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Abstract

There are two main models of time perception, attention-based models, and memory-based models. The aim of this study was to determine which model best explained retrospective time perception of a long and monotonous task. The monotonous task was a Sustained Attention to Response Task (SART) that lasted 1390s. The monotony of the task was altered by the addition of musical stimuli. Participants were randomly assigned to either a silent condition, or one of three music conditions that differed in song familiarity and performing instrument. Participants were 48 adults, primarily recruited from Edith Cowan University. The perceived duration of the task, the number of errors on the SART, and the number of songs remembered was measured. Difference in perceived duration between the conditions provided limited support for both attention-based and memory-based models. However, from the non-significant results of the number of errors on the SART, and the number of songs remembered, neither model was able to explain how participants perceived the duration of the task. The presence of a ceiling effect on perceived duration may have limited the size of some of the effects. Overall, the results suggest that the relevance of attentional processes and memory may not be as significant as what is proposed by the current models in explaining retrospective time perception of long tasks, and this should be explored in future research.

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"Time flies when you're having fun" is a popular expression, but what happens to people's perception of time when they are not having fun and become bored? One model of time perception predicts that our attention becomes focussed on 'keeping track of time' and therefore the elapsed time duration seems longer. However, another model predicts that when we are focussing on time, we remember and encode less information around us and therefore the elapsed time duration seems shorter. The present study used music to 'break up' the monotony of a task and to distract attention away from the passage of time, whilst also creating information to be stored in memory, to determine which model best explains retrospective time perception of a long and monotonous task.

Attention is considered the key psychological process in regulating time perception (Brown & Boltz, 2002). However, the significance of the role that attention plays in directing temporal and non-temporal processing is an issue in the current time perception literature (Grondin, 2010). Temporal processing refers to the explicit and implicit thought processes involved in monitoring the passage of time, whilst non-temporal processing refers to thoughts unrelated to the passage of time (Bailey & Areni, 2006b). Attention-based models propose that perceived time duration is regulated by the amount of attentional resources provided to temporal and non-temporal processing (Brown, 1985; Grondin, 2010). Memory-based models however, propose that perceived duration is determined by the memory and reconstruction of events that occur during the elapsed time period (Block & Reed, 1978; Grondin, 2010; Ornstein, 1969).

Attention-based Models

Attention-based models are constructed on the premise that there are limited attentional resources (Grondin, 2010). They propose that when two concurrent tasks are performed, attention is divided between the two tasks. Therefore, the performance on each task is decreased compared to when the tasks are performed separately. Attention-based models of time perception propose that when an individual performs dual-tasks, their attentional resources are split between temporal and non-temporal processing (Brown, 1985). When more attentional resources are provided to non-temporal processing, fewer attentional resources are provided to temporal processing. As fewer attentional resources are provided to temporal processing, less temporal information is encoded and the elapsed time duration is perceived as shorter. Alternatively, when attentional resources are directed towards temporal processing, more temporal information is encoded, and the duration is perceived as longer (Droit-Volet, Bigand, Ramos, & Bueno, 2010; Grondin, 2010; Ziv & Omer, 2011). A dominant attention-based model in the field of time perception is the pacemaker-counter model (Grondin, 2010; Treisman, 1963).

The pacemaker-counter model proposes that temporal judgements of elapsed time duration are based on a single internal clock, the pacemaker-counter device (Treisman, 1963). However, this early pacemaker model, as proposed by Treisman (1963), provided a limited explanation of the experience of time (Block, 1990). The pacemaker in Treisman's model was considered autonomous and unaffected by external influences on temporal processing (Block, 1990). Thus, the model did not consider the influence of external factors, such as counting strategies, on temporal processing (Block, 1990). In general, pacemaker models are able to explain simple relationships between arousal and time perception, but are limited in their explanation of more complex relationships (Block, 1990; Zakay & Block, 1995). The concept of a pacemaker-counter device has provided the basis for many other theoretical propositions of time perception (Grondin, 2010; Zakay & Block, 1995).

Zakay and Block (1995) extended Treisman's (1963) pacemaker-counter device model by including an attentional gate that controls additional cognitive factors. Similar to Treisman's model, the attentional-gate model includes a pacemaker device and a counter device (Block & Zakay, 2006; Zakay & Block, 1995). Perceived duration of a time period is determined by the number of pulses emitted by the pacemaker and received by the counter. Pulses are emitted at a constant rate and pass through the attentional-gate to the counter. When attention is directed towards temporal processing, the attentional-gate is open and pulses are transferred to the counter (Block & Zakay, 2006; Zakay & Block, 1995).

Errors in perceived time duration can be accounted for by gate errors (Block & Zakay, 2006; Zakay & Block, 1995). Gate errors occur when attention is diverted away from temporal processing. When attention is directed to non-temporal processing, the attentional-gate closes and fewer pulses are received by the counter. Therefore, less temporal information is encoded regarding the passage of time, and the elapsed duration is perceived as shorter (Block & Zakay, 2008; Grondin, 2010; Zakay & Block, 1995).

Attention-based models of time perception share the underlying concept of limited attentional resources, in that, when attention is directed towards non-temporal processing, less attention is given to temporal processing, and therefore the duration is perceived as shorter (Brown & Merchant, 2007; Field & Groeger, 2004; Grondin, 2010; Zakay, 1998). The finding that the presence of a concurrent task reduces the perceived duration of an elapsed time period is "the most well-replicated finding in all the time perception literature" (Brown, 2008, p. 119).

Memory-based Models

Cognitive researchers have developed models of time perception that do not include the presence of an internal clock (Block & Zakay, 2008; Grondin, 2010). Rather, it has been proposed that perceived time duration is regulated by memory, and the experience of contextual changes (Block & Reed, 1978; Ornstein, 1969; Poynter, 1983). Memory-based models propose that perceived time duration is a reconstruction of remembered events, or contextual changes that are experienced and remembered, during an elapsed time period.

Ornstein (1969) was one of the first critics of the attention-based internal clock models (Block, 1990) and proposed a memory-based ‘storage-size’ model. According to this model, more storage space in memory is occupied when a greater number of stimuli are stored, or when stimuli are stored in more complex ways. When more space in memory is occupied, the duration is perceived as longer (Brown & Boltz, 2002; Ornstein, 1969; Ziv & Omer, 2011). However, the storage size of memory is unable to be measured (Block, 1974), and support of this model has been inconsistent (Block & Reed, 1978; Block, 1974, 1990; Brown, 1985; Brown & Boltz, 2002; Zakay & Block, 2004). Subsequent studies have suggested that it is not the complexity of the individual stimuli, but rather the complexity of the sequence of stimuli, that results in a longer perceived duration (Block & Reed, 1978; Block, 1974, 1990). Thus, an alternative memory-based model, the contextual-change model, was developed (Block & Reed, 1978).

The contextual-change model proposes that a longer perceived duration is the result of a greater number of contextual changes experienced, rather than the number of stimuli, stimulus size, or stimulus complexity (Block & Reed, 1978). These contextual changes can include changes in the presented stimulus, as well as changes in the individual’s mood or arousal (Block, 1990; Block & Reed, 1978; Block & Zakay, 1997; Zakay & Block, 2004; Zakay, Tsal, Moses, & Shahar, 1994). According to the contextual-change model, during the time period, events are encoded into memory along with the contextual changes associated with each event (Block & Zakay, 2008). When the retrospective judgement is to be made, the availability of events associated with the relevant contextual change are assessed, and then retrieved. Perceived duration is thus based on the number of different contextual changes retrieved (Block & Zakay, 2008). When more contextual changes are available and retrieved, the duration of the event is perceived as longer (Zakay & Block, 2004). However, findings supporting the contextual-change model have also been inconsistent (Block & Zakay, 1997; Zakay & Block, 2004). Various studies have found that other variables also influence perceived duration (Poynter, 1983; Zakay & Block, 2004; Zakay et al., 1994).

Poynter (1983) proposed that the segmentation of information affects perceived duration, rather than the number or the complexity of the stimuli. The memory-based segmentation model suggests that the number of meaningful events or segments recalled during the elapsed time period influences its perceived duration (Poynter, 1983; Zakay et al., 1994). These events serve as markers in the individual's memory, therefore the more events and markers remembered, the longer the perceived duration (Poynter, 1983).

Memory-based models of time perception share the underlying assumption that perceived duration is influenced by the encoding and retrieval of memories (Block & Reed, 1978; Ornstein, 1969; Poynter, 1983). When a duration is to be determined, the elapsed time period is reconstructed based on the memories of events, contextual changes, and segments that occurred during the period. Thus, when more events, changes, or segments are remembered, the duration is perceived as longer (Block & Zakay, 2008).

