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AN EXPECTANCY MODEL OF JUDGED DURATION: AN ECOLOGICAL PERSPECTIVE

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

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CHAPTER ONE

INTRODUCTION

An activity that we frequently perform each day, yet is one that's poorly understood is the judgment of duration. We've all had the experience of estimating how much time has elapsed since last glancing at our watches, and being mildly surprised at the accuracy of our estimate. Yet on other occasions, certain activities and events seem to induce under or overestimations of duration. Consider, for example, the illusory flight of time when absorbed in certain tasks, particularily ones of a pleasing or "fun" nature. Boredom, on the other hand, will often create an experiential "dragging" of time (Harton 1939). Consider another phenomenom that frequently occurs when listening to the radio or watching television. Here, one event such as a song or visual scene will often appear to transpire more quickly than another even though both are the same physical duration.

Why is it that we are often very accurate in our judgments of perceived duration and yet in other situations we have under or overestimated an event's duration to a significant degree? When reminiscing about the past, why do we remember some events as happening very quickly while others seem to have unfolded much more slowly? Are internal factors such as mood and interest the sole determinants of time judgments or can the physical structure of an event determine how its duration will be judged and/or remembered? Finally, is an event's duration judged the same regardless of its preceding context? These various questions have been periodically addressed in the psychological literature and in turn have generated a substantial amount of research in search of their answers.

Historical Background

Historically, the psychological study of time can be traced back to Wundt's school of introspectionism. It wasn't until much later, however, that the first empirical studies were conducted. The psychophysical approach dominated this initial attempt and investigated whether Weber's Law holds for the relationship between perceived duration and actual stimulus duration. Their experimental task simply asked subjects to report when they "just noticed a difference" between two stimulus durations. If Weber's Law holds, then the jnd between two durations is a constant proportion of the shorter of the two durations. Several researchers performed this sort of experiment and, in general, found that Weber's Law in its simplest form does not apply to time discrimination (see Allan & Kristofferson 1974 for a review). This finding later provoked others to introduce a modified version of Weber's Law which has been fairly successful in describing the experimental data (ie. Treisman 1963; Gettys 1975).

It is surprising that actual theories and models of time discrimination did not appear until the 1960's. This occurred with the advent of the information-processing paradigm. The earliest of these models were concerned with data relevant to Weber's Law and suggested the mediation of various memory stores and processing mechanisms. Both Creelman (1962) and Treisman (1963), for example, proposed "counting models" of time discrimination. Here an internal mechanism is assumed which accumulates counted pulses for a presented interval. The summed number of pulses are then stored in memory for later processes of retrieval and comparison.

As the cognitive approach evolved, however, interest began to shift from the topic of time discrimination proper to questions concerning the effects of nontemporal information upon judged duration. The most popular experimental issue to emerge from this research is known as the "filled interval effect". That is, two equivalent intervals of time are not always judged as such but are influenced by the nature of items that fill these intervals. For example, many experiments have investigated how relative duration is influenced by stimulus familiarity (Avant & Lyman 1975; Thomas & Weaver 1975), complexity (Ornstein 1969; Hogan 1975; Schiffman & Bobko 1974), number of items (Ornstein 1969; Adams 1977; Buffardi 1971), sensory modality (Goldstone & Goldfarb 1964; Goldstone & Lhamon 1974) and task difficulty (Burnside 1971; Hicks, Miller, Gaes & Bierman 1977). Although experimental findings are often contradictory (eg. Avant & Lyman 1975 vs. Devane 1974; Schiffman & Bobko 1974 vs. Poynter 1983), the common assumption is that intervals requiring greater information-processing will be experienced as longer.

Contemporary models of judged duration have been primarily developed to explain this filled interval effect. Each assumes that relative duration estimates will be affected by different information-processing demands - these models vary however in terms of what particular processing mechanism is assumed to mediate judged duration. In general, current models have proposed that experienced duration is determined by a) size of memory storage (Ornstein 1969), b) attentional effort (Underwood & Swain 1973; Thomas & Weaver 1975) or c) changes in processing strategy (Block 1978). As we shall see, no given model is preferred over the others because each lacks reliable experimental support.

Overall Plan of Dissertation

The primary purpose of this thesis is to critically examine the literature and theorizing associated with the "filled interval effect". Since this research has been influenced by the information-processing paradigm, Chapter Two will acknowledge those underlying assumptions and methodologies used in current investigations. This will be followed by a summary of the relevant literature and various processing models of judged duration. Chapter Three will then evaluate the utility of these models and point out numerous problems that exist on both a theoretical and experimental level. It is suggested that many of these problems may be resolved by adopting a different theoretical approach to perception. Chapter Four will thus consider how time research may benefit from the influence of Direct Perception Theory (Gibson 1966; 1979) and more specifically, the Rhythmic Attending Theory of behavior proposed by Jones (1976).

An alternative model of judged duration is proposed in Chapter Seven which is in fact generated from Jones' theory. It proposes that experienced duration should be investigated with "natural events" - events that dynamically change during an interval marked by a perceptible beginning and end. The basic idea is that natural events within the environment contain a hierarchical organization of spatio-temporal structure that remains invariant over transformations of change. This invariant structure can be used by a perceiver to generate expectancies about the event's future course, including when the event will end. If an event ends as expected, then duration estimates are predicted to be quite accurate. However, under or overestimations of duration will occur whenever an event ends before or after it is expected. The primary goal of subsequent chapters will be to identify some of the invariants that specify an event's end. Second, several experiments have been conducted to test whether systematic violations of these invariants can result in errors of duration estimate. The last chapter of this dissertation will then attempt to extend this expectancy-based model to other areas of time research.

Let us start at the beginning, however, and examine the current status of research addressing the problem of judged duration.

CHAPTER TWO

SOME INFORMATION PROCESSING THEORIES OF JUDGED DURATION

In his 1962 book, The Structure of Scientific Revolutions, Thomas Kuhn has elegantly described how any area of scientific pursuit is guided by an underlying "paradigm". A paradigm provides an organizational framework for researchers by specifying a set of unifying assumptions and appropriate methodologies for the study of interest. This, however, only characterizes a paradigm during its "normal state". The accumulated data will eventually begin to display anomalies, initiating a "revolution" in which the old paradigm will be replaced by a new one. It is only through alternating periods of normal and revolutionary science, according to Kuhn, that our understanding evolves and expands. In the investigation of human cognition, for example, the Behaviorist paradigm was ousted around thirty years ago and replaced by the current paradigm known as the Information-Processing Approach. Its underlying assumptions have guided contemporary research on judged duration and determined the sorts of experimental strategies that are to be used. The purpose of the present chapter is to make these assumptions and methodologies explicit. This may later help us to identify the source for any conflicting experimental findings. The assumption of most relevance here is that of mediated perception which in turn implies a number of corollaries.

General Paradigmatic Assumptions of the Information-Processing Approach

In its general attempt to explain the activities of perceiving and knowing, many information-processing theories assume that the human mind operates in the manner of a computer and manipulates internal representations of reality (Neisser 1967; Miller, Galanter, & Pribram 1960; Newell & Simon 1972). Objects and activities within the environment presumably cannot be perceived in their natural form. According to several perception theorists, this stimulation contains discrete features that are inherently unorganized and meaningless (Rock 1975; Gregory 1966; Kaufman 1974). Hence, meaningful perception can only occur after the environment has been "processed" by a series of mental or mediational devices. The function of mediational devices is to transform the environment into meaningful information and this is accomplished through processes of filtering, pattern recognition, recoding, and elaboration. The end products of mediational activity are mental codes which can be stored in any one of many hypothetical memory systems. Mental codes are considered to be the referent for an organism's behavior because they presumably reflect "reality" more reliably than the original environment itself.

It has been claimed that the various mediational processes proposed by some information-processing theories operate in terms of "discrete sampling" (Turvey 1977; Michaels & Carello 1981). That is, information-processing activities initially reduce environmental contents to fundamental features and chunks and later redintegrate these chunks to achieve coded referents of behavior. Although environmental stimulation is considered to be continuous, the mental codes which represent this stimulation are constructed through discrete stages of processing activity.

This notion of discrete sampling can be best illustrated by considering the classic multistore approach to memory (Atkinson & Shiffrin 1968). According to this view, attentional activities of filtering (Broadbent 1958; Treisman 1964) or resource allocation (Posner & Boies 1971) initially register an environmental stimulus into a sensory memory system. The contents of sensory memory are very brief in duration (ie. 250 ms to 5 secs) and quite faithfully represent the original environmental stimulus. However, these sensory memories do not acquire meaning for an organism until after a process of pattern recognition has occured. Here, stimuli are reduced to a set of features which are then compared with contents of long-term memory. If feaures of this new stimulus match with those previously enountered, then the stimulus has acquired some meaning and may be transferred to short-term memory. The representation of the stimulus now acquires an acoustical format and consists of "chunks" (ie. the largest unit of meaning) that exist for a limited duration (30 secs). Assuming that forgetting does not occur, the mental code corresponding to the original stimulus is finally transferred to a long-term memory. This code is typically semantic in nature and can be manipulated much in the same way a computer manipulates its input. For example, codes can be elaborated or associated with others to enhance meaning, transferred among different memory systems, and retrieved from memory to mediate the response for any given task or activity.

It is also assumed that some coded representations of world events are more "complex" than others (eg. Vitz & Todd 1969; Garner 1962). Code complexity can be defined in a number of ways, including how much memory space the code consumes, the degree of attentional effort it has expended, or the number of different processing strategies it has engaged. Regardless of how it is defined, complexity is assumed to have signifiant effects upon an organism's behavior and performance level (Newell & Simon 1972; Neisser 1967).

In summary, the information-processing paradigm assumes that organisms behave relative to coded mental representations of environmental stimuli. Within some theories, the mediational activities which produce these codes can be characterized in terms of discrete sampling because environmental stimuli are initially reduced to features and chunks, transferred among separate memory stores, and then redintegrated in their final representation. These general paradigmatic assumptions in turn have influenced many contemporary models of judged duration. What are the specific assumptions of these models and how is the process of judged duration considered to occur?

Assumptions of Contemporary Models Addressing Judged Duration

Within the current literature, the most influential models of judged duration all reflect the general paradigmatic assumption of mediation. Environmental stimuli are presumably processed by discrete stages of mediational activity and are subsequently represented in terms of a mental code. When asked to judge the duration of a stimulus, it is further assumed that a perceiver must _infer_ this estimate from the amount of information-processing that has occurred. Some stimuli are more complex than others because they are either unorganized or contain a greater number of items at the time of presentation. Since complex stimuli require greater information-processing, they will be experienced as longer in duration relative to more simple stimuli which require less information-processing. Judged duration is therefore determined by internal mediational activity which is only _indirectly_ related to the original environmental stimulus itself.

Individual models disagree on what particular mediational activity should be used as the referent for both complexity and duration estimates. In general, these models can be classified into three categories - those that focus on a) storage size, b) attentional or processing effort, or c) cognitive change. Models within the first class (eg. Ornstein 1969) assume that complexity is reflected by the amount of memory storage that a coded stimulus consumes. Experienced duration is thus inferred from the retrieved contents of mental stores and the amount of information retained in memory. The second class of models assume that complexity and judged duration are determined by the amount of expended attention or processing effort associated with a given stimulus (Underwood & Swain 1973; Thomas & Weaver 1975). Lastly, cognitive change models assume that the number of processing changes will determine both complexiy and duration judgments (Block 1978). Each of these models will be shortly discussed in considerably more detail along with the sorts of experiments typically offered as support.

One other assumption underlies at least one of these models just mentioned (ie. Ornstein 1969). It is this: different types of time experiences are considered to be mediated by different memory stores. Apprehension of present time, the experience of "nowness", is derived from short-term storage while the experience of past time is derived from long-term storage (Ornstein 1969). These two types of time experiences may not always correspond for the same interval of stimulation since elaboration and enrichment processes can occur at later stages. For instance, a boring task often seems long in passing but short in retrospect. Conversely, activity that is fun or interesting often seems to transpire quickly but appears long in retrospect (Harton 1939). Presumably the reason for these discrepancies in past time is that interesting experiences have a more enriched and stable memorial representation than boring experiences and hence contain more information on which to construct a time estimate.

To summarize, the models of judged duration that will be considered here can be characterized by three major assumptions:

1) Judged duration is determined by the amount of information processing that has occurred for a given stimulus

2) Complexity, which is differentially defined by various models,

serves to lengthen duration experience

3) Different memory stores mediate different time experience.

These assumptions in turn have determined the sorts of tasks and experimental stimuli that are considered appropriate for studying duration judgments. In the next two sections, we'll respectively consider the nature of experimental stimuli and the methodological context in which they're presented.

Experimental Stimuli Used in Relative Duration Tasks

According to current models, perceivers do not judge the duration of an interval relative to its actual passage in "clock time" - instead judgments are inferred from the amount of informaton processing that has occurred for that given interval. The most common research strategy then is to assess the relative duration of two intervals that differ in their degree of information-processing or "complexity".

Earlier we noted that many perception theorists regard environmental stimulation as being fragmented, unorganized, and meaningless (eg. Rock 1975; Gregory 1966). The selection of experimental stimuli in judged duration tasks often reflects this assumption. For example, subjects have been asked to compare time intervals that are filled with abstract line drawings (Ornstein 1969), lists of words or nonwords (Block 1974; Poynter 1983; Thomas & Weaver 1975), spatial arrangments of static lines (Schiffman & Bobko 1974) or series of auditory clicks (Adams 1977). The complexity of these stimuli is typically defined by the number of items within a time interval (number of words, lines, or visual angles) or how these items are arranged (randomized or blocked presentation). Although these stimuli are of the same physical duration, their perceived duration will presumably lengthen or shorten depending on how much cognitive processing has been required.

Methodological Procedures

In terms of the task situation in which these experimental stimuli are presented, there have been a variety of methods used in the study of judged duration. As Allan (1979) points out, many of these, such as the verbal estimation and production methods, have fallen into disuse because they require subjects to judge duration relative to real clock time. Current research tends to favor the reproduction and comparative judgment techniques since the goal is to determine how the experienced duration of one interval compares, not with clock time, but with an interval that is more simple or complex.

In the method of reproduction, subjects are presented with a stimulus of some given complexity and are then required to reproduce its duration. A comparative judgment task, on the other hand, requires subjects to decide which of two successively presented intervals is longer or shorter. One variation of this technique is known as the method of magnitude estimation. In this sort of task, subjects are given a line length to represent the duration of some initial interval and must then demarcate a second line to indicate the relative duration of a second interval. A value of judged duration is then obtained by assessing the ratio of the two line lengths.

In conjunction with these general methodologies, a "prospective" or "retrospective" technique is also used to study either present or past time. In the prospective paradigm, subjects are instructed before the experiment that time judgments will be required while in the retrospective case, time judgments are taken incidentally after subjects have performed some other task. The prospective method, then, is assumed to reflect the perception of a time period while the retrospective technique has been suggested to reflect the remembering of that interval. The particular models of juded duration that we'll be considering have primarily relied upon the retrospective technique for experimental support. Regardless, the assumptions of these models are proposed to have implications for both the perception and memory of duration experiences.

The information-processing models that are presented in the following section all share the general assumptions and methodological tools that have been reviewed here. Let us now examine the specific phenomenom that these models address - namely, research on the filled interval effect.

Models of Judged Duration and the Phenomena They Address

As the cognitive approach shifted away from issues of absolute thresholds and Weber functions, it became apparent that nontemporal aspects of an interval could influence performance in tasks involving judged duration. This phenomenom became known as the "filled interval effect" and revealed that two equivalent time intervals are not always judged to be equal. Instead, time judgments are affected by the complexity, content, and familiarity of items that fill the time interval. Many of these early experiments were conducted without the guidance of any particular time model, creating a body of literature that was more descriptive than explanatory. Only later was this literature incorporated by various models which attempted to specify the underlying cognitive processes of judged duration. In the following sections, we will first summarize the general experimental literature addressing the filled interval effect. Next we'll discuss some particular models of judged duration that have been influenced by the information-processing paradigm.

The Filled Interval Effect

In one of the earliest experiments, Goldstone & Goldfarb (1963) found that a filled interval (consisting of a constant persisting tone) is judged longer than an empty interval (defined by two click boundaries) of the same length. Others have replicated this effect and shown that an interval filled with discrete intervening elements is judged longer than an empty one - judged duration increasing with the number of intervening events (Adams 1977; Thomas & Brown 1974). In general, these findings suggest that experienced duration lengthens with more stimulus information. This intepretation has been questioned, however, by experiments which report an opposite finding. Using the retrospective technique at intervals longer than one second, an empty interval is often judged longer than an interval filled with some sort of cognitive task (Burnside 1971; McKay & Timothy 1977).

Other researchers have investigated how the particular arrangement of filler items may differentially affect judged duration. In an early experiment conducted by Brown & Hitchcock (1965) it was found that auditory intervals containing events that alternate between two intensities or frequencies are judged comparatively longer than constant filled intervals. Poynter (1983) has recently extended these findings. He reports that salient words (ie. Presidential names), placed at regularly recurring locations within a list of unrelated words, result in longer duration judgments than when the salient words are all clustered at the beginning of an interval. However, an experiment performed by Schiffman & Bobko (1974) provide conflicting results with the use of the reproduction method. They find that if eight discrete lines are spatially arranged in an orderly, predictable fashion, the interval is reproduced as shorter than if the lines are more haphazardly arranged.

The effects of stimulus familiarity has also been examined but again results are inconsistent across different experiments. Avant & Lyman (1975) report that a three-letter word is judged shorter than a three-letter nonword. Devane (1974), on the other hand, finds that familar words are judged longer than unfamilar words, while Thomas & Weaver (1975) demonstrate no difference between the two. In each experiment, however, words or nonwords were judged longer than the presentation of a blank field. Avant & Lyman (1975) suggest that these inconsistencies may be explained by the total duration of an event. At short intervals, familarity may be the most salient aspect on which to base judgments but at longer durations, other cognitive activities and stimulus properties may become more important.

Lastly, several experiments have investigated the effects of task difficulty upon judged duration. Burnside (1971), for example, asked subjects to perform various mathematical tasks that differed in their level of difficulty (ie. reading numbers vs. multiplication). When later asked to reproduce the time interval in which a task was performed, subjects judged the more difficult tasks as shorter in duration. Although others have replicated this finding (eg. Hicks, Miller, and Kinsbourne 1976; Hicks, Miller, Gaes, & Bierman 1977), many experiments have provided contradictory results (Block & Reed 1978; Underwood & Swain 1973).

In summary, the existing literature on the filled interval effect has failed to provide any reliable findings. Experimental manipulations of stimulus arrangement, familiarity, task difficulty, and stimulus "emptiness" have all yielded conflicting results. Some of these inconsistencies may arise from the usage of different durations, tasks and techniques across different experiments. Later I'll illustrate how these inconsistencies may also be due to imprecise definitions of complexity and usage of artificial stimuli.

<u>Three Information-Processing Models of Judged Duration</u>

Many of the current theories of time perception have been offered in response to these general findings on the filled interval effect and the role of nontemporal information upon judged duration. All assume that a filled interval is judged longer than an empty one because the former is more complex and therefore requires more information processing. A major goal of these models, however, has been to extend this concept toward explaining why <u>two filled intervals</u> of the same duration are differentially judged. As mentioned earlier, these models can be categorized into those that emphasize the mediation of storage size, processsing effort, or cognitive change. Let's consider each in turn along with the sorts of experiments they have generated.

<u>Storage Size Models</u>

In her 1959 dissertation, Frankenhauser proposed the notion that:

> "The experience of a certain duration is related to the total amount of experience (sensations, perceptions cognitive and emotional processes, etc. which takes place within this time period, in short, the <u>amount of mental content.</u> (p. 14)"

Ten years later, Ornstein (1969) combined this concept of time with the structural model of information-processing (ala Atkinson & Schiffrin 1968) to develope the "Storage Size Hypothesis" of time perception. According to this model, estimates of time depend upon the amount of information retained in short-term memory (for estimates of present time) or in long-term memory (for estimates of past time). In addition, the more chunks of information retained in storage the longer the time judgment. Filled intervals create a longer temporal experience because their codes not only are more "complex" and contain more chunks of information to process, but require organization during the encoding process. As support for these claims, he has conducted a series of experiments using the magnitude estimation task in conjunction with the retrospective technique.

In some experiments, Ornstein investigated the effects of complexity on judged duration. He hypothesized that a more complex stimulus would require more storage space in memory and would therefore result in a longer time estimate. Complexity was defined in some experiments as an increased number of angles within figure drawings while in others, it was defined as a randomized (vs. blocked) presentation of auditory or visual sequences. Using time intervals ranging between 30 secs. and 10 mins., his results showed that experienced duration increased with greater stimulus complexity, but only up to a certain point. This point was assumed to be a type of ceiling effect where no further information could be stored or processed and hence serve to further lengthen duration experience.

In another set of experiments, Ornstein tested the assumption that coding processes affect judged time. One experiment, for instance, reasoned that a person responding automatically to a situation is less aware of the stimulus array, and should therefore experience less duration than a person not responding automatically. To test this notion, subjects were trained to different levels of automaticity in a pursuit rotor task. They were then asked to compare the duration of this motor task to an equivalent duration of auditory stimulation. Subjects achieving levels of greater automaticity judged the motor task as being shorter, presumably because they could attend to less of the motor situation.

For several years, Ornstein's model was immensely popular since it appeared to handle the filled interval data quite well. As additional research accumulated, however, conflicting findings caused several investigators to question the validity of the Storage Size Hypothesis. Using Ornstein's methodology, Block (1974) for example reported that a sequence of word blocked by semantic category was judged to have a greater duration than a random arrangement of the same words. Since a random arrangement presumably contains more chunks of information than a blocked one, this contradicts Ornstein's model. Poynter (1983) found a similar result: word sequences segmented by salient words were judged longer than more complex, unsegmented sequences. Block (1974) suggests that Ornstein's notions of complexity and storage size are too simplistic and can be reintepretted in terms of a cognitive change hypothesis that will be discussed shortly.

Processing Effort Models

Another major criticism of Ornstein's model derives from Underwood & Swain's (1973) claim that the role of attention is ignored. Although Ornstein does suggest that increased vigilance causes more information to reach storage and that this results in lengthened time judgments, Underwood & Swain correctly point out that this isn't necessarily true. Increased selectivity of attention may not always result in a greater amount of information being retained in memory but rather can involve the processing of a narrower range of information. They suggest that nonselective attention incorporates a broader range of varied stimulation and could, in fact, result in more informational "chunks" being retained in short-term storage. By this rationale, then, Underwood & Swain argue that duration judgments are determined by the degree of processing effort (or selective attention) that a subject expends - greater effort or selectivity leading to longer time judgments. Items containing more chunks of information are judged longer because they require greater attentional effort - not because they consume more storage space in memory.

To justify this claim, Underwood & Swain (1973) conducted an experiment where selective attention was varied independently of information content. Subjects were asked to detect target digits embedded in prose passages that were partially masked by varying intensities of white noise. Upon completion of the detection task, subjects were unexpectedly asked to judge the relative duration of each passage in a magnitude estimation task. Those passages masked by a high intenity noise, thus requiring greater selective attention, were judged longer than those masked by a low intensity noise. Since detection levels indicated that <u>less</u> information was picked-up in these high intensity masked passages, Ornstein's Storage Size Hypothesis is cast into serious doubt.

Thomas & Weaver (1975) provide additional evidence for the claim that processing effort affects judged duration. In their experiments, subjects were first trained to discriminate among short (20 ms), medium (60 ms), or long (100 ms) blank fields. Forty and eighty millisecond stimuli were then flashed that consisted of three letter words or nonwords, or an empty interval defined by two click boundaries. The subjects' task at this point was to identify each stimulus as being long, medium, or short. Results indicated that verbal stimuli were judged longer than empty intervals, and in conditions requiring subjects' to additionally memorize stimuli, the filled vs. empty interval difference increased. Thomas & Weaver (1975) explain such results in terms of a dual cognitive process in which temporal information is obtained from a timer (an f processor) and a visual information (g) processor. The output of the f timer is a temporal encoding of the stimulus duration while the output of the g processor contains an encoding of the nontemporal stimulus features and an encoding of the time spent processing, I. Attention is shared between the f and g processors such that the output of the f processor becomes more unreliable as the g processor captures more attention. When I is large, due to filled intervals or memory demands, the f processor registers an estimated duration that is longer and more variable than when I is small (empty intervals). According to this approach then, judged duration depends on I or the amount of processing time. In contrast to the longer durations used by Ornstein, Thomas & Weaver caution that their model only applies to durations less than 100 ms.

There are other attentional models of judged duration that we have not yet considered. These models generally assume that experienced duration is determined by the amount of attention directed toward the passage of real time (eg. Priestly 1968; Zakay, Nitzan & Glicksjohn 1983). That is, the actual physical duration of a stimulus is presumably recorded by a cognitive timer and estimates are based on how much "real time" has been registered. Since this timer must compete with other cognitive mechanisms for the allocation of attention, more temporal duration will be recorded when other information loads are reduced. To test this model, subjects are asked to perform concurrent tasks that vary in their level of difficulty. Several experiments have in fact reported that "longer" estimates are obtained for easier tasks - presumably because more attention is directed toward actual physical duration (Burnside 1971; Hicks, Miller, & Kinsbourne 1976; Zakay, Nitzan & Glicksjohn 1983).

Although these models generate an opposite pattern of experimental results, comparisons with the previous set of models must be made with caution. In particular, the "cognitive timer" models investigate the duration of intervals filled with cognitive tasks. Conversely, those models proposed by Thomas & Weaver (1975) and Underwood & Swain (1973) examine the duration of intervals filled with environmental stimuli (ie. words, nonsense words, and clicks). The former situation requires a subject to be more actively involved during a given interval of time. It is therefore difficult to conclude whether judged duration is a function of information processing load or whether it depends on the degree of active participation. Although empirical investigations are needed to resolve this issue, there is one existing study that provides some interesting insight. Specifically, Vroon (1970) has shown that experienced duration is shortened with greater cognitive loads (ie.

increasing speed of stimulus presentation), but only if overt responding is required. If no overt activity is required, then greater amounts of information result in longer duration estimates.

In summary, the two classes of attentional models reviewed here are based on different underlying assumptions. Models proposed by Underwood & Swain (1973) and Thomas & Weaver (1975) both assume that duration estimates are determined by the amount of information processing time. The presence of nontemporal information requires more attentional effort which serves to lengthen experienced duration. The cognitive timer models, on the other hand, propose that judged duration depends on how much "real time" has been registered by the organism. Nontemporal information will shorten duration estimates because it directs attention away from the actual physical duration of a stimulus. These latter models will not be considered again because they are only concerned with the effects of cognitive tasks upon judged duration. They do not address the duration of intervals filled with environmental stimuli - which is in fact the topic of this dissertation.

<u>Contextual Change Models</u>

Richard Block has provided a number of studies that are inconsistent with both the storage size and processing effort models of time perception. He suggests that the bulk of time research can be explained by a contextual change hypothesis (Block 1978; 1984). His basic assumption is that experienced duration depends on the amount of change in cognitive context occurring during a given time interval.

Judged duration presumably increases when stimulus or task characteristics create changes in processing strategy. These changes are monitored by an internal cognitive device which later outputs the code complexity for any given time interval.

To contrast the validity of the storage size, processing effort, and cognitive change hypotheses, Block & Reed (1978) conducted a set of experiments where subjects were asked to process a list of words to different depths of processing. For example, some subjects were first asked to judge the typing style of words (ie. a shallow task) and then to categorize a different set of words into various semantic categories (ie. a deep task). Afterwards, all subjects were unexpectedly asked to compare the duration of one task relative to the other. Their results showed that a task processed at a deep semantic level was not remembered as longer than one processed at a shallow level, even though the semantic task should have entailed a greater storage size and processing effort. A second experiment again asked subjects to perform two tasks - but here they were required to process words at alternately deep and shallow levels followed by a task that required a single level of processing (deep). When asked to compare the duration of these two tasks, it was found that the one involving alternate processing was judged longer than the one involving a single level of processing. Since the latter task of deep processing should have resulted in greater processing effort and storage size, theories such as those of Ornstein and Underwood, etal. cannot easily account for these results. The contextual change hypothesis, however, argues that a unique cognitive context is associated with each type of information-processing task. When different tasks are performed, changes in cognitive context and processing strategy result in longer time estimates.

The mediational device that monitors change apparently is also sensitive to changes in environmental context. In one experiment that illustrates this, Block (1982) required three groups of subjects to process a list of words during two 150 sec. sessions. While holding the type of cognitive processing constant, he then varied the environmental context that occurred between the two sessions. Those subjects that were moved to a different room for the second session judged this session as being significantly longer than the first. On the other hand, those subjects who merely left and then returned to the same room perceived the second session as being only slightly longer, while those who remained in the same room perceived no duration difference at all.

These sorts of experiments do support Block's model. However, a problem with this approach is that we are never told how the cognitive change monitor operates. In addition, Block is also vague on how such a hypothesis accounts for the traditional literature on the filled interval effect. Poynter (1983) has recently offered some insight into this latter issue. According to his elaboration of Block's model, filler items within intervals act as referent markers in the segmentation of temporal experience. A filled interval therefore seems longer than an empty one, not because of the amount of information in storage or processing effort, but because fillers create referent codes in memory from which to reconstruct the duration of events. Similarly, an interval containing more chunks will be judged longer than one containing fewer chunks. An increased number of chunks will create more codes or points of cognitive change which are monitored by the presumed cognitive device. In a later publication, Poynter & Homa (1983) conclude that:

> "The duration perception mechanism appears to log time by detecting changes in sensory states (which correspond to changes in physical states of the environment) and organismic states (which corrrespond to changes in the cognitive or physiological environment) (p. 559)"

Chapter Summary

In summary, the present chapter has reviewed the underlying assumptions, methodologies, and issues within contemporary research on judged duration. The guiding tenets of the information-processing paradigm assert that knowledge of the environment is represented in terms of mental codes. These codes are constructed through discrete stages of mediational activity and function as the referents for an organism's behavior. The models of judged duration that we have considered have further assumed that duration estimates are determined by code complexity or the amount of information processing that has occurred for a given stimulus. Intervals that require greater mediational activity are experienced as longer than those requiring less mediation. Specific models, however, differ in the proposed referent for judged duration. Some claim that a perceiver bases her judgment on the amount of information in memory while others believe that the degree of attentional effort or cognitive change is important. How successful have these models been? Models emphasizing memory storage (Ornstein 1969) and attentional effort (Underwood & Swain 1973; Thomas & Weaver 1975) lack experimental support and have yielded conflicting experimental findings. Block's model of cognitive change appears somewhat more successful than others in this respect. However, his model lacks predictive power because he never clearly specifies when a change in processing strategy will occur. Further, we don't know what processes and operations are used by the hypothetical construct which monitors change. In short, the existing literature can be characterized by divergent results and the lack of any one superior model.

As Kuhn (1962) has suggested, the anomalous nature of any scientific area may stem from inadequacies in the underlying paradigmatic assumptions. The next chapter in fact will evaluate some of the consequences and problems that the mediational assumption has wrought on the study of judged duration. We'll first consider whether this assumption has implied a correct description of the environment and its contents. Second, we'll explore the concept of a mediated code in terms of its implications for parsimony and precision of experimental variables. The purpose of this analysis is to argue that an alternative approach to the study of time is warranted - one that is more parsimonious yet one that will paradoxically incorporate issues that were previously ignored. After determining what sorts of pitfalls should be avoided, we can then begin to develope the framework for our new alternative perspective.

CHAPTER THREE

EVALUATION OF THE INFORMATION - PROCESSING MODELS OF JUDGED DURATION

In the previous chapter, we noted that the contemporary literature on the filled interval effect is highly contradictory in nature. Manipulations of stimulus arrangement, familiarity, and complexity have all yielded conflicting results. Particular models of judged duration also display numerous problems. Experimental support is often unreliable and the predictive power of these models is generally weak. The present chapter considers how many of these problems may arise from the paradigmatic assumption of mediated perception. This assumption asserts that various mental processes must occur before a perceiver can obtain a coded representation of environmental stimuli and their temporal durations. Earlier we claimed that these processes can be characterized in terms of "discrete sampling" because the construction of mental codes involves discrete stages of processing. How useful are these assumptions and what are their implications for time research?

First, the notion of discrete sampling may imply an incorrect description of environmental objects and activities. This in turn may encourage the usage of artificial stimuli in tasks of judged duration. The main point of contention here is whether the environment is inherently organized or unorganized and what sorts of stimuli should be compared for relative duration. Next we'll consider how the assumptions of mediation and discrete sampling seem to imply an asymmetrical relationship between a perceiver and her world. It will be suggested that this perspective is not only unparsimonious but creates inprecision in operational definitions of complexity. Lastly, we'll note that although current models have provided an account for both present and past time, they have ignored any concept of future time. That is, it may be the case that the expected outcome of an event, which has not yet occurred, can nevertheless influence the judgment of duration. To address these problems, we'll broadly outline some alternative assumptions for the study of judged duration.

Implications of the Discrete Sampling Assumption for Current Time Research

Description of the Environment

In our earlier review of the information-processing approach, recall that several contemporary theories of perception (eg. Rock 1975) envision the environment as inherently unorganized and meaningless. Its objects and activities presumably contain a set of discrete features or chunks that lack interrelationships and inherent meaning. The existence of various mediational mechanisms is therefore postulated so that environmental stimulation can acquire meaning and organization for a perceiving organism. These cognitive devices extract the features and chunks from a stimulus and later concatenate them into a coded representation of reality. These codes function as the referents for behavior because they provide a more reliable basis for knowledge than the original environment itself.

The temporal duration of an environmental stimulus is conceived in an analogous fashion. The discrete sampling assumption has implied a _linear_ concept of time. That is, the environmental flow of events is conceived as a series of discrete moments that lack interrelationships. These discrete moments are physically independent except for immediate adjacencies. Although these same moments may be later perceived as a continuous time interval, this perceived duration has only resulted from cognitive integration and imposed organization.

Let's briefly consider the description of the environment as envisioned by an alternative approach to perception. According to theorists within the Direct Perception Approach (eg. Gibson 1966, 1979), information-processing theories have incorrectly described the environment. They argue that the organization and meaning of objects exists within the environment itself. This organization is hierarchical in nature such that spatial components of objects are all intrinsically interrelated. Further, they correctly note that environmental objects are rarely static - they change over a time dimension. These changing objects are termed _events_ and it is assumed that these changes in spatial structure maintain a lawful organization. As Jones (1976) notes in a Rhythmic Attending Theory, events also contain a hierarachical organization of temporal structure that similarly changes throughout the course of an event. According to this view, then, environmental stimuli do not acquire organization through cognitive concatenation - instead, events themselves contain interrelated levels of spatio-temporal change. Similarly, the meaning of objects and events is also assumed to exist within the environment. Since organisms have evolved relative to the environment, meaning is characterized in terms of the survival or cultural value that an event offers. This meaning arises from the evolutionary relationship between a perceiver and her environment and is not something that is mentally inferred.

From the perspectives of Direct Perception and Rhythmic Attending Theories, a perceiving organism is assumed to be sensitive to the inherent relationships within environmental events and does not need to "construct" mental codes of reality. By eliminating the constructive phase of perception, these theoretical views have thus achieved greater parsimony. It is important to realize, however, that both Gibson and Jones do not entirely dismiss the role of inference and cognitive construction in organismic behavior. The activites of thinking, planning, and remembering all involve processes of inference and cognitive integration. These mediational processes in turn provide new information and knowledge to the organism without input from the environment. The issue to which these theorists object to is that the activity of <u>perceiving</u> involves a cognitive construction of discrete features.

Given this alternative viewpoint, it no longer seems appropriate to refer to environmental objects and activities as "stimulation" - they are more appropriately termed "events". To summarize, these natural events are assumed to contain:

a) evolutionary meaning for perceiving organisms

b) an inherent organization of spatio-temporal structure and

c) structure that dynamically changes during an interval marked by a perceptible beginning and end

Let's now consider how the description of one's environment may influence the choice of experimental stimuli in tasks of judged duration.

Nature of Experimental Stimuli

Within in our natural environment, we routinely perceive and interact with people performing a variety of activites that include walking, speaking, running, and so on. Similarly, we deal with a host of inanimate objects that either change on their own accord or can be changed through manipulation. In each case, the events or activities unfold over a time span that has a clear beginning and end. Further, each event is somehow evolutionarily significant because it either has survival value or value in terms of psychological coping. As we noted in the previous section, these events also contain multiple levels of interrelated structure that usually change with some sort of temporal regularity.

In situations where we perform duration estimates, estimates normally refer to the kinds of natural events that we have just described. For example, we may judge how long it will take to walk or drive somewhere or how two lectures contrast in their experienced duration. To study the activity of judged duration, it therefore seems logical to employ natural events in laboratory investigations.

Contemporary research, however, has tended to rely upon artificial stimuli.

In the research that we reviewed in the previous chapter, we saw that time intervals were typically "filled" with abstract line drawings (Ornstein 1969), series of auditory clicks (Adams 1977), lists of words or nonwords (Block 1974; Poynter 1983) or spatial arrangements of static lines (Schiffman & Bobko 1974). These types of experimental stimuli differ from natural events in several important ways. First, the evolutionary significance of stimuli is often ambiguous since the clicks and lines that we normally encounter do not occur within an isolated context. Second, stimuli have no definitive beginnings and ends as do natural conversations and visual scenes. Third, notice that these stimuli do not possess interrelated levels of spatio-temporal structure. Stimuli are often unidimensional and do not always change over a space-time dimension. Indeed, static objects are often presented for a given time interval. The presentation of static, unidimensional stimuli does not reflect the possibility that changes in structural levels may affect attending and judged duration. In short, one has to wonder whether the results obtained with such stimuli do in fact generalize to real world situations. Are the processes assumed to mediate judged duration mere artifacts of the laboratory situation?

Within contemporary research, the theoretical justification for employing such stimuli stems from the notion of discrete sampling. Since environmental objects presumably contain a set of discrete and unrelated features, it is considered appropriate to use <u>components</u> of environmental events as experimental stimuli. The rationale is that once the perception of these components is understood, the cognitive psychologist is then in a better position to investigate events containing multiple levels of structure. The irony of this reasoning is that the perception of natural events has become secondary to the understanding of artificial events. It also suggests that the paradigmatic assumption of an arbitrary, unorganized environment, which mediational mechanisms serve to enrich, may arise from the arbitrary nature of experimental stimuli.

The model of judged duration that I will later develop relies upon ecologically valid stimuli. By "ecologically valid" stimuli, I mean stimuli that a) are familiar and normally encountered within the environment, b) contain interrelated levels of structure that dynamically change, and c) possess a surrounding context with a perceptible "beginning and end". In the area of time research, then, an experimenter might ask subjects to compare the duration of two melodies, prose passages, or filmed visual scenes of naturally occurring activities. To understand the activity of judged duration as it occurs within the natural environment, the events involved must be ecologically valid.

To summarize, the assumption of discrete sampling has implied that environmental objects are inherently meaningless and unorganized. Conversely, several theorists have argued that this description is incorrect (Jones 1976; Gibson 1966; 1979). By analyzing the structure of the environment, they've been able to describe its objects and activities in terms of inherent organizations of hierarchical structure. These descriptions in turn have provided a definition of environmental events that replaces the notion of environmental stimulation. These contrasting descriptions of the environment have also been shown to result in a very different choice of laboratory stimuli.

