CONTEXTUAL CHANGE EFFECTS IN RETROSPECTIVE AND PROSPECTIVE DURATION JUDGMENT PARADIGMS USING MUSICAL PIECES

by

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ABSTRACT

This study provides support for differences in prospective and retrospective duration judgment paradigms. These differences have been attributed to the amount of change in processing context. Therefore, the study also examined contextual changes in musical pieces. A 2 x 3 factorial design experiment measured differences in verbal duration estimates made for prospective and retrospective conditions. In these conditions there were three music stimulus pieces: a simple, a complex, and a mixed type. In the retrospective condition, mixed type duration estimates were significantly longer than in the prospective condition. Also in the retrospective condition, mixed type duration estimates were reported as significantly longer than both the simple and complex music types. These findings provide further support for differences in prospective and retrospective paradigms (Block, Hancock & Zakay, 2010; Block & Zakay, 1997) as well as the contextual-change hypothesis for retrospective duration judgment (Block & Reed, 1978).

INTRODUCTION

A basic human experience is that of temporal cognition. It is involved in many waking aspects of human consciousness, ranging from successiveness and simultaneity to past, present and future orientations. Many types of rhythmicity are present in life, both cyclical and successive. Cyclic changes can range from annual seasonal changes to changes of a biological nature such as the human sleeping and waking cycle. Successive changes, which happen one after another in sequence, are constantly being processed and monitored by the human cognitive system. It is proposed that changes in both of these aspects are closely related to duration judgment, memory, attention, and experience of the passage of time (Block, 1989).

At first glance, it may seem hard to apply some common concepts from research on the psychology of time. However, temporal ordering of events allows people to pursue actions and goals. The selection and control of actions can be activated automatically or by using attentional resources and conscious control (Norman & Shallice, 1986). In an action, some type of mechanism allows for the precise timing needed to complete that action. Therefore, this precise timing of automatic and consciously controlled actions guides human behavior.

Previous research distinguishes two types of timing situations: prospective and retrospective timing (Block & Zakay, 1997). When using prospective timing, an individual is actively attending to some aspect of time. This attention to temporal aspects of a situation allows for the correct sequencing of actions. For example, an individual driving a car and turning onto an off ramp needs to actively attend to the time it will take to reach the off ramp, which lane he or she needs to be in, signaling the turn and then maintaining the appropriate speed for accomplishing this goal. These steps would need to be sequenced in a manner that would result in the completion of this goal. Also, a duration estimate must be made in order to manage the amount of time it would take to complete this goal (Block & Hancock, 2014). The attentional-gate model can account for these type of circumstances. It suggests that a process of comparison occurs which uses reference and working memory (Block & Zakay, 2006, 2008). During this comparison information that has been previously encoded about duration length is compared to the current duration length.

Retrospective timing entails different processes, which are applied in different ways. A retrospective estimate of a duration tends to rely more on memory than attention to time (Block & Hancock, 2014). James (1890) first discussed the specious present. He explained this as a situation in which a person perceives a sequence of events lasting a few seconds. The idea of a past, present and future sense of time then becomes apparent. It is temporally important information about our past that concerns retrospective forms of timing. When looking back upon an event from our past, there are instances in which an estimate of duration becomes important. For example, it may be important to reference information in memory about duration length to complete an action sequence correctly. To do this an individual must be able to temporally sequence actions as well as take into consideration current relevant contextual associations (Block, 1978). The contextualist tetrahedral model of temporal experience suggests that remembered duration is a product of the interaction of contextual factors (Block, 1985; adapted from Jenkins, 1979).

The psychological present is a short duration of time that is captured in memory. Many contextual elements influence the encoding, storage and retrieval of this information. These can include spacing, ordering and position of information. Durations judgments can also be influenced by both affordances and changes in environmental context and cognitive context (Block, 1989). Gibson (1975) called incoming patterns of information that a person gathers *affordances*. Most importantly though are the sequence of events and the amount of contextual change that occurs. It is possible that some of the human experience of time comes from a flow of changes which then allows the observer to perceive the flow of time. Retrospective temporal experiences may be best defined by a contextualist model (Block, 1989).

A unique look at temporal aspects of cognition concerns literature about musical timing. Musical timing is an excellent example of both automatic and conscious processes controlling goal-oriented actions. In musical performance, actions must use memory for action sequences of notes to simultaneously create rhythm and melody. Historically, music was often accompanied by dance and this required motor coordination in sequence with rhythmic timing (Levitin & Trivolas, 2009). There are also similarities between music and language. Music, similarly to language, has a grammar of musical style that is influenced by one's musical culture. Therefore, musical phrases are composed of grammatically ordered notes and take on a different meaning when they are randomly ordered (Lerdahl, 2001; Levitin & Trivolas, 2009; Patel, 2003). This research examines duration estimates about musical pieces using prospective and retrospective paradigms.