In summary, attention-based models propose that perceived time duration is shortened when attention is focussed on non-temporal processing, as fewer resources are available for temporal processing. However, memory-based models propose that perceived duration will be lengthened when focussing on non-temporal processing, as a greater number of changes and events will be encoded and remembered. Thus, these two models make contradictory predictions. There are a number of methodological inconsistencies within the time perception literature that have contributed to the contradictions between attention-based and memory-based models (Grondin, 2010; Ziv & Omer, 2011).

Prospective and Retrospective Paradigms

Studies using a prospective method primarily provide evidence for attention-based models, whilst those using a retrospective design provide evidence supporting memory-based models (Block, Hancock, & Zakay, 2010; Block & Zakay, 1997; Brown, 1985; Carmeci, Misuraca, & Cardaci, 2009; Grondin, 2010; Zakay & Block, 2004; Ziv & Omer, 2011). In the prospective paradigm, participants are informed that they will be required to judge the duration of the subsequent time period. It is therefore assumed that, in the absence of a concurrent task, their attention is directed towards the passage of time and temporal cues. In the retrospective paradigm however, participants are informed after the elapsed time period that they will need to judge its duration. Thus, it is assumed that their judgement is based on their memory of temporal cues (Block et al., 2010; Block & Zakay, 1997; Grondin, 2010). Some theorists have attempted to integrate the conflicting results occurring from these two paradigms into a single model (Brown 1985; Brown & Stubbs, 1988, 1992; Cardaci, 2000; Zakay, 1989; Zakay & Block, 2004). For example, Brown (1985) and Zakay (1989) proposed that similar attentional processes are involved for both prospective and retrospective time estimations, whilst, more recently, Cardaci (2000) developed the Mental Clock Model that proposes that a single mechanism controls time perception.

Despite attempts to integrate the findings into a single model, there is general agreement in the time perception literature that different processes are involved in the prospective and retrospective paradigms. Further, it is agreed that attention-based and memory-based models are both needed to explain these differences (Block et al., 2010; Block & Zakay, 1994; Grondin 2010; Zakay & Block, 2004; Zakay et al., 1994).

In two meta-analytic reviews, Block and Zakay (1994), and Block, Hancock, and Zakay (2010) found that perceived time duration was dependent on the paradigm used and the cognitive load of the task. In the prospective paradigm, perceived time duration decreased as cognitive load increased. This supports attention-based models, as tasks with a higher cognitive load reduce the attentional resources available to temporal processing. In the retrospective paradigm, perceived time duration increased as cognitive load increased (Block et al., 2010; Block & Zakay, 1994). This supports both the segmentation and contextual change memory-based models, as tasks with a higher cognitive load are more likely to be segmented into high-priority events. This leads to an increased number of segments, and therefore contextual changes, creating more events to be recalled in memory, resulting in the duration being perceived as longer (Block et al., 2010; Block & Zakay, 1994).

The results of the two meta-analyses (Block et al., 2010; Block & Zakay, 1994) provide evidence to suggest that different processes are involved in time perception, depending on which paradigm is used (Block et al., 2010; Block & Zakay, 1994; Grondin, 2010; Zakay & Block, 2004; Zakay et al., 1994). Thus, the use of either attentional or memory processes in estimating time duration may be influenced by which paradigm is implemented. Further, methodological inconsistencies such as the actual time duration under investigation, can also influence which processes are used (Block & Zakay, 1997; Doob, 1971; Grondin, 2010; Zakay & Block, 2004).

Objective Time Duration

The investigation of time perception in the field of psychology has focussed on durations in the range of 0.1s to a few seconds (Grondin, 2010). Studies using a prospective method primarily investigate durations of a few seconds and provide evidence for attention-based models (Grondin, 2010), whilst those using a retrospective design focus on longer durations and provide evidence supporting memory-based events models (Bisson, Tobin, & Grondin, 2009; Grondin & Plourde, 2007). However, in the time perception literature more than 60s is considered a long duration (Block et al., 2010). Although attention-based models are used to explain results of studies using a prospective design and investigating short durations, it is proposed that attention-based models can also be relevant to explaining retrospective time perception of long durations (Block, 2003; Block & Zakay 1997; Doob, 1971; Zakay & Block, 2004).

In a retrospective paradigm, participants are unaware that they will be required to estimate the time duration and are therefore usually preoccupied with the presented task. However, if the task is easy or induces feelings of boredom due to a lack of non-temporal information over a long period of time, participants may begin to direct their attention to temporal processing. In this case, attention-based models may become relevant to explaining perceived time duration (Block, 2003; Block & Zakay 1997; Doob, 1971; Zakay & Block, 2004). Due to the lack of non-temporal information to be processed, more attentional resources are available for temporal processing and therefore perceived time duration will be longer (Block, 2003). However, in this situation, memory-based models predict that perceived time duration would be shorter due to a lack of events and contextual changes to be remembered (Block & Reed, 1978; Ornstein, 1969; Poynter, 1983). Thus, attention-based models and memory-based models make contradictory predictions about the retrospective time perception of long and monotonous tasks.

The Effects of Music on Time Perception

The aim of this study was to determine whether time perception of a long, monotonous task could be best explained by either attention-based or memory-based models. Music was used as a means to divert participants' attention away from temporal processing whilst also creating events and contextual changes to be recalled in participants' memory.

Music is a complex composition of sounds, varying in pitch, frequency, key, and tempo. Music can also vary on subjective measures of affect, popularity, and familiarity (Droit-Volet et al., 2010; Ziv & Omer, 2011). There have been a range of studies examining the effects of these musical factors on time perception (Ziv & Omer, 2011), as music is a stimulus in which multiple contextual changes occur (Bisson et al., 2009). However, the effects of music on time perception have been inconclusive.

Numerous studies have investigated the effect of musical valence on perceived time duration and have produced inconsistent results (Bisson et al., 2009; Droit-Volet et al., 2010; Kellaris & Kent, 1992). Kellaris and Kent (1992) investigated the influence of musical valence on retrospective time perception by playing the same song in either a major (positive valence) or atonal key (negative valence). Their results supported the memory-based models in that the song played in a major key was perceived as longer than when played in the atonal key. The authors proposed that participants devoted more attention to the major song because it was more pleasant, and that it was therefore easier for participants to store and retrieve information from the major song than the atonal song (Kellaris & Kent, 1992). Thus, as more attention was given to the major song, more contextual changes were remembered as occurring in the song, and it was perceived as longer. These results were supported more recently by Bisson, Tobin, and Grondin (2009) who used classical pieces of music to invoke either joy or sadness in participants. As joyful songs are more pleasant, they are more easily stored into and retrieved from memory, thus the duration is perceived as longer. In contrast, however, Droit-Volet, Bigand, Ramos, and Bueno (2010) found that perceived time duration was under-estimated for both happy (major key) and sad (minor key) music, when compared to a control music condition. Their findings support attention-based models, as music, regardless of its valence, distracts attention away from temporal processing, compared to non-melodic ‘noise’ (Droit-Volet et al., 2010).

The effect of musical complexity on perceived time duration has also been investigated (North and Hargreaves, 1999). North and Hargreaves (1999) found that overall, listening to music shortened participants' perceived time duration, however, there was no difference between the music conditions of different complexities. These results support attention-based models, in that music, regardless of its complexity diverts attention away from temporal processing.

Further, Bailey and Areni (2006a) found that music, regardless of its many inherent variables, affects perceived duration. However, in contrast to North and Hargreaves (1999) findings, Bailey and Areni (2006a) found that perceived duration could be lengthened by listening to music. When eight short songs were played, perceived duration was longer compared to when four long songs were played. These results provide evidence for Poynter's (1989) memory-based segmentation model, as each song marks an event to be stored in memory, thus, the more events remembered, the longer the perceived duration.

Due to the complexity of music as a stimulus, these results of the effects of music on time perception appear inconclusive. However, as with the research on time perception in general, the effects of music on time perception are also influenced by the paradigm used and the objective time duration under investigation (Grondin, 2010; Ziv & Omer, 2011). Kellaris and Kent (1992) used a between-groups design and measured retrospective time perception of an experimenter created song, either played in a major, minor, or atonal key, which lasted for approximately 150s. Bisson and colleagues (2009) used a repeated-measures design and used classical piano songs to invoke either joy or sadness, and a cognitive task to create a neutral emotional state. Each emotional state was presented for three durations, 180s, 300s, and 420s, and perceived time duration for each condition was measured retrospectively after all conditions had been completed, rather than after each individual condition. Droit-Volet and colleagues

(2010) measured prospective time perception, and presented happy, sad, or neutral music for 0.5s and 1.7s. North and Hargreaves (1999) used an independent, retrospective design and used commercially released modern pop songs as the musical stimuli. The musical conditions consisted of five songs lasting 240s each, for a total of 1200s. In Bailey and Areni's (2006a) study, perceived time duration was measured retrospectively, after participants heard either eight short songs, or four long songs, for a total of 1200s.