In the next section, we'll consider how the assumption of discrete sampling has created some different sorts of problems for the study of judged duration. They concern the perception of continuity and the philosophical assumption of dualism.

Problems of Philosophical Dualism and Perceived Continuity

Within the natural environment, most events seem to have a sense of continuity. They appear as unified activities even though the events themselves contain multiple levels of structural change. We are usually unaware of these different structural levels because all appear interrelated and somehow coordinated. For example, the act of walking is not perceived as a succession of swinging legs, arms, and hips, but as a smoothly coordinated activity. Nor is a musical composition perceived as a series of independent notes. Instead, passages or themes seem to evolve from one another with some being repeats or variations of others.

How does this sense of continuity arise? Why do we perceive an event as a unified object and not as independent patterns of change? There are at least two perspectives from which we can answer this question. According to one, perceivers may be directly attuned to continuity that is specified within the event itself. That is, continuity may be described in terms of the lawful relationships within each structural level and, in addition, lawful interrelationships between all structural levels. In short, continuity arises from the intrinsic organization of an event's structure. An alternative perspective, however, might claim that continuity is not an inherent aspect of environmental events but is a mental accomplishment of a perceiving organism. Many information-processing theories, including the judged duration models addressed here, adopt this latter stance. An event is not perceived as an organized and integrated entity until _after_ various mediational processes have occurred. Organization and a sense of continuity are properties of the mental code and only exist within the perceiver - _they are not characteristic of the original environmental event itself._ Further, it is interesting that the perception of continuity is assumed to involve a series of _discrete_ processing activities.

For example, the multistore theory of memory (Atkinson & Shiffrin 1968) that we reviewed earlier assumed that initial stages of processing reduced a coded event to its respective features and chunks Indeed, an event was represented by a series of discrete moments or static snapshots in iconic memory. As the code was then transferred among various memory stores, it gradually acquired more meaning and organization through a cognitive act of concatenation. The models of judged duration that were previously considered appear to reflect this general multistore theory of memory. In addition, each assumes that an auxiliary sequence of processing activities must occur before a duration estimate can be made. Ornstein (1969), for example, claims that a coded event must be first retrieved from memory before its duration can be inferred. In the processing effort model proposed by Thomas & Weaver (1975), an event's duration is outputted from the results of a timer (f processor) and visual information (g) processor. Lastly, Block's (1978) model of cognitive change assumes that duration is inferred from the number of changes in processing strategy. In each case, judged duration involves an adjunct process of inference based upon an antecedent sequence of processing activities.

Implications for Time Research

There is a discrepancy here and this creates a problem. Although events are perceived as continuous entities of a given time duration, the information-processing activity which creates this perception is not continuous in nature - it is discrete. The perception of both continuity and event duration only result from a mental accomplishment of "tearing things down and putting them back together again." This concept not only appears unparsimonious but also suggests an asymmetrical relationship between the environment and perceiver - the former reflects continuous activites while the latter does not.

As a second point, Jones (1984) has noted that this notion of discrete sampling implies that time plays a dual role. That is, the actual duration of an event is encoded into memory in terms of discrete moments or chunks. These same durations, however, are also assumed to act as time intervals during which processing can occur. Each event then has both an actual duration and a duration of processing time, the latter being used as the referent for time perception. This assumption of duality, however, appears to lack both precision and parsimony. If temporal information exists within the environment, then there is no need for a mental construction - it becomes redundant. Further, any experimental manipulations must be made relative to the referent for judged duration - which here is a mental code. These manipulations become imprecise, however, because the code is an unseen mental entity which is only _indirectly_ related to the event itself. This will create conflicting definitions of the variable of interest which in turn will produce conflicting experimental results. In the next section, I attempt to show that the variable of complexity is in fact subject to these sorts of problems.

Definitions of Complexity

Within contemporary research, recall that manipulations of stimulus complexity are predicted to have major effects upon judged duration. Complexity presumably increases the amount of information-processing which in turn lengthens experienced duration. But what exactly does the notion of complexity imply here?

Within Ornstein's model, the concept has been operationally defined in a variety of ways including distinctions between more vs. less "experiential" chunks, more vs. less "experiential" redundancy, and more vs. less random orderings of "experiential" units. It is important to note that such definitions do not directly refer to the nature of environmental events. Instead they refer to properties of the presumed referent for judged duration, the mental code, and the reduction of uncertainity to which these codes can be represented. Problems and potential confusion arise, however, in trying to specify what exactly is the "chunk" and "unit of redundancy" that mediational devices process and store in memory. What stimulus characteristics determine and demarcate these units? Do these units change with different types of stimuli and experimental situations? We can never really answer these questions because mental codes are hypothetical constructs which can never be seen, only inferred - thus we can never really know the nature of their "chunks" and complexity.

Models of processing effort (Underwood & Swain 1973; Thomas & Weaver 1975) fall victim to similar pitfalls. These theories claim that increased processing effort or selective attention correspondingly increases judged duration. We therefore need to ask "What is processing effort and how is it increased?" According to the cognitive approach, processing effort arises from the filtering of information that impinges upon a perceiver or alternatively, a depletion of the attentional resource. Such an approach depends in turn on the vague definitions of chunks or changes which will presumably determine the degree of attentional effort required. However, it is unclear what aspects of a filled interval require greater processing effort. Again, theoretical constructs of selective attention and processing effort are defined relative to a mediated process, not to the stimulus structure itself.

Finally, similar problems arise from Block's (1974) theoretical construct of "contextual change". According to this model, time perception depends on the amount of change in cognitive context occurring during a given interval - the more changes, the longer is judged duration. This model is even more vague because the term "change" is not defined except as being changes in cognitive processing. However, what aspects of a stimulus determine a change in cognitive processing and how big must this change be? Or is it the case that the structural characteristics of a stimulus are irrelevant and it is the experimenter's instructions that determine processing changes? Block is unclear on the answers to these questions and the problem of defining a unit of change becomes analogous to defining the basis of complexity.

In short, the theoretical constructs on which current time models are founded, namely those of complexity, contextual change, and processing effort, are vaguely defined and therefore lack predictive power. These ill-defined concepts actually stem from the more fundamental assumptions of mediated perception and discrete sampling. The perception of duration is determined by mental codes or amount of processing, but since these codes are circularly determined by vague notions of complexity, contextual change, and processing effort, this entire approach effectuates imprecision and lack of parsimony. The conflicting nature of current research is suggested to result from these imprecise definitions of stimulus variables.

To summarize, the assumption of discrete sampling has created four major problems for the current study of judged duration. First, its description of the environment has ignored the organized structure of natural events. This has led to the usage of artificial stimuli in laboratory investigations of judged duration. Second, the perception of continuity in stimuli and their durations implies an asymmetrical relationship between the perceiver and its world. While events are perceived as continuous, the activities which mediate this perception are discrete in nature. Third, time is assumed to play a dual role in that the actual duration of an event is represented by an interval of processing time. This view not only lacks parsimony but creates imprecise definitions of stimulus variables. This imprecision and its consequences are apparent in current definitions of compexity.

There is one final problem within comtemporary research on judged duration. Although it doesn't specifically arise from the assumption of discrete sampling, it does stem from the hypothetical memory system of the perceiver. It concerns the issue of "future time".

<u>The Problem of "Future Time"</u>

In everyday behavior, there are many situations where we must extrapolate the present course of an event to estimate when it will end in the future. An outfielder, for example, must extrapolate the trajectory course of a baseball to estimate both when and where it will land. While walking along a crowded sidewalk, we must estimate when to step aside to avoid colliding with another individual. Relatedly, we must extrapolate the future course of our car relative to a stop sign to decide when to brake. All of these examples refer to what we might term "future time" because we are estimating the duration of an event that has not yet ended. How are these kinds of behavior performed?

Contemporary models of judged duration cannot answer this question because they have not incorporated the concept of future time into the structural model of memory. That is, the experience of past or remembered time has been associated with long-term memory and the experience of present or perceived time with short-term memory, but there is no memory store to correspond with future time. Further, it is unclear how these models could be modified accordingly.

A complete theory of judged duration, however, needs to address this issue. Situations of future time frequently occur within the environment and in fact may be involved in most instances of perceived duration. Shortly, we will consider how the problem of future time may be addressed by an alternative theoretical perspective.

<u>Some Alternative Assumptions for Theories of Judged Duration</u>

The various problems that have been outlined in this chapter are instructive. They not only suggest that an alternative approach to judged duration is warranted but what sorts of underlying assumptions may be useful. These assumptions may be summarized as follows:

1) The environment contains objects and <u>events</u> with inherent meaning and organization. Natural events display a hierarchical arrangement of structure that <u>changes</u> between the beginning and end of some temporal interval. The usage of natural events in laboratory

investigations will allow greater generalizability to real world situations.

2) The activity of perceiving involves a symmetrical relationship between the perceiver and its environment. This perceptual activity is continuous in nature, reciprocal with the continuous nature of environmental events.

3) The referent of perceptual behavior is intrinsically related to the structure of natural events. Thus, the particular structure of events will determine the effectiveness of perceptual pickup. Theoretical parsimony will be achieved by eliminating the need for constructed "codes" of reality.

4) Experimental results should be more consistent when experimental manipulations are defined relative to event structure, the presumed referent of perceptual behavior.

5) An explanation of "future time" needs to be addressed in a theory of judged duration. Ideally, this concept should be intrinsic to the perceiving of duration in general, and not require any additional theoretical constructs.

The model of judged duration that I propose in Chapter 7 does rest upon these basic assumptions. These assumptions actually generate from two alternative perspectives of perceptual behavior. One is termed Direct Theory (Gibson 1966; 1979) and the other is a Rhythmic Attending Theory proposed by Jones (1976). The next chapter will discuss these two theories along with their implications for time research.

Chapter Summary

The present chapter has explored a number of problems that exist in the current information-processing approach to judged duration. The paradigmatic assumptions of mediated perception and discrete sampling have created a perceiver who must concatenate discrete moments of processed time in order to judge the duration of a continuous world event. Although the world is considered to contain continuous events, the perception of these events is not a continuous nor a parsimonious process. Second, contemporary models have relied upon arbitrary and artificial experimental stimuli which have questionable generalizability to real world events. In addition, the independent variable that is most commonly manipulated in judged duration experiments involves vague and ill-defined notions of complexity. Lastly, contemporary models do not acknowledge the concept of "future time" and situations where one must estimate where and when an ongoing event will end. To address these various problems, some alternative assumptions of judged duration were considered.

CHAPTER FOUR

BUILDING A FRAMEWORK FOR A NEW THEORY OF JUDGED DURATION: CONTRIBUTIONS FROM THE DIRECT PERCEPTION AND RHYTHMIC ATTENDING THEORIES

In recent years, theoretical alternatives to the general information-processing paradigm have begun to emerge. They offer very novel perspectives on the perceiving and acting activities of human organisms. One approach is termed Direct Perception Theory and stems from the work of James Gibson and his students. Direct Perception Theory was the first to challenge the Information-Processing paradigm and addresses some of the problems that were mentioned in the previous chapter. In particular, this alternative paradigm attempts to offer a more ecological perspective for the human perceiver and, at the same time, a more parsimonious theory of behavior. Although it will provide some valuable underlying paradigmatic assumptions, the current development of Direct Perception Theory has limited applicability to the study of judged duration. However, the assumptions of another ecological approach, Jones' Theory of Rhythmic Attending, provide several concrete implications for the study of time. Let us now examine the basic tenets of each approach in more detail and how they together may provide a framework for building a new theory of judged duration.

Direct Perception Theory

A major assumption within Direct Theory is that the relationship between a perceiver and its environment can be characterized in terms of "reciprocity". According to this doctrine, an organism has evolved relative to a particular environmental niche and displays certain adaptive skills that mirror the demands of this niche. An organism and its environment are necessarily interrelated since each owes its identity to the other. For example, by describing the physiological and anatomical structure of a bird (eg. feathers, wings, and beak), we have in a way described the medium, the predator-prey relationship, and the feeding and nesting habits of its environment. A description of an environmental niche constrains and describes the activities of its organisms, and the organism's perceiving and acting can be described relative to its environment.

To incorporate this notion of reciprocity into a theory of perception, two antecedent conditions are assumed. First, the environment contains lawful, invariant structure and second, an organism is directly attuned to this structure. If both conditions can be met, then there is no need for mediational mechanisms that impose meaning and organization upon the environment. The referent of behavior thus becomes the environmental event itself and not a mental code. Further, if the perceiver and its world are reciprocally interrelated, then the activities of a perceiver will directly correspond to the continuous quality of environmental events. To investigate this sort of perceptual reciprocity in the laboratory, however, it is essential to use ecologically valid stimuli. Otherwise, the researcher risks obtaining experimental artifacts.

Hierarchical Arrangement of Spatial Structure

Much of Gibson's work provides a description of various aspects of our environment. As a departure from classical optics, he prefers to analyze the world in terms of "ecological optics" or the physics of light relative to the animal and its environment. Specifically, light from the sun or lamps is assumed to reflect off surfaces and objects in the environment and provide an ambient optic array. The ambient optic array is what is potentially available to a perceiving organism and can be conceived as a hierarchy of nested solid angles. At the highest level is the earth-sky contrast which provides a "backdrop" for the terrestial environment. The objects within this terrestial environment form an optic array of visual angles that are nested by subordinate levels of size - for example, there are mountains, buildings, trees, people, leaves, and so on. These objects and events move and change, forming events that are nested by duration. Some events unfold over years while others unfold over months, days, hours, and seconds. Lastly, the structure of objects and events themselves are hierarchically organized. In describing the gait pattern of a walking human, for example, all body joints can be shown to be hierarchically nested around a still center in the middle of the body (Cutting, Proffitt, & Kozlowski 1978). In sum, Gibson has demonstrated that the optic array of the world forms a continuous visual field of overlapping objects and events. The spatial arrangement of this visual field is hierarchical such that smaller objects and events are nested within larger ones.

Invariances

Although the world can be shown to contain lawfully organized structure, this structure may not be apparent from static snapshots. Instead, an organism has to actively explore her environment, or conversely the environment has to change for her, in order for the structure to be perceived. In Gibson's terms, there are some structural relationships that remain invariant over transformational changes. These invariant relationships within the environment are the perceiver's referent for behavior and it is these persistent properties of the environment that an organism is said to know. For example, an invariant that we apparently use to identify the gender of a walker is the ratio of shoulder to hip movement (Barclay, Cutting & Kozlowski 1978). The perceiving of impending collision has been shown to depend upon the invariant of optial expansion patterns (Schiff & Detwiler 1979; Todd 1981). Others have identified the invariants used for the perception of depth (Purdy & Gibson 1955; Sedgewick 1973), human faces (Shaw, McIntyre & Mace 1974), and various auditory events (Hahn & Jones 1980).

Affordances

The environment not only contains lawful invariant structures that are used for perception - it is also assumed to contain meaning in the form of affordances . Affordances are what the environment offers to an organism for good or ill. For example, a hammer affords pounding, a chair affords sitting, a car offers transportation, and so on. Affordances are animal-specific as, for example, a rock is a weapon for humans but not for snakes. For Gibson, then, meaning is inherent to objects and layouts in the environment and need not be "inferred" by mediational mechanisms.

Perceptual Pickup

Through the concepts of invariance and affordance, Gibson and his colleagues have provided a description of a lawfully organized environment and generated research showing that organisms are attuned to this structure. But what exactly is attunement and how do organisms come to know their environment? In response, Gibson claims that the perceptual pickup of environmental structure can be characterized in terms of "the education of attention". That is, by actively exploring and performing within her environment, a perceiver's behavior will gradually become more "resonant" to those invariants and affordances which are significant for her needs. Her perceptual-motor activities become more specific to the environment and she begins to differentiate how various objects and events constrain and determine her behavior. The concept of "education of attention" is considered analogous to the process of evolution because both yield an organism that is better adapted and mutually interrelated with its environment.

Summary

These are the basic tenets of Direct Theory and again they were proposed as an alternative to the information-processing paradigm. For instance, contrary to the notion of perceiver-world dualism which engulfed information-processing theorists within an infinite regress of homunculi, the notion of reciprocity attempts to study perception in terms of how the environment determines and constrains the organism's activities. This view is strongly rooted in Darwinian notions of an organism evolving relative to the demands of its environment and it purports to investigate the perceptual activities that have adapted to these demands. Thus, the notion of reciprocity assumes that similar principles apply to both the perceiver and her environment.

Secondly, Direct Theory is more parsimonious than many mediational theories. If one assumes that organization and meaning are already specified within the environment, then there is less need for mediational processes to organize and elaborate upon stimulation. Perceiving can be characterized by an activity of attunement to those invariants and affordances of immediate need.

Finally, Gibson's attempt to describe the perceiving organism in relation to its environment is hoped to stimulate laboratory research that is more "ecologically valid" and representative of what humans actually do in real world situations.

As the preceding points illustrate, Direct Theory does provide an appealing alternative to the information-processing paradigm. Its underlying assumptions and methodologies offer a valuable basis in which to evolve our understanding of perceiving and knowing activities. On the other hand, Direct Theory contains a number of shortcomings that limit its applicability to all areas of cognitive behavior - including the area of judged duration.

Problems With Direct Theory

Its major shortcoming, as several critics have already noted (Jones 1976; Ulman 1980; Fodor & Pylyshyn 1981) concerns the lack of consideration directed toward organismic structure. Shepard (1984) provides a critical analysis of this problem and correctly notes that Gibson never addresses the internal activities which guide pickup and attunement. Direct theorists, in general, have ignored this issue because they wish to avoid any constructs of mediation and indirect representations of reality. For these same reasons, they fail to consider how thinking and remembering processes occur. Gibson in fact maintains that the experiences of dreams, hallucinations, future plans, memories, and images are all outside the realm of perception. Shepard, on the other hand, claims that such experiences are closely akin to perceiving and that all can be parsimoniously incorporated into one theoretical system. To do so, one must first allow that there are certain internal determinants of resonance that match the external determinants (ie. invariants, affordances) within the environment. Shepard & Gibson in fact agree thus far by listing these internal determinants as biological evolution, past experiences, and transitory needs and emotional states. These internal determinants reflect the external determinants and together presumably guide pickup behavior.

An important point of departure between the two theorists, however, is that Shepard claims that these internal determinants can be activated within an organism when the external determinants are either degraded or eliminated. The consequence will then be the internal activities that we term remembering, thinking, dreaming, planning, etc. Unlike Gibson, Shepard also claims that these internal determinants contain their own hierarchical structure (which reflects the environment) and that it is these internal structures which initiate and guide perceiving and knowing activities . Shepard, however, falls victim to his own criticisms of Gibson because he never discribes the nature of this internally organized structure. It is unclear *how* organismic structure guides perceiving and what particular environmental structure it is attuned to.

Another critic of Direct Theory, Jones (1976; 1981), has explicitly addressed these issues in a Rhythmic Attending Theory of behavior. According to her, organisms possess innate rhythms that are evolutionarily attuned to the rhythms of environmental events. The activities of perceiving and knowing simply involve an interlocking of these rhythms through a process of synchronization. Perceiving is guided by changes in the event's temporal structure (ie. accents) and the spatio-temporal relationships that are picked up are correspondingly mirrored within the organism. The event structure that is now reflected within an organism is termed an *expectancy* scheme. Expectancy schemes are rhythmical in nature, and though mentalistic, they are considered to be isomorphic with the original event. They guide perceiving and provide a mental set for perceiving certain structural relationships that may occur in the future. Since these schemes are mentalistic, they can also be internally activated to initiate remembering, planning, dreaming, hallucinating, and so on. Although the nature of these expectancy schemes will soon be discussed in more detail, the main point here is that this notion does address the shortcomings of Direct Theory. The earlier concepts of reciprocity and attunement have been more precisely defined in terms of synchrony, and the schemes which reflect this synchrony act to guide perceiving. Direct theorists may object to the mentalistic nature of schemes but on the other hand they have not been constructed from mediational mechanisms nor are they indirect representations of reality - again they are potentially isomorphic with certain aspects of the event's structure. Of greater relevance to the study of judged duration, the concept of expectancy schemes will explain how organisms can pickup the temporal structure of environmental events and how it is that we able to extrapolate an event's duration into future time.

Implications for Time Estimation

A second deficiency within the current development of Direct Theory concerns the role of temporal structure within environmental events. Although a dynamic event must necessarily unfold over time, Gibson and his followers have never attempted to determine whether there are certain temporal invariants within an event's structure that are used for perceiving. Instead, the temporal dimension has been primarily regarded as a medium of transformational change in which spatial invariants are revealed. For example, some have investigated the perceptual invariants that are used to determine the imminent collision of a car (Schiff & Detwiler 1979) or baseball (Todd 1981). They conclude that the perception of "time to contact" is specified by patterns of optical expansion and size changes in the object's projected angle. This research thus considers what _spatial_ invariants are yielded by transformations _over_ time but ignores any temporal invariants that may be revealed by transformations _in_ time. For example, consider a car moving along a street marked by trees, telephone poles, and stop signs all regularly spaced in time. Relative to these background objects, the optical expansion pattern of the approaching car may be characterized by a nested set of temporal periodicities (ie. meter). Similarly, the pattern of acceleration and deceleration (created by stop signs or other cars) creates a type of rhythm in the car's temporal course. The identification of these temporal invariants may in turn explain how a perceiver is able to predict _when_ in time an object will reach its ending point.

In his later writings, Gibson (1979) does acknowledge that the temporal structure of environmental events may be described in a hierarchical fashion - much like the structure of spatial layout. Again, however, he never attempts to specify what these temporal invariants might be or how they may be used by a perceiving organism. In the following section, we'll review the major tenets of Rhythmic

Attending Theory which does consider the role of temporal invariants in attending and perceiving behaviors. This theory not only addresses the major shortcomings of Direct Theory, but will also provide an underlying foundation for a new theory of judged duration.

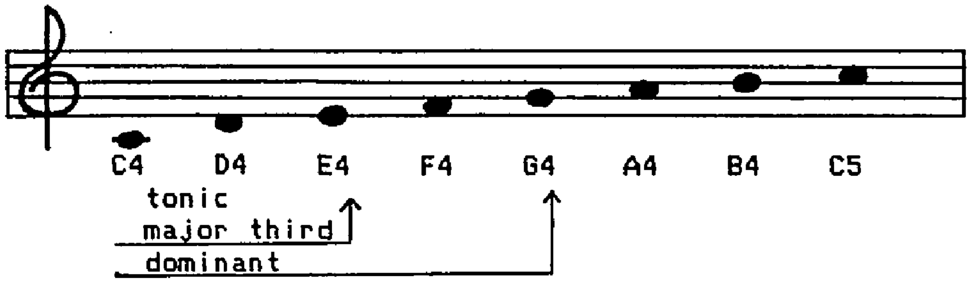
The Theory of Rhythmic Attending

All natural events within the environment have a natural beginning and end, and structural relationships that continuously unfold in between. Jones' theory (1976) is primarily concerned with how an event's structure is both spatially and temporally arranged to yield a rhythmic description of that event. A spoken utterance, for example, contains a sequence of words that occur at certain locations in time. According to her, this utterance as well as many other events, can be described in terms of hierarchical arrangements of spatio-temporal periodicities. Each periodicity is defined by the span of some transformational change that occurs within an event's total duration. Periodicities that transform over smaller time spans are nested within those transform over larger time spans. These various transformations will reveal certain invariants within the event that are behaviorally significant to a perceiving organism. To describe how organisms pickup invariants, Jones argues that we are rhythmic organisms, possessing temporal periodicities as an innate part of organismic structure. Activities of attending and perceiving, then, involve a process of synchrony where an organism's internal rhythms can lock into phase with the temporal periodicities of environmental events.

Although her theory is intended to be a general one that applies to both visual and auditory events, Jones has primarily formulated and tested her ideas within the medium of music. Music elegantly illustrates how nested sets of transformations and invariants can describe an event (ie. a melody) that is both predictable and artistic. Specifically, musical transformations can involve changes in either the pitch (spatial) or rhythmic (temporal) structure of a melody. Temporal transformations involve changes in the relative duration of tones while pitch transformations arise from changes in musical rule application. These changes act as accents that function to induce synchronization and perceptual pickup. As we shall see, attending will be guided to points of temporal change (temporal accents) which in turn tend to be lawfully related to changes in pitch (melodic accents). Let's now consider her description of the auditory environment and this attunement process of synchrony.

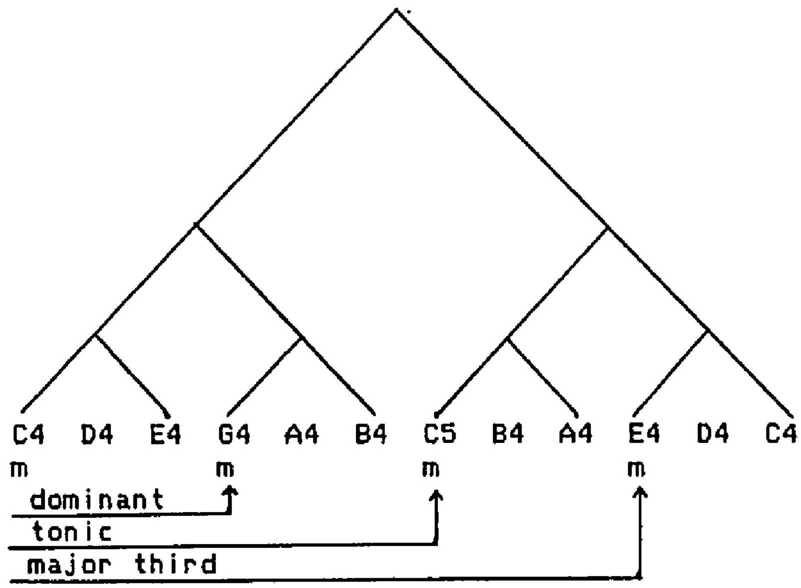
The Hierarchical Organization of Pitch (Melodic) Structure

During the course of a day, we are bombarded with music from car and transistor radios, stereos, and even TV. Through this continual exposure, most of us have at least a tacit knowledge that all melodies are based on a musical scale or key. The common musical scales in Western music are termed "diatonic". A diatonic scale can begin on any key (or tonic), but the "octave" which it spans contains seven different notes that are adjacent to one another on the piano. In the C major scale, for example, notice that the relationship between successive notes can be described as an increment of one step:



Within each scale, there are harmonic relationships between certain notes that are musically important. These relationships all refer to the tonic and consist of the relationship between a) the tonic and the third note of the scale (major third) and b) the tonic and the fifth note of the scale (major fifth or dominant). For example, the major third in the C major scale is C4-E4 and the dominant is C4-G4. These three notes together (eg. CEG) form the scale's <u>major chord.</u> By hearing this chord alone, a musically sophisticated listener can often identify a melody's underlying scale.

In generating a melody, a composer will initially select a subset of notes from a scale and then transform these into other sequences of notes by certain conventional rules. In the following melody, for example, the initial period of (C4 D4 E4) has been transformed into the period of (G4 A4 B4) (where subscripts indicate octave):



The result is a hierarchical description of the melody where four tonal groups are nested within one another. For example, the smaller group of C4 to G4 is nested within the larger group of C4 to C5. Notice that within each tonal group, the interval distance between adjacent tones is always invariant (ie. 1 step). However, the transformatonal rule which is applied at the end of each group creates a noticeable pitch skip that essentially marks the beginning of a new group. This pitch skip, provided by the onset of a new transformational rule, functions as a melodic accent (m) that regularly recurs after every three notes. An accent is something that captures our attention because it represents a deviation from the preceding context - the (m) accents shown above, for example, represents a deviation from the previous inter-pitch distance of one scale step.

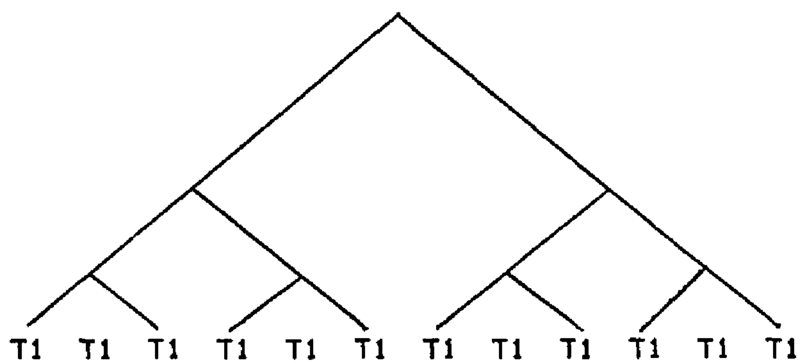
Since accents do capture a listener's attention, a composer will often strategically select those notes that initiate a musical rule transformation. The most common convention is to select notes that are harmonically related to the tonic (ie. are major chord members). In the melody shown above, for example, melodic accents correspond with G4 (dominant), C5 (tonic) and E4 (major third). The purpose of this convention is to "anchor" a melody to its underlying scale, providing a sense of stability and coherence to the entire melody.

To summarize, we've shown that a melody can be described as a hierarchical arrangement of tonal groups where all groups are interrelated through an application of musical rules. Notes that begin a musical rule tranformation (ie. melodic accents) tend to highlight a melody's scale because they are members of the major chord.

The Hierarchical Organization of Temporal Structure

So far we've considered the transformational nature of a melody in terms of its pitch relationships, but a melody is not a frozen object - it flows over time. Jones (1981a; 1981b; 1981c) has shown that the temporal relationships within a melody can also be hierarchically represented with certain underlying invariants. In music, the temporal aspects of a melody are referred to as meter, rhythm, and tempo. The meter refers to the basic grouping of beats within a measure of music and is determined by the time signature assigned by a composer. If, for example, we take the melody illustrated earlier and assign it the meter of 3/4 timing, it will appear as the following:

The 4 indicates that the beat unit is a quarter note (ie. ♩) and that there are three beats within each measure (demarcated by the bar lines). Other time signatures that are commonly used are duple (2/4), quadruple (4/4), and sextuple (6/8). The meter of any melody, however, can be hierarchically represented where smaller time periods are nested within larger time periods. For example, if we assign the duration value for each quarter note as being 200 ms. (ie. T1=200 ms), then the twelve tonal durations can be described in terms of the following hierarchy:



Notice that the largest time span of the melody (T12) contains a nesting of smaller time periods of T3 + T3 = T6 and still smaller nested periods of T1 + T1 + T1 = T3. The meter then serves to interrelate all time periods within a melody.

A melody's <u>rhythm</u> , on the other hand, refers to transformations of a melody's time structure. That is, the duration of certain notes may be changed such that they receive extra beats. These prolonged notes, however, will always bear specific ratios of duration relative to other notes. For example, if the beat unit of a meter is a quarter note, then a half note will be twice as long as each quarter note, and a whole note will be twice as long as each half note. For a melody written in 4/4 meter, then, a measure may contain four quarter notes, two half notes, one half note and two quarter notes, or one whole note. Notice that while rhythm has transformed the durational value of notes within a measure, the melody's meter is left invariant.

The temporal transformations that arise from rhythm create a pattern of temporal accents (t) within a melody. Again, these accents signify a change in the melody's time structure and frequently arise from notes that are relatively longer than the beat unit. There is, however, another way that temporal accents can be created within a melody and this is through the use of pausing or "rests". That is, a composer may insert a period of silence where a note may normally occur - resulting in what might be called a "missing beat". Since pauses signify a temporal change, they too will create accents on notes that actually exist within a melody. These accented notes, however, will be those that immediately <u>follow</u> a pause.

Regardless of whether temporal accents arise from pauses or prolonged durations, their relative occurrence within a melody is usually isochronous - temporal accents usually recur after an invariant number of beats. Like melodic accents, temporal accents are psychologically salient because they serve to capture a listener's attention.

Lastly, the tempo of a melody refers to its overall rate which is set by the value of the beat unit. If the beat unit is an eighth note, the melody will be relatively faster than a melody based on a quarter note. Any melody can be slowed down or speeded up and thus be transformed by tempo, but at the same time the temporal relationships between all notes will remain invariant.

At this point, then, we have described a melody in terms of its hierarchical arrangement of pitch and time structure. Music artfully interweaves these two hierarchies such that melodies will perceptually appear as unified events. This sense of unity can be structurally described in terms of lawful interrelationships between melodic and temporal accents. For example, a composer will frequently superimpose a melody's pattern of melodic accents with its pattern of temporal accents such that the two co-occur. By doing so, the melodic accents arising from transformations of musical rules become even more salient when accompanied by a temporal accent. These co-occurring accents further help a listener to identify a melody's key and serve to integrate and anchor the entire melody to an underlying scale.

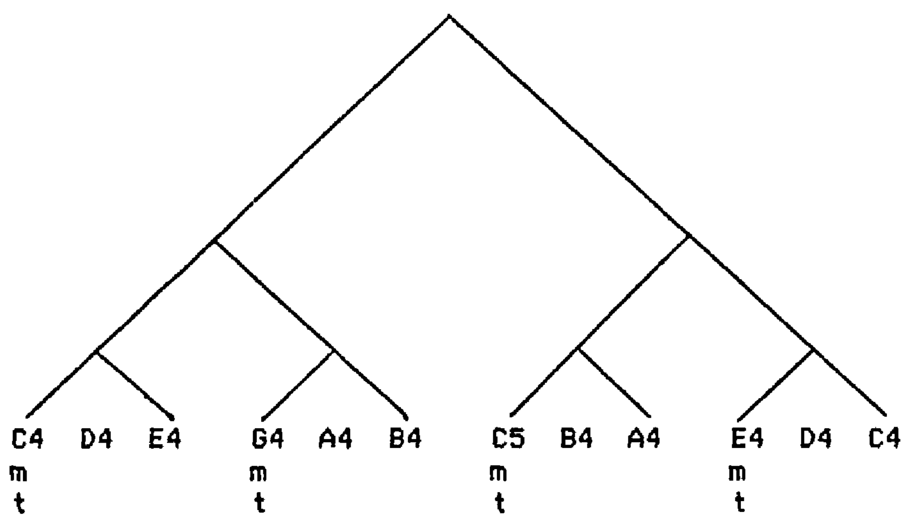
In summary, Jones has demonstrated that the pitch and temporal relations within an auditory event can be described in terms of hierarchically nested periods. These periods are not only inherently interrelated, but they also display certain invariants over transformational changes. In music, these invariants include the pitch and temporal relationship between notes within a period as well as the regular recurrence of both temporal and melodic accents. Given this lawful description of the auditory environment, how do perceivers go about picking up these invariants?

Perceptual Pickup as Synchrony

Jones assumes an ecological perspective and envisions the perceiver-world relationship as one of reciprocity. In this, her approach reveals a strong Gibsonian influence. However, unlike Gibson, she has developed a description of organismic structure that is directly attuned to the temporal structure of the environment. Specifically, Jones (1976; 1982) envisions the perceiver as a rhythmic organism, one that has evolved relative to an inherently rhythmic environment. Whenever we perceive or attend to an event, our internal rhythms lock into phase with certain periodicities of the environment through a process of synchrony. The perceiver and her environment essentially become unified because the rhythmic activities within an organism will reciprocally match those within the environment.

Perceptual Effectiveness of Synchrony

The environment actually determines the degree or effectiveness of synchrony through its particular arrangement of temporal accents. Temporal accents act as points of phaselock. If these accents are well-timed and recur in a regular, predictable fashion, a perceiver can correctly predict when future accents will occur - thus allowing effective pickup of a melody's temporal structure. The pickup of pitch structure will depend upon the relationship between temporal and melodic accents. If these two types of accents co-occur (ie. tm) or display invariant ratios of relative placement (ie.t...m...t...m...t...m), then temporal accents will guide attending to locations of musical rule transformations. Further, a perceiver will be able to generate <u>expectancies</u> about the future course of the melody. Expectancies are future extrapolations of a melody's preceding accent structure. When temporal and melodic accents maintain a predictable and invariant relationship throughout a melody, a perceiver is thus able to correctly anticipate both the what and when of upcoming notes. For example, consider the melody that we examined earlier and assume that a pause occurs after every third note. The pattern of temporal (t) and melodic (m) accents become as follows:



This pattern should be relatively easy to attentionally track because temporal accents regularly recur over time. Further, notice that each (t) accent guides attention to the precise location of pitch change (m). Since this predictable pattern of interrelated accents is expected to continue throughout the pattern, one can anticipate not only "what" tones will occur but also "when" in time they will do so.

In this sort of pattern, these expectancies will in fact be confirmed.

Synchrony Resulting from Perceptual Learning

Most events within the natural environment, such as music, speech, animal sounds, and so on, do in fact display invariant relationships between melodic and temporal accents. Thus perceptual pickup will correspondingly reflect the event's actual structure. Other events, however, contain a less predictable melodic and temporal structure. Since their structure will violate a perceiver's expectancies, perceptual learning will be required for effective synchronization and perceptual pickup. For example, let's suppose that a melody does display a pattern of co-occurring melodic and temporal accents. These accents predictably recur at a certain beat rate but suddenly begin to speed up or slow down. Here, attending will be misguided. By extrapolating the melody's preceding context into the future, a perceiver is expecting future accents to occur at certain locations in time. The change in rate, however, has caused these later accents to be "ill-timed" because they occur earlier or later than expected. Although a perceiver may eventually pickup the event's actual structure, this will require several trials while the perceiver learns to adjust their rate of synchronization.

Other kinds of events may require extensive perceptual learning because their melodic and temporal accent structures are "incompatible". Each type of accent may display an isochronous pattern of recurrence but the interrelationship between melodic and temporal accents is an unpredictable one. As an example, suppose that a melody contains a musical rule transformation (m accent) after every third note but a temporal acacent (t) after every fourth note:

C4	D4	E4	G4	A4	B4	C5	B4	A4	E4	D4	C4
tm			m	t		m		t	m		

How will perceptual pickup be affected by this sort of structure? Since temporal accents predictably recur, the melody's temporal beat structure should be picked up through synchronization. The melody's pitch structure, on the other hand, should be more difficult to attentionally track. Temporal accents do not guide the perceiver to locations of musical rule change, nor can the occurrence of melodic accents be predicted from the pattern of temporal accents. In short, a perceiver cannot reliably anticipate what tones may occur in the future. Although this pattern can eventually be learned, again it may require many trials.

<u>Expectancy Schemes</u>

Regardless of how much perceptual learning has occurred for an event, let's now assume that the event's structure has been picked up. What is the nature of this organismic structure? According to Jones, an organism will internalize an event in the form of an <u>expectancy scheme.</u> These schemes are rhythmic and dynamic in nature and reflect the structural relationships of a natural event. They serve to guide perceiving, preparing the organism for upcoming events, and are continually modified by new information within the environment. In short, expectancy schemes provide a mental set for perceiving and reflect what sorts of structural relationships are expected to occur in future instances of an event. Within the category of music, for example, a perceiver may expect the presence of certain musical conventions because most melodies heard in the past have displayed these conventions. As we mentioned earlier, Jones also assumes that expectancy schemes can be internally activated in the absence of an environmental event. This will create various subjective activities, including remembering, dreaming, planning, fantasizing, and hallucinating.

