therefore, further experimentation using direct manipulations of both memory and attentional factors is required to determine the relative contributions of each of these mechanisms under differing circumstances.

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