Thus, it is clear that the use of experimenter-created or professionally composed songs, short or long durations, number of songs, and prospective or retrospective methods create inconsistencies within the literature investigating the effects of music on time perception (Ziv & Omer, 2011).

Few studies have attempted to control for these complexities in musical stimuli in order to distinguish between attention-based and memory-based models (Bailey & Areni, 2006b; Ziv & Omer, 2011). Ziv and Omer (2011) investigated the effects of paradigm and musical structure on perceived time duration. Their results supported the finding that different cognitive processes are involved when different paradigms are used, that is, attentional processes are used in the prospective paradigm whilst memory processes are used in the retrospective paradigm. However, only one classical song was played in each condition, for a total of 135s.

Bailey and Areni (2006b) greatly increased the length of the conditions in two experiments. In their first experiment, participants were either asked to complete a brand recall task, or were told that the experimenter was running late and that they would have to wait. In each condition, either familiar contemporary dance music, or unfamiliar country and western music was played. For each music condition, either four songs of 180s or two songs of 360s were played, for a total duration of 720s. It was found that perceived duration was shorter when participants heard familiar music, compared to unfamiliar music. This provides evidence to support attention-based models as familiar music is more likely to divert participants' attention away from temporal processing. However, this was only for the participants who were waiting idly. For the participants engaged in the memory task, there was no difference in perceived duration between the familiar and unfamiliar music conditions. Changing the number of songs played, and their duration, had no significant effect on perceived duration. However, these non-significant results may have been due to a number of factors. It is possible that participants may have used the number of brand names they recalled to estimate time duration, rather than the number of songs they remembered hearing. Further, the memory-based heuristic of estimating time might only become available when a greater number of events/changes exist (Bailey & Areni, 2006b).

In Bailey and Areni's (2006b) second experiment, the type of music and the number of songs were altered in order to create a greater number of contextual changes. Familiar music consisted of the seven most recent 'top of the chart' songs in the country, and unfamiliar music consisted of uncharted songs from 1950 to 1959. For each music condition, either seven songs of approximately 180s or three songs of approximately 360s were played, for a total duration of 1050s. The non-temporal brand recall task was similar to the task in Experiment 1 but altered slightly in an attempt to strengthen the effect of the task. Experiment 2 provided evidence for both attention-based and memory-based models (Bailey & Areni, 2006b). Perceived duration was shorter for familiar music compared to unfamiliar music, when seven short songs were played, but only in the waiting condition. This supports attention-based models as familiar music more easily diverts attention away from temporal processing, resulting in a shorter perceived duration. In the brand recall task, perceived duration was longer for familiar music compared to unfamiliar music, when seven short songs were played, however, no effect was found when three longer songs were played. This evidence suggests that a greater number of events/changes are needed for the memory-based events heuristic to be implemented (Bailey & Areni, 2006b). However, as in Experiment 1, these results could be confounded with the brand recall task.

According to Poynter's segmentation model (1989), duration judgements are based on remembered events, and the inferred duration of each event. Therefore, in a time perception experiment, the non-temporal task needs to include stimuli that cannot be quantified nor suggest duration (Poynter, 1989). However, in Experiment 1, it was proposed that participants used the number of brands they recalled as an estimate for the elapsed duration (Bailey & Areni, 2006b). In Experiment 2, it is possible that this also occurred along with the number of songs remembered, resulting in a significantly longer perceived duration. A further confound of Bailey and Areni's (2006b) experiments was the selection of music used in the familiar and unfamiliar conditions. In Experiment 1, familiar music consisted of dance songs whilst unfamiliar music consisted of country and western songs, whilst in Experiment 2, familiar music consisted of the current top of the chart songs and unfamiliar music consisted of songs from the 1950s (Bailey & Areni, 2006b), thus creating a confound with the familiarity of the conditions.

In summary, studies that have attempted to investigate the effect of music and experimental paradigm on perceived duration (Bailey & Areni, 2006b; Ziv & Omer, 2011) are limited by methodological inconsistencies. Thus, the present study aimed to add to the body of time perception research by improving upon the inconsistencies within previous studies, and extending the actual duration investigated

The Present Study

Memory-based models are often used to explain retrospective time perception (Grondin & Plourde, 2007). However, if the task induces feelings of boredom, attention-based models may also provide an explanation (Block, 2003; Block & Zakay 1997; Doob, 1971; Zakay & Block, 2004). Thus, the aim of the present study was to determine which model could best explain retrospective time perception of a long, monotonous task.

In the present study, the monotonous task was a Sustained Attention to Response task (SART) that lasted 1390s. This duration was chosen as it has been found that individuals become bored between 10 (600s) and 15 minutes (900s) (Scerbo, 1998). The SART was chosen as it can be designed to be monotonous when the target stimulus has a low probability of occurring (Larue, Rakotonirainy, & Pettitt, 2010). The SART involves high Go, low No-Go target detection in which participants respond to common stimuli and withhold responses to rare target stimuli (e.g. press a button when a number appears, except if the number is 4) (Helton, Head, & Kemp, 2011; Larue et al., 2010). Thus, it measures an individual's ability to sustain attention over long periods as well as to respond to critical changes in stimuli (Scerbo, 1998).

Four experimental conditions were created, one silent condition, and three music conditions. In the silent condition, participants completed the SART without listening to music. In three music conditions, music was used to 'break up' the monotony of the SART. The task duration of 1390s allowed for a large number of songs to be used in order to create a large number of events and contextual changes in participants' memory, whilst also directing attention towards non-temporal processing.

The number of contextual changes in the music was altered between groups by varying the number of familiar songs played and the type of instrument used to perform each song. Condition 1 was designed to have the fewest number of events and contextual changes as all songs were familiar, and all songs were played on a piano. In Condition 2, all songs were familiar, but each song was played on a different instrument. Condition 3 was designed to have the greatest number of events and contextual changes as songs alternated between being familiar and unfamiliar, and each song was played on a different instrument. The tempo of musical stimuli can alter the subjective experience of time (Jones, 1990; Large, 2008), therefore all songs were played at a constant tempo. In order to ensure that participants paid attention to the music stimuli, the music was presented through headphones, rather than as atmospheric music as in previous studies (for example, Bailey & Areni, 2006a; 2006b).

Attention-based Hypotheses

According to attention-based models, listening to music will divert attention away from temporal processing. When attention is diverted away from temporal processing, the elapsed time duration is perceived as shorter (Bailey & Areni, 2006b; Droit-Volet et al., 2010).

Hypothesis 1A: The time duration of the music conditions will be perceived as shorter than that of the silent condition.

Hypothesis 2A: The changes in the music stimuli (i.e. changes in the familiarity of the songs and/or the instruments used) will divert participants' attention away from temporal processing. Therefore, the greater the number of changes in the music conditions, the shorter the perceived duration of the elapsed time period. Thus, the elapsed time period will be perceived as shorter in Condition 3 compared to Condition 2, and shorter in Condition 2 compared to Condition 1.

Hypothesis 3A: The changes in the music stimuli will also distract participants' attention away from the SART. Therefore, the greater number of changes in the music, the greater the number of errors on the SART. Thus, the number of errors in the SART will be the smallest in the silent condition, followed by Condition 1, Condition 2, and Condition 3, respectively.

Hypothesis 4A: Attention-based models make no prediction as to the correlation between the number of songs remembered and perceived duration.

Memory-based Hypotheses

Music is a stimulus in which multiple events and contextual changes occur (Bisson et al., 2009). According to memory-based models, when more events and contextual changes are remembered, the duration of a time period is perceived as longer, compared to when less are remembered (Zakay & Block, 2004).

Hypothesis 1B: The time duration of the music conditions will be perceived as longer than that of the silent condition.

Hypothesis 2B: The changes in the music stimuli (i.e. changes in the familiarity of the songs and/or the instruments used) will create contextual changes in participants' memory. Therefore, the greater the number of changes in the music condition, the longer the perceived time duration. Thus, the elapsed time period will be perceived as longer in Condition 3 compared to Condition 2, and longer in Condition 2 compared to Condition 1.