To summarize, Jones' Rhythmic Attending Theory provides an alternative theoretical perspective for the study of perception. It also addresses some major shortcomings of an earlier ecological approach, Gibson's Direct Perception Theory. Although Direct theorists assume that perception is determined by event structure, they have ignored the impact of temporal information upon perceptual behavior. Further, Gibson and his followers never address the issue of organismic structure to explain how a perceiver knows or becomes "attuned" to her environment. By analyzing an event's temporal structure, however, Jones has shown that rhythm may provide the basis for attunement. Rhythms within the organism and environment presumably can interlock through synchronization such that the structure of one provides a reciprocal description of the other. Organismic structure is characterized in terms of expectancy schemes that not only reflect the structure of various kinds of natural events, but function to guide perceiving and remembering activities.

Contrary to the preference of Direct Theory, expectancy schemes are assumed to be mentalistic. It's important to note, however, that they are not dualistic. These internal schemes have been established by the structure of natural events and are directly linked through rhythm. In addition, the continuity of the environment is reflected in the dynamic and continuous nature of internal rhythms. These assumptions directly oppose the assumptions of discrete sampling and mediated perception that are found in the current information-processing approach to perception.

Now that we've examined the basic assumptions within Jones' theory, we next need to consider their implications for time research. What advantages do these concepts of hierarchical time, synchrony and expectancy have to offer to the study of judged duration?

<u>Implications for Time Estimation</u>

In an earlier review, we noted that contemporary models of judged duration display the following problems:

1) inconsistent experimental support that may arise from

   a. usage of artificial stimuli

   b. definitions of complexity relative to a mental code

2) asymmetrical relationship between a continuous environment and discrete perceptual activities

3) general lack of parsimony due to

   a. an extra inference process for judged duration

   b. a dual role of time

4) no explanation for situations involving future time

By adopting an ecological perspective, Jones' theory has addressed many of these problems. First, a hierarchical description of events illustrates that the environment is inherently organized. The structural levels within an event contain nested periodicities that are not only interrelated within a given structural level (eg. pitch) but interrelated with other structural levels (ie. rhythm) as well. Since an event's structure is intrinsically integrated, there is no need for mediational activities that impose organization through a concatenation of chunks. The continuous nature of an event can now be described in terms of its structural interrelationships and not in terms of a mental code. Further, the concept of synchrony offers a reciprocal relationship between a perceiver and its environment. Both are rhythmical in nature and the activity of perceiving mirrors the continuous unfolding of an environmental event. Second, recall that time is an important aspect of an event's structure that is interrelated with other structural levels. If an organism is attending to and perceiving an event, she is necessarily perceiving the temporal relationships within an event. Temporal structure is not inferred from a sequence of processing activities but is inherent to the general activity of perceiving. From this perspective then, time no longer plays a dual role because there is no need for "processing time" to occur during a given interval. The referent for judged duration becomes the original environmental event itself and not a mental code. Third, if the referent for judged duration is the temporal structure of an environmental event, then manipulations of complexity can be more precisely defined within the environment. For example, melodies containing incompatible accent structures or changing tempos may be over or underestimated in relative duration. Since these sorts of structures presumably misguide attending, judged duration should be correspondingly affected. Lastly, the concept of future time has been parsimoniously incorporated into the act of perceiving. The event's unfolding structure allows a perceiver to generate expectancies about the what and when of future notes. In general then, the assumptions within Jones' theory appear to offer a more precise and parsimonious framework for the study of judged duration.

Chapter Summary

The present chapter has attempted to establish some underlying assumptions on which to build an alternative theory of judged duration. These assumptions have been extracted from the Direct Perception and Rhythmic Attending Theories which do not yet approximate the caliber of a paradigm but can, nevertheless, address many of the problems inherent to the current information-processing approach. As an alternative to the notions of perceiver-world dualism and mediated perception, Direct Theory has contributed the concept of reciprocity. Here, the activities of perceiving, acting, and knowing are assumed to directly correspond to the hierarchical structure of the environment, parsimoniously reducing the need for mediational mechanisms. In addition, this approach has persuasively argued that laboratory investigations can better reflect real world situations by using experimental stimuli and methodology that are relative to the organism's evolutionary history. The Theory of Rhythmic Attending has further developed these basic tenets by providing a hierarchical description of the environment in terms of both spatial and temporal structure and a more detailed account of the attunement process. According to this view, an organism perceives and attends to environmental structure through a process of synchrony which in turn allows a perceiver to expect and prepare for upcoming future events.

Although we considered how these various assumptions may apply to contemporary time research, the following chapters will begin to develop these ideas into an alternative model of judged duration.

CHAPTER FIVE

GENERAL ORGANIZATIONAL SCHEME FOR SUBSEQUENT CHAPTERS

The remaining chapters of this dissertation will focus on an alternative approach to judged duration. The purpose of the present chapter is to relate the organizational framework from which this model will be presented. The specific intent of each chapter will be described along with the general methodological strategy that is used in subsequent experiments.

Specific Goals

In the preceding chapters, I've suggested that Jones' Rhythmic Attending Theory provides a new approach to the study of judged duration. The temporal relationships of an event are presumably picked up through synchronization and act as the direct referent for duration estimates. From this view, it follows that the rhythmic structure of an event should exert a major effect on judged duration. The next chapter (Chapter 6) will in fact evaluate this claim and consider some different ways in which rhythm may exert an effect. In particular, two experiments are designed to contrast predictions from the Rhythmic Attending and certain information-processing models of time. As we shall see, the results of these studies will illustrate the potential utility of Jones' theory and suggest what the particular referent for judged duration may be.

Chapter Seven builds on this preliminary framework and presents an Expectancy Model of judged duration. In general, it's argued that perceivers use the melodic and rhythmic structure of an event to generate an expected ending. Judged duration is then determined by whether this event's end confirms or violates the perceiver's expectancy. Chapters Eight and Nine will empirically investigate these assumptions and contrast predictions from both the Expectancy and information-processing models of time. The primary goal is to identify those structural invariants that may signal an event's end and how duration estimates are affected by structural manipulations. Lastly, Chapter Ten will consider some implications of the Expectancy Model for other areas of time research.

The experiments that have been conducted within this dissertation have all relied upon a common methodological strategy. The following section will describe the sorts of experimental stimuli and tasks that were used.

General Methodological Strategy of Conducted Experiments

Experimental Stimuli

In contrast to the artificial stimuli that are frequently used in current time research, all experiments within this dissertation use musical melodies. Some of these melodies were constructed by myself (Experiments One and Two), using musical rules that realize certain diatonic relationships. Others were composed by actual musicians (Experiments Three, Four, and Five). There are several reasons why music offers an ideal medium for studying event perception. First, music is a natural event that we frequently encounter in the environment. More importantly, music contains multiple levels of structure that change during an interval marked by a perceptible beginning and end. By systematically manipulating these levels of change, we can examine how an event's structure may directly affect perceived duration.

Experimental Tasks

Within each experiment, melodies were presented to subjects in three different tasks. These tasks involved a) perceptual ratings b) judged duration and c) recognition memory. In the first, an independent group of subjects was asked to rate melodies for those structural qualities that were manipulated. For example, the first two experiments manipulated a melody's melodic and temporal accent structure. Subjects were therefore asked to rate melodies for their degree of predictability (simplicity), harmony (musicality), and how well they represented the category of music (goodness). In later experiments, I manipulated various melodic/rhythmic relationships that were suggested to specify a melody's end. Experiments 3 and 4, for example, varied properties of the final note and so subjects were asked to rate these melodies for their degree of resolution - whether a melody seemed complete or incomplete. Lastly, Experiment 5 varied a melody's accent timing and the harmony of accents. Thus subjects were asked to rate the accents of these melodies for their appropriateness of harmony and timing.

In all experiments, the initial rating task served two purposes. First, it assessed the effectiveness of relevant experimental manipulations. Were the melodies defined as predictable, resolved, harmonically appropriate, etc. actually perceived as such by a random sample of listeners? Second, the rating task provided an index of "complexity" for each melody that referred to its structural qualities. Since these melodies were later used in a judged duration task, I could determine whether differences in the perceptual complexity of melodies were related to differences in judged duration. Once melodies had been rated for their respective properties, they were then presented to a different group of subjects for duration judgments. The particular method that I used throughout was the comparative judgment task. Here a subject was presented with pairs of melodies and asked to judge whether the second melody of a pair was longer or shorter than the first. Although both melodies of a pair always contained the same physical duration, this method allowed me to determine whether structural differences between melodies created over or underestimation of duration.

Since the purpose of this dissertation is to investigate perceived duration, the comparative judgment task was presented within a "prospective" context. Subjects were always instructed in advance that relative duration judgments would be required. This contrasts with the retrospective technique where subjects perform an initial task unrelated to duration and are later asked for duration judgments. This latter technique is used to study the <u>remembering</u> of duration -

an issue that will not be investigated here.

The prospective technique, though appropriate for studying perceived duration, may encourage subjects to use spurious strategies such as counting and tapping in the estimates of relative duration. In an attempt to discourage these sorts of strategies, all subjects were told to carefully attend to the notes of all patterns because a recognition memory task would later be required. On the following day, subjects (of Experiments 1, 2, and 3) did in fact return and were asked to distinguish among the OLD patterns of the previous day and a set of NEW distractor items.

Although the primary purpose of this memory task was to encourage optimal attending during the judged duration task, it was also designed for a second purpose. Previous research by Goodman (1980) and Dowling (1978) has found that items more typical of a category (prototypes) are better recalled but more poorly recognized than items that are less typical (nonprototypes). Presumably, prototypes are represented in a common cognitive schema where members are poorly differentiated from one another. This schema provides superior recall but poor recognition. Nonprototypes, on the other hand, are assumed to be stored in a more isolated and differentiated representation. This promotes superior recognition but poor recall. If this claim is valid, then similar results should be obtained here. That is, the perceptual rating data essentially indicates how well each melody represents the category of music. These more "prototypical" melodies should therefore be more poorly recognized than more nonprototypical melodies.

When the recognition memory data was analyzed, however, results did not support this prediction. Results varied with different measures of memory (ie. percent correct and Ag) and did not provide any consistent and comprehensible intepretation. These anomalies probably arose from the nature of memory distractors and do not necessarily invalidate the prototypicality hypothesis. Regardless, this memory data will not be discussed within the text of the dissertation. Instead, results from each experiment (ie. Experiments 1, 2, 3) are presented in Appendix B.

Chapter Summary

The purpose of the present chapter was to relate the overall organizational format of remaining chapters. An alternative model of judged duration will be presented that emphasizes the impact of temporal structure within naturally occurring events. The experiments that will test this model were then broadly outlined. The particular goal of each study was described along with the sorts of experimental stimuli and tasks that are used.

CHAPTER SIX

DOES RHYTHM INFLUENCE JUDGED DURATION? IF SO, HOW? SOME PRELIMINARY RESEARCH

In previous chapters, we suggested that some of the problems associated with current time research may be addressed by adopting an alternative theoretical approach to perception. Jones' Rhythmic Attending Theory was considered to be particularly appealing because it assumes that the multidimensional structure of environmental events is hierarchically organized and rhythmical in nature. Further, an organism is assumed to perceive her environment through a process of synchrony where rhythms within the organism and environment become interlocked. The present chapter pursues the various ways in which an event's rhythmic structure may conceivably affect perceiving and the pickup of event duration. After assessing these various possibilities through a series of two experiments, we can then determine whether rhythm really does have an influence upon judged duration as Jones' theory claims. If so, this finding will allow us to build an alternative model of judged duration.

Rhythmic Attending and Judged Duration

A primary assumption of Rhythmic Attending Theory is that natural events contain interrelated levels of structure that dynamically change during some time interval. One structural level that is intrinsic to all events, but which has been ignored by both Information-Processing and Direct Theory, is the event's organization of temporal periodicities or rhythm. Rhythm, according to Jones, has primary significance for a perceiving organism because a predictable pattern of temporal accents induces a process of synchronization. Through synchronization, attending is guided throughout event structure and thus allows perceptual pickup.

Although Jones' theory was originally proposed as a general theory of perceiving and knowing, the assumptions that we've just mentioned can also provide an account of perceived duration. Specifically, relative time is assumed to be an inherent structure of world events. Whenever an organism attends to and perceives an event, she is by necessity using and perceiving its inherent temporal structure. In contrast to the information-processing models, duration judgments do _not_ require an extra processing stage where duration is inferred from a mental concatenation of discrete moments. Nor does time play a dual role, acting as an actual interval of duration and an interval during which processing time occurs. Instead, the present view assumes that the perception of duration is concomitant to the perception of dynamic events and that its rhythmical pickup mirrors the rhythmical nature of the environment. This approach then is potentially more parsimonious than current models of judged duration.

To determine the relative utility of the Rhythmic Attending View, however, we need to investigate whether perceivers are in fact sensitive to the rhythmic structure of events. More importantly, we need to experimentally contrast the role of rhythm as envisioned by both the Rhythmic Attending and Information-Processing Theories. Let's consider how the rhythmic structure of events may vary and some alternative ways of conceptualizing the effect of rhythm upon judged duration.

<u>How Might Rhythmic Structure Affect Judged Duration?</u>

According to Rhythmic Attending Theory, perceptual pickup is determined by the arrangement of accents within an event. Accents arise from changes in a structural level and in the case of a melody, may be melodic or temporal in nature. Synchronization and the pickup of temporal structure is facilitated when temporal accents recur in a regular and predictable manner. If melodic accents bear a systematic relationship to temporal accents, then a perceiver is also able to anticipate the melody's future notes. For example, let's examine the structure of the following melody where a SOA (stimulus onset asynchrony) value (in ms) has been assigned to each tone:

<u>Melody with Compatible Rhythm</u>

300	300	500	300	300	500	300	300	500	300	300	300
C4	D4	E4	G4	A4	B4	C5	B4	A4	E4	D4	C4
tm			tm			tm			tm		

This particular melody is generated from a set of musical rules that have transformed one periodicity of pitch (eg. C4 D4 E4) into another (eg. G4 A4 B4). A new rule has been applied after every three tones to create an isochronous pattern of melodic accents (m). Notice that this melody also contains an isochronous pattern of temporal accents (t) that co-occur with melodic ones. These temporal accents arise from the structure of a "Four Beat" rhythm which has inserted a pause after every third tone. Each pause acts as an implied beat for a missing tone and serves to accent the note that actually follows the pause. According to Jones, this isochronous arrangement of temporal accents should induce attentional synchrony within the unfolding melody. A perceiver is able to anticipate not only "when" future notes will occur but also "what" notes they will be.

Next consider the consequences of a "Five Beat" rhythm imposed on the same sequence of tonal relationships. The total duration of this melody is the same as before but the SOA value for tones is as follows:

<u>Melody with Incompatible Rhythm</u>

300	300	300	600	300	300	300	600	300	300	300	300
C4	D4	E4	G4	A4	B4	C5	B4	A4	E4	D4	C4
tm			m	t		m		t	m		

As before, melodic accents isochronously recur after every third tone as a result of musical rule transformations. Here, however, a Five Beat rhythm has inserted a pause, or implied beat, after every fourth tone. The pattern of temporal beats is an isochronous one but temporal accents do not co-occur with melodic ones. Jones has suggested that the melodic information of this sort of pattern should be more difficult to attend to. Temporal accents do not guide attending to the points of pitch rule change (m accents) because (m) and (t) accents are not systematically interrelated. Thus a perceiver cannot reliably predict the what and when of future notes.

Suppose that we now ask subjects to compare the relative duration of these two melodies. Although both contain the same sequence of tones and the same total duration, the rhythmic structure of one is compatible with melodic accents while the other is not. Will the two melodies seem to have the same duration or will one seem longer or shorter than the other? If differences in judged duration do occur, why is this so?

The Rhythmic Attending Theory generates two alternative possibilities, the Missing Beat Hypothesis and the Average Accent Hypothesis. Each hypothesis assumes that judged duration is determined by the structure of temporal periodicities within the event. These two alternatives will differ, however, in terms of the significance attached to the role of melodic accents. The predictions of these two hypotheses will contrast with those generating from the information-processing models of judged duration. These models ignore the possibility that perceivers may <u>use</u> the rhythmic structure of an event for duration judgments - instead they focus on the amount of information-processing that is required by an event. Let's consider each of these three alternative views in turn.

<u>The Missing Beat Hypothesis</u>

A critical assumption within Rhythmic Attending Theory is that perceptual pickup involves an act of synchronization. Since synchronization involves an interlocking of temporal periodicities, the rhythmic beats within the environmental event will be presumably mirrored within the organism. While listening to a melody, for example, a series of internal pulses will be established by the melody's rhythm and will correspond to those beats that arise from both actual tones and "missing tones" implied by rhythmic pauses. The extent to which these internal pulses will be established depend upon the predictability of the melody's rhythm. The relative occurrence of melodic accents, though important for pickup of melodic information, are irrelevant. Internal temporal beats are generated from a rhythm containing predictably recurring accents and whether this rhythm will guide attending toward the pickup of melodic information is a secondary issue.

Given these assumptions, it is quite possible that a perceiver may base her comparative duration estimate on the relative number of beats within each melody. That is, the number of beats within an initial melody may establish an expected referent for later melodies. If a later melody contains a fewer number of beats, it may appear to end too early and thus seem shorter in relative duration. Conversely, a melody with a greater number of beats may seem longer because it appears to end relatively late. Judgments of equivalent duration should be observed whenever two melodies contain the same number of rhythmic beats. Let's now consider the relative duration judgment of the two melodies depicted earlier. The melody with the compatible Four Beat rhythm contains 12 actual tones plus 3 "missing" tones implied by rhythmic pauses. It therefore contains a total of 15 rhythmic beats. Next examine the melody containing the incompatible Five Beat rhythm. Its beat period of 300 ms. is the same as the previous melody's, but its isochronous pattern of temporal accents has created a total of 14 rhythmic beats - 12 arising from actual tones and 2 from missing tones. Although the duration of both melodies is equivalent, the second should be judged shorter than the first because it contains a fewer number of expected beats.

According to this hypothesis, then, judged duration depends on the relative number of beats established by a melody's rhythm. These internal beats are induced by a rhythm containing regularly recurrent accents and is unaffected by the arrangement of melodic accents. In contrast, the next hypothesis assumes that melodic accents do play an important role in judged duration.

The Average Accent Hypothesis

Like the previous hyupothesis, this view assumes that the temporal structure of an event guides attending and is correspondingly mirrored within a perceiving organism. In contrast, however, it assumes that a perceiver uses both melodic and temporal accents in judging relative duration. That is, accents presumably capture our attention because they mark the beginning of any change in the periodicity of pitch (ie. m accents) or relative duration (t accents). According to this view, a perceiver will average the durations of the various accent periods within an initial melody and use this average as an expected referent for relative duration estimates. If a second melody contains a larger mean value, it will seem relatively longer. A melody with a smaller mean value will seem relatively shorter. This hypothesis therefore predicts that a melody with an incompatible rhythm will be judged shorter than one with a compatible rhythm yielding co-occurring accents. A melody containing co-occurring temporal and melodic accents will have both fewer and longer time periods between accents. Its average value will thus be larger than that for the incompatible rhythm.

For example, consider the melody shown below where the temporal accents (t) of the Four Beat rhythm co-occur with the pattern of melodic accents (m). Here, (tm) marks the accent periods of 1100 ms:

	1100 ms			1100 ms			1100 ms				
tm			tm			tm			tm		
300	300	500	300	300	500	300	300	500	300	300	300
C4	D4	E4	G4	A4	B4	C5	B4	A4	E4	D4	C4

To calculate the mean duration value (TE) of this melody, we sum the time periods between accents, Ta, (both melodic and temporal accents) and then divide by the number of periods: TE = 3(1100)/3. In this case, TE is simply 1100 ms.

Next consider this same melody with the temporal accents of the incompatible Five Beat rhythm. Here more accent periods occur:

	900 ms		600 ms	600 ms			900 ms	300 ms			
tm			m	t		m		t	m		
300	300	300	600	300	300	300	600	300	300	300	300
C4	D4	E4	G4	A4	B4	C5	B4	A4	E4	D4	C4

The average accent period, TE = 900+600+600+900+300/5 = 3300/5 = 660 ms, is a value shorter than that for the previous melody.

In summary, the Missing Beat and Average Accent Period Hypotheses both assume that a perceiver uses the temporal structure of an unfolding melody. The two models differ, however, in terms of what particular kind of information is used for duration judgments. The

Missing Beat Hypothesis assumes that perceivers use the total number of beats that is yielded by a melody's rhythm. While it is important that temporal accents recur in an isochronous manner, the compatiblity of melodic and temporal accents is irrelevant. The Average Accent Period Hypothesis, on the other hand, assumes that perceivers use the time spans marked by both melodic and temporal accents to derive an average duration value. Both hypotheses have predicted that the melody containing the incompatible Five Beat rhythm will be judged shorter than the melody containing the compatible Four Beat rhythm.

Although these two hypotheses may seem mediational in nature, they do distinctly differ from the information-processing models of judged duration. Both the Missing Beat and Average Accent Period Hypotheses assume that the pickup of duration and temporal structure is intrinsic to the perceptual pickup of any event. Duration is not constructed from a series of discrete moments but rather is mirrored within the organism as the event unfolds within the environment. Similarly, the referent for judged duration is not a mental code which reflects the amount of processing time for an event. Instead, the two hypotheses that we've just discussed both assume that the referent is the temporal structure of the environmental event itself. They simply differ in terms of what particular aspect of this temporal structure is used as the referent for duration judgments.

To more fully appreciate the distinction between models generating from the Rhythmic Attending and Information-Processing Approaches, the next section will illustrate how this latter view conceives the effect of rhythm upon judged duration. As we shall see, its predictions are in direct contrast to those advanced by the Missing Beat and Average Accent Period Hypotheses.

<u>Information-Processing Models of Judged Duration</u>

Information-processing models of judged duration have tended to ignore the multidimensional nature of event structure. In particular, they have overlooked the rhythmical organization of temporal periodicities within an event and the potential impact of rhythm upon judged duration. Indeed, much of the current research has not systematically manipulated rhythm and has frequently presented static arrangement of lines, words, or abstract drawings for some interval of time.

Although the information-processing models do not explicitly address the issue of rhythm, the melodic and temporal accents within a melody can be reasonably conceived as "chunk boundaries or points of cognitive change" (Bower & Winsenz 1969; Deutsch 1980; Handel 1973). Accents effectively reduce a melody to a linear sequence of chunks or discrete moments of time that will be eventually concatenated by various cognitive mechanisms. Events containing a greater number of chunks will presumably increase the amount of information processing and code complexity. Since code complexity is assumed to function as the referent for judged duration, it therefore follows that events containing a greater number of chunks will be judged longer than those containing a fewer number.

Recall that individual models of judged duration disagree on the particular cognitive process that mediates code complexity and judged duration. Ornstein (1969) claims that duration depends on the amount of information in memory storage and that variables of complexity and chunk number increase storage size. Attentional effort models (ie. Underwood & Swain 1973; Thomas & Weaver 1975) believe that increased complexity and chunk number increase processing effort and thus judged duration. Lastly, Block (1978) proposes that longer duration judgments result from an increase in cognitive change - changes in pattern structure (ie. accents) presumably causing changes in processing mode. Regardless of the underlying mediational device, this class of models makes an identical prediction. Specifically, the melody with the compatible Four Beat rhythm contains co-occurring accents that segment the melody into four chunks. Conversely, the conflicting accents of the incompatible Five Beat rhythm segment this same melody into six chunks. This second melody should therefore be judged longer than the first.

In summary, we have considered three distinct ways in which rhythm may affect relative duration judgments. The two models generated from the Rhythmic Attending Theory, namely the Missing Beat and Average Accent Period Hypotheses, both assume that a perceiver uses the rhythmic structure of a melody as the referent for judged duration. Both have predicted that incompatible rhythms will yield shorter duration estimates than compatible rhythms with co-occurring accents. In contrast, the information-processing models make an opposite prediction. Here, a perceiver does not use rhythm as a referent for duration judgments - instead rhythm functions to segment an interval into discrete chunks that must be cognitively concatenated. A greater number of chunks increases information-processing and code complexity, which in turn lengthens experienced duration.

In the following section, we'll consider how these various hypotheses are evaluated by the design of Experiment One. The general intent is to determine whether rhythm does exert a major impact upon judged duration and if so, what the underlying reason may be.

<u>Experimental Design of Experiment One</u>

In this first experiment, four types of melodies were constructed that differed in their complexity of melodic and rhythmic structure. As seen in Figure 1, these melodies varied in terms of their presence or absence of melodic accents (rule, no-rule) and their placement of temporal accents (Four or Five Beat rhythm). The most simple melodies were assumed to contain melodic accents (m) that resulted from the application of musical rules. In addition, these melodic accents coincided with the temporal accents of a Four Beat rhythm (Rule-Four Beat rhythm). A more complex structure was achieved by imposing a Five Beat rhythm upon these same rule-generated melodies (Rule-Five Beat rhythm). As shown in Figure 1, temporal accents of these melodies, although isochronous in nature, did not coincide with melodic accents. The most complex melodies were assumed to be those labelled as NoRule Four Beat and NoRule Five Beat rhythm. Although these melodies contained the same contour (pattern of ups and downs in

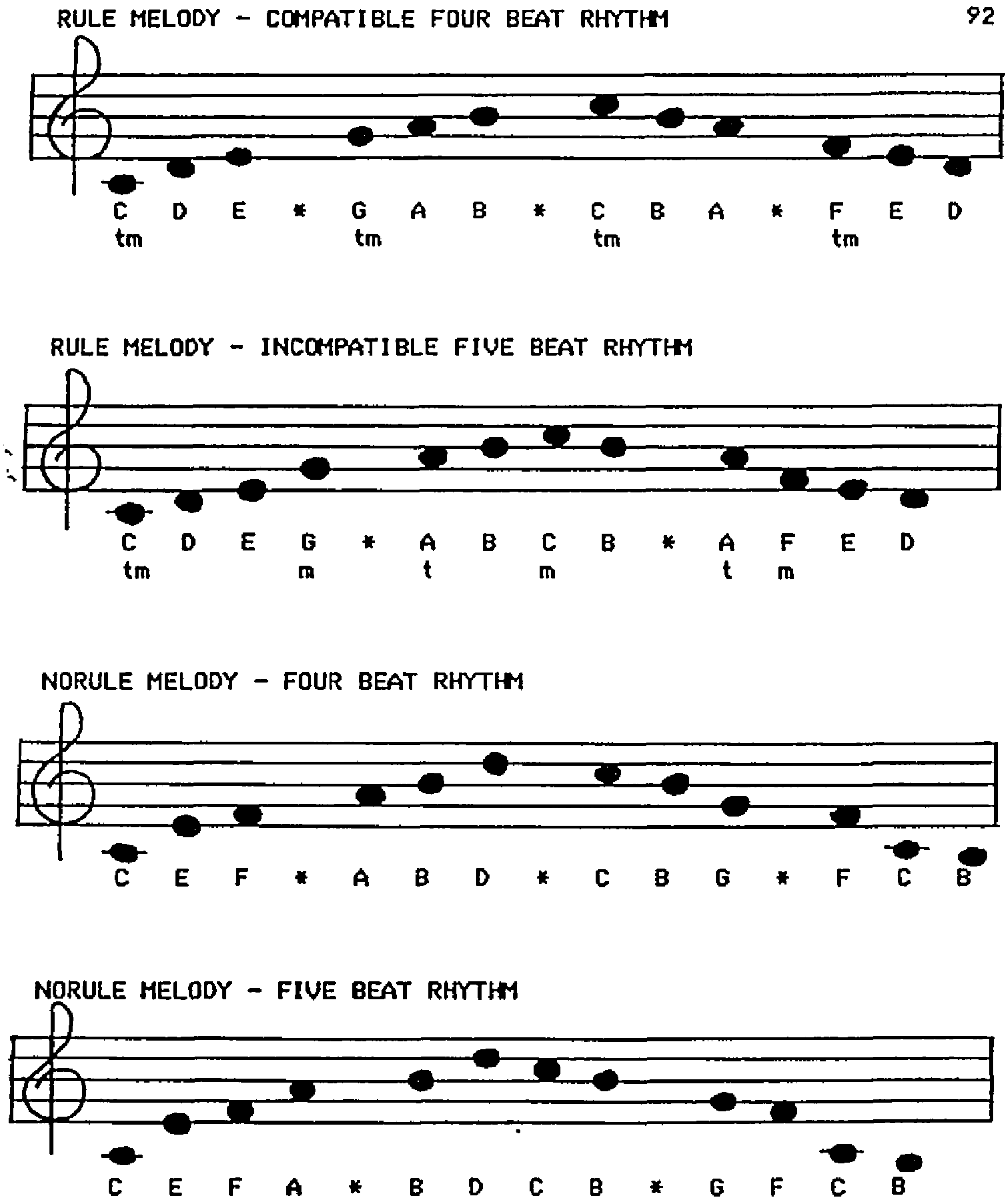


FIGURE 1. THE FOUR MELODY/RHYTHM CONDITIONS OF EXPERIMENT 1A AND 1B. THE MELODIC ACCENTS (m) OF RULE-GENERATED MELODIES ARE COMPATIBLE WITH THE TEMPORAL ACCENTS (t) OF A FOUR BEAT RHYTHM BUT INCOMPATIBLE WITH THOSE OF A FIVE BEAT RHYTHM. NORULE MELODIES, THOUGH CONTAINING THE SAME CONTOUR AS A RULE-BASED COUNTERPART, LACKED A MELODIC ACCENT STRUCTURE.

pitch) and rhythm as their rule counterparts, they did not contain melodic accents. Their tones were not related by a musical rule structure and so these melodies effectively contained a linear sequence of 12 unrelated tones.

To validate the structural complexity of these melodies, an independent group of subjects were asked to rate all patterns on three perceptual dimensions: a) simplicity or degree of predictability b) musicality or degree of harmony and c) goodness or the degree of typicality to the general category of music. It was predicted that melodies containing a more simple melodic and rhythmic structure would be rated as more predictable, more musical, and better representatives of music.

After these ratings were obtained, patterns were then paired for presentation in a comparative duration task. Patterns were paired such that a given pair either consisted of: two-rule based melodies; a rule melody followed by a no-rule melody; or a no-rule melody followed by a rule melody. In addition, the patterns of a pair either contained the same rhythm (ie. Four-Four Beat or Five-Five Beat) or a different rhythm (Four-Five Beat or Five-Four Beat). Patterns within a pair, then, either did or did not differ in their degree of accent complexity.

Given this experimental design, the three hypotheses mentioned earlier each predict a different pattern of results. Let's first consider the predictions of the Missing Beat Hypothesis. According to this hypothesis, the rhythmic beats of a melody's actual and missing tones (implied by pauses) establish corresponding beats within the organism. When judging relative duration, an organism will use the total number of beats within an initial melody as an expected referent. A second melody will seem longer if it contains a greater number of beats and shorter if it contains a fewer number of beats. In this experiment, the rule and no-rule melodies with a Four Beat rhythm both contain 15 beats. Conversely, melodies with a Five Beat rhythm contain 14 beats. This hypothesis thus predicts that, regardless of rule structure, Four Beat melodies will be judged longer than Five Beat melodies.

These predictions contrast with those of the Average Accent Period Hypothesis. This view claims that a perceiver uses the average duration of all accent periods as the expected referent. A second melody will seem shorter or longer depending on whether its average value is less than or greater than the expected referent. Table 1 has calculated the average duration value for each of the four melodies within this experiment. Notice that rule and no-rule melodies of the Four Beat rhythm are not predicted to differ because both contain the same average duration value (ie. TE = 1100 ms). In the Five Beat rhythm, however, rule melodies (TE = 660 ms) should be judged shorter than no-rule melodies (TE = 1500 ms). Further, this interaction between rule and rhythm should also reveal that Rule-Four Beat melodies will be judged longer than Rule-Five Beat melodies (TE = 1100 vs 660 ms.) but that the reverse should be found for no-rule melodies (TE = 1100 vs 1500 ms).

TABLE 1

"COMPLEXITY" VALUES FOR PATTERNS IN EXPERIMENT 1A AND 1B AS CONTRASTED BY THE MISSING BEAT, AVERAGE ACCENT PERIOD, AND INFORMATION-PROCESSING HYPOTHESES.

CONDITION	NUMBER OF BEATS	MEAN ACCENT PERIOD DURATION	NUMBER OF CHUNKS
RULE - FOUR BEAT (COMPATIBLE RHYTHM)	15	1100 ms.	4
NORULE - FOUR BEAT	15	1100 ms.	12
RULE - FIVE BEAT (INCOMPATIBLE RHYTHM)	14	660 ms.	6
NORULE - FIVE BEAT	14	1500 ms.	12

Lastly, the information-processing models predict a very different set of results. According to these models, a perceiver does not use the temporal information that is given by a melody's rhythm. Instead, rhythm serves to segment a melody into tonal groups or chunks. Since cognitive concatenation is then required to integrate these chunks, an increased number of chunks will increase code complexity and judged duration. However, the temporal accents of rhythm will only facilitate the processing of rule-based melodies whose tones are lawfully interrelated. If individual tones can be grouped by musical rules, these effectively form melodic chunks which are the units of concatenation (Restle 1972). The temporal accents of a rhythm may then parse these melodic chunks in a compatible or incompatible fashion. The Rule-Four Beat and Rule-Five Beat melodies of Figure 1 illustrate these two conditions respectively and show that an incompatible rhythm will increase chunk number. The tones of no-rule melodies, on the other hand, are not chunked by musical rules and so the unit of concatenation here is the individual tone. Since each tone must be concatenated to the next, rhythm will not really facilitate this process. As seen in Table 1, the no-rule melodies of both rhythms thus contain 12 chunks - a number that is significantly larger than that of rule melodies. When these melodies are now compared for relative duration, the following results are predicted. The Rule-Four Beat melody contains the fewest number of chunks (ie. 4) and should be judged shorter than the Rule-Five Beat melody and the two no-rule melodies. The two no-rule melodies should be judged the longest of all but not significantly different from one another. The predictions for all hypotheses are summarized in Table 1.

To evaluate these various hypotheses, the following experiment was conducted. The perceptual rating task will be presented first followed by the comparative judgment task.

Experiment 1a

The purpose of this first experiment was to determine how well a constructed set of melodies successfully discriminated among different levels of melodic and rhythmic complexity. Here, an independent group of subjects were asked to rate melodies for their degree of simplicity, goodness, and musicality. Those melodies containing musical rules and a compatible Four Beat rhythm are predicted to be rated as the most simple, the most musical, and the best exemplars of the general category of music. Increasing complexity should be associated with Rule-Five Beat melodies and NoRule melodies of the two rhythmic conditions.

Method

Design and Subjects

The design was a 2 x 2 x 2 x 2 x 2 mixed factorial. Two levels of pattern type (rules, no-rules) were crossed with two levels of rhythm (Four Beat, Five Beat) and two levels of total pattern duration (Long, Short). The two between-subjects factors were counterbalance order of trial presentation (I, II) and melodic instance group (A, B).

Thirty-six undergraduates participated in the experiment in return for course credit in Introductory Psychology. Each had at least 4 years of musical training within the past 6 years. Nine subjects were randomly assigned to one of the four between-subjects conditions.

Stimulus Materials

A set of musiclike patterns was constructed such that patterns would vary in their degree of melodic and rhythmic complexity. This was achieved by crossing two kinds of melodies (rule, no-rule) with two types of rhythm (Four Beat; Five Beat). The details of melodic and rhythmic constructions are as follows:

Melodic Construction

A total of sixteen pitch patterns were constructed, each containing 12 square wave tones from notes of the C major diatonic scale. Patterns were of two types: rule melodies or no-rule contour control melodies.

The eight rule-based melodies, shown in Figure 2, were generated by applying successive musical rules (see Jones 1981b) to a common tonal argument of (C D E). A melodic rule change thus occurred on every third note, creating a melodic (pitch) accent.

No-rule contour control melodies, also shown in Figure 2, lacked interval regularity but preserved the "ups and downs" of pitch changes in their respective rule-based counterparts. Notice that pattern NR1A within Figure 2, for example, contains an identical contour to pattern R1A. As with rule melodies, each no-rule melody began on middle C.

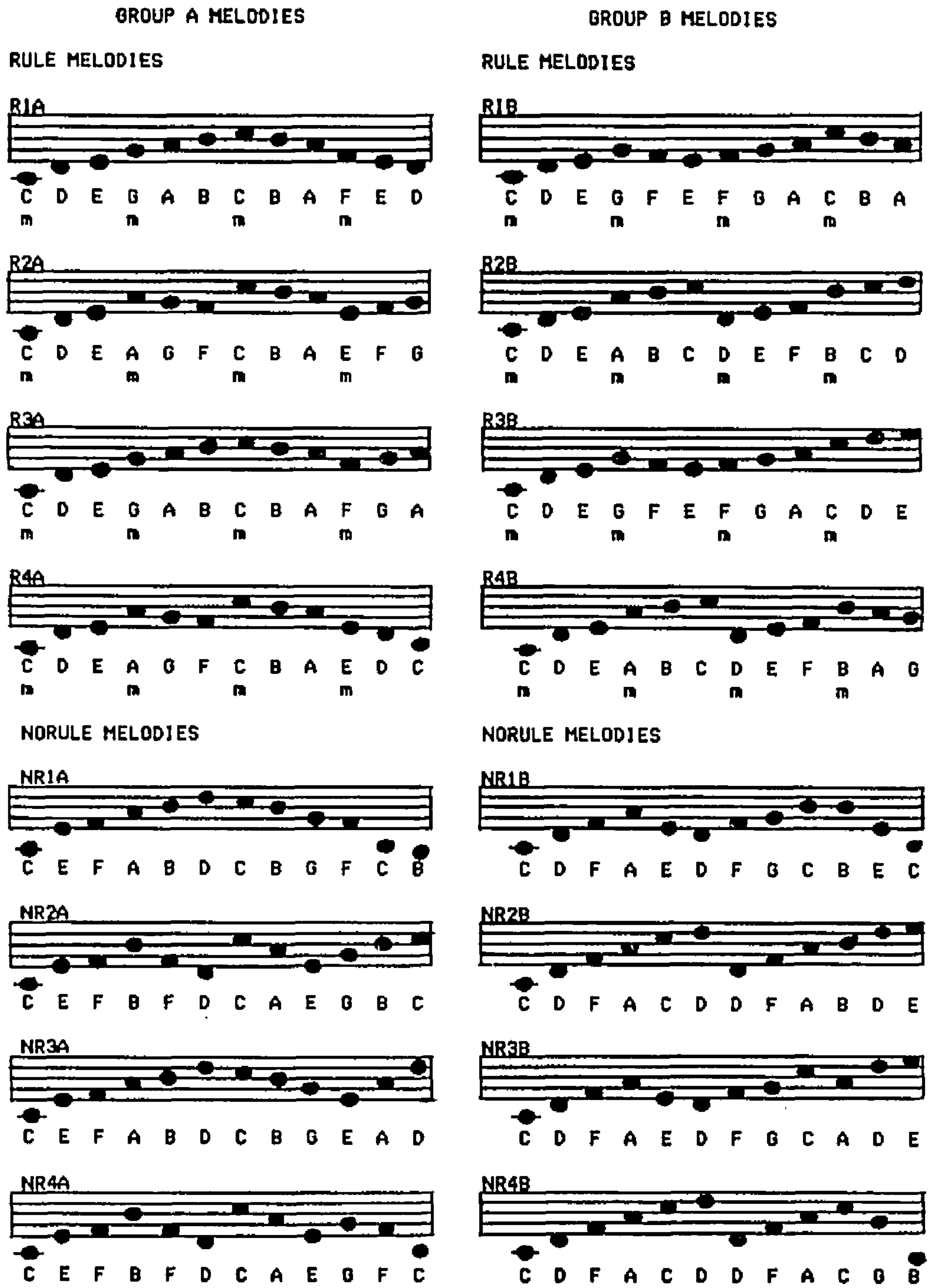


FIGURE 2. MELODIES USED IN EXPERIMENTS 1A AND 1B. THE MELODIC ACCENTS (m) WITHIN RULE MELODIES INDICATE POINTS OF MUSICAL RULE TRANSFORMATIONS.