Music perception researchers have predicted that musical events may effect estimates differently than traditional cognitive events. There may be something special about music that makes it unique to other types of cognitive events. Jones and Boltz (1989; Boltz 1998) suggested that musical events may differ because they have high coherence. Specifically, in musical pieces rhythm and melody tend to be coherent. Previous research from the cognitive time estimation literature examined the effect of cognitive events on duration estimates. These events can include levels of processing (Block & Zakay, 1997), memory and attention tasks, cognitive load (Block, Hancock & Zakay, 2010), segmentation of events (Poynter, 1983) and amount of processing changes (Block & Reed, 1978). The current study conceptually matches a study by Block and Reed (1978) which used a shallow processing level condition and a deep processing level condition. In addition, a third condition examined retrospective duration estimates of a mixed shallow and deep processing task. This study will be the first to compare the effect of processing changes as well as complexity in music in a prospective and retrospective paradigm. It is important to look at prospective against retrospective judgments because they are often influences by different underlying processes and mechanisms.

Prospective and Retrospective Duration Judgments

Prospective duration timing involves attentional processes. In the prospective paradigm, participants are given instructions stating that they will later be asked to provide an estimate of duration. This type of estimate is termed *experienced duration*

(Block, 1990). In this paradigm participants can allocate more attentional resources for temporal information processing. Previous research has used dual-task conditions that require participants to share attention between temporal and nontemporal stimuli. When less processing is required during a task, such as if a task is easy, duration estimates tend to be longer (Hicks, Miller, & Kinsbourne, 1976; Zakay and Block, 1997). Therefore, if less nontemporal processing is required, participants can give more attention to temporal information. Nontemporal information processing is considered to use similar resources as those which are used when attending to time (Block & Zakay, 2001). Models that have been proposed for experienced duration are attention-based and describe a relationship between temporal and nontemporal processing of information (Block & Zakay, 1996; Brown, 1998; Macar, Grondin, & Casini, 1994; Zakay & Block, 1996). Thus, the amount of attention that is allocated for nontemporal information predicts experienced duration.

Retrospective duration judgments are given if participants are unaware that they must provide an estimate until after the stimulus events have been presented. This type of estimate has been called *remembered duration* (Block, 1990). In retrospective duration judgments, theorists typically use memory-based models for explanations (Block & Zakay, 2001). Two theories emerged during the 1960s, one concerning storage size (Ornstein, 1969) and the other the number of remembered changes (Fraisse, 1963). Works by both researchers first highlighted the effects of the number of events and complexity of events on duration judgments. In Ornstein's research an increase in the number of events retrieved resulted in an increase in duration estimates. However, Fraisse suggested that duration estimation was based on the number of remembered changes from an event. These theories were then followed up by research from Block and Reed (1978) regarding encoded and retrieved contextual changes and from Poynter (1983) regarding interval segmentation of events. Thus, research provided further evidence which suggested it was not just an increase in contextual elements but an increase in contextual changes that affected duration judgments (Block & Zakay, 2001).

There is a connection between retrospective and prospective timing: Information which is used in a prospective timing situation may use information which was previously encoded retrospectively (Block & Zakay, 2001). There are important differences as well. Findings from a meta-analysis conducted by Block and Zakay (1997) revealed that retrospective duration estimates are more variable then prospective duration estimates. This is because during prospective duration tasks participants are allocating more attentional processing resources for attending to temporal information. Also, Block and Zakay (1999) found that as individuals gain more knowledge and experience with specific timing situations their duration estimates become more accurate and less variable.

A recent meta-analytic review examined how cognitive load affects duration judgments differently depending on paradigm (Block, Hancock & Zakay, 2010). The findings showed that in a prospective temporal paradigm, estimates were influenced by response demands, divided or selective attention, and processing difficulty. In a retrospective temporal paradigm, high cognitive load lengthened estimates of duration compared to low cognitive load. Therefore, remembered duration and experienced duration estimates are very different when considering cognitive load. Two other similar differences were found for familiarity and processing changes. Processing changes did not influence experienced duration but did influence remembered duration. This research provides substantial evidence for the influences of different cognitive load types on prospective and retrospective duration estimates.

Several theories have been developed and have suggested similar models to explain attentional mechanisms that may be involved in prospective duration estimation. These include a model proposed by Treisman (1963), the scalar-timing model (Church, 1984), and the attentional-gate model (Zakay & Block, 1996, 1997). Treisman's model held only a pacemaker which produced a series of pulses dependent on arousal level, arousal level was seen to be modified by a calibration unit. Pulses enter a counter which transfers information to a store and then it all enters a comparator which provides a response. In this example, the response is the duration estimate.

The scalar expectancy theory is best known as a theoretical account which describes animal time-related behavior (Block, Hancock & Zakay, 2010). The model has a pacemaker, switch, and accumulator. The pacemaker generates pulses and timing begins when something triggers a signal which then opens a switch. Pulses collect in the accumulator and are then counted (Church, 2006; Gibbon, Church & Meck, 1984). The scalar expectancy theory assumes an internal clock is involved. However, internal clock models cannot adequately explain the intricate workings of human timing behavior. For example, they cannot explain variations in attentional processes which are involved in prospective duration estimation.