Hypothesis 3B: Memory-based models make no prediction as to the relationship between the number of errors made on the SART and the changes in the music conditions.

Hypothesis 4B: When more events and contextual changes are remembered, the duration of a time period is perceived as longer. Therefore, the number of songs remembered will be positively correlated to perceived time duration.

Method

Design

Once participants are made aware that the study is investigating time perception, they are unable to repeat the experiment (Grondin & Plourde, 2007), therefore, an independent measures design was used. The number of contextual changes in the music was altered between groups by varying the number of familiar songs played and the type of instrument used to perform each song. Participants were randomly allocated to one of four conditions. In the silent condition, participants only completed the SART. In Condition 1, all songs were familiar, and all songs were played on a piano. In Condition 2, all songs were familiar, and each song was played on a different instrument. In Condition 3, songs alternated between being familiar and unfamiliar, and each song was played on a different instrument.

A post-task questionnaire asked participants to record their perceived duration of the task. Subjective time estimation is prone to a response bias whereby participants commonly round their answers to the nearest five minutes (Zakay, 1990). To reduce this bias, the questionnaire asked participants to record the estimated task duration in minutes and seconds.

The post-task questionnaire also asked participants to record the percentage of songs they thought were familiar, the titles of songs they remembered hearing, as well as their age and sex (Appendix A). In the silent conditions, the post-task questionnaire only asked participants for their perceived duration of the task, and their age and sex (Appendix B). The number of errors made on the SART was also recorded for each participant.

Participants

Forty-nine individuals participated in the study. One participant assigned to the silent condition withdrew during the experiment. Therefore, a replacement participant was recruited so that there were 12 participants in each condition, for a total of 48 participants ($M_{age} = 31.33$, $SD = 10.98$), consisting of 12 males and 36 females.

Recruitment involved convenience sampling at Edith Cowan University (ECU) Joondalup campus, and inviting students from the ECU Cognition Research Group Participant Register. This register was compiled by the ECU Cognition Research Group for use by staff and students undertaking psychological cognitive research. To compile the register, students from several undergraduate and postgraduate Psychology classes were invited to complete a form with their name, age, gender, marital status, number of children, course of study, and contact details if they were interested in participating in research (Appendix C). The information contained on the register is only available to the ECU Cognition Research Group, and associated students, and will be destroyed at the end of 2012.

Each participant received an entry into a draw to win one of five $50 shopping vouchers, provided by the ECU Cognition Research Group, if they were recruited from the Participant Register and/or provided their details at the end of the post-task questionnaire.

Ethical Considerations

This research project received approval from the Edith Cowan University Human Research Ethics Committee.

Potential participants received a copy of the Information Letter (Appendix D) during the recruitment phase. Participants also received another copy prior to the commencement of the experiment. Informed consent was obtained from participants prior to conducting the experiment (Appendix E). Participants were informed that the experiment was investigating the effects of listening to music on cognitive performance. Participants were informed that they would be listening to either music or no music whilst completing a computer task, and that they would then need to complete a short questionnaire upon completion. Participants were also informed that the experiment would take no longer than 45 minutes. After completing the computer task and the questionnaire, participants were debriefed and informed that the study was investigating time perception. Participants were also informed of the actual duration of the task (23 minutes 10 seconds), and the current time.

The use of music for educational purposes, including research, as part of a school or university does not breach the music copyright licence as covered by the

Australasian Performing Right Association and Australasian Mechanical Copyright Owner's Society (APRA & AMCOS, 2011). A list of the resources used to obtain the musical notation of the songs is provided in Appendix F.

Materials

An information letter (Appendix D) and an informed consent form (Appendix E) were provided to participants prior to the experiment. Upon completion of the computer task, participants in the silent condition were asked to complete the post-task questionnaire (Appendix B), and participants in the music conditions were asked to complete a modified post-task questionnaire (Appendix A).

A computer with music writing software, Finale SongWriter (2007), was used to prepare the 62 songs for the music conditions, and to manipulate the instrument used to perform the songs. Songs were simple one-line melodies of well-known children's songs, such as Baa Baa Black Sheep, and popular movie and television show theme tunes, such as The Flintstones. Unfamiliar songs were simple one-line melodies of less-familiar children's songs. Due to software constraints, the order of the songs could not be randomised (see Appendices G and H for a full list of songs and the order in which they were presented). The songs ranged from 8s to 55s in duration. The songs were played at a constant tempo that allowed the majority of songs to be recognisable. The songs were played at a tempo of 120 beats per minute, unless a recommended tempo was provided with the original music transcript. Participants listened to the songs through headphones whilst completing the SART.

The songs in Condition 1 and Condition 2 were the same familiar songs, and were presented in the same order. In Condition 3, songs alternated between familiar and unfamiliar. The familiar songs in Condition 3 were a selection of songs that were also in Condition 1 and 2. In Condition 1, all songs were manipulated to sound like they were played on a piano. In Condition 2 and 3, the songs were manipulated to sound as if played on either a flute, mandolin, electric guitar, oboe, violin, acoustic guitar, piano, organ, harp, or banjo. The instruments were randomly ordered so that no instrument was repeated consecutively.

SuperLab 4.5 (Abboud, Heller, Matsak, Schultz, & Zeitlin, 2011) was used to create the SART. In the experimental version of the SART, single digits ranging from 1 to 9 were displayed individually for 500ms each. Numbers were presented in a random order, a total of 90 times each. An *X* was displayed for 1150ms after each number as an inter-stimulus interval. The target stimulus was the number *4*, and had a probability of 0.11 of appearing. This low-target probability has previously been used to create a monotonous task (Larue et al., 2010). The numbers and inter-stimulus intervals were presented in the Ariel font, size 48, in the middle of the screen.

Participants also completed a trial SART before commencing the experiment. The trial SART followed the same format as the experimental version of the SART, except that the numbers were displayed for 750ms instead of 500ms, and the numbers 1 to 9 were presented twice each.

Procedure

Upon arriving at the laboratory, participants were provided with the Information Letter (Appendix D) and asked to sign the Consent Form (Appendix E). Participants were asked to remove their watch and turn off their phone, with the explanation that their full attention was required for the task.

Prior to completing the experimental computer task, participants completed a short trial task, without music or headphones, to familiarise themselves with the computer task. The experimenter waited in the room to provide any assistance or answer any further questions. When the trial was complete, the experimenter set up the experimental computer task, asked the participant to put on the headphones and to begin the task when they were ready, and then left the room.

Instructions on the computer screen asked participants to not press the spacebar when the number 4 or an 'X' appeared, to press the spacebar for every other number, and explained that the computer task would continue even if they made a mistake. Participants were also informed that the numbers would be presented slightly faster than in the trial version. After completing the computer task, instructions were presented on the screen asking participants to turn over the questionnaire that was face down beside the computer. Participants then recorded their perceived duration of the task (Appendix B), and if in a music condition, also recorded the percentage of songs they thought were familiar, and the titles of songs they remembered hearing (Appendix A). After receiving the questionnaire from the participant, the experimenter debriefed the participant, informed them of the nature of the study, and thanked them for their participation.

To confirm that the familiarity of the songs in Condition 1 and Condition 2 was significantly different from the familiarity of the songs in Condition 3, song familiarity was examined for its accuracy of fit to the assumptions of the Analysis of Variance (ANOVA). The distribution of song familiarity was significantly non-normal in Condition 1, $W(12) = 0.76$, $p = .003$ (skewness = -2.05, $SE = 0.64$), and in Condition 3, $W(12) = 0.80$, $p = .010$ (skewness = -0.36, $SE = 0.64$), but was normal in Condition 2, $W(12) = 0.93$, $p = .363$. The variance of song familiarity was significantly not equal across the three music conditions, $F(2, 33) = 10.80$, $p < .001$. Due to its robustness against violations of normality, an ANOVA was conducted. There was a significant difference in the familiarity of the songs between the music conditions, $F(2, 33) = 3.56$, $p = .040$, $r^2 = 0.18$. The results of the planned comparison confirmed that the songs in Condition 1 and Condition 2 combined ($M = 89.27\%$, $SD = 11.61$), were perceived as being significantly more familiar than the songs in Condition 3 ($M = 74.67\%$, $SD = 21.25$), $t(14.33) = 2.22$, $p = .043$, $r^2 = 0.26$.

The errors recorded on the SART included both incorrect presses on the spacebar (pressing the spacebar when the number 4 was presented) and incorrect misses on the spacebar (not pressing the spacebar when the other numbers were presented).