<u>Rhythmic Construction</u>

All sixteen melodic patterns were crossed with two different rhythms of two different total durations, resulting in a total of sixty-four stimulus sequences. The two rhythms (Four Beat; Five Beat) within the long duration (total time = 4100 ms) shared a common tonal duration (on time) for all tones of 200 ms. Rhythms differed with respect to intertone interval (ITI): a) Four Beat rhythms had an ITI of 100 ms. except after every third tone where ITI was 300 ms. b) Five Beat rhythms had an ITI of 100 ms. except after every fourth tone where ITI was 400 ms. For the short duration (total time = 3075 ms), the tonal duration was always 150 ms. and ITI was 75 ms. except in the Four Beat rhythm where ITI was 225 ms. after every third tone and in the Five Beat rhythm where ITI was 300 ms. after every fourth tone. Table 2 depicts the Four and Five Beat rhythms at each duration.

In this experiment, the Four Beat rhythm is compatible with the melodic accent structure of rule melodies - the pauses which occur after every three notes coincide with points of melodic rule change. The Five Beat rhythm, on the other hand, contains pauses after every four notes, thus creating temporal accents that are incompatible with melodic accents.

The 64 stimulus patterns were divided into two groups of 32 patterns each (Group A,B). The melodic instances of each group, shown in Figure 2, consisted of four rule and four no-rule melodies at each of the four rhythm x duration conditions. For each group, two different random orders of 32 pattern sequences were constructed. In

TABLE 2

THE TWO RHYTHMS OF EXPERIMENT 1B AT THE SHORT DURATION (TOTAL TIME = 3075 MS) AND LONG DURATION (TOTAL TIME = 4100 MS).

SHORT DURATION

FOUR BEAT RHYTHM

Tonal Event	On Time	Off Time
1	150	75
2	150	75
3	150	225
4	150	75
5	150	75
6	150	225
7	150	75
8	150	75
9	150	225
10	150	75
11	150	75
12	150	75

FIVE BEAT RHYTHM

Tonal Event	On Time	Off Time
1	150	75
2	150	75
3	150	75
4	150	300
5	150	75
6	150	75
7	150	75
8	150	300
9	150	75
10	150	75
11	150	75
12	150	75

LONG DURATION

FOUR BEAT RHYTHM

Tonal Event	On Time	Off Time
1	200	100
2	200	100
3	200	300
4	200	100
5	200	100
6	200	300
7	200	100
8	200	100
9	200	300
10	200	100
11	200	100
12	200	100

FIVE BEAT RHYTHM

Tonal Event	On Time	Off Time
1	200	100
2	200	100
3	200	100
4	200	300
5	200	100
6	200	100
7	200	100
8	200	300
9	200	100
10	200	100
11	200	100
12	200	100

the actual rating task, each group of subjects received two blocks of 32 sequences, yielding two presentations of each pattern.

Apparatus

All patterns consisted of square wave tones generated by a Wavetek Model 159 waveform generator that was controlled by a Cromemco Z-2 microcomputer. In generation, a custom built envelope generator imposed 10 ms. rise and fall times on all tones. Tonal frequencies, in Hertz, were taken from the equally tempered scale of International Pitch (A4 = 400 hz). Tones were subjectively equated for loudness in the actual pattern context according to reports of two judges. Sequences of tones, programmed by the microcomputer, were recorded on a Nakamichi LX-3 cassette recorder. During an experimental session, the sets of prerecorded tonal sequences were presented through AKG headphones at a comfortable listening level.

Procedure

Eighteen subjects were randomly assigned to each of the two pattern group conditions. Recorded instructions informed subjects of pattern presentation details and task requirements. On each trial, a one sec. warning tone (5000 hz) preceded a 12 tone melodic pattern by two secs. Three seconds later, this same pattern was again presented for the benefit of the listener. During a seven sec. response interval, subjects were then asked to rate this pattern for its degree of goodness, simplicity, and musicality. To relate the concept of goodness, subjects were instructed to imagine a "good" representative example of a musical pattern. It was suggested that such a melody may possess a particular pattern of pitch directions, a lawful relatedness between successive tones, and a particular type of rhythm. For ratings of simplicity, subjects were asked to consider a pattern's degree of predictability and how easily its notes could be anticipated. Lastly, in rating musicality, subjects were asked to consider a pattern's degree of harmony and how well is could be incorporated into a musical composition. Subjects were also informed that all patterns were generated from a computer, and in addition to sounding unlike conventional music, would be relatively shorter and much more basic than the music they were used to hearing. They were asked to keep these considerations in mind and to concentrate more upon the structural relationships of a pattern. A 12 point scale was provided on each trial for each of the three ratings. Subjects were informed that a value of 1, 2, or 3 on the scale indicated that the pattern was a very good exemplar (or very simple or very musical). Conversely, values of 10, 11, and 12 would indicate that the pattern was a very poor exemplar (or very complex or very unmusical). It was encouraged that the entire range of the scale be used to represent their judgments.

Each experimental session was approximately 45 mins. in duration, a brief 3 min. rest period being provided after 32 trials. Prior to the experimental session, subjects were presented with 4 practice trials to acquaint them with the procedure. These consisted of an unfamilar set of patterns at each of the four rhythm x duration conditions.

Results

An analysis of variance was performed on each rating measure and in all cases, data was collapsed over duration (short, long) and counterbalance order (all F's < 1). The results of each analysis will be considered in turn. To summarize the predictions, it was expected that patterns containing rules and a compatible Four Beat rhythm would be judged the most simple, most musical, and the best exemplars of music-like patterns. Conversely, Rule melodies containing an incompatible Five Beat rhythm should be rated lower while NoRule melodies should be judged as the most complex, most unmusical, and worst exemplars.

Goodness Ratings

Data analyses on the goodness measure confirmed these predictions. Although there was no main effect for rhythm, a pattern main effect ($F_{1,32} = 77.6$, $p < .0001$, $MSe = .557$) revealed that rule melodies were rated as more representative of music than no-rule melodies. Pattern interacted with rhythm ($F_{1,32} = 10.29$, $p < .003$, $MSe = .143$), and as Table 3 illustrates, Four Beat rule melodies were rated highest for goodness followed by Five Beat rule melodies (Bonferroni $F = 3.48$, $p < .01$). The lowest ratings were obtained for the no-rule melodies of both rhythmic conditions (which did not significantly differ from one another.

Musicality Ratings

Since results obtained with the musicality dimension converged with those for goodness, the F statistics for this measure are

TABLE 3

MEAN GOODNESS RATINGS IN EXPERIMENT 1A FOR RULE AND NORULE PATTERNS AS A FUNCTION OF RHYTHM. LARGER VALUES INDICATE THAT MELODIES WERE POOR EXEMPLARS OF MUSIC.

		PATTERN TYPE		
		RULES	NORULES	MEANS
RHYTHM	FOUR BEAT	4.86	6.16	5.51
	FIVE BEAT	5.17	6.06	5.62
	MEANS	5.02	6.11	

presented in Appendix A. Only the results that are discrepant with the goodness dimension will be discussed.

The rhythm x pattern interaction, shown in Table 4, revealed that Four Beat rule melodies were rated as the most musical followed by the Five Beat rule melodies. Four Beat no-rule melodies were rated as less musical and the Five Beat no-rule melodies were rated lowest of all. Post hoc comparisons among the four means were all significant. A significant pattern x group interaction was also obtained and indicates that although both groups rated the rule melodies as significantly more musical than no-rule melodies, the difference was much larger for Group B.

Simplicity Ratings

Results obtained with simplicity ratings yielded a similar pattern of significance as found with the goodness and musicality ratings. Hence the F statistics for this dimension are presented in Appendix A.

Rhythm did produce a significant main effect and indicated that a Four Beat rhythm was rated as more simple than a Five Beat rhythm. Rhythm also interacted with pattern and as shown in Table 5, the nature of this interaction slightly differs from that found for the other two dimensions. Here, Four Beat rule melodies were judged as the most simple, followed by Four Beat no-rule melodies. Increasing complexity was associated with Five Beat rule melodies and Five Beat no-rule melodies. Post hoc comparisons among these four conditions were all significant. A significant rhythm x group interaction was

TABLE 4

MEAN MUSICALITY RATINGS IN EXPERIMENT 1A FOR RULE AND NORULE PATTERNS AS A FUNCTION OF RHYTHM. LARGER VALUES INDICATE THAT MELODIES WERE VERY UNMUSICAL.

		PATTERN TYPE		
		RULES	NORULES	MEANS
RHYTHM	FOUR BEAT	5.21	6.25	5.73
	FIVE BEAT	5.45	6.56	6.01
	MEANS	5.33	6.41	

TABLE 5

MEAN SIMPLICITY RATINGS IN EXPERIMENT 1A FOR RULE AND NORULE PATTERNS AS A FUNCTION OF RHYTHM. LARGER VALUES INDICATE GREATER COMPLEXITY

RHYTHM	PATTERN TYPE: RULES	NORULES	MEANS
FOUR BEAT	4.35	5.82	5.09
FIVE BEAT	6.19	7.21	6.70
MEANS	5.27	6.52	

also obtained, indicating that although both groups rated the Four Beat rhythm significantly more simple than the Five Beat, the difference was much larger for Group B.

Discussion

The purpose of this first experiment was to determine whether perceptual ratings would validate the structural definition of complexity. Convergence was obtained. The Four Beat rule melodies were consistently judged as the most simple, most musical, and the best exemplars of music. Five Beat rule melodies and no-rule melodies received significantly lower ratings. Although results sometimes differed among the two melodic instance groups, the presumed definition of complexity appears to warrant continued usage in subsequent experiments.

Experiment 1b

The second experiment was designed to investigate effects of melodic and rhythmic complexity on relative duration judgments. Three sets of hypotheses were evaluated. Two, the Missing Beat and Average Accent Period Hypotheses, were generated from the Rhythmic Attending Theory while the third reflects assumptions within the information-processing approach. To evaluate these contrasting sets of predictions, shown in Table 1, subjects were presented with the melodic patterns of Experiment 1a in a comparative duration task.

Method

Design and Subjects

The design was a 2 x 2 x 2 x 3 x 4 mixed factorial. Two levels of total duration (long, short) were crossed with four levels of rhythmic pairs (Four-Four Beat; Five-Five Beat; Four-Five Beat; Five-Four Beat) and three levels of pattern pairs (Rule-Rule; NoRule-Rule; Rule-NoRule). The two between-subjects variables were counterbalance order (I, II) and melodic instance group (A, B).

Forty-four undergraduates participated in the experiment in return for course credit in Introductory Psychology. Each had at least four years of musical training within the past six years. Eleven subjects were assigned to one of the four between-subjects conditions.

Stimulus Materials

The two groups of melodies (Group A, B) from Experiment 1a were again utlized. The 32 stimulus patterns within each group were paired with one another to result in a total of 96 experimental trials. On each trial, the total duration of each pattern (short or long) was always kept constant. Pairings, however, could differ with respect to rhythm (Four or Five Beat) and pattern type (Rule, NoRule). Specifically, the various melodic rule instances within each group were paired with one another to achieve the Rule-Rule pattern type; rule melodies were also paired with their respective NoRule contour control melodies to obtain Rule-NoRule pairs and NoRule-Rule pairs. All pattern pairs were then crossed orthogonally with the two rhythms.

Thus the six pattern pair types either had the same rhythm (Four-Four Beat or Five-Five Beat) or a different rhythm (Four-Five Beat or Five-Four Beat). When the 48 pattern x rhythm pairs within each group were crossed with the two durations, 96 experimental trials resulted. Trials were randomized for presentation and divided into two blocks of 48 trials. The apparatus used for presentation was identical to that of Experiment 1a.

Procedure

Subjects were told that time judgments would be requested and to therefore remove their watches. Recorded instructions informed subjects of task requirements and experimental details. Subjects were also told that they would be tested for their memory of these patterns the following day. On each trial, a one sec. warning tone (5000 hz) preceded an initial 12 tone pattern by two secs. Two seconds later, a second 12 tone pattern was presented. During a 7 secs. response interval, subjects were then asked to judge whether the time duration of this second pattern was the same, longer, or shorter than the first. Judgment were indicated by circling one of the seven numbers on the following scale:

very much longer	quite longer	somewhat longer	same duration	somewhat shorter	quite shorter	very much shorter
-3	-2	-1	S	+1	+2	+3

Subjects were also asked to judge the certainity of this judgment on a confidence scale ranging from 1 to 7: 1 meaning very certain and 7 meaning very uncertain.

Each experimental session was approximately one hour in duration with a brief 3 min. rest period provided after 48 trials. Prior to the experimental session, subjects were presented with 4 practice trials to acquaint them with the procedure. These consisted of a novel set of patterns at each of the four rhythm x duration conditions.

Results

Table 6 presents the mean judged duration as a function of pattern pairs (Rules-NoRules; NoRules-Rules; Rules-Rules) and rhythmic pairs (Four-Four Beat; Five-Five Beat; Four-Five Beat; Five-Four Beat). Since scores from the duration response scale were converted into values of 1 to 7, a mean of 4 denotes that the two events were judged to have the same duration; values greater than 4 denotes that the second stimulus was judged shorter; and values less than 4 denotes that the second stimulus was judged longer. Means in Table 6 are collapsed over counterbalance order and total duration since these factors failed to attain significance. Means are also collapsed over melodic instance group (A, B).

The three hypotheses that are evaluated here, the Missing Beat, Average Accent Period and Information-Processing hypotheses, generate a different set of predictions for melodic pairings. A key issue on which these models vary concerns the main effect of rhythm. The Missing Beat Hypothesis predicts that the Four Beat rhythm will be judged longer than the Five Beat because the former contains <u>three</u> missing tones (implied by pausing) in addition to the 12 actual tones

TABLE 6

MEAN JUDGED DURATION FOR PATTERN PAIRS IN EXPERIMENT 1B AS A FUNCTION OF RHYTHM PAIRS. A VALUE OF 4 INDICATES EQUIVALENT JUDGED DURATION; VALUES <4 INDICATE THE SECOND PATTERN WAS JUDGED LONGER AND; VALUES >4 INDICATE THE SECOND PATTERN WAS JUDGED SHORTER.

		RHYTHM PAIRS				
		FOUR-FOUR BEAT	FIVE-FIVE BEAT	FOUR-FIVE BEAT	FIVE-FOUR BEAT	MEANS
PATTERN PAIRS	RULE - NORULE	3.92	3.64	4.18	3.71	3.86
	NORULE - RULE	3.92	3.96	4.00	3.80	3.92
	RULE - RULE	3.98	3.96	4.26	3.75	3.99
	MEANS	3.94	3.85	4.15	3.75	

of a melody - in contrast, The Five Beat contains only _two_ missing tones to yield a total of 14 beats. The Average Accent Period hypthesis makes a similar prediction. The average duration of accent periods within the Four Beat rhythm is slightly higher (ie. 1100 ms) than that of the Five Beat rhythm (ie. 1050 ms) and so again, it should judged longer. The information-processing models, however, make an opposite prediction. The Four Beat rhythm has segmented a melody into fewer chunks and so it should be judged _shorter_ than the Five Beat rhythm. To contrast these predictions, the critical comparison is between the rhythmic pairs of the Four-Five Beat and Five-Four Beat conditions.

Results supported the predictions of the Rhythmic Attending hypotheses. A significant main effect for rhythm pairs ($F_{3,120} = 8.21$, $p < .0001$, $MSe = .445$) is illustrated in the column means of Table 6. Here, the Four-Five and Five-Four Beat conditions do significantly differ (Bonferroni $F = 2.86$, $p < .01$) and indicate that the Four Beat rhythm is judged _longer_ than the Five Beat rhythm. By determining the average deviation from the "same duration" value (ie. 4.00), it was also determined that the Four Beat rhythm was judged significantly longer than a same judgment ($F = 3.33$, $p < .01$). The two control conditions, namely Four-Four and Five-Five Beat pairs, are quite orderly in that patterns containing the same rhythm do not significantly differ from one another nor from a judgment of "same duration".

A second issue in which these three models all differ from one another concerns the variable of melodic rule pairs and its effect at different levels of rhythm pairs. By looking at Table 1, notice that the Missing Beat hypothesis doesn't predict any effect of rules - Four Beat melodies should always be judged longer than Five Beat melodies, regardless of rule structure. The Average Accent hypothesis, on the other hand, does predict an interaction of melodic rule pairs and rhythm pairs. Although rule and no-rule melodies of the Four Beat rhythm should not differ, Rule Five Beat melodies should be judged shorter than NoRule Five Beat melodies. Further, Rule Four Beat melodies should be judged longer than Rule Five Beat melodies while the reverse should be true for NoRule melodies. The information-processing models also predict an interaction but its nature is quite different. The Rule Four Beat melodies contain the fewest number of chunks and should be judged shorter when paired with any other melody (ie. Rule Five Beat melodies and the NoRule melodies of both rhythms). The NoRule melodies of both rhythms contain the most chunks and should be judged longer than other melodies, but not different from one another.

As Table 6 illustrates, a rule x rhythm interaction was obtained in this experiment ($F_{6,240} = 5.63$, $p < .0001$, $MS_e = .103$). The nature of this interaction, however, did not uniformly support any one hypothesis. By comparing the rhythm pairs of Four-Five versus Five-Four Beat, notice that Four Beat melodies are always judged longer than Five Beat melodies regardless of rule structure (all

Bonferroni post hocs significant at .01). This is contrary to predictions of both the Average Accent Period and Information-Processing hypotheses. Instead, it supports the Missing Beat hypothesis. Now consider the melodies within the Four-Four Beat versus the Five-Five Beat rhythm conditions. Consistent again with the Missing Beat hypothesis, patterns containing the same rhythm are judged as equivalent in duration. The one anomaly occurs in the Five Beat condition where the no-rule pattern is judged longer than the rule melody ($F = 4.67$, $p < .01$). A significant group x rule interaction ($F_{2,80} = 6.01$, $p < .0004$, $MSe = .126$) suggests that this anomaly arises from melodic instance effects. As shown in Table 7, Group B judged no-rule melodies as being relatively longer than rule melodies while Group A judged the two as equivalent in duration. These melodic instance effects are also responsible for a significant rule main effect ($F_{2,80} = 5.52$, $p < .006$, $MSe = .126$). As the row means of Table 6 show, the no-rule pattern is judged longer when preceded by a rule pattern. The other two levels of pattern pairs, however, are judged as equivalent in duration.

In an attempt to isolate the anomaly within the 5-5 Beat condition of Group B, the mean judged duration for each individual pattern pairing was determined. This analysis revealed that the effect arises from two sources: a) the pairing of the rule-based melody (R1B) with its contour control (NR1B) and b) the pairing of the rule melody (R4B) with its contour control (NR4B). In both cases, the no-rule contour control melody is judged significantly longer than its

TABLE 7

MEAN JUDGED DURATION FOR PATTERN PAIRS IN EXPERIMENT 1B AS A FUNCTION OF MELODIC INSTANCE GROUP.

PATTERN PAIRS	RHYTHM PAIRS: RULE - NORULE	NORULE - RULE	RULE - RULE	MEANS
GROUP A	3.97	3.90	4.05	3.97
GROUP B	3.76	3.95	3.93	3.88
MEANS	3.86	3.92	3.99	

preceding rule melody. It is not known at this time why this result is obtained. By examining the means for the remaining pattern pairings, however, the data appears quite orderly.

Discussion

The overall pattern of results obtained in this experiment seem to most strongly support the Missing Beat Hypothesis. Melodies containing a Four Beat rhythm were consistently judged longer than those containing a Five Beat rhythm. Although the Average Accent Period Hypothesis predicted this same finding, its predicted effects of melodic rules upon rhythmic structure did not emerge. The presence or absence of melodic rules, in fact, had little effect upon judged duration. The one exception occurred in the Five-Five Beat condition where a no-rule melody was judged longer than a rule melody. This result, though consistent with both the Average Accent and information-processing models, does not appear to be a reliable one in that it only occurred with two instances of Group B melodies.

These results then do suggest that rhythm has a more critical impact upon judged duration than melodic rule structure. Contrary to the Average Accent Hypothesis, perceivers do not seem to use melodic accents (at least as they have been defined here) as markers for temporal intervals. Instead, the rhythmic beats of a melody are apparently mirrored within an organism and are used as an expected referent to estimate relative duration. These beats arise both from actual tones and missing tones implied by pauses, and their pickup is unaffected by either the presence or location of melodic accents.

This view of rhythm and its effect upon judged duration is quite different from that of current information-processing models. According to these models, rhythm serves to segment a melody into discrete chunks that must be cognitively concatenated. If temporal accents coincide with the melodic accents of a rule melody, then a more simple mental code will result that serves to decrease experienced duration. If melodies contain incompatible accents or lack a melodic rule structure, code complexity will presumably increase as well as judged duration. This view, however, was not supported by the present experiment. While it is true that rule melodies with a compatible Four Beat rhythm were judged more simple in Experiment 1a, these melodies were judged longer , not shorter, than those with an incompatible Five Beat rhythm. Further, no-rule melodies were not always judged longer than rule melodies - instead, duration judgments depended upon the number of rhythmic beats associated with a given melody.

Although results of this first experiment were generally consistent with the Missing Beat Hypothesis, the one effect of melodic rule structure within the Five-Five Beat condition could be cited as partial evidence for the other two hypotheses. In addition, the melodies used in this first experiment did display some structural problems. First, notice that the missing tones within the pauses of the Four Beat rhythm, shown in Table 2, occur with a temporal periodicity of 250 ms. In contrast, the melody's actual tones occur with a periodicity of 300 ms. Ideally, the temporal periodicity of missing tones should match that of actual tones - as is true within the Five Beat rhythm. Although it is not clear how this confounding may have affected the present set of results, the temporal periodicity of beats should be kept constant both within and between rhythms. Second, one could argue that no-rule melodies, though lacking interval predictability, did contain a predictable contour (pattern of ups and downs in pitch). The contour of these melodies was in fact identical to a corresponding rule melody and as seen in Figure 2, was often symmetrical in shape. A listener may have grouped tones on the basis of contour direction and, if so, these no-rule melodies did not contain 12 psychological chunks as claimed earlier. In short, the chunk size of no-rule melodies cannot be precisely specified and so the information-processing models may have been unfairly evaluated by this first experiment.

Experiment Two

A second experiment was therefore designed to test the same set of hypotheses with a more carefully constructed set of melodies. In particular, all melodies were generated from musical rules and so complexity was only defined in terms of the compatibility or incompatibility of melodic and temporal accents. Since no-rule melodies have been eliminated, this should provide a more fair evaluation of the information-processing models. As before, all melodies contained 12 tones but here, patterns were generated from a three tone argument or a four tone argument. By orthogonally crossing these two types of melodies with a compatible and incompatible rhythm, four patterns of melodic (m) and temporal (t) accent structures result. They are depicted in Figure 3. Assuming that the temporal periodicity or SOA of a tone is always 180 ms. throughout all patterns, notice that all four pattern types contain the same number of actual (12) and implied (6) tones (actual tones are indicated by digits 1-12). When temporal accents are considered in conjunction with melodic accents, notice also that the first two conditions contain compatible accent structures in that (t) and (m) coincide. The latter two patterns, however, contain conflicting accent structures. If one now orthogonally combines these four pattern types into all possible standard-comparison pairs, 16 conditions result as shown in Table 8. These 16 conditions display a different set of predicted results for the various hypotheses to be addressed. First consider the hypotheses that generate from the Rhythmic Attending Theory.

Missing Beat Hypothesis

This view assumed that people use the total number of rhythmic beats within a standard pattern as an expected referent. A comparison pattern containing a fewer number of beats will appear to end relatively early and will therefore seem shorter. A pattern with a greater number of beats will seem longer while one with the same number of beats as the referent will appear to have the same duration.

In contrast to the first experiment, the Five and Seven Beat rhythms of this experiment contain the same temporal periodicity and the same number of actual and implied tones. Thus, this hypothesis

I. THREE TONE ARGUMENT - FIVE BEAT RHYTHM

```
        900 ms              900 ms              900 ms
tm                  tm                  tm                  tm
x   x   x   x   x   x   x   x   x   x   x   x   x   x   x   x   x   x
1   2   3           4   5   6           7   8   9          10  11  12
```

II. FOUR TONE ARGUMENT - SEVEN TONE ARGUMENT

```
           1260 ms                     1260 ms
tm                          tm                          tm
x   x   x   x   x   x   x   x   x   x   x   x   x   x   x   x   x   x
1   2   3   4               5   6   7   8               9  10  11   12
```

III. FOUR TONE ARGUMENT - FIVE BEAT RHYTHM

```
        900 ms      180 ms    720 ms      360 ms    540 ms
tm                  t   m               t       m           t
x   x   x   x   x   x   x   x   x   x   x   x   x   x   x   x   x   x
1   2   3           4   5   6           7   8   9          10  11  12
```

IV. THREE TONE ARGUMENT - SEVEN BEAT RHYTHM

```
    540 ms       720 ms      360 ms        900 ms      180 ms
tm          m               t       m                   t   m
x   x   x   x   x   x   x   x   x   x   x   x   x   x   x   x   x   x
1   2   3   4               5   6   7   8               9  10  11  12
```

FIGURE 3. THE FOUR CONDITIONS OF EXPERIMENT TWO WHERE PATTERNS CONTAIN A MELODIC ARGUMENT OF THREE OR FOUR TONES AND A FIVE OR SEVEN BEAT RHYTHM. THE FIVE BEAT RHYTHM IS COMPATIBLE WITH A THREE TONE ARGUMENT AND THE SEVEN BEAT RHYTHM IS COMPATIBLE WITH A FOUR TONE ARGUMENT. ASSUME THAT THE SOA BETWEEN EACH TONAL EVENT IN ALL PATTERNS IS 180 MS.

TABLE 8

EXPERIMENTAL DESIGN OF EXPERIMENT 2.

SECOND PATTERN

FIRST PATTERN	FOUR-TONE SEVEN-BEAT	THREE-TONE FIVE-BEAT	THREE-TONE SEVEN-BEAT	FOUR-TONE FIVE-BEAT
FOUR TONE - SEVEN BEAT				
THREE TONE - FIVE BEAT				
THREE TONE - SEVEN BEAT				
FOUR TONE - FIVE BEAT				

predicts that all patterns should be judged as equivalent in duration, regardless of their melodic and temporal accent in(compatibility). There should be no significant main effects or interaction.

Average Accent Period Hypothesis

In contrast to the previous hypothesis, this model assumes that people use a melody's temporal and melodic accent structure in duration judgments. Specifically, a perceiver presumably attends to the time periods between melodic and temporal accents and uses their average duration as the referent for behavior. As seen in Table 9, melodies with a compatible accent structure contain both both fewer and longer accent periods. Their average duration is thus longer than incompatible melodies whose accent periods are both shorter and more frequent. This hypothesis also predicts that the two incompatible melodies of this experiment will be judged as equivalent in duration but that the Three Tone-Five Beat melody will be judged shorter than the Four Tone-Seven Beat melody.

Information-Processing Models

This class of models assumes that the temporal accents of a rhythm serve to parse a melody into chunks of information. As seen in Table 9, melodies with conflicting temporal and melodic accents contain a greater number of chunks. They should therefore be judged longer than more simple melodies with compatible accents. In addition, Three Tone-Five Beat melodies should be judged longer than Four Tone-Seven Beat melodies while no difference should be obtained with the two incompatible melodies.

TABLE 9

"COMPLEXITY" VALUES FOR PATTERNS IN EXPERIMENT 2 AS CONTRASTED BY THE MISSING BEAT, AVERAGE ACCENT PERIOD, AND INFORMATION-PROCESSING HYPOTHESES.

CONDITION	NUMBER OF BEATS	MEAN ACCENT PERIOD DURATION	NUMBER OF CHUNKS
THREE TONE- FIVE BEAT (COMPATIBLE RHYTHM)	18	900 ms.	4
THREE TONE-SEVEN BEAT (INCOMPATIBLE RHYTHM)	18	540 ms.	6
FOUR TONE-SEVEN BEAT (COMPATIBLE RHYTHM)	18	1260 ms.	3
FOUR TONE-FIVE BEAT (INCOMPATIBLE RHYTHM)	18	540 ms.	6

To assess these various hypotheses, the following experiment was conducted.

Method

Design and Subjects

The design was a 2 x 2 x 4 x 4 x 4 mixed factorial. Four levels of rhythm pairs (Five-Five Beat; Seven-Seven Beat; Five-Seven Beat; Seven-Five Beat) were crossed with four levels of melodic argument pairs (Three-Three; Four-Four; Three-Four; Four-Three), two levels of total duration (Short, Long), and four levels of melodic instance. Two levels of counterbalance order (I, II) was the single between-subjects factor.

Twenty-two undergraduates were recruited from the enrollments of Introductory Psychology, each having four years of musical experience within the past six years. Eleven subjects were randomly assigned to each counterbalance order.

Stimulus Materials

A total of eight melodic patterns were constructed from the set of musical rules described by Jones (1981b). Each contained 12 square wave tones from notes of the C major diatonic scale, but half were generated from a three tone argument (C4 D4 E4 or C5 B4 A4) while the remainder were based on a four tone argument (C4 D4 E4 F4 or C5 B4 A4 G4). All patterns are depicted in Figure 4.

All eight melodic instances were crossed with two types of rhythm. A Five Beat rhythm, compatible with melodies based on a three tone argument, contains a pause after every third tone. This in

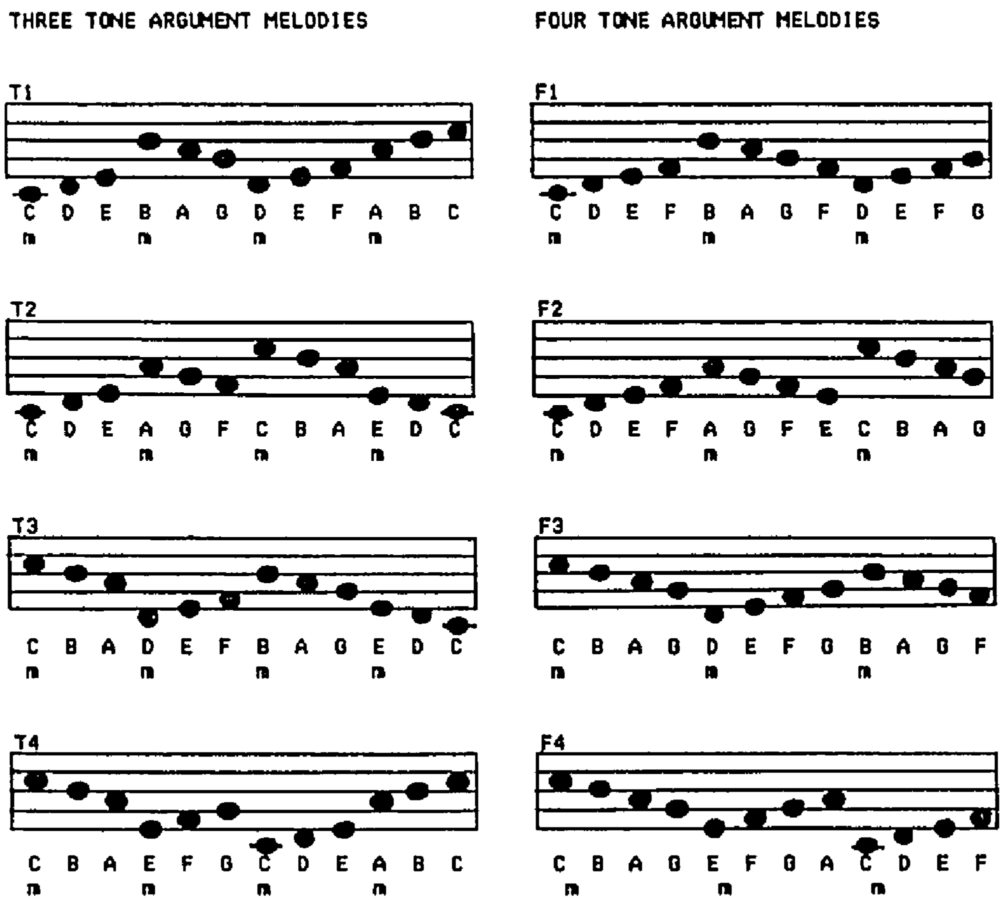


FIGURE 4. MELODIES USED IN EXPERIMENT 2. THE MELODIC ACCENTS (m) INDICATE POINTS OF MUSICAL RULE TRANSFORMATIONS.

effect results in 2 implied beats between serial positions 3-4; 6-7; and 9-10 of all patterns. A Seven Beat rhythm is compatible with melodies based on a four tone argument since it creates a pause after every fourth tone. The duration of these pauses is such that three implied beats occur between serial positions 4-5 and 8-9. For both rhythms, then, the number of implied (and actual) beats is equated.

Lastly, all rhythmic-melodic patterns were crossed with two different total durations to yield 32 experimental patterns. Table 10 depicts the Five Beat and Seven Beat rhythms at both the short (total time = 3240 ms.) and long durations (4860 ms.). The rationale for using two different total durations was three-fold: First, it extends the generalizability of obtained results (if no difference in duration is observed); Second, since patterns within a pair are equivalent in actual duration, subjects may be less apt to notice this if different durations are used; Third, the usage of two durations allows a particular pattern to be presented a second time for purposes of statistical reliability.

These 32 patterns were then paired with one another such that 128 experimental trials resulted. Melodic instance (1 or 2), initial tone (C4 or C5), and total duration of a pattern (long or short) was always the same across standard and comparison members of a pair. Patterns within a pair, however, may or may not vary in accent compatibility. By combining the 16 conditions of Table 8 with the two total durations and four melodic instances, 128 experimental trials are yielded. Two randomized blocks of 64 trials were generated and thus resulted in one

TABLE 10

THE TWO RHYTHMS OF EXPERIMENT 2 AT THE SHORT DURATION (TOTAL TIME = 3240 MS) AND LONG DURATION (TOTAL TIME = 4860 MS).

SHORT DURATION

FIVE BEAT RHYTHM

Tonal Event	On Time	Off Time
1	120	60
2	120	60
3	120	420
4	120	60
5	120	60
6	120	420
7	120	60
8	120	60
9	120	420
10	120	60
11	120	60
12	120	60

SEVEN BEAT RHYTHM

Tonal Event	On Time	Off Time
1	120	60
2	120	60
3	120	60
4	120	600
5	120	60
6	120	60
7	120	60
8	120	600
9	120	60
10	120	60
11	120	60
12	120	60

LONG DURATION

FIVE BEAT RHYTHM

Tonal Event	On Time	Off Time
1	180	90
2	180	90
3	180	630
4	180	90
5	180	90
6	180	630
7	180	90
8	180	90
9	180	630
10	180	90
11	180	90
12	180	90

SEVEN BEAT RHYTHM

Tonal Event	On Time	Off Time
1	180	90
2	180	90
3	180	90
4	180	900
5	180	90
6	180	90
7	180	90
8	180	900
9	180	90
10	180	90
11	180	90
12	180	90

presentation of each stimulus pair for a given subject.

Apparatus and Procedure

Identical to the previous experiment.

Results

Table 11 depicts the mean judged duration as a function of the first and second pattern presented within a pair. By combining melodic argument size (Three vs. Four Tones) with rhythm (Five vs. Seven Beat), the four pattern types reflect differences in melodic and temporal accent compatibility. As in the last experiment, scores from the duration response scale were converted into values ranging from 1 to 7 where 4 denotes that both patterns were judged as the "same" duration; values less than 4 indicate that the second pattern was judged longer; and values greater than 4 indicate that the second pattern was judged shorter. Since counterbalance order, total duration, and melodic instance all failed to achieve statistical significance, the means of Table 11 are collapsed over these variables.

The easiest way to summarize these results is to say that nothing happened. There were no main effects for the variables of rhythm pair and melodic argument pair nor any interaction between these two variables. This null pattern of results supports one model generated from Rhythmic Attending Theory, the Missing Beat Hypothesis. Since all patterns had an identical number of beats, they were judged as equivalent in duration. The implications of this model for the study of judged duration will be considered next.

TABLE 11

MEAN JUDGED DURATION FOR PATTERN PAIRS IN EXPERIMENT 2 AS A FUNCTION OF RHYTHM AND MELODIC ARGUMENT COMBINATIONS. A VALUE OF 4 INDICATES EQUIVALENT JUDGED DURATION; VALUES <4 INDICATE THE SECOND PATTERN WAS JUDGED LONGER AND; VALUES >4 INDICATE THE SECOND PATTERN WAS JUDGED SHORTER.

FIRST PATTERN	SECOND PATTERN: FOUR-TONE SEVEN-BEAT	THREE-TONE FIVE-BEAT	THREE-TONE SEVEN-BEAT	FOUR-TONE FIVE-BEAT	MEANS
FOUR TONE - SEVEN BEAT	3.90	3.85	3.70	3.68	3.78
THREE TONE - FIVE BEAT	4.36	4.05	4.14	4.14	4.17
THREE TONE - SEVEN BEAT	4.00	3.79	3.88	3.79	3.87
FOUR TONE - FIVE BEAT	4.27	4.06	4.34	4.14	4.20
MEANS	4.13	3.94	4.02	3.94	

General Discussion

The purpose of this chapter was to determine the relative utility of Rhythmic Attending Theory as an alternative approach for studying judged duration. Since temporal information is presumably used in synchronization and perceiving, it was necessary to determine whether rhythm does in fact influence judged duration. Second, it was necessary to examine rhythmic effects from the contrasting perspectives of Rhythmic Attending and Information-Processing Models. Three models were evaluated in a set of two experiments.

One, the Missing Beat Hypothesis, proposed that perceivers use the number of rhythmic beats within an initial melody as the referent for duration estimates. Although two melodies may have the same duration, one may be judged shorter than another because it contains a relatively fewer number of beats. A second view suggested that people use the time periods that are marked by both temporal and melodic accents. A perceiver is assumed to average the various accent periods within an event and to use this value as an expected referent for other events. Both views claim that a perceiver uses the temporal information within an event as the referent for judged duration. In contrast, current information-processing models assume that rhythm has a less critial and active role in time estimates. A perceiver does not use rhythmic information as a referent for behavior - instead, temporal and melodic accents can provide "chunk boundaries or points of cognitive change". Since chunks must be concatenated and require processing time, events containing more chunks will have a more complex mental code. They will therefore seem longer than events with less chunks.