According to the attentional-gate model as proposed by Zakay and Block (1995; Block & Zakay, 1996), attention to time influences incoming pulses. The attentional-gate model can be applied in both experienced duration situations as well as in prospective remembering (Block & Zakay, 2006). In this model, first a pacemaker emits signals or pulses. These are released at a constant rate with the only changes resulting from changes in arousal level. It is suggested that these pulses may exist in specialized neural networks and consist of synchronized neural firings (Block & Zakay, 2006). Following this release, the signals then must pass through an attentional gate. This is controlled by executive functions including resource allocation specifically for timing. In this way, if more resources have been allocated for time, the wider a metaphorically described attentional gate will open. Thus, when less allocation of resources for timing are available, a smaller amount of pulses will pass through. Following the opening of a gate, a switch operates with the meaning assigned to the task. For example, when meaning implies a target interval the switch will open allowing pulses to pass to the accumulator. At the end of an interval, the switch closes to stop the flow of pulses. The accumulator acts as a storage for the number of pulses which have passed through both the attentional-gate and the switch opening. The number of pulses in the accumulator represent an interval of time. Several processes then take place. Information in the accumulator is transferred to working memory. From long-term memory, a representation of a similar interval can be accessed in reference memory. Reference memory contains these representations as well as information about pulse counts that have been translated into verbal or numerical units (Block & Zakay, 2001). This access can also take place and enable a steady comparison as an interval unfolds in time. This is referred to as a *cognitive comparison*, and it is an important function when attending to and estimating durations (Block & Zakay, 2006).

Other hypotheses have been proposed in past attempts to explain the nature of processes that influence retrospective judgment of duration (Block & Reed, 1978). These are event-memory, attentional, and informational hypotheses. Event-memory hypotheses are proposed for remembered durations based on an amount of available event-type stimuli which has been stored and can be retrieved. This information is thought to influence remembered duration such that the greater the event stimuli that is accessible the longer the resulting remembered duration. This type of hypothesis found some support from work conducted by Ornstein (1969). He was one of the first to suggest that duration judgments encoded and retrieved in memory use a type of storage size to judge time that has passed.

Although the attentional-gate model is used to explain prospective timing, other research has used attentional hypotheses to explain variations in retrospective duration judgments. According to Underwood (1975; Underwood & Swain, 1973) the amount of selectivity of attentional demands can increase remembered duration of an interval. For example, the higher the attentional demands the greater the selectivity of attention, but low attentional demands can allow for more attending to the passage of time.

Informational hypotheses take the most consideration into types of information which are presented and tasks in which participants are engaged. The meta-analytic findings from Block and Zakay (1997) revealed that information processing can affect prospective and retrospective estimates differently. Using a retrospective paradigm, Vroon (1970) investigated attention and task processing in relation to duration estimation. Participants either were told to pay attention to some presented info or were told to press a button if a certain tone was played. Those asked to press a button per tone recognition, estimated a shorter duration. Also, if the number of tones was increased, remembered duration was lengthened. However, later findings by Hicks, Miller, and Kinsbourne (1976) varied temporal outlook. They also varied amount of information that was processed. The amount of information processed only influenced duration judgments in the prospective condition. The duration was experienced as shorter if participants had processed more information. These two studies present differing findings in regard to informational hypotheses.

Researchers have found that more than one type of contextual change can also affect remembered duration. One example comes from research by Block (1982), which examined changes in environmental context. These experiments manipulated environmental context by either disrupting environmental context or changing environmental context between two time durations. In both circumstances, the second of the two time periods were reported as longer in duration. This differs from what would normally be expected given time-order effects (Block, 1989). A positive-time order effect is observed when participants give duration judgments from two time periods of equal length in which the first judgment is reported as longer than the second. This is considered a robust effect (Block, 1989). This suggests that the strength of changes of environmental context are equally robust as they showed a negative time-order effect.

Block's (1985) tetrahedral model depicts a four-way interaction of variables. One of the four factors is the type of temporal behavior that is investigated. For example, these can include judgments of simultaneity, successiveness, rhythm, order spacing or duration. A second cluster of variables which make up a factor are the characteristics of the time period. These can vary substantially, but some examples include the actual duration of a time period as well as the contents of the interval. Such as, characteristics of an event for amount, complexity, sequence or cognitive processes. Yet another factor is the characteristics of the experiencer. These are fixed factors such as species and sex, but some tend to be more changeable. These for example can include personality, interests, and previous experiences. Finally, a last factor considers activities in which a participant engages in during an interval. Different levels of attending can be influenced by given instructions as well as by previously learned strategies.

Block and Reed (1978) examined several variables from the tetrahedral model. The research compared the event memory, attentional, informational, and contextual-change hypotheses. They proposed a contextual-change model, which suggests that memory for a duration is based on the overall change in cognitive context. They used a type of processing context which can be defined as changes in cognitive processing that may result in dynamic changes in internal context. The authors created several conditions using both unmixed and mixed intervals with either shallow processing, deep processing or a mixed version of shallow and deep types of processing. One dependent variable measured recognition performance for both semantic categories. Results showed that information in the deep-processing condition showed higher recognition performance than that from the shallow-processing condition. However, the remembered duration for the deep-processing condition was not different than remembered duration for the shallow processing task. Importantly, they found that in the mixed-processing condition in which there were processing context changes, the time period was remembered as longer in duration. Similar to this research, my study uses three conditions: a simple musical piece, a complex musical piece and a mixed-version simple and complex musical piece. Based on these findings regarding processing context changes, similar results are expected and the mixed musical piece should be remembered as longer in duration.

Many factors are most likely involved in retrospective duration estimation. It is important to examine these factors and the ways in which they may modulate experienced durations. Previous research has shown that there are differences in prospective and retrospective duration estimations (Block & Zakay, 1997). Therefore, it is important to examine these separately.