Results

Hypotheses 1 and 2

Prior to analysis, perceived duration was examined for its accuracy of fit to the assumptions of the ANOVA. The distribution of perceived duration was normal in the silent condition $W(12) = 0.96$, $p = .698$. However, the distribution of perceived duration was significantly non-normal in Condition 1, $W(12) = 0.86$, $p = .047$ (skewness = -0.93, $SE = 0.64$), Condition 2, $W(12) = 0.86$, $p = .049$ (skewness = -0.33, $SE = 0.64$), and Condition 3, $W(12) = 0.83$, $p = .023$ (skewness = 0.23, $SE = 0.64$). The error variance of perceived duration was homogenous across the four conditions, $F(3, 44) = 0.75$, $p = .530$. It was expected that there would be an effect of conditions on perceived duration, therefore it was expected that the distributions would also be affected, thus they were not manipulated to achieve normality. Further, any transformations to the distributions would minimise the size of the effects. An analysis of the distributions of the music conditions revealed negative skewness, in that 44.44% of participants perceived the task duration to be longer than 1800s (30 minutes). The maximum possible perceived duration would have been 2700s (45 minutes) as participants had been informed that the task would take no longer than 45 minutes.

Due to its robustness against violations of normality, an ANOVA was conducted to examine the effect of experimental condition (silent, Condition 1, Condition 2, and Condition 3) on perceived duration. The results of the ANOVA were confirmed with a Kruskal-Wallis test, indicating that the skewness of the data did not affect the ANOVA. The results of the ANOVA revealed a significant effect of experimental condition on perceived duration of the task, $F(3, 44) = 4.58$, $p = .007$, $r^2 = .24$.

Planned contrasts revealed that the perceived time duration of the silent condition (*M* = 1099.50s, *SD* = 480.56) was significantly shorter compared to the three music conditions combined (*M* = 1458.56s, *SD* = 462.41), $t(44) = 2.31$, $p = .026$, $r^2 = .11$. The perceived duration of Condition 1 (*M* = 1774.42s, *SD* = 464.29) was significantly longer than the other two music conditions combined (*M* = 1300.63s, *SD* = 461.46), $t(44) = 2.87$, $p = .006$, $r^2 = .16$. However, there was no significant difference in perceived duration between Condition 2 (*M* = 1258.75s, *SD* = 532.70) and Condition 3 (*M* = 1342.50s, *SD* = 377.00), $t(44) = 0.44$, $p = .663$.

Post hoc comparisons revealed that only the perceived duration of Condition 1 was significantly greater than the Silent condition ($p = .006$). There were no other significant differences, however the difference between Condition 1 and Condition 2 approached significance ($p = .058$).

A Kruskal-Wallis test was conducted, and confirmed the results of the ANOVA, in that there was a significant difference between the four conditions, $H(3) = 8.98$, $p = .030$, $r^2 = .07$. Mann-Whitney tests were used to follow up the finding of the Kruskal-Wallis test, and confirm the findings of the post hoc comparisons. Therefore, the silent condition and Condition 1, and Condition 1 and Condition 2 were compared. A Bonferroni adjustment was applied, and all effects are reported at a .025 level of significance. Perceived duration was significantly greater in Condition 1 than in the silent condition, $U = 25$, $p = .003$, $r^2 = .31$. Further, perceived duration was also significantly greater in Condition 1 compared to Condition 2, $U = 38.50$, $p = .024$, $r^2 = .16$. The differences in perceived duration between the experimental conditions are shown in Figure 1.

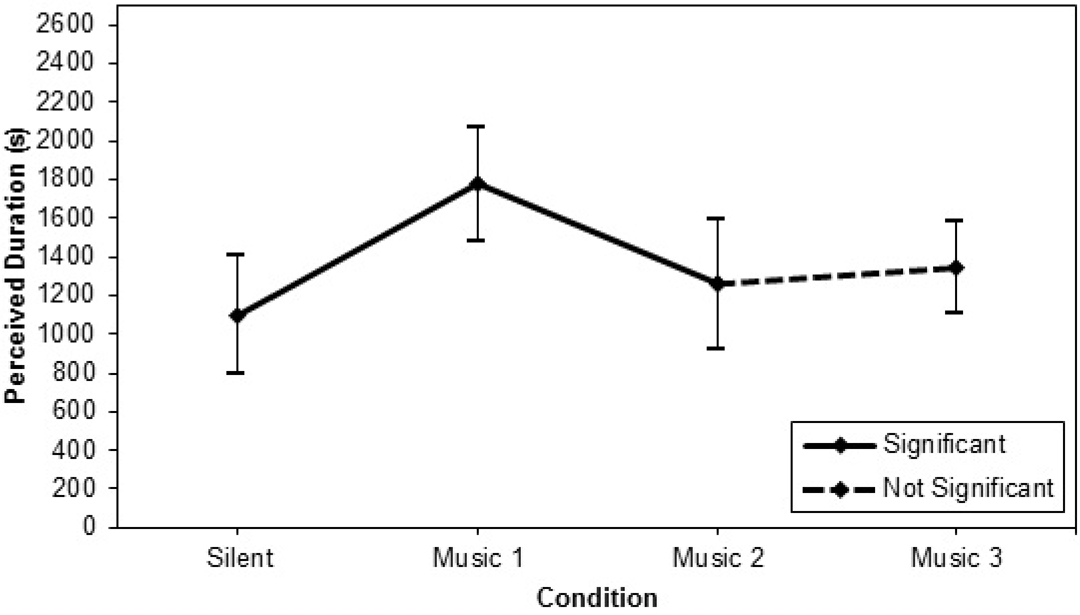

Figure 1. Differences in perceived duration between conditions, as indicated by Mann-Whitney comparisons, at a Bonferroni adjusted significance level $p < .025$. Error bars represent 95% confidence intervals.

Hypothesis 3

The number of errors on the SART was normally distributed in the silent condition, $W(12) = 0.88$, $p = .090$, Condition 1, $W(12) = 0.94$, $p = .453$, Condition 2, $W(12) = 0.94$, $p = .583$, and Condition 3, $W(12) = 0.91$, $p = .237$. The variance of errors on the SART was significantly not equal across the four conditions, $F(3, 44) = 11.86$, $p < .001$. Due to its robustness against violations of the assumption of homogeneity of variances, an ANOVA was conducted to examine the effect of experimental condition on the number of errors made on the SART. The number of SART errors was the greatest in the silent condition ($M = 131.67$, $SD = 89.00$), followed by Condition 1 ($M = 105.25$, $SD = 35.92$), Condition 3 ($M = 99.92$, $SD = 42.41$), and Condition 2 ($M = 85.75$, $SD = 33.77$). However, there was no significant effect of condition on the number of errors made on the SART, $F(3, 44) = 1.42$, $p = .249$

Hypothesis 4

Prior to analysis, perceived duration and the number of correct songs remembered in the music conditions were examined for their accuracy of fit to the distributions and the assumptions of Pearson's correlation. The distribution of the number of songs remembered was significantly non-normal, $W(36) = 0.92$, $p = .013$ (skewness = 0.89, $SE = 0.39$). The distribution of perceived duration was also significantly non-normal, $W(36) = 0.92$, $p = .009$ (skewness = -0.26, $SE = 0.39$). Therefore, Kendall's tau was calculated, rather than Spearman's rho, as the sample size was small, with a large number of tied ranks. There was no significant correlation between the number of songs remembered and perceived duration, amongst the music conditions, $\tau = -0.07$, $p = .297$.

Discussion

Attention-based models and memory-based models make contradictory predictions about how individuals retrospectively perceive the duration of long and monotonous tasks. Attention-based models propose that the duration of a long and monotonous task will be perceived as shorter when listening to music, whilst memory-based models propose that perceived duration would be longer when listening to music (Zakay & Block, 2004). Therefore, the aim of the present study was to determine whether attention-based or memory-based models could best explain retrospective time perception of a long, monotonous task. Overall, the results of the present study provide limited support for both attention-based and memory-based models in explaining retrospective time perception of a long and monotonous task.

The duration of the silent condition was perceived as significantly shorter than the music conditions, therefore hypothesis 1B was supported, and hypothesis 1A was not. Condition 1 was perceived as longer than Condition 2, however no other significant differences in perceived duration between the music conditions were found, therefore hypothesis 2B was somewhat supported and hypothesis 2A was not supported. There was no significant difference in the number of errors made on the SART between the four conditions, therefore Hypothesis 3A was not supported. There was no significant correlation between the numbers of songs remembered and perceived duration of the three music conditions, therefore Hypothesis 4B was not supported.

Hypothesis 1

The main finding of the present study provides evidence to support a memory-based model of retrospective time perception, as the overall duration of the music conditions was perceived as longer than that of the silent condition.