The two experiments that were conducted here discounted this latter view and supported predictions of the Missing Beat Hypothesis. In Experiment One, subjects judged the relative duration of melodies that varied in the presence or absence of melodic accents (ie. Rules vs. NoRule melodies) and in the (in)compatibility of melodic and temporal accents (Five vs. Four Beat rhythm). Information-processing models predicted that NoRule melodies would be the most complex because they contained the most chunks. Rule melodies contained the fewest number of chunks and so they would be the most simple. Although a preliminary rating task confirmed these predictions of perceptual complexity, a comparative duration task found that judged duration was not determined by chunk number. Similarly, estimates were unrelated to the average duration of accent periods. Contrary to both hypotheses, melodic structure had little effect upon judged duration. Instead, melodies containing a greater number of rhythmic beats (ie. Four Beat melodies) were judged longer than those with fewer beats (ie. Five Beat melodies). This finding was consistent with the Missing Beat Hypothesis.

A second experiment reevaluated the various hypotheses with a more carefully constructed set of melodies. Here, rule melodies were either generated from a three or four tone argument such that melodic accents were either compatible or incompatible with the temporal accents of a Five or Seven Beat rhythm. Unlike the previous study, the two rhythms of this experiment were also equated for the total number of rhythmic beats. When these melodies were presented in a comparative judgment task, accent in(compatibility) again had no effect on judged duration. As predicted by the Missing Beat Hypothesis, all melodies were judged as equivalent in duration.

These two experiments suggest that rhythm does play an active role in judged duration. Assuming that an event contains a predictable pattern of temporal accents, beats arising from both actual and missing tones will be correspondingly mirrored within an organism through synchronization. In relative duration tasks, a perceiver may then use the number of rhythmic beats for each melody as the referent for behavior.

The results revealed here also suggest that the pickup of rhythmic beats is unaffected by the in(compatibility) of melodic and temporal accents. This implies that a predictable pattern of temporal accents is the minimal requirement for pickup of temporal information. On the other hand, the potential impact of melodic accents upon judged duration should not be prematurely discounted. Although melodic accents may not affect the first role of rhythm, that of synchronization, they are considered essential in the second role of rhythm - that of generating expectancies. As we discussed in previous chapters, a lawful relationship between melodic and temporal accents presumably allows a perceiver to anticipate what particular notes will occur in the future and when in time they will do so. It may also be the case that these accent structures, together, allow a perceiver to anticipate exactly when a melody will end. If so, judged duration may be affected by whether the last note of a melody ends as expected or whether it ends earlier or later than expected. According to this suggestion then, melodic accents may not affect the pickup of rhythmic beats but given a lawful relationship to temporal accents, they may affect when and how these beats are expected to end - which in turn may affect judged duration. The next chapter will in fact incorporate this idea into an alternative model of judged duration and begin to experimentally assess its validity.

Regardless, the present set of experiments are important in that they question current information-processing models of judged duration. Rhythm does not appear to provide discrete chunks of time that are later processed by mediational devices. Similarly, the referent for duration does not appear to be the amount of memory storage (Ornstein 1969), expended attention (Underwood & Swain 1973; Thomas & Weaver 1975), or cognitive change (Block 1978) that these chunks have created. Instead, the present results suggest that rhythm dynamically induces internal rhythmic beats that are directly used to judge duration. This view, generated from Rhythmic Attending Theory, is thus more parsimonious than traditional models. There is no need to assume that discrete moments of time are concatenated into a mental code. Nor does judged duration need to be inferred from properties of this mental code. The view that is offered here assumes that the pickup of temporal information is intrinsic to perceiving and is reciprocally mirrored within a perceiving organism. The temporal structure of the event itself is then used in duration estimates.

The present set of experiments also illustrate that the Rhythmic Attending perspective can offer greater percision to experimental manipulations. Since environmental events act as the referents for behavior, variables of complexity are therefore defined within the structure of natural events. This approach is more precise than defining complexity in terms of an unseen mental code. Code complexity, or the amount of information-processing, is presumably increased by the number of chunks within an event. A mere enumeration of chunks, however, fails to capture the inherent organization of structural levels and how the structure itself may guide perceiving. In these studies, for example, pauses were not considered to offer missing beats - instead, they offered chunk boundaries. However, it was these rhythmic beats, not chunk number, that determined duration estimates. In short, the present experiments suggest that the study of judged duation may benefit by using natural events as experimental stimuli. The dynamic role of rhythm that was revealed here has not previously emerged from the usage of static and artificial stimuli.

Chapter Summary

Two experimnts investigated the role of rhythm as contrasted by models generated from the Rhythmic Attending and Information-Processing Approach. Contrary to predictions of information-processing models, results suggested that perceivers use the number of rhythmic beats within an event as the direct referent for duration estimates. Although two events may have the same total duration, one event will be judged shorter than another because it contains a fewer number of beats. Experimental findings more generally illustrated that Jones' Rhythmic Attending Theory can provide greater parsimony and precision for the study of time.

In the next chapter we will build upon this preliminary framework to develop an alternative model of judged duration. In particular, we'll consider the role of rhythm in generating listener expectancies and how expectancies may create lawful under or overestimations of duration.

CHAPTER SEVEN

AN EXPECTANCY MODEL OF JUDGED DURATION

The model of judged duration that will be proposed here rests on the preliminary framework provided by the previous chapter. There we assumed that the temporal structure of natural events is picked up through synchronization. As indicated by the results of Experiments One and Two, perceivers apparently use the rhythmic relationships of events for relative duration judgments.

Although this preliminary view can be argued to offer greater parsimony and precision than contemporary models, its current state of development is incomplete. In particular, we have not yet incorporated the concept of future time to explain how we're able to predict <u>when</u> an event will end. When listening to a speaker, for example, we can usually guage quite accurately when he or she will finish speaking. Similarly, we can often anticipate the ending of a symphony or musical composition. In the present chapter, we'll consider how this issue of future time may be addressed through the concept of "expectancy". Specifically, it's suggested that a listener can use certain melodic and rhythmic relationships to anticipate a melody's upcoming completion. This assumption will then be elaborated into an "Expectancy Model" of judged duration. The basic idea is that duration estimates are determined by the expected ending of an event.

If an event ends as expected, then duration estimates are predicted to be quite accurate. However, under or overestimations of duration will occur whenever an event ends before or after it is expected. The following section considers how the rhythmic structure of music may create expectancies within listeners.

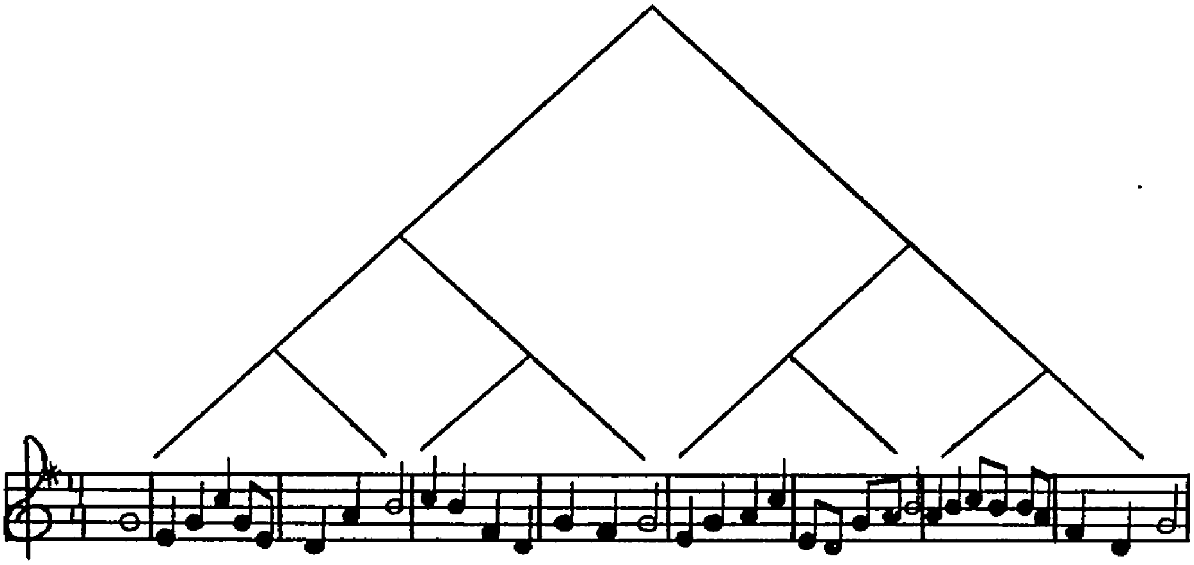
Role of Rhythm in Creating Expectancies

Recall that the purpose of the first two experiments was to investigate whether rhythmic structure affects judged duration. To contrast the Rhythmic Attending Approach with information-processing models, it was necessary to vary melodic rule structure and accent compatibility. The results of these experiments led to a Missing Beat intepretation where listeners presumably use the number of rhythmic beats within an initial event as an expected referent. The perceptual pickup of these beats was shown to be unaffected by melodic structure and simply required a predictable pattern of temporal accents.

This Missing Beat intepretation could imply that melodic structure may never influence judged duration and that two melodies with the same number of rhythmic beats will always be judged as equivalent. These broad generalizations, however, are not intended because it's acknowledged that results are based on a restricted subset of melodies. In contrast to the incompatible accent structure of melodies used in Experiments 1 and 2, most Western music displays predictable relationships between melodic and temporal accents. This "more natural" music allows a second role of rhythm to emerge that has not yet been investigated - namely its role in generating expectancies. That is, interrelated accent structures not only induce synchronization but, in addition, are assumed to create expectancies about the what and when of future notes (Jones 1976). If these accents also allow one to accurately anticipate a melody's ending, then judged duration may be influenced by whether this expectancy is confirmed or violated. This would extend earlier findings by showing that related accents generate an expected end for a melody's sequence of rhythmic beats. To better relate the rationale for these claims, let's briefly review the nature of accent structures and the concept of expectancy.

Expectancies Generated From Accent Structures

A major assumption within Jones' Rhythmic Attending Theory is that natural events contain a hierarchical arrangement of temporal periodicities. In music, these nested periodicities are established by a melody's meter which determines what kind of note will act as the beat unit and how many beats will occur in a measure. The following melody, for example, has a meter of 4/4 timing which indicates that a quarter note is the beat unit and that four beats will occur in a measure. As depicted in this figure, meter serves to interrelate all temporal beats into a common hierarchical framework:



All melodies, however, also possess a rhythm where some notes are prolonged relative to others, or alternatively, pauses are placed at points where notes would normally occur. Rhythm will always preserve meter but simply changes the relative duration value of certain notes. The structural consequence of rhythm is that temporal accents (t) are created at points of prolonged notes (and pauses). These accents themselves recur in an isochronous, predictable fashion at a higher level in the metrical hierarchy (here after 8 beats).

Since accents capture our attention, composers carefully select those notes that co-occur with temporal accents. For example, notes that begin a musical rule transformation are often members of the melody's major chord. In addition, these notes are typically preceded by a pause to yield a co-occurring accent structure. Some of the melodies from Experiments One and Two were in fact of this sort. However, while these particular melodies displayed a rule span of 3 or 4 notes, it is often the case that a melodic rule will span over several notes to create a rather lengthy passage. Hence, a second type of accent is frequently created within this musical rule span. Specifically, a composer will often conclude a measure with a member of the melody's major chord and then temporally prolong this note. In the melody shown above, for example, those notes marked (tm) are illustrative of this technique. Since major chord members are harmonically related to the tonic, this convention serves to "anchor" the melody to its underlying scale (Bharucha 1984; Lerdahl & Jackendoff 1983; Berry 1976; Benjamin 1984). In sum, temporal accents often co-occur with major chord members ending a measure and those notes initiating a musical rule transformation. Together, these two types of co-occurring accents recur isochronously throughout the entire melody.

An isochronous pattern of co-occurring accents is psychologically important because it allows a listener to generate "expectancies" about forthcoming notes. A predictable pattern of temporal accents presumably induces synchronization such that a melody's rhythmic beats are correspondingly mirrored within the organism. When temporal accents co-occur with melodic ones, however, attention will be directed to points of musical rule change and/or to notes that are harmonically related to the tonic. In the melody shown earlier, for example, the initial context establishes that temporal accents recur after 8 beats and that major chord members coincide with these accents. After hearing a given accent, a perceiver can then anticipate that the next prolonged note will also occur after 8 beats and will be one of the major chord members. In short, the accent structure of this melody has generated expectancies about the what and when of notes in future time - which in this case will be confirmed.

Expected Endings

All natural events end at some point and in many situations, we as perceivers also seem able to anticipate when an event will end. For example, the smooth exchange of speaking roles implies that a listener can anticipate a speaker's final utterance (Wiemann & Knapp 1975). Similarly, dancers, singers, and musicians are all able to anticipate the end of one solo performance to initiate a continuous transition into another. How are people able to do this, and more specifically, are there certain structures that prepare us in advance for an event's end?

These sorts of structures can in fact be found in music and involve properties of phrase endings. For example, a composer invariably ends a melody on the tonic (the melody's underlying key or scale) and, in addition, prolongs the duration of this tonic such that it's longer than any preceding note. The tonic ending returns a listener to the melody's beginning, or at least its underlying scale, while the end-lengthening effect enhances the feeling of finality. It is interesting to note that a similar phenomenom exists in speech. A speaker frequently begins and ends an utterance with the same pitch frequency (Pike 1946) and end-lengthens the final word (Lehiste 1975).

Through exposure to Western Music, it is assumed here that we have come to expect this convention of resolution whenever we listen to music. Conventions are incorporated into an "expectancy scheme" which contains those structural properties that normally occur in a melody. This scheme guides attending and generates the expectancy that musical conventions which have occurred in the past will also appear in new melodies. In the present situation, for example, a listener will expect a melody to be resolved because past melodies have displayed this property.

In the model that will be proposed here it is suggested that a predictable accent structure can generate expectancies about this tonic ending before it actually occurs. Given that major chord members are temporally accented and recur after a fixed beat period, a listener can anticipate that an upcoming accent may be the final tonic. When one finally reaches the tonic note that is end-lengthened, the melody will then seem completed. In other words, we are able to predict what note will end the melody, namely the tonic, because preceding accents are notes that are harmonially related to the tonic. In addition, the invariant beat period between accents has allowed us to predict when the final tonic will occur.

In the model of judged duration that is presented next, it is assumed that the expected ending for an event will determine the accuracy or inaccuracy of time judgments. Since expectancies are created by accents and properties of the final note, systematic manipulations of these structures should correspondingly affect duration estimates. Let's now examine this Expectancy Model of judged duration in more detail.

An Expectancy Model of Judged Duration

In contrast to the information-processing models, the present model is intended to offer a more ecological perspective for the study of judged duration. A primary emphasis concerns the usage of natural events as experimental stimuli. These events contain interrelated levels of dynamic structure and offer some sort of survival or cultural significance to a perceiving organism. In accordance with Rhythmic Attending Theory, the present approach also envisions the act of perceiving as one of synchronization. Perceiving is future-oriented because a predictable and co-occurring pattern of accents will generate expectancies about the what and when of future events. These expectancies are extrapolations of previous pattern structure and are directed toward the event's end.

We now address the focal question of contemporary research, namely, "Why is one event judged longer or shorter than another when both are the same physical duration"? As we saw in the previous chapter, one event may be judged shorter than another because it contains a relatively fewer number of rhythmic beats. On the other hand, we also noted that those melodies did not always contain co-occurring accents as do many events within the natural environment. It therefore seems quite possible that two events with the same number of rhythmic beats may not always be judged as equivalent. Instead, one may seem longer or shorter than another because each has generated a different expectancy about when its sequence of rhythmic beats will end. This possibility has in fact been elaborated into an Expectancy

Model of judged duration.

The basic assumption of this model is that judged duration is determined by the extent to which an event's end confirms or violates the perceiver's expectancies about <u>when</u> the event should end. In general, an event which confirms our expectancies should produce accurate duration estimates relative to a standard referent (ie. clock time or the duration of another event). Events which violate our expectancies, however, should produce over or underestimations of duration. These kinds of errors can be predicted from a pattern's structure and will depend on whether the ending of an event occurs before or after it is expected.

Let's first consider the case where a melody confirms our expectancies. As seen in Figure 5, suppose that temporal accents isochronously recur after a fixed number of beats (8 beats here) and coincide with notes that are major chord members. In addition, the melody ends on the prolonged tonic as expected by musical convention. Since this melody satisfies those expectancies established by both prior context and musical convention, its duration estimate should be quite accurate.

In contrast, a melody which does not end as expected will be over or underestimated in duration. Underestimations will arise whenever a melody ends before it is expected. Relative to its expected duration, its actual duration is shorter. Conversely, overestimations will be observed whenever a melody ends after it is expected. Here, the actual duration is longer than what was expected. As we mentioned

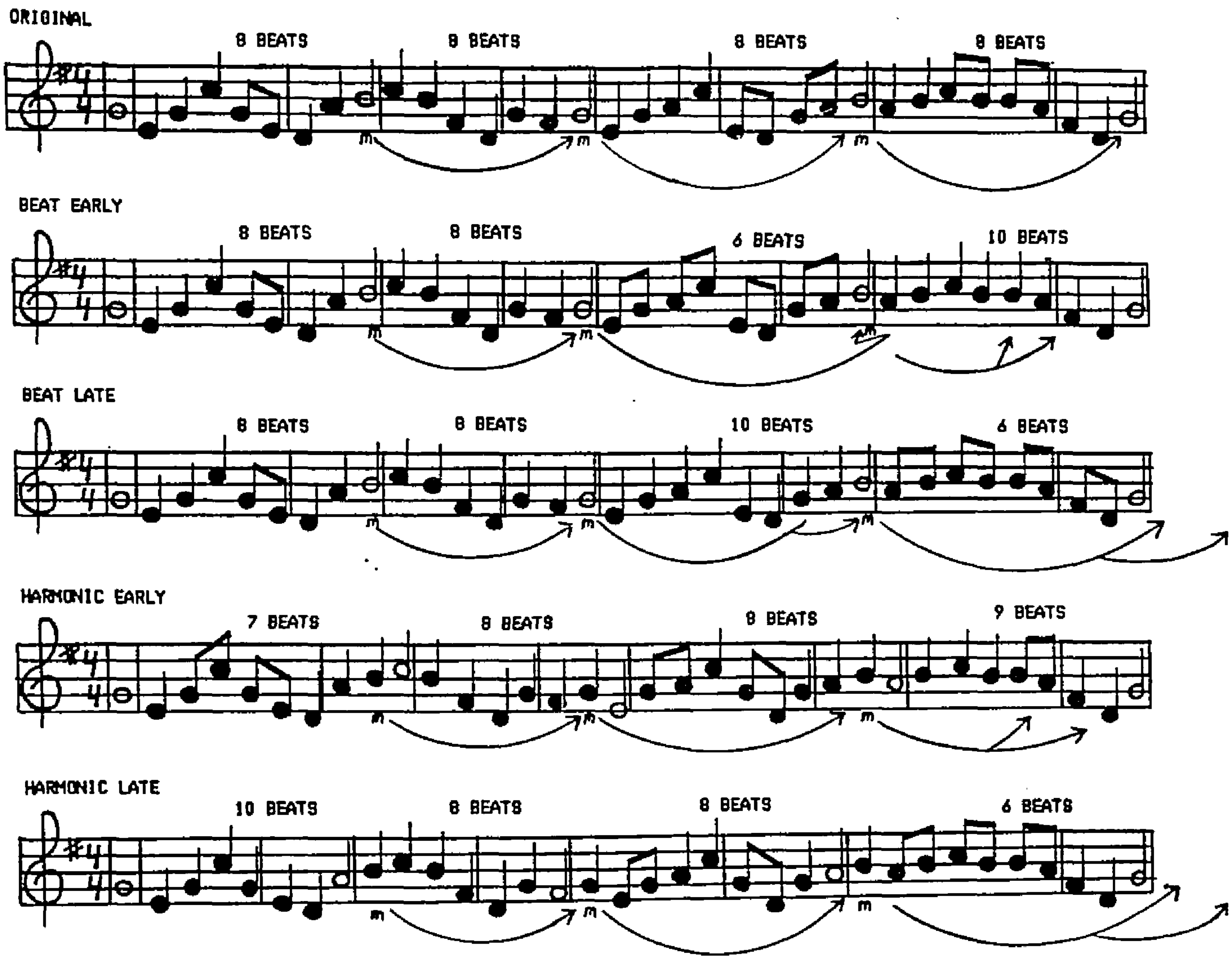


FIGURE 5. THE FIVE EXPERIMENTAL CONDITIONS OF EXPERIMENT 5. A PERCEIVER'S EXPECTANCIES (INDICATED BY ARROWS) ARE PREDICTED AS A FUNCTION OF THE MELODIC ACCENTS (m) FOR EACH RHYTHM CONDITION.

before, the occurrence of under or overestimations can be precisely predicted from the melody's structure. In particular, errors will arise from two sorts of structural manipulations:

1) Under or overestimations will occur whenever the ending of a melody deviates from prior context. The melody contains a perceptible ending but structural deviations have generated an <u>expected</u> ending that is either too early or too late.

2) Overestimations alone will arise when properties of the final note are isochronous to prior context. The musical convention of resolution has been violated such that the melody lacks a perceptible end. Thus the listener will extrapolate the preceding context into an appropriate ending, thereby increasing experienced duration.

The following section describes what sorts of structural manipulations will create these two classes of errors.

<u>Errors Arising From Structural Deviations</u>

Within this class of errors, <u>both</u> under and overestimations of duration are predicted to occur. Melodies will have a perceptible ending but the closing structure of a pattern will deviate from previous context. Consequently, the melody will violate the perceiver's expectancies and end before or after it is expected. There are probably multiple ways in which an event's structure can violate its expected end but the structures considered here involve the nature of melodic and temporal accent structure and properties of the final note. Each is discussed in turn.

Violations of Accent Structure

In a preceding section, we discussed how musicians will frequently conclude a measure with a major chord member and then prolong this note's duration. If these accents isochronously recur, it is assumed that a listener can anticipate future notes, including the final note of the melody. As shown in Figure 5, for example, the listener can anticipate the end-lengthened tonic because melodic accents (m) are always harmonically related to the tonic and recur after 8 beats.

Suppose that we now vary this melodic/rhythmic structure as shown in the melody labelled as Beat Early in Figure 5. Major chord members are still accented and the melody contains the same number of rhythmic beats as before. The fourth and last accents, however, deviate from the preceding context by occurring after 6 and 10 beats respectively. How will judged duration be affected? According to the Expectancy Model, this melody will be overestimated because it ends later than expected. Specifically, the preceding context has established that accents recur after 8 beats or 6 beats. As a listener approaches the end, they should therefore expect the next accent to also occur after 8 or 6 beats. Since the last note actually occurs after 10 beats , this last note should be perceived as occurring relatively too late. Thus the pattern's duration should be overestimated. The opposite effect is predicted to occur with the melody labelled as Beat Late. Here the third accent period contains 10 beats, leading the listener to expect the final note after 8 or 10 beats. Since it actually occurs after only 6 beats, the pattern should seem to end too early and thus shorter in duration. In sum, these sorts of errors are predicted to arise from violating the invariant beat period between accents. Although all melodies contain the same number of rhythmic beats, errors are predicted as a function of *when* these beats are expected to end.

A similar sort of finding should emerge by violating the relationship between temporal accents (𝅗𝅥) and major chord members (m). Suppose that temporal accents *do* recur after an invariant beat period, and although they do not coincide with major chord members, they maintain a lawful relationship with these notes. For example, consider the melody labelled as Harmonic Early in Figure 5. Here the composer has maintained an invariant beat period between all temporal accents but has prolonged the duration of the note *before* the major chord member. Unlike temporal accents, the beat period between major chord members (m) is not always an invariant 8 beats - the second member occurs after 7 beats while the final tonic occurs after 9 beats.

Consider how a perceiver's expectancies may be affected by this manipulation. Since melodic and temporal accents are lawfully related, a perceiver can anticipate the occurrence of future major chord members. In this sort of pattern, however, the final tonic will occur later than expected. This is because the final tonic does not occur after the expected 7 or 8 beats as is true for preceding major chord members - instead it occurs after 9 beats. The melody ends later than expected and so its duration is predicted to be overestimated. The opposite effect (ie. underestimation) should be obtained with the melody labelled as Harmonic Late in Figure 5 where temporal accents occur on the notes after the major chord members. The final tonic is expected to occur after 8 or 10 beats because this was true for preceding major chord members. However, the ending actually occurs after 6 beats which is earlier than expected.

These structural manipulations all address the role of rhythmic expectancies upon judged duration and are investigated in Experiment 5 of this dissertation. There are, however, other structural properties that are predicted to violate a melody's expected end. The most important of these should involve properties of the final note since these are used to create a sense of resolution. Recall that musicians normally end on the melody's tonic and, in addition, lengthen this note such that it's relatively longer than any preceding note. How will judged duration be influenced by systematic violations of these two structures?

Violations of Resolution

Let's first consider a melody whose final note is end-lengthened but which is not the tonic. Here the prolonged ending signals that the melody is meant to be completed. Yet the nontonic ending should "leave us hanging" because we expect another note to occur - namely the tonic. Since this melody has ended earlier than expected, it is predicted to result in an underestimation of duration.

Let's next consider a melody whose final note is <u>shorter</u> than any preceding note. Since the temporal duration of this last note deviates from the preceding context, the melody should contain a perceptible (abrupt) ending. Again, a melody ending on a nontonic note should appear to end relatively early because the resolved tonic is missing. Hence, this melody should be underestimated in relative duration. These various sets of predictions are investigated in Experiment 4.

To summarize, we've considered how errors in judged duration may arise from certain structural deviations of a melody's preceding context. This initial context presumably generates an expected ending that is later violated by a melody's accent structure or properties of its final note. According to predictions of the Expectancy Model, a melody ending before or after it is expected will produce corresponding under and overestimations of duration. This model also predicts that overestimations alone will result from a second class of structural manipulations - these that fail to provide a perceptible end.

<u>Errors Arising From "A Missing End"</u>

Throughout this dissertation, I've assumed that natural events contain some sort of perceptible beginning and end. The ending of a speech utterance or melody, for example, is marked by a prolonged "tonic". Although infrequent, there may be occasions when a speaker or musician does not lengthen or shorten the duration of this final tonic - instead, its duration is isochronous to preceding accents.

Since the tonic itself can occur on any given accent, the event should lack a perceptible end. How will judged duration be affected by this sort of structural property?

According to the Expectancy Model, an event which lacks a perceptible end may encourage listeners to mentally extrapolate that event to its expected ending. By doing so, they have provided their own sense of finality and completeness. This mental extrapolation of missing pattern structure in turn will lengthen experienced duration. For example, a melody containing a nontonic ending should lead a listener to mentally continue the melody to its expected tonic ending. This melody should therefore seem longr than a melody which does ends on the tonic. This prediction will be investigated in Experiments 3 and 4.

It should be mentioned that this mental extrapolation is not considered to be a construction from mediational devices. Instead, it's simply a continuation of a melody's preceding structure. Again, mental extrapolations provide a sense of completeness and should only occur when an event lacks a perceptible end.

Summary

The Expectancy Model assumes that judged duration is determined by the expected ending of a natural event. Depending on the particular type of structural ending, three classes of predictions are generated. First, duration estimates should be relatively accurate whenever an event ends as expected. Second, under and overestimations will be obtained whenever an event ends before or after it is expected. Lastly, events lacking a perceptible end will generate a mental extrapolation to some expected end. This mental extrapolation provides a subjective sense of finality but results in overestimations of event duration.

The Expectancy Model that has been presented here does offer a novel perspective for the study of judged duration. In the following section, we'll consider the major contrasts of this approach with current information-processing models.

Contrasts Between the Expectancy and Information-Processing Models of Judged Duration.

Perhaps the most important advantage of the Expectancy Model is that it provides a more parsimonious view of judged duration. The concept of synchronization assumes that an organism uses the inherent temporal structure of an event for attending and perceiving behaviors. Thus there is no need for mental concatenation processes to achieve perceptual continuity and inferences of judged duration. Since a predictable rhythmic structure is assumed to generate expectancies within a perceiver, the issue of future time has also been parsimoniously resolved.

There is a more subtle advantage of claiming that judged duration is a function of the confirmation or violation of established expectancies: the judged duration of a given event can be compared relative to both clock time and the judged duration of other events. That is, if we determine what expected invariants are being violated in a natural event, then it's reasonable to claim that any judged deviations from actual clock time were caused by these experimentally violated expectancies. The information-processing approach (eg. Ornstein 1969), on the other hand, has claimed that is is both inappropriate and impossible to derive such conclusions because duration is not part of the actual environment - it's a psychological phenomenom that is only achieved through mediational processes. Thus, this approach maintains that it's only appropriate to study the judged duration of one processed event relative to another. If we think about it, however, there are many occasions when we judge an event or activity relative to clock time: "How long will it take me to walk from home to the office?, Can I finish this project within the next fifteen minutes?", and so on. These sorts of estimates are frequently made throughout the day and yet the information-processing approach can offer no explanation as to how they occur. From the present perspective, however, the accuracy of these estimates will be determined by the extent to which the event's structural invariants confirm or violate our expectancies.

A third contrast involves the issue of complexity. The information-processing models have defined complexity in terms of the contents of memory, processing effort, or the degree of cognitive change. The problem is that complexity is defined relative to hypothetical constructs and does not clearly apply to the structure of natural events. The Expectancy Model, however, has redefined the concept of complexity in terms of violated expectancies where expectancies are determined by preceding event structure.

Manipulations of "complexity" involve variations of those structural invariants which a perceiver has expected to occur. This then results in a more precise definition of complexity and an experimental variable that can be consistently manipulated across different tasks and laboratories.

In summary, the information-processing and expectancy models of judged duration offer two different perspectives on the "filled interval effect". According to the present view, the relative judgment of two filled intervals will depend on the event's structure. If the event's rhythmic structure does not generate listener expectancies, then judged duration will be determined by the total number of rhythmic beats. Otherwise, duration estimates will be determined by the extent to which an event's end confirms or violates a perceiver's expectancies.

In the next two chapters, support for this expectancy model will be sought in terms of the various experiments that I outlined earlier. Chapter 8 examines effects of pattern resolution while Chapter 9 will investigate effects of beat variance upon judged duration.

Chapter Summary

In the present chapter, an alternative theory of judged duration has been offered. Based upon the assumptions of Rhythmic Attending Theory, this view claims that natural events contain an inherent temporal structure that is used for guiding attending. Attending is future-oriented because a predictable event structure will generate expectancies about <u>when</u> an event will end. Duration estimates are then determined relative to the confirmation or violation of these expectancies. If an event ends as expected, then no time errors will occur. However, overestimations of duration will arise whenever an event ends later than expected and, conversely, underestimations will occur whenever an event ends earlier than expected. In addition, events that lack a perceptible end will encourage a mental extrapolation of pattern structure - thereby increasing experienced duration.

Contrasted with the information-processing approach, this Expectancy Model was argued to offer greater parsimony and ecological validity.

CHAPTER EIGHT

EFFECTS OF PATTERN RESOLUTION UPON JUDGED DURATION

EXPERIMENTS THREE AND FOUR

In the course of a day's activities, there are many situations where we are required to anticipate an event's end. The smooth exchange of speaking roles, for example, implies that a listener can anticipate when a speaker will finish her utterance (Wiemann & Knapp 1975). Similarly, we must anticipate the future time course of our car in order to brake for stop signs, passing pedestrians, or other cars.

Although there are many situations like these, the existing literature does not tell us how a perceiver is able to anticipate the future ending of an event. The information-processing paradigm has ignored the issue while Direct Perception theorists have only examined situations involving "time-to-collision" - that is, judging when one event (ie. a car) will collide with another given their present velocity course. This literature may describe how a perceiver responds to an <u>interrupted</u> ending but it fails to address how we are able to perceive and anticipate a more natural ending.

One purpose of the present chapter is to determine whether there are certain structural invariants that specify the ending of an event - in particular, the natural ending of a musical composition. If so, then listeners may be attuned to these invariants and expect their presence whenever a melody is heard. This in turn may explain how a listener can often anticipate the future ending of a melody. A second and more important goal is to determine whether violations of a melody's ending creates under and overestimations of judged duration. Experiment 3 investigates how judged duration is affected by melodies that lack a perceptible end. According to assumptions of the Expectancy Model, perceivers may mentally extrapolate the time course of melody to its completion, thereby increasing experienced duration. Experiment 4, on the other hand, examines the duration estimates of melodies containing a perceptible end but one which violates a perceiver's expectancies. Here, underestimations are predicted to occur whenever melodies end before expected. These various experiments then are designed to test some assumptions of the Expectancy Model. As before, predictions will be contrasted with those generating from the information-processing approach. The following section considers some structural invariants that may specify a melody's end and how behavior may be affected by the presence or absence of such invariants.

Musical Resolution

According to the writings of musicians, there are several conventions used to signify a melody's end. Many of these techniques are relatively complex and involve variations of melodic passages. A very simple one, however, involves properties of the final note. As Meyers (1956) has stated in his book Emotion and Meaning in Music:

> "A feeling of harmonic completeness arises when the music returns to the harmonic base from which it began or moves to one which was in some way implicit in the opening materials." (p. 150)

In other words, musicians will typically end a composition on the tonic or the key which is introduced at the composition's beginning. By returning us to the point where we first began, the composer has created a subjective sense of stability and closure. The tonic note by itself, however, will not necessarily impart a sense of finality because it can occur throughout a melody. Thus, a musician will prolong the duration of this final tonic so that it's relatively longer than any preceding note. This end-lengthening effect, according to Meyers (1956), communicates that the tonic will not initiate a new melodic passage but concludes the passage that has immediately preceded. The conventional usage of a prolonged tonic at a melody's end is termed resolution . Musicians assume that listeners will eventually learn this convention and know that it's intended to signify melodic completion. If so, then a listener should come to expect a prolonged tonic whenever they encounter a new musical composition.

Resolution is not exclusive to music but also occurs in speech. A speaker's pitch intonation will often fall at the end of an utterance to signal that she has finished speaking (Pike 1946). In addition, the duration fo the final word is prolonged relative to preceding words (Lehiste 1975). James Martin (1972), in fact, has incorporated this end-lengthening effect into his theory of language behavior. In this theory, he demonstrates how the rhythmic structure of speech can be hierarchically represented in terms of accent rules. One of these is termed the "terminal rule" and specifies that the final word of an utterance will always be prolonged. Lehiste (1975) has further demonstrated that speakers of the English language have a tacit awareness of this convention. Using a speech synthesizer, she produced a series of four-word sentences where the duration of each word could be experimentally manipulated. When subjects were asked to judge the duration of various words, she found that the last word was underestimated when it was of the same duration (isochronous) as preceding words. That is, subjects expected the last word to be prolonged and when it wasn't, it was perceived as being relatively shorter.

Assuming that listeners are attuned to musical resolution, how will the violation of this convention affect psychological behavior? According to Meyers, musical listeners expect a melody to unfold to its proper completion and when it doesn't, feelings of frustration and anxiety are created. This is an unresolved experience. Of greater interest here, consider how judged duration may be affected by an unresolved melody. This lack of resolution may be created through manipulations of the temporal or harmonic relationship of the final note. For example, let's first suppose that the melody's final note is end-lengthened but is a nontonic note. Although the prolonged ending signals a sense of finality, the non-tonic note does not return us to the melody's beginning - it leaves us "hanging". Since the melody should appear to end too early, its duration is predicted to be underestimated. This possibility will be explored in Experiment 4.

Let's next suppose that the duration of the final note is identical (ie. isochronous) to that of preceding notes. Even though the melody may end on the tonic, a sense of completeness should be lacking. The tonic note itself can occur throughout the melody and it is really the end-lengthening effect which uniquely specifies a sense of finality. Since the melody lacks a perceptible end, the Expectancy Model predicts that listeners will mentally extrapolate the duration of the final note to its <u>expected</u> length. This not only provides a psychologial sense of completeness but also lengthens experienced duration. Duration estimates should be even longer if the melody ends on a nontonic note. Here the listener is assumed to mentally extrapolate <u>both</u> the missing tonic and the end-lengthening effect. Relative to a melody ending on the tonic, a melody with a nontonic ending should therefore seem longer in duration. The purpose of Experiment Three is to examine this hypothesis.

Before investigating these various predictions, however, it is first necessary to determine whether listeners are in fact attuned to the conventional properties of the final note. Do listeners really expect a melody to end on a prolonged tonic? If so, what sorts of melodies seem to be the most unresolved? To address these questions, an initial rating study was conducted. Several short songs were modified such that the first and final notes were always the tonic. These melodies were then varied such that the final note displayed different harmonic relationships with the tonic. In some, the final note maintained an intimate relationship with the tonic (ie. major chord members) while in others, the relationship was more distant (ie. non-major chord members). Subjects were then presented with these melodies and asked to rate each for its degree of resolution. The details of this rating study are presented next.

<u>Experiment 3a - Ratings</u>

The purpose of this initial study is two-fold. First, we must demonstrate that melodic completion is signalled by properties of the final note - otherwise, it becomes pointless to study judged duration as a function of pattern resolution. Second, we must determine what sort of final note is most apt to make a melody seem unresolved - as it the melody has been interrupted before its expected ending.

There is some existing literature that provides some guidelines for addressing this latter question. This work has been conducted by Carol Krumhansl (1979) who has attempted to identify how the abstract tonal system of Western music is mentally represented. She proposes that each diatonic scale, which provides the foundation for any given melody, is represented in terms of a tonal hierarchy. Those notes acting as organizational foci, or cognitive reference points, are those that are harmonically related to the tonic. These notes can be easily identified for any given scale because they comprise the notes of the major chord. In the C major scale, for example, these notes are C (tonic), E (major third), and G (dominant). At the next lower level of the tonal hierarchy are the remaining notes of the scale (ie.

D F A B), and at the lowest level of all are those notes outside that given diatonic scale (D#, F#, G#, B^b, C#). Using a wide variety of experimental tasks, Krumhansl and her students have demonstrated that listeners do seem differentially sensitive to these various levels of the tonal hierarchy (eg. Krumhansl & Shepard 1979; Krumhansl, Bharucha, & Castellano 1982; Bharucha & Krumhansl 1983).

In regard to the issue of pattern resolution, Krumhansl's model generates some specific predictions. Notes that are harmonically related to the tonic (ie. members of the major chord) should provide greater pattern resolution than notes which are lower on the tonal hierarchy. Thus, if the final tonic of a melody is replaced by the dominant or major third, this melody should seem more resolved than a melody ending on one of the remaining scale notes.

There is, however, another possibility that Krumhansl's model ignores. That is, notes that are more distantly related to the tonic may not create the same degree of unresolvedness. As some have illustrated (eg. Butler & Brown 1984; Brown & Butler 1981), the perception of harmonic relationships often depends on a melody's preceding context. In this case, a melody may seem more unresolved if its final note is identical to that initiating the last measure. Here, the ending does not return us to the melody's beginning (ie. the tonic) but to some other note that has recently occurred - leaving us in a circular loop with no exit. Similarly, a sense of unresolvedness may arise from an ending that involves the leading tone. The leading tone is that note which immediately precedes the tonic in a diatonic scale (ie. B in C major scale). Since this leading tone often precedes the final prolonged tonic, a melody ending on the leading tone should appear interrupted. To determine how resolution ratings are determined by these various sorts of harmonic relationships, the following study was conducted.