Musical Timing

In the time estimation literature, it is common to discuss the different effects of temporal and nontemporal information. However, it has also been suggested that musical pieces are a combination of both of these. For example, musical events can be categorized as having high coherence or low coherence. The coherence of an event can range on a continuum. The structural remembering approach originally only considered forms of attending to events (Jones & Boltz, 1989). It has also been adapted to include temporal and nontemporal coherence information (Boltz, 1992, 1995). It states that the way an event in time is remembered is defined by the environmental context, such that, retrospective memory is better when the degree of coherence is high between temporal and nontemporal information (Boltz, 1998).

A highly coherent event is one in which temporal information is highly integrated with nontemporal information. Musical timing is considered to be a highly coherent event. This is because as a pattern of pitches unfold over time it creates in the listener a sense of melody. Melody is perceived by the relationships and patterns of notes that occur, sometimes repeatedly such as a chorus, over the course of a musical piece (Krumhansl & Cuddy, 2010). The melody is also interpreted by the listener within a rhythmic context. Similar to the learning of a melody is the learning of a rhythm. Typically, different accents in note hierarchies which unfold within a piece of music are matched by accents in rhythm. In a musical piece, both rhythm and melody then provide a context in which the other can be interpreted (Boltz, 1998).

Therefore, in a highly coherent event such as music, the listener can attend to either nontemporal or temporal information. Regardless of which type of information is attended they are both integrated together such that remembering one will cue remembering of the other (Boltz, 1998). This provides a unique situation concerning time estimation in that temporal information may be remembered even if attention is not directed toward it. In a low-coherency event, there is low integration of temporal and nontemporal information. As such, memory does not cue one based off of the other and memory for these events tends to be more variable and less accurate (Boltz, 1998). In addition, memory for highly coherent events is less variable and more accurate (Boltz, 1998).

In addition, Jones and Boltz (1989) examined what they termed *dynamic attending*. Dynamic attending refers to the different ways in which an individual attends to time. Two types were proposed: Future-oriented attending and analytic attending. Future-oriented attending is used during highly coherent events such as music which have characteristic rhythmic patterns and structural predictability and which occur over non arbitrary time spans. Analytic attending is used during events with low coherence. These are events that have little structure or predictability and occur over arbitrary time spans. For example, this type of event might be participating in or completing a new task. Jones and Boltz presented evidence that temporal expectancies in regard to music and the manipulation of structurally important tones can affect duration estimates.

Ziv and Ommer (2011) studied the effect of paradigm on tonal and atonal musical pieces. Tonal music is in a pleasant key which is well known and recognized by most listeners. Atonal music does not follow any key and therefore does not create in the listener any sense of a pattern and is not typically pleasant. Their findings show that in the prospective condition tonal music is estimated shorter and atonal music is estimated longer. In the retrospective condition tonal music is estimated as longer and atonal music is estimated as shorter. However, in this study their interaction findings match the findings for the likability of music. Therefore, it is likely that researchers were examining the effect of likability on time estimation. This is an interesting finding because they used music as a stimulus and showed that music can also influence likability findings.

I propose that within a musical piece there are processing changes. These processing changes occur between notes as well as in rhythm. In the beginning of a musical piece, the melody and rhythm are not yet learned. The listener must attend to each incoming note individually until a melody is extracted. The melody is a pattern of notes which, once understood, is then recognized during the remainder of a song. The same is true for the rhythmic structure of a song. Therefore, during the beginning of a musical piece, there is more active processing of information. After learning the melody and rhythm the listener can form expectancies. These expectancies help to orient the listener as well as allow the listener to use less processing.

It is possible, that at this point the listener assumes a more passive processing of the music. However, when an expectancy is violated or changes occur in the musical piece, more cognitive control may be allocated. This will increase the amount of attentional processes used and the listener will again use more active processing which requires a higher degree of cognitive control. This idea borrows from research in cognitive psychology regarding cognitive control. Norman and Shallice discussed the idea of *contention scheduling* and a *supervisory attention system* (SAS). Contention scheduling is responsible for the scheduling action which also includes conflict resolution between competing *source* schemas. The SAS becomes active when a conflict arises. To overcome conflict, the SAS strengthens or inhibits activation which helps in the selection of schemas. The concepts of contention scheduling and the SAS have been supported by

Miller and Cohen who examined the *prefrontal cortex* (PFC) and the *anterior cingulate cortex* (ACC). Therefore, during the beginning of a musical piece these systems will allocate more control for processing of important information. As the musical piece progresses and expectancies are formed less attention is needed because there is less need for processing. When a conflict arises, such as a violation of an expectation more attentional control will be allocated for processing the musical piece.

Retrospective judgments are affected by the amount of contextual-change. Duration is estimated as longer when there is an increase in contextual-change. Specifically, processing changes are occurring when listening to music. Processing changes are remembered and affect remembered duration. Thus far, there is no evidence that processing changes affect prospective judgments. However, prospective judgments derive from a different set of processes. The attentional-gate model predicts that attention can be allocated for temporal and non-temporal information. Prospective judgments are more based on attentional allocation which is why levels of processing and cognitive load affect these estimates.