According to memory-based models, when an individual's attention is focussed on the non-temporal processing of musical stimuli, discrete events and contextual changes are created in their memory (Block & Zakay, 2008; Block & Reed; Brown & Boltz; Ornstein, 1969; Zakay & Block, 2004; Ziv & Omer, 2011). Thus, in the present experiment, when participants were required to estimate the duration of the task, the elapsed time period was reconstructed based on the events and contextual changes available in their memory. In the music conditions, the songs provided a large number of events and contextual changes to be recalled in memory, whilst in the silent condition, there were no non-temporal stimuli to act as events or to provide contextual changes. Therefore, the durations of the music conditions were perceived as longer compared to the silent condition, supporting memory-based models.

The finding that the silent condition was perceived as shorter than the music conditions is inconsistent with what is predicted by attention-based models. According to attention-based models, during a long and monotonous task, more attentional resources are available for temporal processing and therefore the duration of the task is perceived as longer (Block, 2003; Block & Zakay 1997; Doob, 1971; Zakay & Block, 2004). Thus, in the present experiment, the silent condition would have been more monotonous than the music conditions and therefore would have been perceived as longer. However, as the silent condition was perceived as longer than the music conditions, this does not support attention-based models.

Hypothesis 2

The second finding of the present study, that Condition 1 was perceived as longer than Condition 2, provides some support for attention-based models.

According to memory-based models, music conditions with a greater number of events and contextual changes will be perceived as longer than music conditions with fewer events and changes (Zakay & Block, 2004). Thus, Condition 3 would be predicted to be perceived as longer than Condition 2, and Condition 2 would be perceived as longer than Condition 1.

Attention-based models, however, predict that the greater number of events and contextual changes would divert participants' attention away from temporal processing models (Block & Zakay, 2008; Grondin, 2010; Zakay & Block, 1995). Therefore, Condition 3 would be predicted to be perceived as shorter than Condition 2, and Condition 2 would be perceived as shorter than Condition 1.

As the music conditions were perceived as significantly longer than the silent condition, and therefore supported the memory-based hypothesis, it would be assumed that the differences between the music conditions would also support the memory-based hypothesis. However, the results conformed, albeit partially, to the attention-based hypothesis in that the only significant difference between the music conditions was that Condition 1 was perceived as longer than Condition 2. Thus, although initial support was provided for memory-based models, the differences between the music conditions partially support attention-based models (Block & Zakay, 2008; Grondin, 2010; Zakay & Block, 1995).

It is currently unclear as to why the difference between Condition 1 and Condition 2 was the only significant difference. According to attention-based models, if Condition 1 was perceived as longer than Condition 2, then it would also be perceived as longer than Condition 3. Thus, although the difference between Condition 1 and

Condition 2 is consistent with attention-based models, this was the only significant difference and therefore the support for attention-based models is limited. It is possible however, that Condition 1 was also perceived as longer than Condition 3 but this effect was not seen due to the presence of the ceiling effect on perceived duration.

The investigation of time perception in the present study was limited by a necessary design constraint. Due to ethical requirements, participants were required to be informed of the approximate duration of the experiment, and this created a ceiling effect. Informing the participants that the experiment "would take no longer than 45 minutes" was a compromise between providing an ethically acceptable estimation of participation time without being too close to the task duration, and an excessive and inaccurate estimation, for example longer than one hour, that may have deterred individuals from participating. There is evidence that this created a ceiling effect, as almost half of responses were between 30 minutes and the maximum 45 minutes. Thus, participants were limited in the maximum duration that they could report even if they perceived the task duration as longer, and this would have limited the size of the differences in perceived duration. Therefore, without the presence of the ceiling effect, Condition 1 may also have been perceived as significantly longer than Condition 3, and this would further support attention-based models. However, it remains unclear as to why the differences between the music conditions provides some support for attention-based models, whilst the difference between the music conditions and the silent condition supports memory-based models.

Presently, the results provide limited support for both memory-based and attention-based models in explaining retrospective time perception of a long and monotonous task. Overall, the music conditions were perceived as longer than the silent condition. Thus, a long and monotonous task will be perceived as shorter when listening to no music, compared to when listening to music. Memory-based models propose that this is due to the music creating events and contextual changes in memory (Zakay & Block, 2004). Thus, the more that is remembered as occurring during an elapsed time period, the longer its perceived duration. However, within the music conditions, the music condition that was designed to have the fewest number of events and contextual changes was perceived as longer than a condition designed to have a greater number of events and changes. This finding is inconsistent with memory-based models and rather, supports attention-based models. Attention-based models propose that a greater number of changes will divert more attention away from temporal processing compared to fewer changes, and therefore the duration will be perceived as shorter (Block & Zakay, 2006; Zakay & Block, 1995). To determine how participants were estimating time, the number of errors made on the SART, and the number of songs remembered was measured.

Hypothesis 3

The third finding of the study, that there was no significant difference in the number of SART errors between the conditions, does not provide evidence to support attention-based models.

According to attention-based models, when a non-temporal task is long and monotonous, attentional resources are available for the processing of temporal and non-temporal information (Block & Zakay, 2006; Zakay & Block, 1995). However, when an additional non-temporal task is to be performed, the amount of attentional resources available decreases (Brown, 1985). Therefore, fewer resources are available to perform the non-temporal tasks and performance on each task decreases. Further, fewer resources are available for temporal processing and the perceived duration decreases. The number of errors on the SART was measured to determine whether the music diverted participants' attention from temporal to non-temporal processing, as predicted by attention-based models.

As there were no significant differences in the number of errors on the SART between the conditions, the music stimuli did not significantly divert attention away from the SART. This suggests that participants had enough attentional resources available to listen to the songs without it affecting their performance on the SART and that there would have been sufficient resources available for temporal processing in all four conditions. Under these assumptions, perceived duration would be equal across all conditions. However, this was not found, as perceived duration varied between conditions. Therefore, the present results do not support attention-based models, but rather suggest that retrospective time perception is not based on the amount of attentional resources available to temporal processing. This conclusion is inconsistent with the proposal that the amount of attentional resources available becomes relevant to explain retrospective time perception of a long and monotonous task (Block, 2003; Block & Zakay 1997; Doob, 1971; Zakay & Block, 2004).

Hypothesis 4

The fourth finding of the present study does not provide evidence to support memory-based models, as there was no significant correlation between perceived duration and the number of songs remembered.

Despite the music conditions being perceived as significantly longer than the silent condition, the differences between the music conditions make it unclear as to what events and contextual changes participants used to estimate the duration of the task. Memory-based models predict that perceived duration would increase as the number of events and contextual changes increased (Block & Reed, 1978; Ornstein, 1969; Poynter, 1983). However, although Condition 1 was perceived as significantly longer than Condition 2, there was no significant correlation between the number of songs remembered and perceived duration.

Ornstein's (1969) storage size model and Poynter's (1983) segmentation model propose that the more events or segments that are remembered, the longer the perceived duration. Therefore, this lack of correlation between number of songs remembered and perceived duration suggests that retrospective time perception may not be based on memories of specific events as suggested by Ornstein's storage-size model and Poynter's segmentation model. Although the present findings do not support these two memory-based models, it remains unknown whether the results may support Block and Reed's (1978) contextual-change model.

As the present study significantly extended the duration of the task beyond what has commonly been measured, it is possible that different processes are involved in retrospective judgements of short and long durations. In a meta-analytic review of the effect of cognitive load on perceived duration, Block and colleagues (2010) found that memory does influence retrospective judgements, however they proposed that recall memory (availability) is more involved in the judgement than recognition memory (familiarity).

The contextual-change model proposes that it is the availability of events and associated contextual changes, as well as the actual number of events and changes that influence perceived time duration (Block & Reed, 1978). However, the model does not propose a method of how to independently measure a cognitive-change, nor how to assess what information is available or not available in memory prior to recall (Block, 1990). It is also difficult to determine which cognitive processes are involved in remembering a cognitive change, in the same way in which it is difficult to determine the amount of attention allocated to cognitive processes or the amount of storage space required by varying pieces of information (Block, 1990). Thus, as the availability of songs in participants' memory could not be measured, the ability of the contextual-change model to explain retrospective time perception of a long task remains unexplored.

Further, it is possible that the lack of correlation between the number of songs remembered and perceived duration was due to the presence of a ceiling effect. As previously discussed, the maximum perceived duration that participants could report was limited, resulting in perceived duration being negatively skewed. Thus, participants were limited in the maximum duration that they could report, even if they perceived the task duration as longer, and this in turn would have limited the size of the correlation with the number of songs remembered.