Method

Design and Subjects

The design is a 4 x 5 x 2 mixed factorial. Four levels of song are crossed with five levels of melodic ending (Tonic, Dominant, Major Third, Leading Tone, Previous Context Note). The single between-subjects variable is counterbalance order (I, II).

Ten subjects, recruited from Introductory Psychology, participated in the experiment for course credit. None had ever played a musical instrument. Five were randomly assigned to each counterbalance order.

Stimulus Materials

Four melodies (Figure 6) were selected from an elementary musical composition book. These melodies reflect a diverse range of music and differ in terms of total number of notes (range = 16 to 27 notes); meter (2/4, 3/4, 4/4); total duration (range = 6600 ms. to 8700 ms); and musical key (C or F major). In all cases, however, the first and final note of each melody is always the tonic (C or F). In addition, the tonal duration of the final tonic is always isochronous to that of preceding notes.

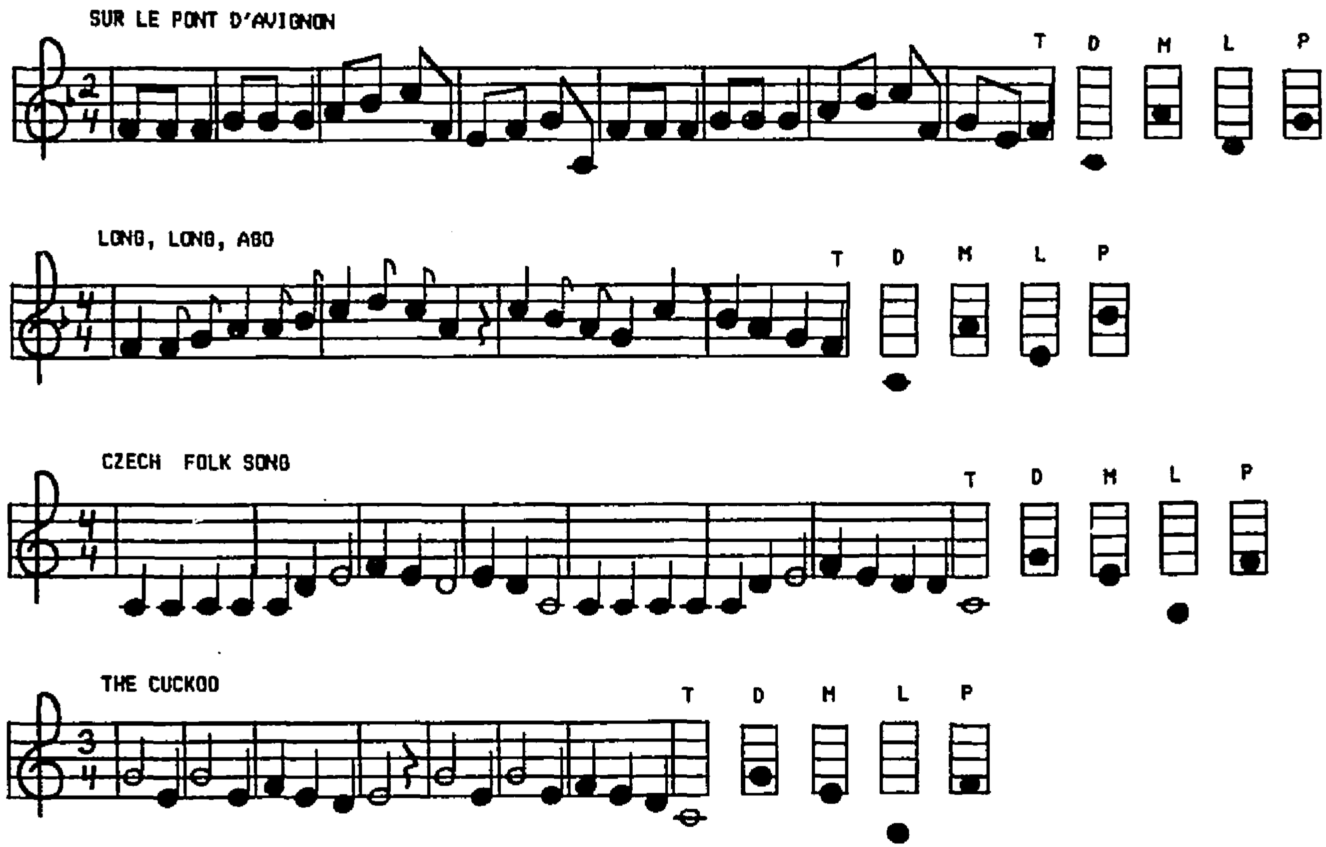


FIGURE 6. THE MELODIES USED IN EXPERIMENTS 3A, 3B, AND 4. THE VARIOUS LEVELS OF HARMONIC ENDING ARE DEPICTED WHERE T = TONIC; D = DOMINANT; M = MAJOR THIRD; L = LEADING TONE; AND P = PREVIOUS CONTEXT NOTE.

For each melody, the final tonic was replaced by four other notes. Two of these were members of the melody's major chord: the dominant and major third. The remaining two notes bore a more distant relationship to the tonic. One is termed the Leading Tone and is that note which immediately precedes the tonic in its diatonic scale. The other is termed the "Previous Context Note" because it is the same note that begins the melody's last measure. All final note types preserved a melody's total duration and are shown in Figure 6.

The factorial combination of four melodies with the five types of melodic endings yielded twenty different experimental patterns. Trials were randomized into three blocks of twenty, resulting in three presentations of each melody for a given subject.

Apparatus

Identical to previous experiments.

Procedure

Recorded instructions informed subjects of pattern presentation details and task requirements. On each trial, a one second warning tone (5000 hz) preceded a melody by 2 seconds. During a 7 second response period, subjects were then asked to rate a melody for its degree of resolution. A resolved melody was described as "having an appropriate harmonic ending - an ending that is satisfying and makes the melody sound in fact like it is over." An unresolved melody was described as "having an inappropriate harmonic ending whose final note makes the melody sound incomplete and like it ended before it should have." A ten point rating scale was provided. Subjects were informed that a rating of 1, 2, or 3 indicated that the melody was unresolved, and that values of 8, 9, or 10 would indicate that a melody was resolved. A third kind of perceptual judgment was represented by the value of 5 on this scale. Subjects were told to circle this number if the melody seemed "atonal". An atonal ending would sound neither resolved nor unresolved but as if the musician had made an error on the last note. Subjects were encouraged to use the entire range of numbers to represent their judgments.

Each subject received 3 blocks of 20 trials, a brief rest being provided after each block. An entire experimental session was approximately 30 minutes in duration.

Results

Two sorts of analyses were performed on these perceptual ratings. One determined the proportion of "atonal" ratings for each experimental pattern. That is, what percentage of subjects on all trials assigned the value of 5 to a given melody, indicating that its last note sounded like a musical error. Since the goal of this experiment is to obtain a set of resolved and unresolved melodies, any melodic ending that's judged as significantly atonal will be discarded for later usage. The second analysis determined the mean resolution rating for each pattern when these atonal ratings were removed.

Proportion of Atonal Ratings

The results of this analysis revealed that some melodies were in fact rated as significantly atonal. Table 12 depicts the proportion of atonal ratings for each song as a function of its harmonic ending.

TABLE 12

MEAN "ATONAL" RATINGS FOR SONGS OF EXPERIMENT 3A AS A FUNCTION OF HARMONIC ENDING.

SONG	HARMONIC ENDING: TONIC	DOMINANT	MAJOR THIRD	PREVIOUS CONTEXT	LEADING TONE	MEANS
CZECH	.00	.17	.13	.33	.87	.30
AGO	.00	.33	.03	.23	.67	.25
PONT	.00	.37	.47	.37	.67	.38
CUCKOO	.00	.10	.03	.20	.87	.24
MEANS	.00	.24	.17	.28	.77	

A main effect for harmonic ending ($F_{4, 32} = 62.99$, $p<.0001$, MSe = .052) reveals that melodies ending on the leading tone were rated as highly atonal. Its mean value of .77 significatly differed from zero atonality (Bonferroni $F_{2, 32} = 7.4$, $p<.01$) and the other four levels of harmonic ending (all Bonferronis signifiant at .01). Melodies ending on the tonic, dominant, major third, and previous context note were not rated as significantly atonal.

Results also revealed a significant song x harmonic ending interaction ($F_{12, 96} = 4.06$, $p<.0001$, MSe = .037). This interaction is primarily an ordinal one where the leading tone appears more atonal on some songs (ie. Czech, Cuckoo) than on others (ie. Ago, Pont). One anomaly occurs when the Pont song ends on the major third. Relative to other melodies with this harmonic ending, this particular song is rated as significantly atonal ($F_{2, 96} = 5.5$, $p<.01$). This may stem from the fact that this is the only song in which the major third is not temporally accented during the melody's preceding context. This lack of temporal accentuation may cause the harmonic relationship between the major third and tonic to be perceptually less salient.

In summary, melodies ending on the leading tone sound neither resolved or unresolved - instead, the musician appears to have made a performing error. Since subsequent studies are designed to investigate effects of pattern resolution, these atonal melodies were eliminated for further evaluation.

Mean Resolution Ratings

Table 13 depicts the mean resolution rating for melodies ending on the tonic, dominant, major third, and previous context note. In calculating these means, the atonality rating of 5 was always ignored. Higher values within this table indicate that melodies seemed resolved and had a sense of finality. Lower values indicate that melodies seemed unresolved and ended too early.

According to musical convention, melodies ending on the tonic should be rated as the most resolved. High resolution ratings should also be associated with melodies ending on the dominant and major third because these notes are harmonically related to the tonic. The most unresolved melodies should be those ending on the same note as that initiating the final measure. A main effect for harmonic ending ($F_{3, 24} = 99.43$, $p < .0001$, $MSe = 2.32$) revealed that the tonic ending did in fact provide the greatest sense of finality. Its mean value of 8.54 significantly differed from the other three types of harmonic ending (all Bonferronis significant at .01). Conversely, those notes relating to a melody's previous context were rated as the most unresolved (Bonferronis also all significant). Melodies ending on the dominant and major third were rated as somewhat in between and did not significantly differ from one another. This pattern of results applies to all songs, with one exception creating a song x harmonic ending interaction ($F_{9, 72} = 3.82$, $p < .0006$, $MSe = 1.15$). The source of this interaction stems from the song "Cuckoo" where the major third ending is rated as significantly more resolved than its dominant ending

TABLE 13

MEAN RESOLUTION RATINGS FOR SONGS OF EXPERIMENT 3A AS A FUNCTION OF HARMONIC ENDING. LARGER VALUES INDICATE A GREATER SENSE OF RESOLVEDNESS (COMPLETENESS).

HARMONIC ENDING

SONG	TONIC	DOMINANT	MAJOR THIRD	PREVIOUS CONTEXT	MEANS
CZECH	8.50	3.95	3.37	3.18	4.75
AGO	7.77	4.07	3.98	2.58	4.60
PONT	8.97	4.97	4.28	3.08	5.33
CUCKOO	8.93	4.72	6.47	2.90	5.76
MEANS	8.54	4.43	4.53	2.94	

($F_{2, 72} = 3.65$, $p < .01$). This particular result has also contributed to a main effect for song ($F_{3, 24} = 6.41$, $p < .002$, $MSe = 1.77$). Here, the song "Cuckoo" is rated as more resolved than the other songs.

Discussion

The two goals of this experiment were achieved. First, it was demonstrated that listeners are sensitive to the convention of resolution. Those melodies ending on the tonic, the melody's key, were rated as the most resolved and were never judged as sounding atonal. Second, we determined what sort of harmonic ending makes a melody seem unresolved-namely, those notes which return to the beginning of a melody's final measure. These finding not only provide a set of musical stimuli for subsequent experiments but they also allow the usage of nonmusicians as subjects. This will permit greater generalizability for any effects of resolution upon judged duration.

Results are generally consistent with previous research on music perception. Krumhansl's model, for example, has suggested that the perception of a melody is influenced by its underlying diatonic scale. Notes that are intimately related to the tonic presumably act as organizational foci or cognitive reference points. The present results did in fact find that melodies ending on a major chord member (ie. tonic, dominant, and major third) were rated as the most resolved. Similarly, results converge with research showing that perception is influenced by a melody's preceding context (ie. Butler & Brown 1984; Brown & Butler 1981). The most unresolved melodies of this experiment were those ending on the same note which initiated the final measure. These melodies created a greater sense of expected continuation than those ending on the leading tone.

Since we now have a set of experimental stimuli that reflect different degrees of pattern resolution, let's consider how judged duration may be affected by this manipulation.

Experiment 3b - Judged Duration

The major question addressed in this next set of experiments involves duration judgments of resolved and unresolved melodies. The rating data has produced a set of melodies that vary in their degree of perceived finality. According to predictions of the Expectancy Model, these melodic pairs should yield differences in relative judged duration. Specifically, musical convention specifies that melodies will end on a final prolonged tonic. The end-lengthening effect uniquely specifies the melody's completion because the tonic can occur within a melody's unfolding context. In the present set of melodies, however, this end-lengthening effect is missing since the final note's duration is always isochronous with that of preceding notes. Relative to music that we normally encounter, these melodies should therefore seem to lack a truly perceptible end. This in turn may enourage listeners to mentally extrapolate a melody to its expected end. In this case, melodic pairings should reveal the following results:

1. An unresolved melody, ending on a previous context note, should be overestimated whenever it is paired with a resolved melody ending on the tonic or a major chord member (ie. major third). Those notes that normally lead to the tonic are missing within the

unresolved melody and so listeners may mentally extrapolate their occurrence. This should lengthen experienced duration.

2. No differences in judged duration should emerge when both melodies in a pair end on a major chord member (eg. tonic vs. major third). As results of the previous rating study indicate, these melodies seem resolved and should not require a mental extrapolation of missing notes.

A comparative judgment task was used to test these predictions. Melodies within a pair contained varying degrees of resolution. By referring to Table 14, notice that the first melody of a pair either ends on the tonic, the major third, or the "previous context" note (where the last note is identical to that initiating the final measure). Similarly, the second pattern of a pair is one of the same three types. Since patterns within a pair are equated for all variables except that of harmonic ending, those predictions shown in Table 14 are derived as a function of the previous rationale.

Consider how these predictions contrast with those generating from the information-processing models. According to the Storage Size (Ornstein 1969) and Attentional Effort Models (Underwood & Swain 1973; Thomas & Weaver 1975), all melodies pairings should produce judgments of "equivalent" duration. These models assume that duration estimates are determined by complexity or the number of cognitive chunks. The present set of melodies, however, all contain the same rhythm and total number of notes. The only difference among melodies is the

TABLE 14

EXPERIMENTAL DESIGN OF EXPERIMENT 3B. THE PREDICTIONS OF THE EXPECTANCY (EM) AND CONTEXTUAL CHANGE (CC) MODELS ARE CONTRASTED FOR EACH CONDITION (WHERE 1 AND 2 REFER TO THE FIRST AND SECOND PATTERN OF A PAIR.

		SECOND PATTERN		
FIRST PATTERN		TONIC	MAJOR THIRD	PREVIOUS CONTEXT
TONIC	EM	2=1	2=1	2>1
	CC	2=1	2>1	2>1
MAJOR THIRD	EM	2=1	2=1	2>1
	CC	2<1	2=1	2=1
PREVIOUS CONTEXT	EM	2<1	2<1	2=1
	CC	2<1	2=1	2=1

harmonic relationship of the final note. Since these theorists do not consider the inherent structural relationships within a melody nor the invariants that specify an event's end, all melodies are assumed to be equally complex.

The Cognitive Change Hypothesis (Block 1978), on the hand, does predict differences in judged duration as a function of harmonic ending. From this perspective, any final note other than the tonic constitutes a "change" in stimulus structure which will serve to lengthen duration judgments. Given this rationale, Blocks's model predicts the results shown in Table 14. Notice that melodies ending on the previous context note are also predicted to be judged longer than those ending on the tonic. In contrast to the Expectancy Model, however, melodies ending on the major third should seem <u>longer</u> than melodies ending on the tonic. Further, judgments of <u>same</u> duration are predicted whenever a major third ending is paired with a previous context ending. This is because each pattern contains one change from the tonic. This approach, then, does not distinguish among varying degrees of perceived finality but simply enumerates the total number of "changes".

To examine these three sets of predictions, the following experiment was conducted.

Method

Design and Subjects

The design is a 9 x 2 x 4 2 mixed factorial. Nine levels of pattern pairs (shown in Table 14) are crossed with two levels of task type (comparative duration; melody recognition), and four songs (Pont, Ago, Czech, Cuckoo). The single between-subjects variable is counterbalance order (I, II).

Sixteen undergraduates were recruited from the enrollements of Introductory Psychology. No constraints were placed on musical ability. Eight subjects were randomly assigned to each counterbalance order.

Stimulus Materials

Twelve melodies were selected from the total set of melodies used in Experiments 3a and 3b. Specifically, for each of the four songs shown in Figure 6 (Czech, Ago, Pont, and Cuckoo), those versions ending on the tonic, major third, and previous context note were used in the present experiment. The results of the earlier rating studies had indicated that these three versions were respectively judged as the most resolved, somewhat resolved, and most unresolved.

Patterns were then paired such that 168 experimental trials were yielded. Seventy-two of these trials required comparative duration judgments and were obtained by crossing the three levels of pattern type (Tonic, Major Third, and Previous Context Ending) with the first and second pattern to yield the nine pattern pairs of Table 14. These nine pattern pairs were then crossed with the four songs and a repeated presentation factor to yield 72 trials.

The remaining 96 trials required a recognition memory judgement. These were obtained by crossing the four songs with a repeated presentation factor and twelve pattern pairs. Nine of these twelve pairs are the same as Table 14. However, since there are three "same" and six "different" pattern pairs, each "same" was presented twice to render an equal number of "sames" and "differents". (This is necessary to conduct an Ag analysis for the memory data). For both tasks, melodies within a pair always contained the same song and total duration.

These 168 experimental trials were randomized and divided into four blocks of 42 trials.

Apparatus

Same as previous experiments.

Procedure

The experiment spanned two days with subjects receiving 2 blocks of 42 experimental trials on each day. The procedure was identical to earlier duration experiments except for the following change: Subjects were informed that the warning tone, which signals the onset of each experimental trial, would either be very high (3522 hz) or low pitched (131 hz). The low warning tone signalled that a comparative duration task was required and that they should indicate their duration judgment (on the scale used before) along with the confidence of this judgment (on the previous 7 pt. scale). If the warning tone was very high, then a melody recognition response was required. Here, subjects were told to circle "same" or "different" as well as the confidence rating on a 7 pt. scale.

Subjects received six preliminary practice patterns that represented the various types of stimuli.

Results

Only the results of the judged duration task will be presented. The recognition memory data is summarized in Appendix B.

Judged Duration

Table 15 displays the mean judged duration for pattern pairs as a function of their harmonic ending. Means are collapsed over song and counterbalance order since these variables were both nonsignificant (F's <1). As before, scores from the duration response scale were converted into values ranging from 1 to 7. A mean of 4 indicates that both patterns were judged as the same duration; values <4 indicate that the second pattern was judged longer than the first; and values >4 indicate that the second pattern was judged shorter.

This present set of data evaluates three sets of predictions. The Expectancy Model predicts that unresolved melodies, namely those ending on the previous context note, will be overestimated relative to resolved melodies ending on the tonic or major third. This is because the lack of end-lengthening should encourage a mental extrapolation of "missing" notes within the unresolved melodies. In addition, melodies ending on the major third should be judged the same as those ending on the tonic because both melodies are resolved. These predictions contrast with those of the Storage Size and Attentional Effort Models. These models assume that the present set of melodies are equally complex and therefore will not produce any differences in judged

TABLE 15

MEAN JUDGED DURATION FOR MELODIES IN EXPERIMENT 3B AS A FUNCTION OF HARMONIC ENDING. A VALUE OF 4 INDICATES EQUIVALENT JUDGED DURATION; VALUES >4 INDICATE THE SECOND PATTERN WAS JUDGED SHORTER; VALUES <4 INDICATE THE SECOND PATTERN WAS JUDGED LONGER.

FIRST PATTERN	SECOND PATTERN: TONIC	SECOND PATTERN: MAJOR THIRD	SECOND PATTERN: PREVIOUS CONTEXT	MEANS
TONIC	3.97	3.89	3.43	3.76
MAJOR THIRD	4.04	3.93	3.58	3.85
PREVIOUS CONTEXT	4.50	4.36	3.99	4.28
MEANS	4.17	4.06	3.67	

duration. Lastly, Block's Model predicts that any change from the tonic should result in greater complexity and longer duration judgments. Since the major third and previous context endings both contain one change, they should be judged equivalent to one another but longer than the tonic ending.

A pattern main effect ($F_{8, 112} = 20.2$, $p < .0001$, $MSe = .088$) reveals that judged duration did differ as a function of harmonic ending. This eliminates the Storage Size and Attentional Effort Models from further evaluation. To contrast the Expectancy and Cognitive Change hypotheses, a series of Bonferroni post hoc comparisons were conducted. For each set of counterbalanced pattern pairs (eg. Tonic-Major Third vs. Major Third-Tonic), duration estimates were first subtracted from the value of 4.00 (a "same" duration judgment). These two difference values were then averaged to determine the mean deviation from a "same" judgment. Table 16 depicts these values and indicates which melody of a pair was overestimated.

The results of this post hoc analysis shows that melodies ending on the previous context note are judged longer than melodies ending on the tonic ($F_{2, 112} = 5.1$, $p < .01$) or the major third ($F_{2, 112} = 3.71$, $p < .01$). No difference in judged duration is obtained when a major third ending is paired with a tonic ending ($F < 1.00$). These findings are consistent with predictions of the Expectany Model.

Discussion

The present set of results supports a major hypothesis of the Expectancy Model. Events which lack a structurally marked ending

TABLE 16

THE MEAN DIFFERENCE FROM A JUDGMENT OF EQUIVALENT DURATION FOR PATTERN PAIRS IN EXPERIMENT 3B.

HARMONIC ENDING OF PATTERN PAIRS	MEAN DIFFERENCE	SECOND PATTERN WAS:
RESOLVED (TONIC) - UNRESOLVED	.54 $p < .01$	OVERESTIMATED
RESOLVED (TONIC) - RESOLVED (MAJOR THIRD)	.08 NS	
RESOLVED (MAJOR THIRD) UNRESOLVED	.39 $p < .05$	OVERESTIMATED

seem longer in relative duration. To achieve a sense of finality, a perceiver presumably extrapolates the time course of an event to its expected completion. This in turn creates an overestimation of judged duration.

Within the realm of music, melodic completion is signified by an end-lengthened tonic. Since the tonic note can occur throughout a melody, it is a change in the final tonic's duration which uniquely specifies a definitive ending. In the present experiment, this definitive ending was missing in all melodies because the final note's duration was always identical (ie. isochronous) to that of preceding notes. Since melodies ending on a previous context note are perceived as unresolved, it was predcted that listeners would mentally continue the time course of these melodies to their "appropriate" tonic ending. Results showed that unresolved melodies were in fact overestimated relative to resolved melodies ending on a major chord member.

A second prediction that was tested here concerned the duration estimates of melodies ending on a major chord member (ie. tonic and major third). These sorts of endings return a listener to a melody's underlying scale and thus provide a relative sense of finality. It was predicted that these melodies would be judged as equivalent in relative duration because no mental extrapolation should occur. This finding was indeed obtained.

The results of this experiment do have some implications for duration estimates within the natural environment. In contemporary music, there are occasions when a melody lacks a definitive ending.

Particularly in rock compositions, a musician doesn't always end on a prolonged tonic. Instead, they use a "fadeout technique" where the closing bars of a song are gradually decreased in volume. The last few notes are so soft that we often cannot discern exactly <u>when</u> the song has ended. Since this sort of melody lacks a perceptible ending, the present set of findings suggest that a listener might mentally continue the song to a more "appropriate" ending. If so, then this melody should seem longer than one ending on the tonic note. An analogous phenomenom can be observed in speech. Some speakers do not appropriately end their utterances on an end-lengthened word. Instead, their utterances "trail off" or decrease in amplitude before the last word is actually uttered. Again, a conversation with such speakers should seem relatively long in duration.

Finally, the results of this experiment illustrate some problems with current models of judged duration. The Storage Size and Attentional Effort Models, for example, have defined complexity simply in terms of the number of cognitive chunks. As shown here, however, events containing the same number of chunks are not always judged as equivalent in duration. Duration estimates depend upon the structural relationships within an event and whether that event's end is structurally specified. The concept of "chunks" does not capture this structural organization and so its predictive power is limited. Blocks' Cognitive Change Model displays similar difficulties. Although "changes" presumably increase complexity and experienced duration, the results obtained here show that not all changes create overestimations. For example, major third endings were not judged longer than tonic endings nor were melodies with one change apiece (ie. Major Third-Previous Context Note pairs) judged equivalently. These findings suggest that an event's complexity can be more precisely defined in terms of the reciprocal relationship between an organism and an event's structure.

In summary, this experiment has investigated the judged duration of events that lack a perceptible end. The next experiment examine duration estimates for melodies that do contain a perceptible end but one which violates a perceiver's expectancies.

Judged Duration of Melodies Containing a Perceptible End

There is a second assumption within the Expectancy Model that has not yet been tested. It concerns how duration estimates may be affected by events which contain a structurally specified ending but one which explicitly violates a perceiver's expectancies. In this sort of situation, the Expectancy Model predicts that duration estimates are determined by whether the actual end occurs before or after the expected end. If an event ends earlier than expected, then duration should be underestimated. Conversely, overestimations should be observed whenever an event ends later than expected.

Let's consider how these premises may apply to the issue of musical resolution. Regardless of whether a melody does or does not end on the tonic, an end-lengthening effect should always convey a definitive ending. By placing the longest tonal duration at the end, the composer signals that the melody is over. An end-lengthened melody may nevertheless appear to end too early if the harmonic relationship of this final note does not signify resolution. For example, a melody ending on the previous context note will seem to lack those notes leading to the expected tonic. A mental continuation of these notes would be inappropriate because the end-lengthening effect disrupts the temporal continuity with preceding notes - in addition, this convention specifies the melody's completion. Since an unresolved melody ends before the expected tonic, its duration should be underestimated.

A similar result should be observed when the final note's duration is relatively shorter than that of preceding notes. Although this sort of temporal ending violates musical convention, a final note that is short and abrupt should indicate that the melody is over. There is no continuity with preceding notes (induced by isochrony) and so a mental continuation of missing tones should not occur. Again, the unresolved melody may seem shorter than a resolved one because it ends before the expected tonic.

In summary, the Expectancy Model predicts that duration estimates of unresolved melodies will interact with a melody's temporal ending. An ending that is temporally isochronous with preceding notes should create overestimations because a listener may mentally continue the melody to its expected ending. This effect was in fact observed in the previous experiment. An unresolved melody that is either end-lengthened or shortened, however, should reveal underestimations because the melody ends before the expected tonic. Experiment Four was designed to test these predictions.

Experiment Four

This experiment required subjects to judge the relative duration of melodies that did or did not contain a perceptible ending. This was achieved by factorially manipulating the temporal and harmonic ending of melodies presented in a comparative judgment task. As the design of Table 17 illustrates, melodies were paired to obtain four different levels of harmonic ending. In the first condition, both melodies were resolved because both ended on the tonic. In the second, both were unresolved because they ended on the previous context note. The third and fourth conditions consisted of a resolved melody paired with an unresolved one.

In addition, the temporal ending of melodies was also varied. Both melodies within a pair contained a final note whose duration was either lengthened, shortened, or isochronous with the duration of preceding notes. This decision to maintain temporal ending constant within a pair was based on the results of a preliminary pilot study. Here it was found that response bias occurred when melodies within a pair contained a different temporal ending (eg. Isochronous-Long). Subjects apparently based their judgments on the final tonal duration of the second melody and not on the duration of the entire melody. Thus, the temporal ending of melodic pairs was held constant in this experiment to eliminate this sort of bias.

The duration estimates of this study were also observed in both an Adaptation and Test Phase. In the Adaptation Phase, three

TABLE 17

EXPERIMENTAL DESIGN OF EXPERIMENT 4. THE PREDICTIONS OF THE EXPECTANCY (EM) AND CONTEXTUAL CHANGE (C) MODELS ARE CONTRASTED FOR EACH CONDITION (WHERE 1 AND 2 REFER TO THE FIRST AND SECOND PATTERN OF A PAIR.

			TEMPORAL ENDING		
			ISOCHRONOUS	LONG	SHORT
HARMONIC ENDING	RESOLVED - RESOLVED	EM	2=1	2=1	2=1
		CC	2=1	2=1	2=1
	UNRESOLVED - UNRESOLVED	EM	2=1	2=1	2=1
		CC	2=1	2=1	2=1
	RESOLVED - UNRESOLVED	EM	2>1	2<1	2<1
		CC	2>1	2>1	2>1
	UNRESOLVED - RESOLVED	EM	2<1	2>1	2>1
		CC	2<1	2<1	2<1

independent groups of subjects were exposed to only one type of temporal ending - one that was either lengthened, shortened, or isochronous. After the Adaptation Phase, however, these three groups of subjects all received the same set of Test Phase patterns. Here the temporal ending of pattern pairs differed across trials. The rationale for using both an Adaptation and Test Phase was two-fold. First, the effects of harmonic and temporal ending could be investigated in both a between-subjects (ie. Adaptation Phase) and within-subjects design (ie. Test Phase). If results are identical across both phases, then a source of converging operations has been obtained. Second, this particular design also allows one to determine whether adaptation set creates effects of differential magnitude. For example, subjects adapted to a short ending may perceive the long ending of the test phase as being longer than those subjects adapted to either an isochronous or long ending. Although the overall pattern of results should be identical across both phases, a magnitude difference may reveal whether the resolution convention can be altered by recent prior experience.

The manipulations of this experiment do generate contrasting sets of predictions for the various time models of interest. The Expectancy Model predicts that the harmonic ending of a melody will interact with its temporal ending. An unresolved melody should be judged shorter than a resolved one when the temporal ending of the last note is either lengthened or shortened. Since these endings presumably create a sense of finality, the unresolved melody should appear to end earlier than expected. The opposite effect should occur in the isochronous condition. The temporal continuity with preceding context fails to signify melodic completion. If listeners mentally extrapolate an unresolved melody to its expected tonic, then it should seem longer than a resolved melody.

The predictions of the Expectancy Model, shown in Table 17, are quite different from those of the various information-processing models. According to the Storage Size and Attentional Effort models, all melodies should be judged as equal in duration. Again, these models assume that judged duration depends on the number of cognitive chunks that are delineated by melodic and temporal accents. The present set of melodies should therefore be equally complex because all contain the same rhythm and accent structure.

Block's Cognitive Change Hypothesis generates a third set of predictions. This model assumes that duration estimates will increase with the number of changes from the resolution convention. Since temporal ending is always held constant within a melodic pair, a previous context ending should <u>always</u> seem longer than a tonic ending. The variable of temporal ending then should <u>not</u> interact with harmonic ending.

These three sets of predictions, summarized in Table 17, were evaluated in the following experiment.

Method

Design and Subjects

The present experiment incorporates both an adaptation and test phase. Since the results of these two phases will be analyzed separately, the design of each will be described in turn. Specifically the design of the adaptation phase was a 4 x 3 x 3 x 2 mixed factorial. Four levels of harmonic ending (Tonic-Tonic; Previous Context Note-Previous Context Note; Tonic-Previous Context Note; Previous Context Note-Tonic) were crossed with three songs. The two between subject variables were temporal ending (Short, Long, Isochronous) and counterbalanced order of trial presentation (I, II).

For the test phase, the design was 4 x 3 x 3 x 3 x 2 mixed factorial. Four levels of harmonic ending pairs (Tonic-Tonic; Previous Context Note-Previous Context Note; Tonic-Previous Context Note; Previous Context Note-Tonic) were crossed with three levels of temporal ending pairs (Long-Long; Isochronous-Isochronous; Short-Short) and three songs. The two between subjects variables were counterbalance order (I, II) and adaptation set (Short, Long, Isochronous).

Thirty-six undergraduates were recruited froom Introductory Psychology in return for course credit. No constraints were placed on musical ability. Six subjects were randomly assigned to one of the six between-subjects conditions.

Stimulus Materials

Three of the four songs, shown in Figure 6, were again used as experimental stimuli. Of the four shown, the Pont song was discarded to reduce the total number of experimental trials. This particular song was selected over the others since its resolution ratings were relatively more variable.

For each song, those versions ending on the tonic and previous context note were chosen. Each of these six melodies were then given three types of temporal ending. In the isochronous condition, the ontime of the final note was the same as its previous note values. The set of ontimes for each song was identical to those used in Experiment 3a and 3b. In the long condition, the ontime of the final note was roughly 65% longer than that of preceding notes. By referring to Tables 18a and 18b, notice that the ontimes of all other notes within a song are decreased relative to values within the isochronous condition. These tonal durations were decreased such that they a) did not sound noticeably "clipped" and b) maintained the same total duration as in the isochronous condition. Lastly, final notes within the short condition contained an ontime that was 65% shorter than the ontime of preceding notes. The ontimes of the remaining notes in this condition were lengthened relative to those of the Isochronous condition. These ontime values were assigned such that a) their relative magnitude difference was comparable to values with the long condition and b) the total duration of the pattern was preserved. The set of duration values for all songs is shown in Tables 18a and 18b.

TABLE 18

THE STIMULUS ONSET ASYNCHRONIES (SOA'S) FOR THE MANIPULATIONS OF TEMPORAL ENDING USED IN EXPERIMENTS 3 AND 4.

LONG, LONG, AGO

	ISOCHRONOUS		LENGTHENED		SHORTENED	
NOTES	ON-TIME	OFF-TIME	ON-TIME	OFF-TIME	ON-TIME	OFF-TIME
F4	300	150	290	150	310	150
F4	150	75	145	75	155	75
G4	150	75	145	75	155	75
A4	300	150	290	150	310	150
A4	150	75	145	75	155	75
A#4	150	75	145	75	155	75
C5	300	150	290	150	310	150
D5	150	75	145	75	155	75
C5	150	75	145	75	155	75
A4	300	600	290	600	310	600
C5	300	150	290	150	310	150
A#4	150	75	145	75	155	75
A4	150	75	145	75	155	75
G4	300	600	290	600	310	600
A#4	300	150	290	150	310	150
A4	150	75	145	75	155	75
G4	150	75	145	75	155	75
F4	300	100	420	100	180	100

CZECH FOLK SONG

C4	200	100	195	100	202	100
C4	200	100	195	100	202	100
C4	200	100	195	100	202	100
C4	200	100	195	100	202	100
C4	200	100	195	100	202	100
D4	200	100	195	100	202	100
E4	200	400	195	400	202	400
F4	200	100	195	100	202	100
E4	200	100	195	100	202	100
D4	200	400	195	400	202	400
E4	200	100	195	100	202	100
D4	200	100	195	100	202	100
C4	200	400	195	400	202	400
C4	200	100	195	100	202	100
C4	200	100	195	100	202	100
C4	200	100	195	100	202	100
C4	200	100	195	100	202	100
C4	200	100	195	100	202	100
D4	200	100	195	100	202	100
E4	200	400	195	400	202	400
F4	200	100	195	100	202	100
E4	200	100	195	100	202	100
D4	200	100	195	100	202	100
D4	200	100	195	100	202	100
C4	200	100	320	100	152	100

TABLE 18 (continued)

THE STIMULUS ONSET ASYNCHRONIES (SOA'S) FOR THE MANIPULATIONS OF TEMPORAL ENDING USED IN EXPERIMENT 3 AND 4.

THE CUCKOO

	ISOCHRONOUS		LENGTHENED		SHORTENED	
NOTES	ON-TIME	OFF-TIME	ON-TIME	OFF-TIME	ON-TIME	OFF-TIME
G4	200	400	193	400	203	400
E4	200	100	193	100	203	100
G4	200	400	193	400	203	400
E4	200	100	193	100	203	100
F4	200	100	193	100	203	100
E4	200	100	193	100	203	100
D4	200	100	193	100	203	100
E4	200	700	193	700	203	700
G4	200	400	193	400	203	400
E4	200	100	193	100	203	100
G4	200	400	193	400	203	400
E4	200	100	193	100	203	100
F4	200	100	193	100	203	100
E4	200	100	193	100	203	100
D4	200	100	193	100	203	100
C4	200	100	305	100	155	100

SUR LE PONT D'AVIGNON

NOTES	ON-TIME	OFF-TIME
F4	150	75
F4	150	75
F4	300	150
G4	150	75
G4	150	75
G4	300	150
A4	150	75
A#4	150	75
C5	150	75
F4	150	75
E4	150	75
F4	150	75
G4	150	75
C4	150	75
F4	150	75
F4	150	75
F4	300	150
G4	150	75
G4	150	75
G4	300	150
A4	150	75
A#4	150	75
C5	150	75
F4	150	75
G4	150	75
E4	150	75
F4	300	150

Two sets of pattern pairs were constructed. One set was designed for an adaptation phase and another for a test phase.

Pattern Pairs for the Adaptation Phase

For each type of temporal ending, patterns were paired such that the harmonic ending would either be the same (ie. Resolved-Resolved; Unresolved-Unresolved) or different (ie. Resolved-Unresolved; Unresolved-Resolved) within a pair. All pattern pairs, however, always contained the same song, the same total duration, and the same temporal ending. By crossing the four levels of harmonic ending with the three songs and a repeated presentation factor, 24 randomized trials were obtained. For each type of temporal ending, two blocks (I, II) of 24 trials were devised for the factor of counterbalance order.

Pattern Pairs for the Test Phase

Patterns were again paired such that harmonic ending was either the same or different within a pair - yielding four types of harmonic ending pairs. Also as before, patterns within a pair always contained the same song, same temporal ending, and same total duration. Here, however, the temporal ending of pattern pairs could differ across experimental trials. Thus, by crossing the four types of harmonic ending with the three types of temporal endings (long-long; short-short; and isochronous-isochronous), three songs, and a repeated presentation factor, 72 test trials were yielded. Trials were randomized and divided into two blocks of 36 trials.

Apparatus

Same as before.

Procedure

Twelve subjects were randomly assigned to one of the three adaptation phases (Long, Short, Isochronous). Within each group, half were assigned the 24 trials of Block I and six were assigned those of Block II.

On each trial, a high pitched warning tone (5000 hz) preceded an initial melody by two secs. Following the presentation of the first melody, a second melody occurred two seconds later. During a 7 sec. response interval, subjects were then asked to judge the duration of the second melody relative to the first one. A response scale, that was modified from earlier studies, required subjects to circle one of the following numbers:

very much shorter	quite shorter	somewhat shorter	same duration	somewhat longer	quite longer	very much longer
-3	-2	-1	S	+1	+2	+3

Although the response categories are the same as before, smaller numbers now refer to shorter judgments and larger numbers refer to longer judgments. This scale was felt to be more consistent with the convention of assigning larger numbers to greater quantities. In addition to indicating their duration judgemnt, subjects were also asked to judge the certainity of their response on a 7 pt. scale.