In short, different timing processes are involved when estimating duration prospectively or retrospectively. Because of these differences, it is important to use prospective and retrospective paradigms when researching duration estimation. Several models have been proposed to explain the underlying cognitive mechanisms which may be involved in duration estimation. Using music as a stimulus provides an excellent opportunity to observe processing changes in a high coherence event. Processing changes which occur in a high coherence event should be even more salient than processing changes in a low coherence event. The following research examines differences in musical complexity, specifically processing changes, and uses the two estimation paradigms across conditions.

EXPERIMENT

The current study uses a similar method to that in the Block and Reed (1978) study. Participants were tested in both prospective and retrospective conditions. There were also three experimental groups: one with a simple musical piece, one a complex musical piece and one with a mixed version of simple and complex. Harmonics were used in the complex and mixed musical pieces which added complex sound waves (Tan, Pfordresher & Harre, 2010). Following the results of the Block and Reed study, the mixed version should require more processing of contextual changes. In this condition, there was the most contextual change. The complex condition did not include any contextual change, but did include more auditory information. Thus, there was more auditory processing involved in the complex piece than with the simple piece. However, previous research has not shown significant effects of increased processing demand on retrospective judgments (Block et al., 2010). The opposite has been found in prospective duration judgments such that they tend to be underestimated due to increased processing demands (Block et al., 2010). Following in methods previously used from Jones and Boltz (1989; Boltz, 1991, 1995), musical pieces were used which were all highly coherent. There were no low-coherency conditions used in this experiment. All pieces of music were manipulated by adding harmony in a coherent fashion. I expect to find differences in prospective and retrospective estimation. I expect to replicate findings from Block and Reed (1978), but will add music as a novel extension. It will be advantageous to use music because of the high-coherency, which will make processing changes in the music more salient. This study examines music and time estimation together with a focus on processing changes in music and the affect they have on retrospective time estimation. This would provide a different explanation for findings from the music cognition literature regarding time estimation.

Hypotheses

Hypothesis one predicts that there will be a significant interaction between the prospective and retrospective paradigms and musical stimuli. In the retrospective condition, the simple and complex pieces will be judged as shorter in duration and the simple and complex in the prospective condition as longer. However, there will be no differences in duration estimates for the mixed piece, they will be similar in length for both the prospective and retrospective conditions. Previous research has found that retrospective duration judgments tend to be estimated as shorter than prospective duration estimates (Block & Zakay, 1997). Hypothesis two predicts that there will be a difference in variance for paradigm with prospective estimates having less variance than retrospective estimates. Hypothesis three predicts that in both the simple music stimulus and the complex music stimulus duration estimates will be similar with no significant difference. In several experiments, Ornstein (1969) found an effect of complexity on retrospective duration estimation such that complexity alone can lengthen estimates. However, additional research has shown this effect to be small and unreliable (Block, 1990). Therefore, a significant difference is only predicted in the retrospective condition with the mixed version of stimuli judged as longer in duration than the other two musical stimuli. Prospective estimates tend to be shortened due to the amount of processing required (Block & Zakay, 1997). However, I don't expect the music manipulation to be strong enough to affect prospective estimates across the musical conditions.

METHOD

Participants

A total of 263 participants volunteered to participate in exchange for introductory psychology course credit. Participants were randomly assigned to the experimental conditions. According to recommendations (e.g., Keppel & Wickens, 2004), 8 subjects who made duration judgments at least 2.5 standard deviations from the cell mean were deleted as being outliers; all these outliers made judgments greater than the cell mean. This left a total sample size of 255, and each of the six cells contained data from 40–44 subjects.

Materials

The music used in the study consisted of two musical pieces. These musical pieces were recorded specifically for the current studies purposes. Both pieces were in the key of C, followed a ¾ meter, and were very similar in tempo. These two musical pieces were then manipulated three different ways. Using harmonics to add complex sound waves (Tan, Pfordresher & Harre, 2010) these pieces of music were manipulated to create a simple, a complex, and a mixed simple/complex version. The style of music was folk/classical and was recorded by professional musicians in a recording studio using only a violin and a guitar. This particular style of music was used because it is not considered to be a familiar genre to Introductory Psychology students. Duration estimations were recorded immediately after the stimulus was presented to the listener.

They were recorded using seconds, or minutes and seconds. Participants reported estimates in packets which were provided by the experimenter and also answered several questions which were added to measure any possible covariates.

Design and Procedure

Participants ranged between 40 and 44 participants per condition. Each participant was exposed to one of the six treatment conditions. The two factors in a 2 x 3 factorial design were Paradigm (retrospective vs. prospective) and Music Type (simple vs. complex vs. mixed).

In the retrospective conditions, participants were instructed to listen to a piece of music that they would be asked some questions about it and did not know until the end they would be asked for a duration estimate. In the prospective conditions, participants were instructed to listen to a piece of music and that they would be asked some questions about it. They were also informed that a duration estimate would be asked at the end of the piece of music. Participants in both estimation paradigms listened to either a simple, complex, or mixed-musical piece. Two pieces of music were used for the three conditions. The simple version had only a fundamental melody. In the complex version a harmonic melody was added to the fundamental melody and played together. The mixed version alternated between the simple and complex versions. Duration estimates were collected at the end of each piece of music in each condition. Follow up questions included likability of the music stimulus, measure of music listening, and experience as a musical performer.

The dependent variable in this study was the verbal (numerical) duration estimates. Verbal estimates were made for the complex, simple and mixed pieces of music to which participants listened.