General Discussion

Overall, the results of the present study provide limited support for both the memory-based and attention-based models. The finding that the music conditions were perceived as longer than the silent condition suggests that the songs provided a large number of events and contextual changes to be recalled in memory, and therefore, support memory-based models. The difference in perceived duration between the music conditions, however, was inconsistent with the memory-based hypothesis.

To further determine whether memory-based models could explain retrospective time perception, the number of songs remembered in the music conditions was measured. According to memory-based models, there would be a correlation between perceived duration and the number of songs remembered, as the songs would act as events and contextual changes (Block & Reed, 1978; Ornstein, 1969; Poynter, 1983). However, there was no significant correlation. It is possible that the correlation was limited by the presence of a ceiling effect on perceived duration, but may also suggest that the explicit memory of events is not as relevant in explaining perceived duration as previously thought (Block et al., 2010).

Although the difference in perceived duration between the music conditions and the silent condition supports memory-based models, the difference in perceived duration between two of the music conditions provides some support for attention-based models. Attention-based models propose that the greater number of events and contextual changes would distract participants' attention and therefore lead to a shorter perceived duration (Block & Zakay, 2006; Zakay & Block, 1995). This hypothesis was supported by the finding that Condition 2 was perceived as shorter than Condition 1. However, there were no other significant differences between the conditions, limiting the support for attention-based models.

To further determine whether attention-based models could explain retrospective time perception, the number of errors on the SART was measured. According to attention-based models (Block & Zakay, 2006; Zakay & Block, 1995), the increasing number of events and contextual changes between the conditions would distract participants' attention and therefore create a larger number of errors on the SART. However, there was no difference in the number of errors on the SART, suggesting that the influence of attentional resources on retrospective time perception of long tasks is limited.

As previously discussed, studies that have attempted to investigate the effect of music and experimental paradigm on perceived duration have used relatively short durations (Ziv & Omer, 2011), whilst studies that do use longer durations are limited by methodological inconsistencies (Bailey & Areni, 2006b). Thus, the present study added to the body of time perception research by improving upon the inconsistencies within previous studies, and extending the actual duration investigated.

Previous support for attention-based and memory-based models has been limited by the duration of the experimental task (Grondin, 2010; Ziv & Omer; 2011) and the number of stimuli presented (Bailey & Areni, 2006b; Ziv & Omer, 2011). The present study extended the duration of the task to 1390s, and presented 62 songs in the music conditions. The finding that the music conditions were perceived as longer than the silent condition provides evidence that memory-based models are able to explain retrospective time perception when a greater number of stimuli are presented over a long duration, compared to what has been previously tested (for example, Bailey & Areni, 2006b; Bisson et al., 2009; Kellaris & Kent, 1992; Ziv & Omer, 2011).

However, the finding that there was no correlation between perceived duration and the number of songs remembered, and no difference in the number of SART errors between the conditions, makes it unclear as to how participants determined the duration of the task. As previously discussed, it is difficult to determine the amount of attention allocated to different processes, as well as determining the availability of an event, or measuring a cognitive change (Block, 1990). Further, “virtually all time-estimation tasks involve perception, memory, attention, decision-making, and other processes to varying degrees, and one can choose to emphasize some processes over others in the interpretation of results” (Brown & Stubbs, 1992, p. 554). It is possible that retrospective time perception of long tasks involves a different combination of processes than what has been proposed by attention-based and memory-based models of short tasks (Block et al., 2010). This is evidenced by the finding that one pattern of results of perceived duration supported memory-based models, whilst another supported attention-based models. Further, there were no differences in attentional resource allocation between conditions as measured by the number of errors on the SART, or a relationship between perceived duration and the number of events or contextual changes as measured by the number of songs remembered. Thus, this suggests that other processes may be more relevant in explaining retrospective time perception of long tasks, and this should be explored in future research.

The aim of the present study was to determine which model best explained retrospective time perception of a long task, therefore, the application of the findings to non-experimental conditions are somewhat limited. However, aspects of the experimental design have been related to real world situations. For example, the SART was used in this experiment because it provided a non-temporal task that included stimuli that cannot be quantified nor suggest a duration (Poynter, 1989). However, using the SART was also beneficial in that it was developed to relate to real-world vigilance tasks that require continuous monitoring and responses to stimuli, whilst being prepared to respond to infrequent stimuli (Helton et al., 2011; Larue et al., 2010). Examples of real-world vigilance tasks include driving, industrial quality control, X-ray baggage screening, closed circuit television (CCTV) surveillance, and air traffic control (Donald, 2008; Larue et al., 2010). Although the present experiment was not designed to replicate such real-world situations, the results show that when completing a long and monotonous task, listening to music will increase its perceived duration.

Although the number of errors on the SART was used to measure the focus of attentional resources, it may also be used as a preliminary measure of cognitive performance and may have significance outside of the laboratory. The number of errors on the SART was not significantly different between the conditions, even though some listened to music whilst others did not. Further, there was no difference in the number of errors on the SART even though some perceived the duration as being longer than others. This suggests that cognitive performance was not affected by the presence of the music used in the study, nor was it affected by subjective estimates of time duration. Future investigations should be conducted into whether objective levels of cognitive performance, for example vigilance decrements, are affected by the perceived time on task.

Some limitations, both unavoidable and avoidable existed in the present study. As previously mentioned, informing participants of the maximum possible duration of the task created a ceiling effect on perceived duration and this may have reduced the size of the effects of experimental condition, and relationship with other dependent variables. Participants were also informed that the study was investigating cognitive performance rather than time perception. This may have resulted in participants directing an extra amount of cognitive resources towards performing the SART than would otherwise be applied to a monotonous task. This would explain why there was no difference in the number of errors on the SART, as all participants were attempting to perform at their best. Thus, future studies should attempt to avoid creating a ceiling effect and an experimental bias. Further, the present study used simple one-line melodies of nursery rhymes and theme tunes, thus the effects of music on perceived duration are limited. Future research should therefore investigate the effect of different genres of music, whilst still controlling for the complexities inherent in musical stimuli. The present results could also be extended upon by further increasing the duration of the task. In doing so, additional evidence may be found to distinguish between attention-based models or memory-based models, alternatively, a new model may need to be developed to explain the retrospective time perception of long tasks.

In conclusion, the results of the present study provide limited support for both memory-based and attention-based models. The silent condition was perceived as shorter than the music conditions, supporting memory-based models, while the difference between the music conditions did not support memory-based models. Instead, limited support was provided for attention-based models. However, there was no difference in the number of errors on the SART, nor was there a correlation between the number of songs remembered and perceived duration, limiting the support for either model. The lack of significant findings may have been due to the presence of a ceiling effect on perceived duration. Overall however, the present results may suggest that the relevance of attentional processes and memory in explaining the retrospective time perception of a long task, may not be as great as previously proposed by attention-based and memory-based models, and this should be explored in future research.

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Appendix A

Post-task Questionnaire for the Music Conditions

Questionnaire

- Age: Gender:
- Estimate how long you think the computer task lasted for:
  _______ Minutes _______ Seconds
- Overall, what percentage of songs were familiar to you (even if you recognised the song but didn't know it's title):
  _______ %
- List the title of any songs that you remember hearing (if you don't know the title, write some of the lyrics):

___________________	___________________	___________________
___________________	___________________	___________________
___________________	___________________	___________________
___________________	___________________	___________________
___________________	___________________	___________________
___________________	___________________	___________________
___________________	___________________	___________________
___________________	___________________	___________________
___________________	___________________	___________________
___________________	___________________	___________________
___________________	___________________	___________________

Thank you for participating in this research.

If you would like to be entered into the draw to win one of five $50 shopping vouchers, please fill in your details below:

Name:

Contact info phone/email:

Appendix B

Post-task Questionnaire for the Silent Condition

Questionnaire

- Estimate how long you think the computer task lasted for:
  _______ Minutes _______ Seconds
- Age:
- Gender:

Thank you for participating in this research.

If you would like to be entered into the draw to win one of five $50 shopping vouchers, please fill in your details below:

Name:

Contact info phone/email:

Appendix C

ECU Cognition Research Group Information Letter and Participant Details Form

EDITH COWAN UNIVERSITY
School of Psychology and Social Science

Cognition Research Group **Research Participation Register 2012**

The staff and research students of the Cognition Research Group at the School of Psychology and Social Science regularly conduct research projects that require the participation of volunteers. These volunteers are asked to engage in activities such as completing questionnaires, perform simple tasks on a lab computer or online. Participation in such research projects obviously aids the conduct of the research, but it can also provide a useful and interesting perspective on the field of Cognitive Psychology. In particular research participants can gain an insider's view on how psychologists gather data, and have some input to the issues that are currently considered 'hot'.