After receiving the 24 trials of the adaptation phase, short rest break was provided (ca. 2 mins). All subjects were then asked to judge the relative duration of melodies within a test phase. Two counterbalanced blocks of 36 trials were presented. separated by a short 2 min. break. An entire experimental session was approximately one hour in duration.

Results

Results of the adaptation and test phases were analyzed separately. Since the duration estimates of the Test Phase are of greater interest, they will be considered first.

Test Phase

Table 19 displays the mean judged duration as a function of harmonic and temporal ending. Means are collapsed over adaptation set, song, and counterbalance order (F's all nonsignificant). Scores from the duration response scale were converted into values ranging from 1 to 7 but the direction of these values are now reversed from previous experiments. Values < 4 indicate that the second pattern was judged shorter than the first; values > 4 indicate that the second pattern was judged longer ; and values equal to 4 denote equivalent judged duration.

Three sets of predictions are evaluated within this experiment. According to predictions of the Expectancy Model, temporal ending should interact with harmonic ending. Relative to a tonic ending, a previous context ending should be overestimated in the Isochronous condition and underestimated in both the Long and Short conditions.

TABLE 19

MEAN JUDGED DURATION FOR TEST PHASE MELODIES OF EXPERIMENT 4 SHOWN AS A FUNCTION OF HARMONIC AND TEMPORAL ENDING. A VALUE OF 4 INDICATES EQUIVALENT JUDGED DURATION; VALUES <4 INDICATE THE SECOND PATTERN WAS JUDGED SHORTER; VALUES >4 INDICATE THE SECOND PATTERN WAS JUDGED LONGER.

HARMONIC ENDING	TEMPORAL ENDING: ISOCHRONOUS	LONG	SHORT	MEANS
RESOLVED - RESOLVED	4.00	4.06	3.99	4.02
UNRESOLVED - UNRESOLVED	4.00	4.02	4.00	4.01
RESOLVED - UNRESOLVED	4.32	3.66	3.77	3.92
UNRESOLVED - RESOLVED	3.86	4.13	4.05	4.01
MEANS	4.05	3.97	3.95	

The Storage Size and Attentional Effort Models predict no differences in judged duration while the Cognitive Change Hypothesis simply predicts a main effect for harmonic ending. Regardless of temporal ending, a previous context ending should always seem longer than a tonic ending.

Consistent with predictions of the Expectancy Model, an significant interaction between harmonic and temporal ending was obtained ($F_{6,180} = 41.47$, $p < .0001$, $MSe = .047$). A series of Bonferroni post hoc comparisons were conducted to determine the nature of this interaction. As before, the duration estimates for a counterbalanced pattern pair were subtracted from a value of 4.00 to obtain the average difference from a "same" judgment. Table 20 depicts these values and indicates which pattern of a pair was under or overestimated.

Within the Isochronous condition, melodies ending on the previous context note were in fact judged longer than melodies ending on the tonic ($F_{2, 180} = 4.60$, $p < .01$), Conversely, the previous context ending was judged <u>shorter</u> than a tonic ending in both the Long ($F_{2, 180} = 5.70$, $p < .01$) and Short ($F_{2, 180} = 2.80$, $p < .01$) conditions. The magnitude of these effects were comparable across subjects and were not influenced by adaptation set ($F < 1.00$).

Within this test phase, a main effect for temporal ending was also obtained ($F_{2\ 69} = 13.93$, $p < .0001$, $MSe = .097$). As the column means of Table 19 reveal, melodies containing a long ending were judged relatively longer than melodies containing a short ending

TABLE 20

THE MEAN DIFFERENCE FROM A JUDGMENT OF EQUIVALENT DURATION FOR PATTERN PAIRS IN EXPERIMENT 4.

TEMPORAL ENDING	MEAN DIFFERENCE		UNRESOLVED PATTERN WAS:
ISOCHRONOUS	.23	$p < .01$	OVERESTIMATED
LENGTHENED	.24	$p < .01$	UNDERESTIMATED
SHORTENED	.14	$p < .05$	UNDERESTIMATED

TABLE 21

MEAN JUDGED DURATION FOR ADAPTATION PHASE MELODIES OF EXPERIMENT 4 SHOWN AS A FUNCTION OF HARMONIC AND TEMPORAL ENDING. A VALUE OF 4 INDICATES EQUIVALENT JUDGED DURATION; VALUES <4 INDICATE THE SECOND PATTERN WAS JUDGED SHORTER; VALUES >4 INDICATE THE SECOND PATTERN WAS JUDGED LONGER.

		TEMPORAL ENDING			
		ISOCHRONOUS	LONG	SHORT	MEANS
HARMONIC ENDING	RESOLVED - RESOLVED	4.00	4.04	4.00	4.01
	UNRESOLVED - UNRESOLVED	4.02	3.97	3.99	3.99
	RESOLVED - UNRESOLVED	4.58	3.63	3.77	3.99
	UNRESOLVED - RESOLVED	3.54	4.71	4.11	4.12
	MEANS	4.04	4.09	3.97	

($F_{2, 60} = 2.71$, $p < .05$). This suggests the presence of response bias and that subjects were more apt to respond "long" if the melodies' ending were long. These effects of response bias, however, cannot explain the lawful harmonic-temporal ending interaction obtained here.

<u>Adaptation Phase</u>

Table 21 displays the mean judged duration for melodies within the adaptation phase. Melodies differing in harmonic ending are shown as a function of temporal ending where means are collapsed over song and counterbalance order ($F < 1.00$).

A primary purpose of this Adaptation Phase was to determine whether the results of a between-subjects design would converge with those of a within-subjects one (ie. Test Phase). A significant interaction between harmonic and temporal ending ($F_{6,90} = 33.87$, $p < .0001$, $MSe = .07$) showed that results did in fact converge. Relative to a tonic ending, the previous context ending was overestimated in the Isochronous condition ($F_{2,90} = 8.67$, $p < .01$) and underestimated in both the Long ($F_{2,90} = 9.00$, $p < .01$) and Short conditions ($F_{2,90} = 2.83$, $p < .01$). Again, these results support the predictions of the Expectancy Model and clearly contradict those of the various information-processing models.

Discussion

The primary purpose of this experiment was to determine whether duration estimates would be influenced by the presence or absence of a structurally marked ending. According to musical convention, an end-lengthened tonic specifies that a melody is completed. The

Expectancy Model assumes that listeners are attuned to these invariants and expect their presence whenever listening to music. If resolution does not occur as expected, then systematic time errors should arise. Melodies lacking a perceptible end should encourage a mental continuation to the <u>expected</u> end. This not only provides a greater sense of resolution but also lengthens experienced duration. In contrast, underestimations are predicted to occur whenever a melody ends earlier than expected. These melodies do contain a perceptible end but one that violates a perceiver's expectancies.

The effects observed within this experiment support the Expectancy Model. By removing the end-lengthening effect, for example, the melody's ending was isochronous with the preceding temporal context. These melodies therefore lacked a definitive end and appeared as if they should continue on to the expected prolonged tonic. Subjects presumably extrapolated this expected completion when the melody ended on a previous context note. Relative to a tonic ending, this sort of melody yielded overestimations of judged duration.

These same melodic pairs, however, displayed underestimations when the temporal ending was either prolonged or shortened. Short and long endings apparently impart a sense of finality by deviating from a melody's temporal context. A prolonged ending in fact conforms to musical convention while a short ending implies an abrupt interruption. In both cases, melodies ending on the previous context note lack those notes leading to the tonic. Relative to a melody that does end on the tonic, these melodies end earlier than expected and therefore seem shorter in duration.

These results appear to be very reliable ones. The effects of harmonic and temporal ending were identical in both a between-subjects (ie. adaptation phase) and within-subjects design (ie. test phase). In addition, the magnitude of effects was not influenced by adaptation set. The convention of musical resolution appears to be a deeply engrained one that cannot be altered by recent prior experience.

The present set of results cannot be explained by the various information-processing models evaluated here. For example, one definition of "cognitive chunks" suggests that complexity depends on the number of temporal accents that parse a melody into discrete moments of time. These chunks, however, do not reflect the harmonic and temporal relationships which specify a melody's end. Thus the Storage Size (Ornstein 1969) and Attentional Effort Models (Underwood & Swain 1973; Thomas & Weaver 1975) were unable to predict differences in judged duration as a function of the final note. Although the Cognitive Change Hypothesis predicts that any change in resolution will increase experienced duration, the effects of different kinds of change are not addressed. Hence, Block's model cannot explain the qualifying effects of temporal ending and the sorts of expectancies that melodic structure may generate. Again, these sorts of problems demonstate that complexity can be more precisely defined within an event's structure.

Chapter Summary

The experiments that were conducted here examined the effects of musical resolution upon judged duration. By manipulating the temporal and harmonic relationships of a final note, two assumptions within the Expectancy Model were assessed. According to one, melodies which lack a perceptible end should promote a mental extrapolation to the expected ending. This was predicted to yield overestimations of judged duration. This predicted effect was indeed observed when a melody's temporal ending was isochronous with previous context. Relative to a melody ending on the tonic, a melody ending on a previous context note was overestimated - presumably because listeners extrapolated the melody's missing notes.

The second assumption concerned the duration estimates of melodies containing a perceptible end but one which violated a perceivers expectancies. Here, melodies were predicted to yield underestimations whenever they ended earlier than expected. Melodies ending on a lengthened or shortened tonal duration displayed these effects. Since the previous context melodies ended before their expected tonic, they appeared shorter than melodies containing a tonic ending.

These results served to illustrate some problems within the information-processing models of judged duration. These models assume that duration is determined by the number of cognitive chunks or changes wihin an event. These concepts of complexity, however, have limited predictive ability because they ignore the effects of structural relationships upon perceiving.

Although these experiments do reveal what sorts of invariants signify an melody's end, we have not entirely answered a question that was posed at this chapter's beginning. There we asked "How is it that we can anticipate an event's end before it actually occurs?" The convention of pattern resolution only refers to properties of the final note, and yet we are able to anticipate the ending of a melody long before this point. Similarly, the smooth exchange of speaking roles implies that a listener can anticipate a speaker's last word before it actually occurs. This suggests that there are other kinds of structural invariants that direct our attending toward an event's end. In the next and final set of experiments, we will investigate whether those invariants are revealed by a melody's unfolding rhythm and the way that it temporally accents certain melodic relationships.

CHAPTER NINE

SOME EFFECTS OF RHYTHMIC EXPECTANCIES UPON JUDGED DURATION

EXPERIMENT FIVE

The experiments conducted in the previous chapter suggest that a melody's completion is structurally marked by a final prolonged tonic. When the temporal duration and harmonic relationship of this final note were changed, duration estimates varied according to predictions of the Expectancy Model. The purpose of the present chapter is to determine whether rhythmic accent structure can guide attending in advance toward a melody's completion (ie. a resolved ending). In particular, we'll examine whether judged duration is influenced by two musical conventions concerning a) the number of beats between temporal accents and b) the harmonic relationship of accents to the melody's underlying scale. If these structures are used for attentional tracking, then systematic violations of rhythmic context may lead a listener to expect the final prolonged tonic before or after it really occurs - resulting in under and overestimations of judged duration. In the following section, we'll briefly reconsider how rhythm may generate expectancies about a melody's end.

Role of Rhythmic Expectancies in Musical Resolution

According to assumptions of both Rhythmic Attending Theory and the Expectancy Model that is proposed here, auditory events can be described as a hierarchical organization of pitch and temporal structure. The temporal periodicities within a melody are characterized by meter which not only specifies the beat unit, but how many beats will occur in a measure. For example, a melody based on a 3/4 meter signifies that a quarter note (♩) acts as the beat unit and that there are 3 beats in a measure. But we've also noted that a melody contains temporal changes in the form of rests (ie. pauses) and notes of lengthened duration. These sorts of changes create a particular pattern of temporal accents, or rhythm. Rhythm is considered to be psychologically important because a regular recurrence of temporal accents can induce synchronization and enable the perceptual pickup of a melody's duration.

Most melodies display a melodic accent structure that is lawfully interrelated with the occurrence of temporal accents. In fact, temporal and melodic accents often co-occur and unfold in a regular, isochronous fashion. This not only facilitates synchronization but presumably allows a listener to anticipate the "what and when" of future notes. The particular "what" of future notes can be anticipated because melodic accents often involve members of the melody's major chord. Similarly, the "when" of these notes can be anticipated because accents will reappear after an invariant beat period. For example, a musical rule change is often initiated with a note that is intimately related to the tonic (ie. major third, dominant, or tonic itself). Since this sort of melodic accent is also preceded by a pause (ie. a temporal accent), a listener is able to anticipate when a future rule change will occur and what note is likely to initiate this change. As noted previously, however, a musical rule will often span over several notes to create a rather long "passage". To insure that this passage remains sufficiently anchored to its underlying scale, a composer may thereore create a second type of melodic/temporal accent. Here, a major chord member is inserted at the end of a measure and, in addition, its temporal duration is prolonged. Again the purpose of this convention is to "remind" a listener of the melody's key and to provide an overall sense of harmonic stability. As is true of musical rule changes, a listener can presumably anticipate the future occurrence of these accents because they reappear after an invariant number of beats.

If co-occurring accents really do generate expectancies within a listener, then it's likely that a melody's future completion, specified by a prolonged tonic, can also be anticiated. To consider how this may be so, let's examine the melody labelled "Original" in Figure 5. This melody was created by a composer and actually represents the final passage (ie. the final musical rule span) of the melody's complete version. Notice that each temporal accent (t and corresponding to a whole note, o) co-occurs with a melodic accent that is harmonically related to the tonic (ie. major third or tonic itself). Since these co-occurring melodic and temporal accents regularly recur after eight beats, one can attentionally track the melody and anticipate that future accents will also occur after every

8 beats. Further, one is anticipating that this future accent will either be the tonic or major third since the previous context has established this. The anticipated sense of resolution will be satisfied when an end-lengthened tonic occurs. In other words, the tonic ending has been anticipated throughout the melody given the convention of temporally accenting notes that are harmonically related to the tonic. In addition, one can also predict when the final tonic may occur because accents always reappear after an invariant beat period.

In summary, then, we are claiming that a melody's unfolding rhythm contains at least two invariant properties which signal a melody's end. One involves the temporal accentuation of notes that are harmonically related to the tonic (ie. are major chord members). The other involves an invariant number of beats which separates all accents. Assuming that listeners are attuned to these two invariants, how might their violation affect judged duration?

Judged Duration and the Violation of Accent Structures

This issue is intimately related to questions addressed earlier in Experiments One and Two. There we investigated how judged duration is affected by "clashing" patterns of melodic and temporal accents. This sort of accent incompatibility, for example, can be observed in melodies that contain a musical rule span of three notes but a pause after every fourth note. When asked to judge the duration of these melodies relative to those containing co-occurring accents, we found that people judged them to be essentially of similar durations. It is important to note, however, that these rhythmic manipulations did not preserve a lawful relationship between melodic and temporal accents - a musical rule change could not be predicted from the melody's pattern of temporal accents. Thus a perceiver presumably could not generate expectanices about the melody's future course.

In contrast to these earlier manipulations, suppose that we now violate a melody's rhythm such that a predictable relationship maintains between melodic and temporal accents. A listener should be able to generate expectancies about the melody's future course. However, the particular structure of the melody's rhythm may generate an expected ending that occurs relatively earlier or later than the melody's actual ending. According to predictions of the Expectancy Model, this will correspondingly give rise to over and underestimations of judged duration.

These kinds of expectancy errors should in fact arise from violating the invariant beat period between accents. For example, consider the melody labelled "Beat Early" in Figure 5. This melody contains the same number of rhythmic beats (ie. 32) as its "Original" counterpart (shown at the top of this figure). In addition, the duration of major chord members is prolonged such that temporal and melodic accents co-occur with one another. However, notice that the meter between accents has been violated such that the third and fourth beat period contain, not 8 beats, but 6 and 10 beats. How will judged duration be affected by this violation? Here a listener will perceive that the first two periods between accents is an invariant 8 beats, and that this convention has been violated by the 6 beats of the third period. During the final period, then, a listener will expect the final tonic to occur after either 8 or 6 beats - but the final note does not actually occur until after *10 beats* . Since this last note occurs *later than expected* , the melody's duration should be overestimated. The opposite effect should be obtained with the melody labelled as "Beat Late". Here the third period contains 10 beats before the temporal accent, leading a listener to expect the final tonic to occur after either 8 or 10 beats. Since it actually occurs after only 6 beats, the pattern should seem to end too early. If so, the Expectancy Model predicts that its duration will be underestimated.

Similar findings should be obtained by violating the co-occurring relationship between melodic and temporal accents. As illustrated in the "Harmonic Early" melody of Figure 5, suppose that temporal accents (𝅗𝅥) always occur on the note immediately *after* the major chord member (m). Since an invariant beat period maintains between temporal accents (ie. 8 beats), a perceiver should pickup the relative location of these "melodic accents". However, if one uses these major chord members to predict the melody's final tonic, one's expectancies will be violated. This is because the final tonic does not occur after the expected 8 beats (relative to the preceding major chord member) - instead, it occurs after 9 beats. This ending occurs later than expected and so the melody's duration should be overestimated. Again, the opposite effect is predicted to occur with the "Harmonic Late" melody of Figure 5. Here, the note immediately before the major chord member is always temporally prolonged. By using the beat period between preceding major chord members, the final tonic of this melody is expected to occur after 8 beats. Since the end actually occurs after 6 beats, relative duration should be underestimated.

To summarize, the judged duration of these various melodies is predicted relative to a perceiver's expectancies. If a pattern ends earlier than expected, it will be judged shorter and it it ends later than expected, it will be judged longer. If these predictions are obtained, then results will converge on some work done by Povel (1984). He asked subjects to rate patterns, like those labelled as Beat Early and Beat Late in Figure 5, for their degree of "rhythmicity" - that is, how much tension does the pattern evoke. Subjects claimed that both sorts of melodies created a high degree of tension because accents seemed ill-timed. The present experiment can serve to extend these findings by demonstrating that violations of invariant beat periods may, in addition, affect one's judged duration.

The last two experiments of this dissertation are designed to test these hypotheses. Experiment 5a is a rating study that will assess the relative effectiveness of rhythmic manipulations. Melodies will then be paired for presentation in a comparative duration task (Experiment 5b).

Experiment 5a - Ratings

The purpose of this initial rating study is two-fold. First it must be demonstrated that listeners are in fact sensitive to those conventions mentioned earlier. Do listeners really expect an invariant beat period beween accents and are these accents expected to be harmonically related to the tonic? Second, are these two conventions interdependent such that the violation of one causes a violation in the other? That is, even though temporal accents may recur after an invariant beat period, will these same accents nevertheless seem ill-timed because they do not co-occur with major chord members? If so, then the violation of either convention may generate an expected ending for a melody that is either too early or too late.

To investigate these possibilities, the five types of melodies shown in Figure 5 were presented for two sorts of ratings. One involved a dimension of "Accent Timing". Subjects were asked whether the temporal accents within a melody (ie. prolonged notes) were well or ill-timed. The second dimension was one of "Harmonic Appropriateness". In this case, subjects were asked whether temporal accents corresponded with notes that specified a melody's key.

It was predicted that the temporal accents within Original melodies would seem both well-timed and harmonically appropriate. Here, both musical conventions are confirmed because temporal accents recur after an invariant beat period and correspond with major chord members. In contrast, the accents within the Beat Early and Beat Late should seem ill-timed because they do not recur after an invariant beat period. Even though temporal accents correspond with major chord members, accents may be perceived as somewhat harmonically inappropriate if both conventions are interdependent. Lastly, the temporal accents of Harmonic Early and Harmonic Late melodies recur after an invariant beat period but are not harmonically related to the tonic. These accents should therefore seem harmonically inappropriate. If both conventions are interdependent, these temporal accents may also seem somewhat ill-timed. The details of this rating task are presented next.

Method

Design and Subjects

The design was a 5 x 3 x 2 mixed factorial. Five levels of accent type (Original; Harmonic Early; Harmonic Late; Beat Early; Beat Late) were crossed with three songs. Two levels of counterbalance order (I, II) was the single between subjects factor.

Eighteen subjects were recruited from enrollments of Introductory Psychology in return for course credit. All had at least 4 years of musical experience within the past 16 years and were proficient in harmony discrimination. Nine subjects were assigned to each counterbalance order.

Stimulus Materials

Three excerpts of actual songs, shown in Figure 7, were selected from a musical composition book. Each excerpt represented the second half of its original version and was modified

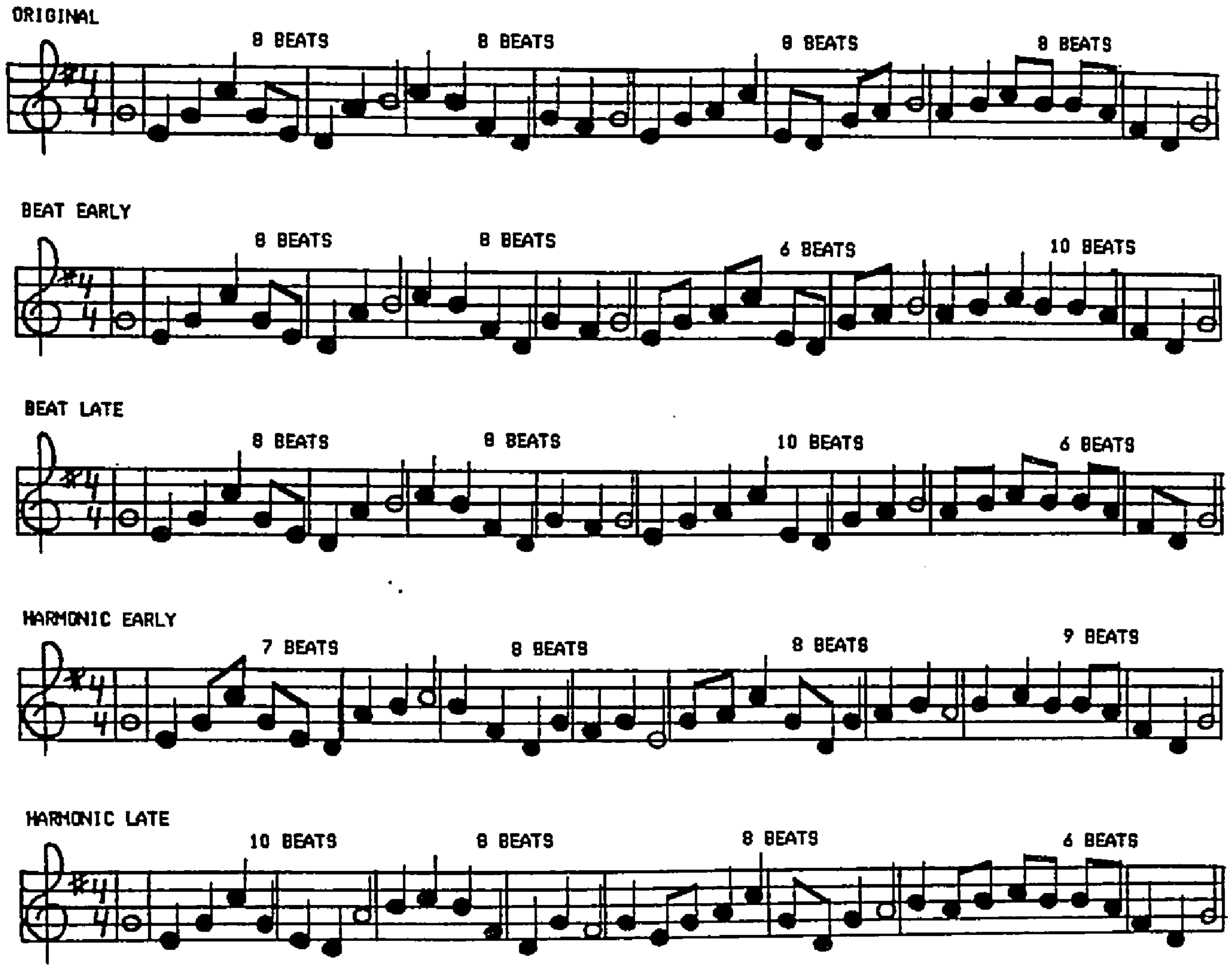


FIGURE 7. MELODIES USED IN EXPERIMENT 5.

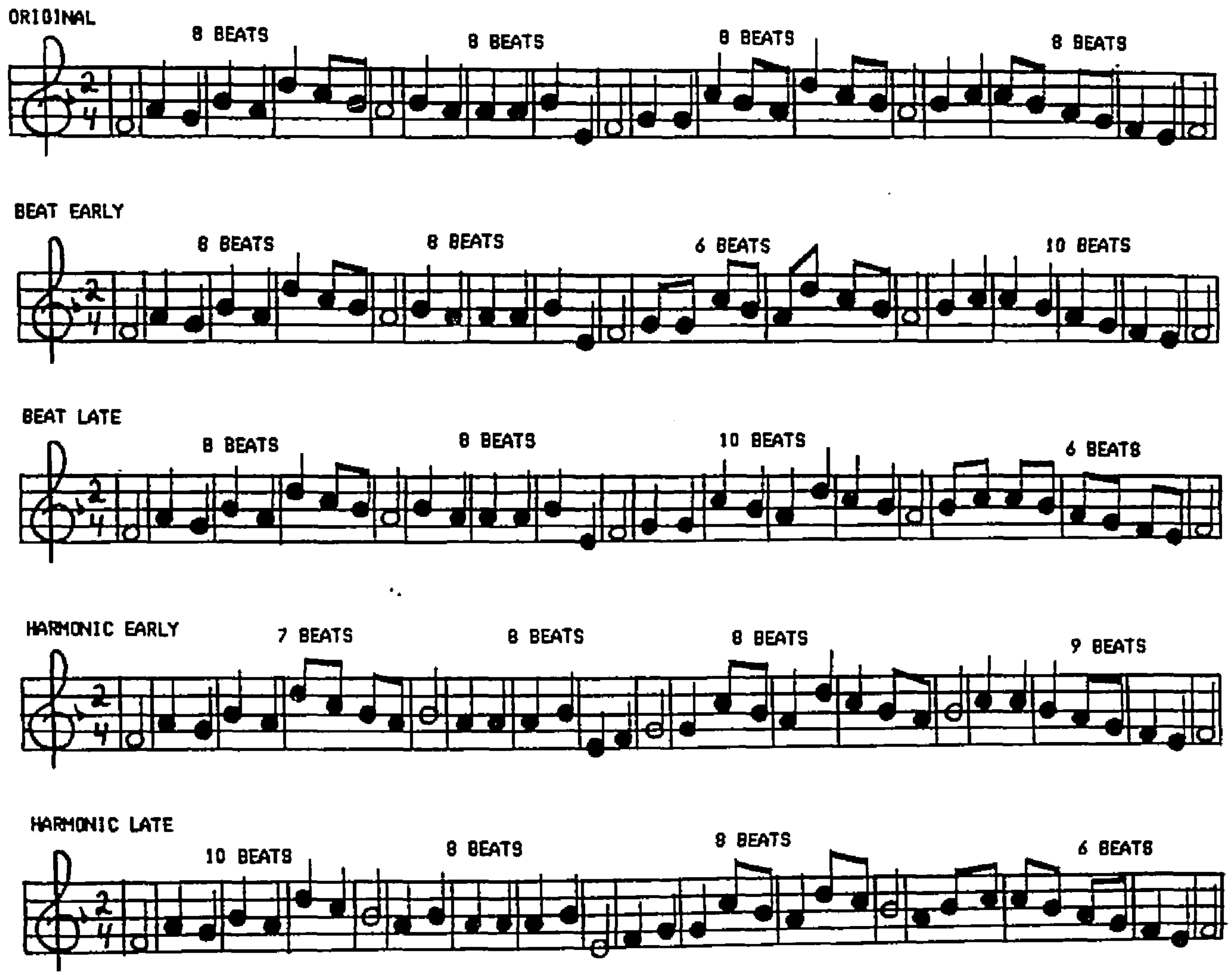


FIGURE 7 (continued)

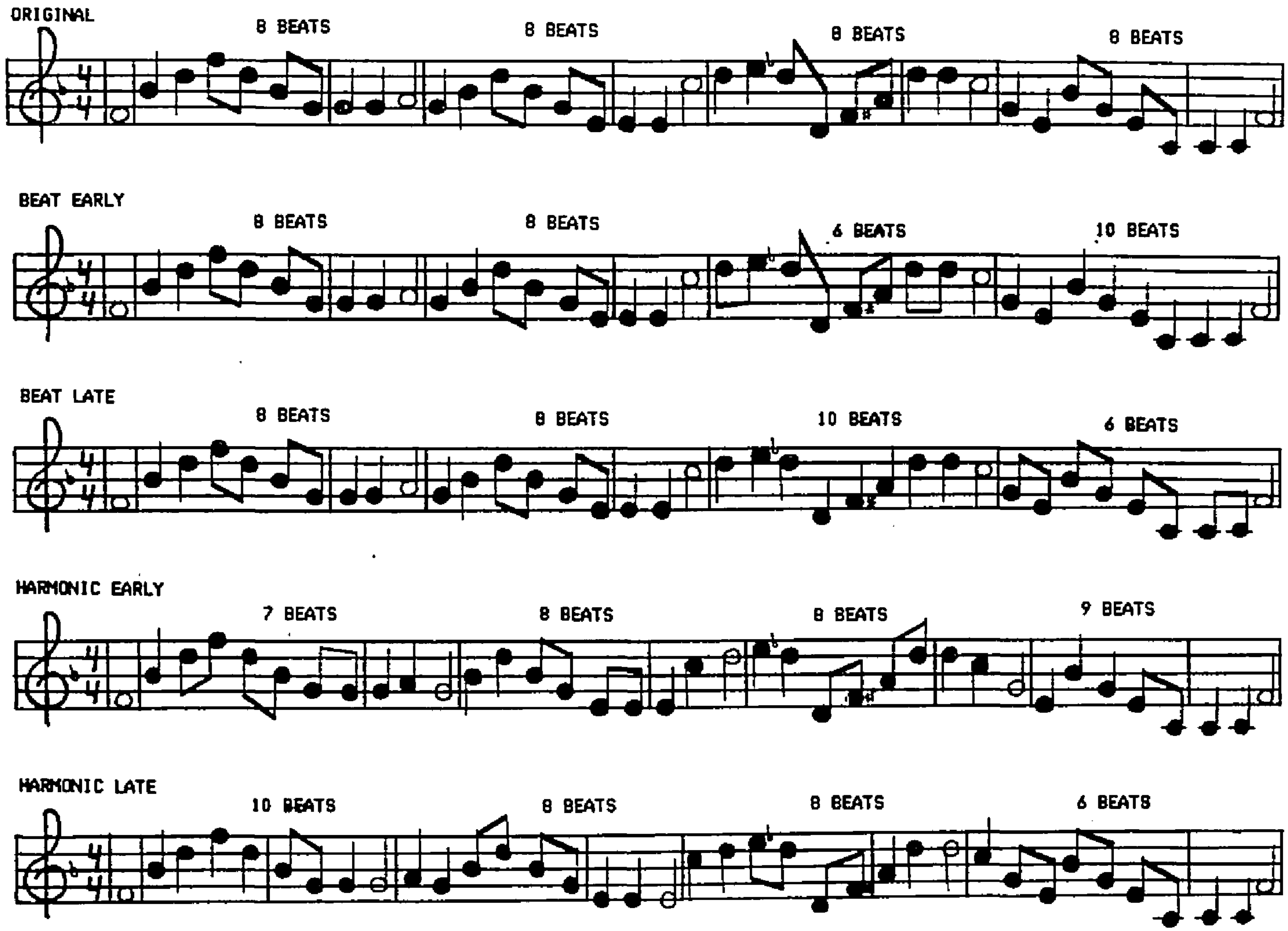


FIGURE 7 (continued)

such that the first and last note was always the tonic. The titles of these original compositions were "I Don't Want to Play in Your Yard"; "Music in the Air"; and "Softly Now the Light of Day".

These melodies represent a diverse range of music in that they differ in a) total number of notes (range = 34 to 37); b) meter (2/4, 3/4); and c) musical key (G or F major). However, all melodies contained an invariant number of beats between accents (ie. 8 beats); accents that were members of the melody's major chord (ie. dominant, major third, tonic); and the same total duration (10.3 seconds). In addition, all melodies began and ended on the tonic and the duration of the final tonic was always lengthened relative to preceding notes.

The rhythmic structure of each original melody was then varied in four different ways. Melodies in the first two conditions always accented (ie. temporally prolonged) the original major chord members but varied the meter or number of beats between accent periods. In the Beat Early condition, the meter of the first two accents periods was always identical to that of the original melody (ie. 8 beats). However the meter of the third and fourth periods was altered such that the number of beats, respectively, were 6 and 10. Conversely, the meter of the third and fourth accent periods was adjusted in the Beat Late condition to contain 10 and 6 beats respectively. Again, the first and second accent periods always contained the same number of beats (ie. 8) as the original melody.

The temporal accents within the two remaining conditions always recurred after an invariant beat period but did not correspond with major chord members. In the _Harmonic Early_ condition, the location of each temporal accent (except for the final tonic) was always displaced one note to the right of its original position. Thus, temporal accents now occur on the note _following_ the major chord members. In contrast, the temporal accents of melodies comprising the _Harmonic Late_ condition were displaced one note to the left of its original position. These temporal accents now occur on those notes _preceding_ the major chord members. In both conditions, the meter of each measure as adjusted to maintain an invariant number of 8 beats between all temporal accents.

In all four conditions, the pattern's total duration was always held constant and was identical to that of the original melody. In addition, the total number of beats for all melodies was never altered, nor was the duration of the first and final tonic.

By factorially combining the three songs with their five rhythmic conditions, fifteen experimental patterns were obtained. Trials were randomized into three blocks of fifteen, resulting in three presentations of each melody for a given subject.

Apparatus

Same as all other experiments.

Procedure

Before the actual presentation of experimental trials, all subjects were given a pre-test to determine whether they could discriminate among different harmonic relationships. This pre-test was devised from one developed by Butler & Brown (1984) and is described as follows:

Pre-Test

Seven different melodies, shown in Figure 8, were selected from a musical composition book. Each contained a different underlying key and a pattern of temporal accents which reinforced that melody's major chord members. All melodies differed in total duration and total number of notes but each ended on a prolonged tonic.

These seven melodies were then computer generated and recorded such that on each trial, the following sequence of events occurred: A high pitched warning tone (5000 hz) preceded each melody by two seconds. The melody was then played and two seconds later, followed by a single tone. This single tone was either a member of that melody's major chord or was a note that did not belong to the melody's underlying scale. The subject's task on each trial was to decide whether the single tone belonged to the melody's key (YES) or whether it did not (NO). Those subjects who were correct on at least 5 of the 7 trials were selected as subjects for the ensuing rating task. Although all subjects who performed this pretest were actually allowed to participate in the next experiment, the data of those who failed were discarded. (Comparable to Butler & Brown's (1984) results, approximately 50% of all subjects failed the pretest).

Rating Study

Of the eighteen subjects who passed the pretest, nine were randomly assigned to one of two counterbalance orders. Recorded instructions related task requirements and pattern presentation

FIGURE 8. PRETEST MELODIES OF EXPERIMENT 5. EACH QUARTER NOTE (♩) = 300 SOA; AN EIGHTH NOTE (♪) = 150 SOA; AND EACH HALF NOTE (𝅗𝅥) = 600 SOA.

details. On each trial, a one second warning tone (5000 hz) preceded a melody by two seconds. Two seconds later this same melody was presented a second time. During a 7 second response period, subjects were then asked to rate the melody on two perceptual dimensions. For a dimension of Accent Timing, subjects decided whether a melody's temporal accents seemed well-timed, occurring when expected, or whether they seemed ill-timed - occurring earlier or later than expected. Responses were indicated on a 10 point scale where values of 1 , 2 and 3 indicated that temporal accents seemed well-timed and values of 8, 9 or 10 indicated that accents seemed ill-timed.

Subjects also rated each melody on a dimension of Harmonic Appropriateness. Here they had to decide whether a melody's temporal accents seemed appropriate to the melody's key - that is, are they the notes that are expected to be accented and do they help one to identify the melody's key. A 10 pt. scale was again provided where subjects circled a 1, 2 or 3 if accents seemed harmonically appropriate and a 8, 9 or 10 if they seemed harmonically inappropriate. For both ratings, subjects were encouraged to use the entire range of the response scale.

Each subjects received 3 blocks of fifteen trials, a brief rest (2 minutes) being provided after each block. An entire experimental session was approximately 45 mins. in duration.

Results

Each perceptual dimension was analyzed separately and so the results of each will be presented in turn.

Accent Timing

Results indicated that the various rhythmic conditions of this experiment did differ on the dimension of accent timing. Table 22 depicts the mean accent timing rating as a function of the five rhythmic conditions. Lower values indicate that accents seemed well-timed and occurred when they were expected. Higher values indicate that accents seemed ill-timed and occurred either too late or too early. Means are collapsed over song and counterbalance order (F's < 1).

Since melodies within the Original, Harmonic Early, and Harmonic Late conditions all maintain an invariant beat period between accents, their accents should be perceived as relatively well-timed. Conversely, melodies within the Beat Early and Beat Late conditions violate this convention and so their accents should seem very ill-timed. As mentioned earlier, there is the possibility that the two conventions of interest are interdependent. If so, then the Harmonic Early and Late melodies are predicted to seem somewhat ill-timed.

These predictions are in fact supported by a significant main effect for rhythmic condition ($F4, 64 = 29.33$, $p < .0001$, $MSe = 1.13$). Bonferroni post hoc comparisons confirm that accents within the Beat Early and Beat Late conditions are rated as significantly more ill-timed than those of the remaining conditions (all Bonferronis significant at .01). Accents within the original melodies are considered to be the most well-timed and significantly more so than

TABLE 22

MEAN RATINGS OF "ACCENT TIMING" FOR THE RHYTHMIC CONDITIONS OF EXPERIMENT 5A. SMALLER VALUES INDICATE THAT TEMPORAL ACCENTS SEEM VERY WELL-TIMED.

ORIGINAL	BEAT EARLY	BEAT LATE	HARMONIC EARLY	HARMONIC LATE
3.10	6.22	6.11	4.85	4.56

melodies within the Harmonic Early ($F_{2, 64} = 5.0$, $p < .01$) and Harmonic Late conditions ($F_{2, 54} = 4.17$, $p < .01$).

These latter findings do indicate an interdependence between the two conventions. When temporal accents are anisochronous or fail to correspond with major chord members, these accents appear to unfold earlier or later than expected. In sum, the rhythmic manipulations of this experiment successfully differentiate among varying degrees of accent timing.

Harmonic Appropriateness

Results also show that the harmonic appropriateness of temporal accents differs as a function of rhythmic structure. Table 23 displays the mean harmonic appropriateness rating for each rhythmic condition. Lower values indicate that a melody's accents seemed harmonically appropriate to a melody's key. Higher values indicate that accents seemed harmonically inappropriate and were not the notes that were expected to be temporally prolonged. Again, means are collapsed over song and counterbalance order.