The objective duration of each piece of music for all conditions was between 59 s and 61 s. Each participant reported his or her subjective estimate following the music. Each was given a form to fill out asking for either minutes and seconds or seconds for the estimated duration.

Verbal estimation was determined to be the most appropriate measurement tool. It is commonly used when studying time estimation. In addition, when conducting studies involving time estimation, it is important to be aware of possible time-order errors. A positive time-order error occurs when the second of two duration judgments is judged as longer the first. According to Zakay (1990), both positive and negative time-order errors can occur. Positive time-order errors are robust in retrospective conditions. It is also necessary to take care that a retrospective estimate does not actually become a perceived prospective estimate (Zakay, 1990). As a result, researchers cannot take a second retrospective duration estimate from a participant. This is because the participant has perceived that an estimate will be asked of them, therefore creating a prospective condition. For the previous reasons, the current experiment only took one duration estimate from each participant. These verbal estimates were then corrected to ratios using subjective duration divided by objective duration of the musical piece. It is important to use ratio data because it is continuous, ordered, and has standardized differences between values.

RESULTS

A 2 × 3 × 2 factorial ANOVA revealed no significant main effect or interaction with music piece as the third factor, all *F*s < 1. Several factorial 2 × 3 (Paradigm × Stimulus Type) ANOVAs were then conducted. Three additional variables were examined: likability, listening, and musical performance, but no significance effect was found. Deletion of outliers from the analyses did not change the significance (or lack of significance) of any main effect or interaction factor. A series of planned comparisons (*t* tests) was conducted in order to test the three hypotheses.

Duration Judgment Ratio

The overall mean for prospective duration estimates did not differ significantly from retrospective duration estimates [$F(1, 249) = 0.96$, $p = .33$, $\eta_p^2 = .004$]. The overall estimates for musical pieces did not significantly differ [$F(2, 249) = 1.84$, $p = .16$, $\eta_p^2 = .015$]. The Paradigm × Stimulus Type interaction was significant [$F(2, 249) = 5.50$, $p = .005$, $\eta_p^2 = .042$]. This is mainly attributed to the relatively high duration-judgment ratio in the retrospective condition with mixed stimulus type. Figure 1 shows these cell means. Planned comparisons (*t* tests) showed that in the retrospective condition the mixed-music condition was estimated as significantly longer than the combined simple and complex music conditions [$t(69) = 2.591$, $p = .012$, $d = 0.62$]. They also showed that in the retrospective condition the mixed-music condition was estimated as significantly longer than the mixed music condition in the prospective condition [$t(67) = 3.032$, $p = .003$, $d = 0.73$]. In the prospective condition, marginal significance was found [$t(96) = 1.767$, p =

.08, *d* = 0.36] such that mixed-music type was estimated as slightly shorter than the combined simple and complex music conditions. There was no significant difference between simple and complex type in the prospective condition [$t(81) = 0.56$, $p = .588$, $d = 0.12$] and in the retrospective condition [$t(82) = 1.518$, $p = .133$, $d = 0.33$]. In addition, there was no difference overall between the simple and complex music types [$t(158) = 1.544$, $p = .125$, $d = 0.25$].

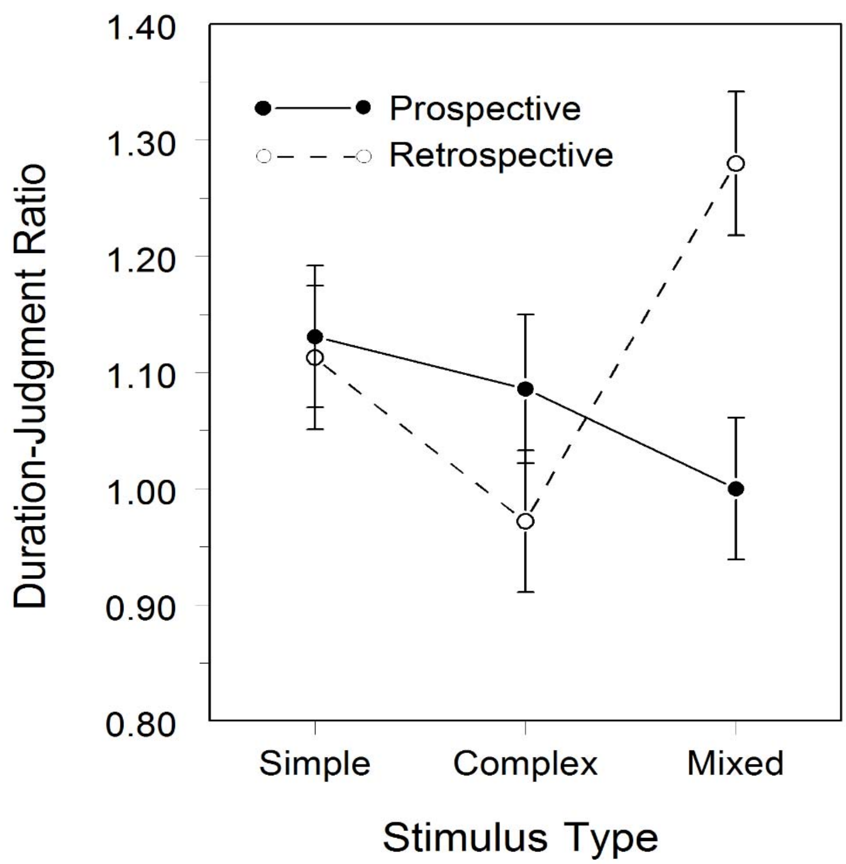

Figure 1. Overall duration-judgment ratio for paradigm (prospective and retrospective) and for musical type (simple, complex, and mixed). Error bars show the SE of each mean.