Each year, students of Edith Cowan University are asked if they wish to be included on a register of potential research participants. They are asked to fill out a very short questionnaire (attached) requesting details that may be relevant for the Cognition Research Group's research projects. Research students and staff of the Cognition Research Group who require participants for their projects can then access the register and contact appropriate volunteers. Those people contacted through the register will be provided with full details of the research project, and will then be completely free to decide whether or not they wish to participate in that project.

All details provided by volunteers will be entered onto a computer database that will be accessible only by staff and Postgraduate research students of the Cognition Research Group (contact details will be those that are normally accessible with regard to currently enrolled students). When volunteers are required by a particular project, the researcher will have to supply details of the kind of participant they require. The database will be searched according to these requirements, and then the researcher will be provided with a list of suitable volunteers to contact. At the end of each year, the database will be erased, and a new register will be compiled the following year. Furthermore, a person who is on the database can request that their details be removed at any time by contacting Dr. Guillermo Campitelli (g.campitelli@ecu.edu.au).

Although the Cognition Research Group feels that participation in research projects is rewarding on itself, an added incentive is provided. Volunteers will be given a raffle ticket for each hour/session of an officially sanctioned research project they participate in. These tickets will be entered into a draw at the end of 2nd semester. There will be 5 (five) cash prizes of $50 in the way of gift cards. Further, some researchers may be in a position to offer reimbursement for travel expenses, and the like.

If you would like to have your name included on the Cognition Research Group's Research Participation Register, please complete the questionnaire overleaf, and hand back to Dr. Guillermo Campitelli (room 30.122) or Katrina Muller-Townsend. Feel free to leave particular sections blank if you do not wish to supply this information.

EDITH COWAN UNIVERSITY
School of Psychology and Social Science

Cognition Research Group **Research Participation Register 2012**

If you would like to have your name included on the Cognition Research Group's Research Participation Register, please complete the following questions, and leave this sheet with Dr. Guillermo Campitelli (room 30.122). Feel free to leave particular sections blank if you do not wish to supply this information.

Name: ____________________ Age: ________ Gender: __________

Phone (daytime):____________________ (night-time): __________

Or Mobile: ______________________________

Email: ____________________ Student number: __________

Marital Status (please circle): Single Married De Facto Separated/Divorced Other

Number of children: __________

Course: ______________________________

Course Year (1st, 2nd, 3rd, etc.): __________________

Number of Years of Education:__________________

Previously on Research Participation Register (please circle)? Yes No

Appendix D

Effects of Music on Cognitive Performance of a Long Task

Information letter

My name is James Brooks, I am a Psychology Honours student at Edith Cowan University, and this research project is being undertaken as part of the course requirements.

I am interested in the effects that music has on cognitive performance over an extended period of time. The aim is to determine whether listening to music is beneficial or harmful to cognitive performance. Participation in this project will involve completing a computer-based reaction time task whilst listening to either music or no music, and then completing a short questionnaire. The total duration of the task is expected to take no longer than 45 minutes. You will also go into the draw to win one of five $50 shopping vouchers.

This project has been approved by the ECU Human Research Ethics Committee. Any information recorded will remain confidential and will only be available to myself and my supervisor, Prof. Craig Speelman. The results of this study will not include any personally identifiable information. Participation in this study is voluntary, and you will be free to withdraw at any time with no explanation or justification needed. Should you choose to withdraw, any information or results collected will not be used in the study.

Your participation in this study would be greatly appreciated. If you have any questions or require any further information about the research project, please contact:

James Brooks	Mobile: 0404688776	Email: jbrooks2@our.ecu.edu.au
Prof. Craig Speelman	Phone: 6304 5724	Email: c.speelman@ecu.edu.au

Regards,

James Brooks

If you have any concerns or complaints about the research and wish to talk to an independent person, you may contact:

Research Ethics Officer
Edith Cowan University
270 Joondalup Drive
JOONDALUP WA 6027
Phone: (08) 6304 2170
Email: research.ethics@ecu.edu.au

Appendix E

Effects of Music on Cognitive Performance of a Long Task

Informed Consent Form

Contact Details:

Primary Researcher:	Supervisor:
James Brooks	Prof. Craig Speelman
Mob. 0404688776	Ph. 6304 5724
jbrooks2@our.ecu.edu.au	c.speelman@ecu.edu.au

I have been provided with a copy of the Information Letter explaining the research study. I have read and understood the information provided. I have been given the opportunity to ask questions and any questions I have asked have been answered to my satisfaction. I am aware that if I have any additional questions I can contact the research team.

I am aware that participation in this research project will involve completing a computer-based reaction time task whilst listening to music, and then completing a short questionnaire. I am aware that the total duration of the task is expected to take no longer than 45 minutes.

I am aware that information provided will be kept confidential, and that my identity will not be disclosed without consent. I understand that the information provided will only be used for the purposes of this research project. I understand that I am free to withdraw from further participation at any time, without explanation or penalty.

I freely agree to participate in this project.

Name:

Date:

Signature:

Appendix F

Reference List of Musical Notation

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Appendix G

Musical Stimuli in Condition 1 and Condition 2

1. Home among the gum trees
2. Get Smart theme
3. Frère Jacques
4. The drunken sailor
5. Waltzing Matilda
6. The first noel
7. The Brady Bunch theme
8. Silent night
9. Bananas in Pyjamas theme
10. Skip to my lou
11. Star Wars theme
12. Amazing Grace
13. We wish you a Merry Christmas
14. Oh Christmas tree
15. Ten green bottles
16. She'll be coming round the mountain
17. Hush little baby
18. Happy birthday
19. If you're happy and you know it
20. Hickory dickory dock
21. Michael Finnigan
22. Can-can
23. Away in a manger
24. Humpty Dumpty
25. Ten in a bed
26. The Muffin man
27. Jack and Jill
28. The Flintstones theme
29. Bob the Builder theme
30. Inspector Gadget theme
31. Mary had a little lamb
32. Ring a ring of roses
33. I still call Australia home
34. Old MacDonald
35. Advance Australia Fair
36. Baa baa black sheep
37. Here we go round the mulberry bush
38. Row row row your boat
39. Hey diddle diddle
40. Hot cross buns
41. Sesame Street theme
42. Kookaburra sits in the old gum tree
43. Pat a cake
44. Rock a bye baby
45. Under the sea
46. This old man
47. Kumbaya
48. It's raining it's pouring
49. George of the jungle theme
50. Twinkle twinkle little star
51. Pop goes the weasel
52. Chim chim cheree
53. The ants go marching
54. Bewitched theme
55. Good King Wenceslas
56. The Addams family theme
57. Eensy weensy spider
58. He's got the whole world in his hands
59. Mission Impossible theme
60. I'm a little tea pot
61. Polly put the kettle on
62. Yankee Doodle

Appendix H

Musical Stimuli in Condition 3

1. Home among the gum trees
2. Goosey goosey gander
3. Frere Jacques
4. Little Boy Blue
5. Drunken Sailor
6. Alouette
7. Waltzing Matilda
8. Three blind mice
9. Silent night
10. Clementine
11. Bananas in Pyjamas theme
12. Summer goodbye
13. Skip to my lou
14. Charlie is my darling
15. Amazing grace
16. Little Suzy
17. We wish you a Merry Christmas
18. Widdicombe fair
19. Oh Christmas tree
20. Sky boat song
21. Ten green bottles
22. Little David
23. Hickory dickory dock
24. Oh, no John
25. Can-can
26. Missa ram goat
27. Away in a manger
28. Billy boy
29. The Muffin man
30. Dance to your daddy
31. The Flintstones theme
32. Ah pretty Augustine
33. Bob the Builder theme
34. The miller of the dee
35. Inspector Gadget theme
36. Lil Liza Jane
37. I still call Australia home
38. Sally Goodin
39. Old MacDonald had a farm
40. The foggy foggy dew
41. Baa baa black sheep
42. John Riley
43. Sesame Street theme
44. Tom Dooley
45. Kookaburra sits in the old gum tree
46. Scarborough fair
47. This old man
48. In Dulci Jubilee
49. Twinkle twinkle little star
50. The weather witch
51. Pop goes the weasel
52. Unto us is born a born a king
53. The ants go marching
54. As with gladness men of old
55. Eensy weensy spider
56. Green sleeves
57. Mission Impossible theme
58. Golden slumber
59. Polly put the kettle on
60. One more river
61. Yankee Doodle
62. Tom he was a pipers son