Coefficient of Variation

The coefficient of variation (CV) is an index of relative variability of duration judgments. In this factorial design it was calculated for each cell as the SD divided by the mean. The mean CV was greater for retrospective judgments (M = 0.41) than for prospective judgments (0.31). This agrees with Block and Zakay's (1997) meta-analytic findings.

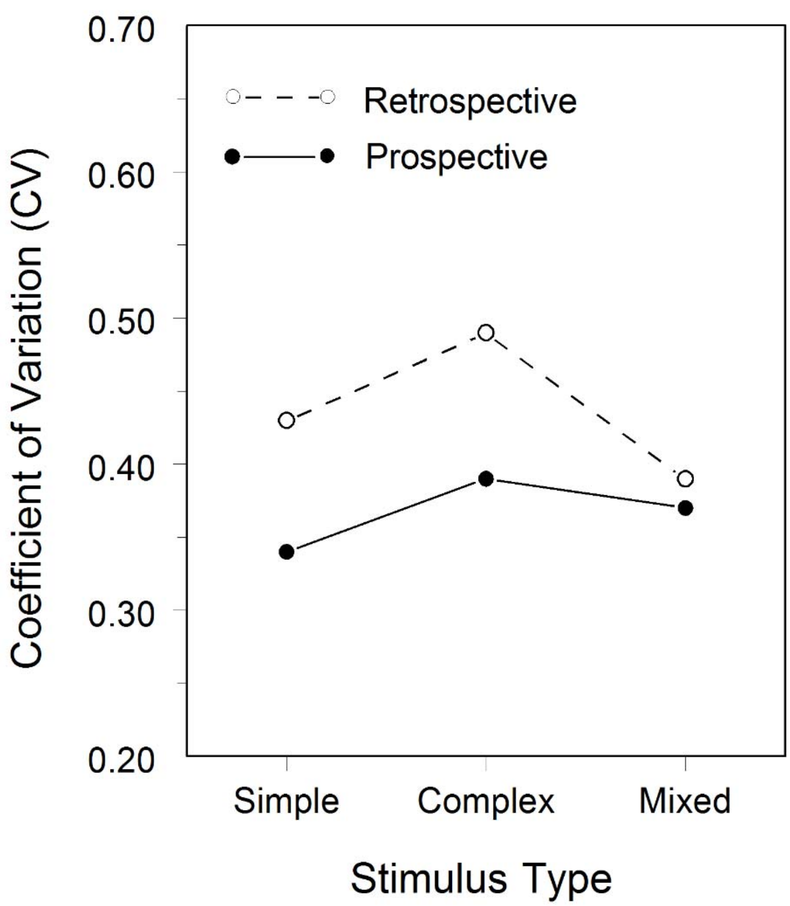

Figure 2.
Coefficient
of Variation for paradigm (retrospective & prospective) and music stimulus type (simple, complex, & mixed).

DISCUSSION

This study added additional support to previous findings (Block & Zakay, 1997) that show differences in estimation for prospective and retrospective paradigms. It also adds additional support to previous findings that show differences in retrospective estimation due to contextual-change (Block & Reed, 1978). Differences in time estimation paradigm and effects of amount of contextual-change in a retrospective paradigm have not previously been examined using a musical interval. Hypothesis one predicted that there would be an interaction between paradigm and musical pieces. This prediction was supported by the current findings. Further planned comparisons showed that there was a significant difference between mean estimates for mixed musical pieces in the retrospective and prospective paradigms. However, this finding goes beyond what hypothesis one predicted. It predicted there would be an increase in duration for the mixed musical piece in the retrospective condition which would be similar to the estimate in the prospective condition. My findings show that the retrospective estimate for mixed musical piece was actually significantly longer in duration than that of the prospective estimate for mixed musical piece.

Hypothesis two predicted that there would be a significant difference in the retrospective condition between the mixed musical piece mean estimate and that of the simple and complex musical pieces mean estimates. The current findings support this prediction. In addition, there were no significant differences between the simple and complex musical pieces as was also predicted in hypothesis two.

Hypothesis three predicted that the variance would be higher for the retrospective condition than for the prospective condition. The findings of this experiment support this hypothesis. This also agrees with Block and Zakay's (1997) meta-analytic findings. They reported differences between the prospective and retrospective paradigms in the coefficient of variance. Block and Zakay found that "retrospective judgments show about 15% greater intersubject variability than do prospective judgments." Therefore, the present study provides additional evidence for these findings. Importantly, these differences in the intersubject variability for the two paradigms suggest that different underlying processes affect experienced and remembered duration.

Processes that have been found to affect intersubject variability and estimates for experienced and remembered duration are processing load, stimulus complexity and duration length (Block & Zakay, 1997). Processing load has differential effects on duration estimation such that the greater the processing demands the shorter prospective estimates become. However, this effect is not seen in retrospective estimates; hence, greater processing demands do not always change remembered duration. This is interesting because it suggests that attentional allocation plays an important role in experienced duration, and plays little or no role in remembered duration. During prospective tasks attention can be allocated to both temporal and non-temporal information. The attentional-gate model can explain these findings (Zakay & Block, 1995; Block & Zakay, 2006). It suggests that as less attention can be given to temporal information processing, experienced duration decreases. Processing load was not systematically varied in the present study, but it is possible that some active processing was used while listening to the music pieces. Interestingly, my study found a marginally significant difference, but in the opposite direction from the retrospective test, in the prospective paradigm for the different levels of musical complexity.

The level of musical type did show a significant difference in the retrospective paradigm. This is consistent with the idea that remembered duration depends on different processes than does experienced duration: Remembered duration involves more memory processes, and previous findings point toward increases in complexity (Ornstein, 1969), changes in processing context (Block & Reed, 1978), and segmentation of high priority events (Poynter, 1983) as important moderators. There were no significant differences found between the simple and complex musical piece, which provides opposing evidence for a memory storage explanation such as Ornstein's (1969) storage-size hypothesis. A storage-size hypothesis would predict longer estimates for the complex musical piece over both the simple and mixed pieces. There were significant differences between the mixed musical piece and those of the simple and complex musical pieces. There were more changes in processing context within the mixed musical piece. This provides support for the contextual-change hypothesis and agrees with previous findings from Block and Reed (1978).

Therefore, retrospective time judgments are made based on encoded contextual information. It is thought that contextual information is encoded relatively automatically. This has been shown in previous research that examined intentional versus incidental memory encoding and found that it did not influence retrospective judgments (Block & Zakay, 1997; Block and Zakay, 2003). Thus, previous research suggests that retrospective duration judgments rely less on attention to temporal and nontemporal information and more on relatively automatic encoding of relevant contextual information.

Ziv and Omer (2011) examined differences in estimation for the two paradigms, using tonal and atonal musical pieces. Their findings showed an interaction between paradigm and musical pieces. However, their findings are also explainable by likeability. They argue that these findings do not support a contextual-change hypothesis because in the atonal music piece there was more contextual change. I disagree with this for several reasons. First, they are considering more levels of processing than processing changes in this scenario. Second, when listening to an atonal piece of music one cannot just assume that the listener is attending as much to it: A person may just stop attending to the music because it is unpleasant and there is little motivation to continue attending under these circumstances. Third, if anything there are more contextual-changes in the tonal musical piece. This is because the listener has found the melody and patterns within, which allows the listener to perceive any changes in these patterns. Also, this research presented several problems, including a small number of participants and high variance within each condition, with standard deviations greater than 0.60. Additionally, participants were asked to identify consonance and keys in the study, but the sample of subjects had no musical experience or background. This would make these questions very hard to answer. Thus, the findings could potentially be attributed to several differing variables. This experiment would have also benefited from using a duration-judgment ratio to calculate their estimate scores.

Jones and Boltz (1989; Boltz 1991, 1995) provided evidence for the importance of temporal expectancies and low versus high coherence of events. However, their research focused on temporal and nontemporal information encoding based on the coherence of events. The basic idea underlying temporal expectancy theories is that based on the coherency of an event, temporal expectancies arise. As mentioned earlier, low coherency events do not easily integrate temporal and nontemporal information. High coherency events, such as music, do integrate both temporal and nontemporal information, such that recall of one automatically brings recall of the other. Their findings, which used music with harmonic accents and unexpected endings, showed that violations of expectations influenced duration judgments. Also, Boltz (1991, 1995) showed that when using music with low coherency versus high coherency duration estimates tended to be less accurate. The current study used highly coherent musical pieces for all conditions. However, there were still significant differences found for musical complexity, specifically changes in processing context, in the retrospective condition. This may suggest that there are more processes involved in retrospective duration judgments than coherency and temporal expectancies alone. Or it may suggest there is a commonality between contextual-changes within music, coherency, and temporal expectancies. It is important to note, that the coherency of these musical events, because it was exactly the same across conditions, fails to explain differences in retrospective duration judgments in the present findings.

Further research regarding retrospective duration judgments should focus on other potential moderating variables. The tetrahedral model of contextual change as proposed by Block (1985) suggests that four factors may influence remembered durations. In addition, these factors can influence each other and a possible four-way interaction of variables can occur. Using this type of model when designing future experiments will help explain both the similarities and differences in time estimation for remembered durations.

In conclusion, my study found similar results as previous studies by using musical pieces manipulated three different ways. Two meta-analytic reviews have been conducted to examine the potential effects of prospective and retrospective paradigms as well as the effects of cognitive load on duration judgments (Block & Zakay, 1997; Block, Hancock & Zakay, 2010). These reviews showed differences in the coefficient of variation for prospective and retrospective findings and showed that cognitive load differentially affects prospective and retrospective duration judgments. Specifically, processing loads that are high or under divided attention will cause prospective estimates to become shorter and not influence retrospective estimates. However, if cognitive loads are high and involve processing context changes retrospective estimates become longer. Thus far, high cognitive loads that involve processing context changes have not been shown to have an effect on prospective estimates. The current study agrees with all of these previous findings such that differences in coefficient of variation were found and also an interaction between paradigm and musical complexity. The findings for differences in musical complexity and paradigm were highly significant. Therefore, using music to examine time estimation show similar findings as previous research that manipulated other stimuli.

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