Melodies within the Harmonic Early and Late conditions should be rated as very harmonically inappropriate because their temporal accents do not co-occur with major chord members. Even though this co-occurrence does exist within Beat Early and Late melodies, these temporal accents should seem somewhat inappropriate - assuming an interdependency between the two conventions. Temporal accents should seem the most harmonically appropriate within Original melodies.

TABLE 23

MEAN RATINGS OF "HARMONIC APPROPRIATENESS" FOR THE RHYTHMIC CONDITIONS OF EXPERIMENT 5A. SMALLER VALUES INDICATE THAT ACCENTS SEEM VERY APPROPRIATE TO THE MELODY'S KEY.

ORIGINAL	BEAT EARLY	BEAT LATE	HARMONIC EARLY	HARMONIC LATE
3.09	4.09	4.02	6.02	6.38

These predictions are supported by a main effect for rhythmic condition ($F4, 64 = 34.37$, $p < .0001$, $MSe = 1.048$). As the means of Table 23 illustrate, melodies in the Harmonic Early and Harmonic Late conditions were, in fact, judged as the most harmonically inappropriate. Although there was no difference between these two conditions, they did significatly differ from the remaining three conditions (all Bonferronis significant at .01 level). The accents of the Original melodies were considered to be the most harmonically appropriate and significantly more appropriate than those within the Beat Early ($F2,64 = 2.94$, $p < .01$) and Beat Late conditions ($F2, 64 = 2.74$, $p < .05$). In sum, violations of rhythmic structure affect the harmonic appropriateness of temporal accents.

Discussion

The results of this experiment indicate that subjects are sensitive to those conventions concerning the usage of temporal accents. Notes that are intimately related to the tonic are expected to be temporally accented and, in addition, these accents are expected to recur after an invariant number of beats. When each convention is independently violated, accents appear harmonically inappropriate (Harmonic Early and Late conditions) and ill-timed (Beat Early and Late conditions).

Results also reveal that both conventions are inherently interrelated - the violation of one convention causes a partial violation in the other. For example, temporal accents that were ill-timed (Beat Early and Late) were also considered somewhat harmonically inappropriate. Although the accents of these melodies did occur on major chord members, as in the Original melodies, their varying beat period apparently affected their harmonic salience. Similarly, temporal accents were perceived as somewhat ill-timed when they failed to coincide with major chord members (Harmonic Early and Late). These accents actually unfolded with an invariant beat period but seemed to occur relatively earlier or later than expected. These findings suggest that the temporal accentuation of major chord members serves to generate expectancies about the melody's future course. When either convention is violated, perceivers cannot reliably anticipate the what and when of future accents.

In sum, this initial rating study has provided a set of experimental patterns that vary in their predictability of accent-timing. The next experiment investigates how judged duration may be systematically affected by these violated expectancies.

Experiment 5b

This final experiment poses the hypothesis that judged duration is influenced by manipulations of temporal accent structure. This hypothesis rests on the assumption that the temporal accentuation of major chord members prepares a listener for a melody's completion. That is, listeners can presumably anticipate when upcoming accents, including the final tonic, will occur by using the invariant beat period between accents. Second, they are able to anticipate the possible occurrence of the final tonic given the past accentuation of major chord members. Assuming that rhythm really does generate these expectancies, then violations of temporal accents should correspondingly violate the expected ending for a melody. The results of the previous rating study in fact imply this possibility. Subjects perceived temporal accents as being ill-timed, occurring earlier or later than expected, when accents were anisochronous and did not coincide with major chord members. Since future accents include the final prolonged tonic, subjects may also be anticipating the melody's completion before or after it actually occurs. According to the Expectancy Model, this should yield under and overestimations of judged duration.

To experimentally assess this possiblity, the melodies within the five rhythmic conditions of Experiment 5a were factorially paired in a comparative judgment task. Relative to an Original melody which confirms both conventions, the Expectancy Model predicts that melodies which violate these expectancies will display the results shown in Table 24. Melodies that are assumed to end too early (ie. Beat Late and Harmonic Late) are predicted to yield underestimations of duration while those ending too late (ie. Beat Early and Harmonic Early) should produce overestimations. This same pattern of results should be observed whenever Harmonic Early and Late melodies are paired with one another and whenever a Beat Early melody is paired with a Beat Late melody.

Table 24 also depicts the predicted judged duration of pairs <u>differing</u> in their violated convention. For example, Harmonic Early and Beat Early melodies are tentatively predicted to be judged as the

TABLE 24

EXPERIMENTAL DESIGN OF EXPERIMENT 5. THE PREDICTIONS OF THE EXPECTANCY (EM) AND CONTEXTUAL CHANGE (CC) MODELS ARE CONTRASTED FOR EACH CONDITION (WHERE 1 AND 2 REFER TO THE FIRST AND SECOND PATTERN OF A PAIR.

		SECOND PATTERN				
FIRST PATTERN		ORIGINAL	BEAT EARLY	BEAT LATE	HARMONIC EARLY	HARMONIC LATE
ORIGINAL	EM	2=1	2>1	2<1	2>1	2<1
	CC	2=1	2>1	2>1	2>1	2>1
BEAT EARLY	EM	2<1	2=1	2<1	2=1	2<1
	CC	2<1	2=1	2=1	2=1	2=1
BEAT LATE	EM	2>1	2>1	2=1	2>1	2=1
	CC	2<1	2=1	2=1	2=1	2=1
HARMONIC EARLY	EM	2<1	2=1	2<1	2=1	2<1
	CC	2<1	2=1	2=1	2=1	2=1
HARMONIC LATE	EM	2>1	2>1	2=1	2>1	2=1
	CC	2<1	2=1	2=1	2=1	2=1

same duration. It may be the case, however, that one will be over or underestimated relative to the other if one sort of violation creates stronger expectancies about the melody's end. Regardless, whenever a Harmonic Early and Beat Late pairing is presented, the latter should be judged shorter than the first.

By referring to Table 24, notice that predictions of the Expectancy Model contrast with those of information-processing models. These models fail to consider how rhythmic accent structure may generate expectanices about the melody's future course. Instead, they assume that temporal accents affect code complexity and the amount of information-processing activity. Both the Storage Size (Ornstein 1969) and attentional effort models (Underwood & Swain 1973; Thomas & Weaver 1975) assume that temporal accents segment a melody into a discrete series of chunks. Since these chunks must be cognitively concatenated, a greater number of chunks will increase code complexity and judged duration. Thus the melodies of the present experiment should all seem to have the same duration. These melodies contain the same number of cognitive chunks and should be equally complex. Block's (1978) model, on the other hand, generates a different set of predictions. According to this appoach, duration estimates are determined by the relative <u>number</u> of changes within events. Since violations of musical convention will presumably create cognitive change, the four conditions of rhythmic variation should all seem longer than an Original melody which confirms musical convention. Further, no difference in judged duration should be obtained when the four types of rhythmic violation are paired wih one another. Block's model does not include the concept of expectancy and so all four conditions should be equally complex.

To contrast these various set of predictions, the following experiment was conducted.

Method

Design and Subjects

The design was a 5 x 5 x 3 x 2 mixed factorial. Three songs were crossed with five levels of rhythm (Original; Harmonic Early; Harmonic Late; Beat Early; Beat Late) for an initial pattern pair member and with five levels of rhythm for a second pattern pair member. Counterbalance order (I, II) was the single between subjects factor.

Sixteen subjects were recruited from enrollments of Introductory Psychology. All were musically sophisticated and had at least 4 years of experience within the past 6 years. Eight were randomly assigned to each counterbalance order.

Stimulus Materials

For each song shown in Figure 7, the five levels of rhythm described in Experiment 6a (ie. Original; Harmonic Early; Harmonic Late; Beat Early; Beat Late) were factorially paired to obtain 25 types of pattern pairs. By combining these 25 rhythm pairs with the three songs and a repeated presentation factor, a total of 150 experimental trials were obtained. Patterns within a pair always contained the same song and total duration. Trials were randomized and divided into 2 blocks of 75.

Apparatus

Same as before.

Procedure

The experiment spanned over two days, subjects receiving 75 trials per day. The 7 pt. rating scale of Experiment Five was again used where values >4 indicate "longer" duration judgments. Conversely, values <4 indicate underestimations of judged duration. In all other respects, this study was identical to the previous comparative judgment tasks.

Results

Results showed that manipulations of rhythmic structure exerted lawful effects upon duration estimates. Table 25 presents the mean judged duration as a function of the rhythmic nature of pattern pairs. Values equal to 4 indicate the same duration; values <4 indicate that the second pattern was judged shorter than the first and; values >4 indicate that the second pattern was judged longer. Means of this table are collapsed over song and counterbalance order (F's <1).

The three hypotheses that are evaluated here all generate a different set of predictions. As summarized in Table 24, the Storage Size (Ornstein 1969) and attentional effort models (Underwood & Swain 1973; Thomas & Weaver 1975) predict no effects of rhythm. Block's (1978) model predicts that melodies violating a convention will always be judged longer than one which confirms both conventions. In contrast, the Expectancy Model predicts that some violations, namely the Beat and Harmonic Early, will produce overestimations of duration

TABLE 25

MEAN JUDGED DURATION FOR PATTERN PAIRS IN EXPERIMENT 5 AS A FUNCTION OF RHYTHMIC STRUCTURE. A VALUE OF 4 INDICATES EQUIVALENT DURATION; VALUES <4 INDICATE THE SECOND PATTERN WAS JUDGED SHORTER; VALUES >4 INDICATE THE SECOND PATTERN WAS JUDGED LONGER.

FIRST PATTERN	SECOND PATTERN: ORIGINAL	BEAT EARLY	BEAT LATE	HARMONIC EARLY	HARMONIC LATE
ORIGINAL	4.04	4.78	3.22	4.60	3.51
BEAT EARLY	3.48	4.07	3.52	4.05	3.83
BEAT LATE	4.51	4.66	4.03	4.22	4.12
HARMONIC EARLY	3.50	4.51	3.59	3.99	3.61
HARMONIC LATE	4.64	4.67	3.66	4.55	4.02

while others, the Beat and Harmonic Late, will produce underestimations.

An overall analysis of variance revealed that the Storage Size and attentional effort models were not supported by the observed set of results. Contrary to their predictions, judged duration did differ between pattern pairs as a function of rhythm (F 16, 224 = 13.67, $p < .0001$, MSe = .088). These two models were therefore eliminated from further evaluation. To distinguish among the Expectancy and Contextual Change Models, a series of Bonferroni post hoc comparisons was conducted to isolate the nature of the interaction. For each set of counterbalanced pattern pairs (eg. BE-O vs. O-BE), duration estimates were first substracted from the value of 4.00 (a "same" duration judgment). These differences were then averaged to obtain a score that reflects the mean deviation from a "same" judgment. These values are depicted in Table 26 where it's also indicated which melody of a pair was over or underestimated in duration.

The first set of comparisons assessed the judged duration of an Original melody relative to melodies containing rhythmic violations. Differences were observed and supported predictions of the Expectancy Model. Melodies that are assumed to end later than expected are in fact overestimated. The Beat Early (F2, 224 = 6.19, $p < .01$) and Harmonic Early melodies (F2, 224 = 5.24, $p < .01$) were both judged longer than original melodies. Similarly, melodies that end earlier than expected produced underestimations of duration. Here the Beat late (F2, 224 = 6.14, $p < .01$) and Harmonic Late (F2, 224 = 5.38, $p < .01$)

TABLE 26

THE MEAN DIFFERENCE FROM A JUDGMENT OF EQUIVALENT DURATION FOR PATTERN PAIRS IN EXPERIMENT 5.

PATTERN PAIR	MEAN DIFFERENCE		SECOND PATTERN WAS:
ORIGINAL-BEAT EARLY	.65	$p < .01$	OVERESTIMATED
ORIGINAL-BEAT LATE	.65	$p < .01$	UNDERESTIMATED
ORIGINAL-HARMONIC EARLY	.55	$p < .01$	OVERESTIMATED
ORIGINAL-HARMONIC LATE	.57	$p < .01$	UNDERESTIMATED
BEAT EARLY-BEAT LATE	.50	$p < .01$	UNDERESTIMATED
HARMONIC EARLY-HARMONIC LATE	.47	$P < .01$	UNDERESTIMATED
HARMONIC LATE- BEAT EARLY	.42	$P < .01$	OVERESTIMATED
HARMONIC EARLY-BEAT LATE	.32	$P < .01$	UNDERESTIMATED
HARMONIC EARLY-BEAT EARLY	.25	$P < .05$	OVERESTIMATED
HARMONIC LATE-BEAT LATE	.23	$P < .05$	UNDERESTIMATED

melodies were both judged shorter than original melodies. Thus in contrast to predictions of the Cognitive Change Model, judged duration is determined by a melody's expected end and not simply by any change from established conventions.

The two models also generate different predictions when pattern pair members <u>both</u> violate a rhythmic convention. According to the Cognitive Change Model, melodies within the Harmonic-Beat, Early-Late conditions are all equally complex and their pairings should thus produce the judgment of "same" duration. The Expectancy Model, on the other hand, predicts that some pairings will produce underestimations of duration while others will produce overestimations.

For example, the Expectancy Model predicts significant judged duration differences to emerge whenever melodies ending earlier than expected are paired with melodies ending later than expected. These differences were in fact revealed by another set of Bonferroni post hoc comparisons. Melodies within the Beat Early condition were judged longer than those within the Beat Late condition ($F2, 224 = 4.71$, $p<.01$). Similarly, Harmonic Early melodies were judged longer than Harmonic Late melodies ($F2, 224 = 4.48$, $p<.01$). If we now compare the duration of melodies that differ in their violated convention, this same pattern of results is obtained. For example, Harmonic Early melodies were judged longer than Beat Late melodies ($F2,224 = 3.00$, $p<.01$) and Beat Early melodies were judged longer than Harmonic Late melodies ($F2, 224 = 4.00$, $p<.01$). Again, these findings are counter to predictions of Block's model and support the Expectancy Model of judged duration.

Lastly, it is of interest to determine whether one kind of violated convention produces a greater magnitude of effects than the other. For example, we might ask "Does the violation of beat invariance produce greater over-underestimations of duration than a violation in harmonic accenting? Or is it the case that a violation of either convention produces the same magnitude of effects?" To answer this question, we must assess the relative judged duration of Harmonic Early-Beat Early pairs and the duration of Harmonic Late-Beat Late pairs. If both violations produce the same magnitude of effects, then judgments of "same" duration will be obtained. However, if one exerts a greater effect on judged duration than the other, then differences among these pairings will be obtained. Bonferroni post hoc comparisons revealed that a violaton of beat invariance produces a greater effect on judged duration than violation of harmonic accents. The pairing of Harmonic-Beat Early melodies were significantly different ($F_{2, 224} = 2.38$, $p < .05$) as were the pairings of Harmonic-Beat Late melodies ($F_{2, 224} = 2.19$, $p < .05$). In both cases, the Beat Early and Beat Late conditions produced a greater overestimation and underestimation of duration, respectively, than did the Harmonic Early or Harmonic Late conditions.

In sum, violations of melodic and temporal accent structure yield systematic errors of judged duration.

General Discussion

The results of this final experiment reeinforce the novel perspective that has been developed here to explain judged duration. This perspective assumes that a perceiver uses the dynamic structure of an unfolding event to generate expectancies about the event's future course, including its upcoming completion. Duration judgments are then determined by whether the event's actual end confirms or violates the perceiver's expectancies.

The present experiment reveals what particular invariants may be used to anticipate the ending of a musical composition. These invariants can be specified within a melody's rhythm and involve an isochronous arrangement of temporal accents that highlight the relationship between major chord members and the melody's tonic. As the results of Experiment 5a illustrate, people within the Western culture are apparently attuned to the conventional usage of these invariants and expect their presence within a melody. Temporal accents that conform to established convention are perceived as well-timed and harmonically appropriate to a melody's key. Conversely, temporal accents appear ill-timed and harmonically inappropriate when either convention is violated. More importantly, the results of the second experiment suggest that the violation of temporal accent structure also creates over and underestimations of judged duration. If the beat period between later temporal accents disconfirms that of preceding accents, then the end presumably occurs before or after it is expected. This correspondingly leads to under and overestimations of judged duration. These same sorts of errors are observed when the temporal accentuation of major chord members is altered. Temporal accents that immediately precede or follow these harmonic relationships seem to generate an expected ending that is too early or too late. Of these two conventions, an invariant beat period between temporal accents seems most important for specifying when the melody will end. When this convention is violated, its effects upon judged duration are of a greater magnitude than when the harmonic relationship of accents is violated.

The effects that have been observed here do have implications for events outside the realm of music. In particular, there is some evidence to suggest that the temporal accent structure of speech is quite similar to that of music. Martin (1972), for example, has proposed a theory of language behavior where beat invariance and harmonic accenting are an integral aspect of his hierarchical desciption of speech. Relying upon research done in speech perception and linguistics, he demonstrates that temporal accents usually fall on content words (ie. nouns and verbs) and that these accents predictably recur throughout an utterance. When these accents are violated, comprehension and recall is not only impaired (Martin 1975), but so is sentence recognition (Wingfield & Klein 1970) and discrimination (Dooling 1974).

According to the rationale developed here, it is suggested that the temporal accent structure of speech may also allow a listener to anticipate the upcoming exchange of speaking roles. If the accentuation of content words is violated, then a listener may unintentionally interrupt the speaker because their utterance has concluded later than expected. Alternatively, the listener may initiate her speaking role relatively late because the previous utterance has ended earlier than expected. These sorts of errors might occur when speaking with a foreigner who has not quite mastered the English language or with individuals afflicted with certain speech disorders. They may also occur when speaking with someone whose speech rhythm (or rate of accent isochrony) is different from the one you've adapted to. For example, a person raised in New York City is accustomed to a somewhat faster rate of speech than someone raised in the South. When the two interact, the New Yorker may often interupt and vocally anticipate the Southerner's speech because it's slower than what's expected or what they're accustomed to. Similarly, the Southerner may display long pauses before speaking because the New Yorker's speech is faster and ends earlier than expected. In addition to these errors in turn-taking behavior, the relative duration of this conversation may be inaccurately judged by both individuals. Of course, these sorts of problems should eventually disappear once both have adapted to these new rates of speech.

The Expectancy Model not only applies to language but also has implications for situations requiring "time-to-collision" judgments. Earlier we mentioned some research that has attempted to identify those invariants specifying the imminent collision of a baseball (Todd 1981) or car (Schiff & Detwiler 1979). These studies conclude that perceivers base their judgments on the rate of optical expansion within the visual field. This conclusion, however, does not explain how an individual is able to anticipate the collision of an object before it actually occurs. Similarly, the invariant of optical expansion, as presently described by these researchers, does not explain how errors in collision estimates may arise. These omissions largely stem from the fact that Direct Theory ignores the nature of organismic structure and a description of temporal invariants within an event's structure. The present approach, however, provides some insight on these issues.

That is, a moving object (such as a car or baseball) is typically perceived relative to other referent objects or events within the surrounding environment (ie. other cars, trees, etc). These background referents may be considered as accents because they capture our attention and act as changes in the environmental backdrop. As the object moves past these environmental referents, a sort of rhythm is created that may generate expectancies about the object's future time course. If these expectancies are confirmed, then time-to-collision judgments should be quite accurate. However, errors may arise whenever there are changes in the object's rate of speed or in the relative placement of the environmental referents. For example, let's consider an individual who's driving on a busy freeway where cars are in close proximity and moving at a high rate of speed. As the person is moving relative to these other cars, the established rhythm allows her to estimate braking responses quite accurately.

However, let's now suppose the person exits off into a quiet residential area where there's fewer cars and the speed limit is much slower. Here, the individual may be braking relatively early because she's still behaving relative to the rhythm (fast pace and close proximity) of the freeway. Conversely, braking responses may be relatively late if she moves from a residential area onto a freeway. Again, the rhythm arising from the relationship between her car and other cars has been altered, and so expectancies about time-to-collision have been violated. Thus by conidering the impact of spatio-temporal relatonships upon a rhythmic organism, the concept of future time can be parsimoniously incorporated into a theory of visual perception.

In sum, the results of this second experiment do support the general framework of the Expectancy Model that has been developed within this dissertation. The melodic-rhythmic structure of an event has been presumed to facilitate the process of synchronization and to allow one to anticipate the occurrence of future events. The findings obtained here extend this model by uncovering at least two ways that this rhythmic structure can also prepare a perceiver for <u>when</u> an event will end. Any systematic violations of these invariants will create differences in judged duration. In this respect then, this last experiment creates some closure with the earlier experiments that were conducted. In the first two experiments, for example, the role of rhythmic structure was also studied. There we varied whether melodic and temporal accents co-occurred, but the relationship <u>between</u> these accents was never a predictable one. Given that manipulations of melodic structure had no effect, listeners presumably could not reliably anticipate the "what" of upcoming accents. Instead, they apparently used the isochronous arrangement of temporal accents to track the number of beats for each pattern. Duration judgments were then determined as a function of these number of beats. However, we have now discovered that if the violation of a rhythm maintains a lawful and predictable relationship between accents, then judged duration seems to be determined relative to an event's expected end. By extrapolating the beat period of harmonic accents into the future, a listener presumably anticipates the temporal location of the final resolved tonic. Errors in juded duration occur when the final beat period concludes before or after it is expected.

This approach to judged duration is a very different one than that offered by the three information-processing models evaluated here. These models generally assume that judged duration depends on code complexity or the amount of information-processing that is consumed by a given event. Their definitions of complexity, however, fail to capture the inherent relationships within an event's structure and how these relationships may serve to guide or misguide attending. The lack of experimental support for these information-processing models serves to illustrate that complexity may exist within the temporal and harmonic interrelationships of a melody. Perceivers apparently use these interrelationships to guide perceptual pickup and to generate future expectancies. Whenever an event's structure violates a perceiver's expectancies, attending becomes misguided and creates errors in duration judgment. By envisioning a reciprocal relationship between an organism and its environment, this approach thus allows more precise experimental predictions and a more parsimonious theory of judged duration.

In the next and final chapter, we will more thoroughly contrast the differences between these two approaches and integrate the set of experimental findings that have been obtained on the "filled interval effect". In addition, we will consider how the Expectancy Model may be generalized to other less traditional areas of time research.

Chapter Summary

The purpose of this final experiment was to explore the way in which a melody's rhythm may prepare a listener for that melody's completion. Established by musical convention, there are at least two types of rhythmic invariants that seem to perform this function. First, temporal accents usually co-occur with notes of the major chord, preparing a listener in advance for the final prolonged tonic. Second, accents recur isochronously after an invariant number of beats, allowing a listener to anticipate exactly when this final tonic will occur. The results of an initial rating study show that listeners are in fact attuned to these two invariants for when they are violated, a melody's accents are perceived as being ill-timed and harmonically inappropriate. Further, if these conventions are violated such that a melody ends before or after it is expected, then respective under and overestimations of duration are revealed. These findings were shown to have direct application for language behavior and situations involving "time to collision" judgments.

CHAPTER TEN

GENERAL DISCUSSION AND SUMMARY

At the beginning of this dissertation, we posed a number of questions pertaining to everyday situations of experienced duration. In one we asked "Why does one event, such as a song or movie, appear to transpire more quickly than another when both are the same physical duration?" This phenomenom, known as the filled interval effect, has been the focal question of interest here and explored from various theoretical perspectives. What have we learned about this illusion and what sort of underlying processes within a perceiver can best explain its occurrence?

In this chapter, we will consider this question from the perspectives of the Expectancy and certain information-processing models of judged duration. The utility of these two views will be contrasted and I will show that the Expectancy Model contains several advantages over the traditional models of judged duration. These advantages are both philosophical and experimental. Despite these advantages, however, it will also be shown that the current development of the Expectancy Model contains at least two major deficiencies. After discussing how these deficiencies may be resolved with future experimentation, we will then consider some applications of the Expectancy Model to other areas of time experience.

Constrasting Perspectives on Judged Duration - A Summary

The contemporary literature, guided by some assumptions reflected in the information-processing approach, claims that the filled interval effect arises from the differential complexity of events. That is, an interval containing more items and a more haphazard arrangement of these items will seem longer than a more sparse and orderly interval of events. This is because increased complexity is assumed to demand greater information-processing activities within a perceiver which in turn serve to lengthen experienced duration. We saw that individual models within this tradition disagree on the precise referent for duration estimates. Some such as Ornstein (1969) claim that we base our judgment on the amount of information in short-term memory (for perceived duration) or long-term memory (for remembered duration). Others argue that memory storage is irrelevant and that judged duration depends on the amount of attentional effort (Thomas & Weaver 1975; Underwood & Swain 1973). Still a third model (Block 1974) experimentally discounts both of these views and proposes a "contextual change hypothesis". According to this approach, an internal mechanism monitors the amount of "change" within an event and derives a longer duration judgment whenever greater change is encountered.

Although the underlying mechanisms of these models are considered appropriate by the Information-Processing paradigm, it is also true that they have unsuccessfully explained the filled interval effect.

Experimental results are often contradictory (ie. Schiffman & Bobko 1974 vs. Poynter 1983; Devane 1974 vs. Avant & Lyman 1975) and no one model has received uniform and reliable support. Further, it is often difficult to generate new experimental predictions from these models. In Block's Contextual Change Hypothesis, for example, the realm of change that the internal monitor responds to is never specified nor are we told just how much change has to occur for judged duration to be affected. In short, the contemporary theories have failed to provide any conclusive statements in regard to the filled interval effect.

In the present proposal, it was suggested that these problems stem from some underlying assumptions that are often associated with the Information-Processing paradigm. The basic assumptions of mediated perception and "discrete sampling" result in quandries of both a philosophical nature and ones of practical experimental conduct. For example, as Direct Perception Theory points out, the concept of mediation necessarily implies a philosophical notion of perceiver-world dualism. Although the world is assumed to contain events of a continuous nature, the processing and perception of these events is not. Instead, processing activities are of a discrete nature where successive moments of events must be sampled, elaborated, stored in memory, and then concatenated to achieve a perception of event continuity. In addition, this approach claims that the dimension of time plays a dual role. The actual physical duration of an event not only acts as an encoded stimulus but also functions as an interval during which processing time occurs. The referent of judged duration has now become a mental code corresponding to some processing duration which is only indirectly related to the original environmental event itself. In other words, an organism's behavior is not determined by an environmental event as such but by an internal representation of this event - which is not necessarily the same thing.

The assumption of mediation has also created problems for experimental conduct. Since an organism is assumed to sample discrete chunks of input from the environment, it is therefore considered appropriate to use components of events as experimental stimuli. Thus we find experiments where subjects are required to compare the duration of abstract line drawings, isolated words and nonsense words, or auditory clicks. The problem arises, of course, in trying to generalize the results of these experiments to real world situations. Since contemporary models of judged duration are founded upon such experiments, are their underlying mechanisms only in reference to experimental artifacts? To a large extent, this may be true. I believe this is particularly apparent when we examine the operational definition of complexity. Increased complexity is usually associated with increasingly more artificial stimuli (ie. nonsense words, random arrangements) and so the interval which is predicted to be the longest is also the one that's the most unlike real world events.

Apart from this, however, the mediational assumption has complicated the issue of complexity in still another way. Code complexity, the presumed referent of judged duration, has been defined in terms of code size in memory, the amount of processing effort or cognitive change. The problem here is that complexity is defined relative to a mental code which cannot be seen. Further, properties of the mental code are not necessarily the same as those of the original event. Thus we don't really know what structural properties of the original event have resulted in greater information processing and thus greater complexity. The operational definition of complexity has become circular and elusive - which may very well explain the conflicting nature of the current literature.

For these various reasons, it was felt that an alternative approach to the problem of judged duration was needed. Based on the tenets of Direct Theory (Gibson 1966; 1979) and Rhythmic Attending Theory (Jones 1976), it's suggested that this approach is more "ecological." Since the emphasis is on using natural events as experimental stimuli, laboratory investigations should have greater generalizability to real world situations. In addition, this alternative perspective, termed the Expectancy Model, is proposed to rectify some of those problems just mentioned - namely, those pertaining to perceiver-world dualism and definitions of complexity.

The most fundamental assumption within the Expectancy Model is that the world is inherently organized. For example, relying upon a description that Jones (1981b) has developed for the auditory environment, musical events can be shown to contain a hierarchical layout of pitch information that can be summarized in terms of a set of transformational rules. These rules leave certain pitch interval relationships invariant throughout a melody's unfolding course. Jones' most useful description, however, comes with the hierarchical layout of an event's temporal information. As for pitch, smaller periods of time can be shown to be nested within larger periods where all periodicities within an interval are thus interrelated. Rhythm, induced by pausing or tone-lengthening, creates certain time transformations where a melody's meter (beat structure) is left invariant. Simultaneously, rhythm imparts a regularly recurring pattern of temporal accents that normally co-occur with melodic ones.

In contrast then to the information-processing paradigm, the world is assumed to contain inherent structure that is necessarily interrelated. Hence, the need for mediational mechanisms is now reduced because an organism can directly attend to and perceive this structure through a biological process of synchrony. That is, organisms are assumed to have evolved relative to this rhythmic environment and to possess internal rhythms that permit organism-world synchrony. The melodic-temporal accents within an auditory event act as footholds for attending and allow one to anticipate the "what, where, and when" of future events.

These basic tenets of Rhythmic Attending Theory have allowed a very direct extension to the study of judged duration. Whenever an organism attends to and perceives an event, she is necessarily perceiving that event's temporal structure. The novel development here, however, is that a listener's set of expectancies are assumed to directly determine judged duration. Since certain structural invariants create anticipations about <u>when</u> an event will end, judged duration will depend on whether these expectancies are confirmed or violated. According to predictions of the Expectancy Model, an event that ends earlier than expected will be underestimated in duration while an event that ends later than expected will be overestimated. Confirmation of expectanices, on the other hand, will create accurate judgments of duration relative to some referent event.

Relative to those models generated from the information-processing paradigm, this Expectancy Model of judged duration can be shown to offer greater utility. For example, the philosophical notion of perceiver-world dualism has now been replaced with one of perceiver-world reciprocity. The structure of the environment and its perceiving organisms are both rhythmic in nature and through evolution, they have come to interlock on the basis of synchronization. The pickup of information, reflected in expectancy schemes, is established <u>by the structure of natural events</u> and does not entail dualistic activities of discrete sampling and concatenation. Thus by eliminating processes of cognitive construction, the Expectancy Model offers greater parsimony as well as a philosophical relationship of reciprocity between the perceiver and its world.

Second, the Expectancy Model provides a more ecological approach to judged duration. Since organisms are presumably attuned to those structural invariants to which they have evolved, one must therefore use or simulate real world events as experimental stimuli. Otherwise, one risks studying experimental artifacts and not the activity of perceiving as it occurs within the natural environment. Here, for example, we investigated judged duration with music although the usage of speech or filmed visual events would have satisfied the same purpose.

Lastly, the variable of complexity has been more precisely defined within the environmental event. By determining what sorts of structural invariants are expected to occur within an event, this structure can then be violated such that one's expectancies are correspondingly violated. Further, the concept of synchrony has allowed us to predict the precise effect of these violated expectancies upon judged duration. In contrast to information-processing models, complexity's effect upon judged duration is defined relative to an event's structure and not to some ethereal mental code.

This alternative perspective, however, cannot be argued to offer greater utility unless it has some sort of experimental support. Further, the results of experimentation must clearly contradict predictions generated from the information-processing models. In a series of experiments that were conducted here, these goals were in fact achieved. A total of five experiments were conducted using the comparative judgment task and in each, a structural invariant that is expected to occur within Western music was violated.

For example, Experiments One and Two examined a common convention concerning the co-occurrence of melodic and temporal accents. Here, subjects were asked to compare the duration of melodies which conformed to this convention with those that violated this expectancy by containing "clashing" accents. The information-processing approach predicted that the latter would be judged longer because accent violation creates more "chunks" of information and thus greater complexity. In contrast, the Rhythmic Attending perspective predicted that "clashing patterns" would be judged shorter. According to one hypothesis, the Average Accent Period Hypothesis, subjects average the durations of the various accent periods within a melody and use this value as an expected referent for relative duration estimates. A melody containing conflicting accents displays both more and shorter time periods between accents and thus should seem shorter than a melody containing co-occurring accents. A second view, the Missing Beat Hypothesis, proposed that subjects use the total number of rhythmic beats within an initial melody as an expected referent for later melodies. Regardless of the compatibility between melodic and temporal accents, melodies containing a fewer number of beats should seem relatively shorter. This Missing Beat Hypothesis was in fact supported by the results of Experiments One and Two. These findings served to illustrate that perceivers do indeed use the rhythmic structure of an event for relative duration estimates.

The next set of experiments (3 and 4) investigated how violations of pattern resolution affect judged duration. Specifically, a listener can anticipate the completion of a melody because most Western music typically ends on a prolonged tonic. Here, it was shown that systematic violations of these two invariants can create under and overestimations of duration. In Experiment Five, for example, melodies ending on the tonic (resolved) were compared with melodies ending on a note that was identical to that initiating the final measure (unresolved). When both contained a definitive ending through an end-lengthened note, the unresolved melody was judged shorter than the resolved one - presumably because the unresolved melody seemed to end before the expected tonic. A similar result was found when melodies contained a definitive (though abrupt) ending via a shortened final note. However, an unresolved melody was judged longer than a resolved one when the final note's duration was isochronous to that of preceding notes. The lack of a structurally marked ending apparently encouraged a mental continuation of the unresolved melody to its expected tonic ending - thereby lengthening experienced duration. These sets of findings were all consistent with predictions of the Expectancy Model.

The last experiment (Experiment 5) demonstrated how invariant properties of a melody's rhythm can prepare a listener for a final prolonged tonic. This study is the first to show that rhythmic context can influence duration judgments. By systematically violating the relationship between melodic and temporal accents and the beat period between accents, a listener was led to expect a melody's ending before or after it occurred. This correspondingly gave rise to under and overestimations of judged duration.

These five experiments collectively support predictions of the Expectancy Model. Listeners expect the presence of certain structural invariants and use this invariant information to anticipate an event's end. When these expectancies are violated, judged duration is affected accordingly. These results serve to question the utility of information-processing models. In each case, these models predicted that violations of established conventions would increase complexity and processing demands, and hence judged duration. However, it was found that violations of certain invariants created both over <u>and underestimations</u> of judged duration. These finding reinforce those criticisms that were previously addressed to the information-processing approach. In particular, we can observe the problems encountered when complexity is defined relative to a mental code in lieu of structural invariants within an environmental event.

Given these sets of experimental findings, can they in any way clarify the conflicting nature of the current literature? Possibly, yes. Since most researchers have ignored the impact of rhythm upon behavior, this variable may have been confounded with the spatial arrangement of stimulus items. For example, Schiffman & BobKo (1974) have found that an orderly spatial arrangement of lines are judged shorter than a more haphazard arrangement. Poynter (1983), on the other hand, has found the opposite effect. It may therefore be the case that the temporal and rhythmic arrangement of these lines created differential expectancies about when that event would end. Perhaps

Poynter's rhythm led perceivers to anticipate the ending after it really occurred while Schiffman & Bobko's rhythm induced an earlier-than-expected ending. Similarly, other anomalies can potentially be resolved if one reconsiders the structural arrangement of experimental stimuli and how this structure may create expectancies of event completion.

To summarize, we have considered various ways in which the Expectancy Model of judged duration may prove superior to existing information-processing models. By envisioning a structured environment that is perceived through synchronization, we have achieved a theory that displays both greater parsimony and a philosophical notion of reciprocity. This relationship of perceiver-world reciprocity also specifies the usage of ecologically valid stimuli because the perception of one's world only occurs relative to a specific evolutionary history and those adaptive skills which have emerged. Finally, the experimental support that has been obtained for this model reflects the utility of defining complexity within an event's structure.

Although the Expectancy Model does seem to provide these cited advantages, the theory in its current form also contains several shortcomings. In the next section, we will examine some problems concerning converging operations and past or remembered time.

Deficiencies of the Expectancy Model

A Need for Converging Operations

According to scientific convention, any new theory of behavior must survive a test of converging operations. That is, experimental hypotheses must be evaluated over a range of tasks and stimuli in order to rule out any alternative explanations. At this point, this has not yet been achieved within this dissertation.

In the five experiments that were conducted here, the comparative duration task was always used in conjunction with the prospective paradigm (informing subjects that time judgments will be later required). The main reason for this strategy was to establish continuity over the various experiments, particularly since these sorts of experimental manipulations have not been previously conducted. By using the same task across studies, results could be attributed to manipulations of event structure and not to task differences. Although this seems a reasonable strategy to maintain when one is developing a novel theory, it is also true that results may be contaminated by response or task bias. That is, subjects were asked to judge the duration of two events that always contained the same physical duration. With such instructions, the experimenter is implying that real time differences exist when in fact they don't. Thus in the course of the experiment, the subject may consciously adopt an artificial response mode to please the experimenter, particularly if one does not hear any real time differences. For example, one may decide to respond "longer" given pattern X, "shorter" given pattern Y, and "same" given pattern Z. If so, then we have not studied effects of expectancies upon judged duration at all, but instead, effects of experimental demand.

Although this possibility exists, there are at least two indications that this did not occur within the present set of experiments. First, if subjects were adopting this sort of response strategy, then we should not expect that all subjects will necessarily adopt the _same_ strategy. For example, some subjects should label pattern X as "longer" while others should label it as "shorter" or the "same". One should thus obtain an anomalous set of results without any significant main effects or interactions. However, these sorts of anomalies were never observed. Results were robust and displayed little variability. In addition, we found lawful interactions of structural invariants with judged duration. Some melodies were overestimated in duration while others were underestimated. Most importantly, these findings were not only consistent within an experiment but replicated across experiments as well (eg. Experiements 3 and 4). It is not clear how response bias could explain these lawful and consistent interactions.

Although one can argue that response bias may not have occurred here, it is nevertheless essential that results be replicated with different tasks. For example, the present set of experimental manipulations could be implemented in a reproduction task. A subject would be presented with some pattern and then asked to reproduce its duration by depressing a button for a given duration. Secondly, one could devise a motor extrapolation task like those used in the "time-to-collision" literature (Todd 1981; Schiff & Detwiler 1979). For example, recall the melodies of Experiment Five where the beat period between accents was varied as well as the temporal accenting of major chord members. Conceivably, one could present only the first three beat periods of these melodies and then require subjects to estimate the completion of the last period given the melody's preceding context. It s similar to the extrapolation of velocity information, but here we would also be examining the effect of rhythm upon "time to completion". Lastly, a third sort of task that could be used for converging operations is the retrospective paradigm. Here a subject would be given a pair of melodies for some sort of incidental task such as perceptual ratings. After the melody has been played, only then would the subjects be asked for a comparative duration judgment. In all three tasks that were mentioned, results should converge with those obtained with the prospective comparative judgment task. If not, then criticisms of response bias may in fact be valid for the present set of experiments.

In addition to seeking converging operations through differential tasks, it is also desirable to replicate the present set of findings with different sorts of experimental stimuli. To venture outside the realm of music, one could also study the effects of violated expectancies in speech and visual scenes. As mentioned earlier, the conventions of beat invariance, temporal accenting of content words, and pattern resolution all occur within language behavior. Similarly, there is some research suggesting that expectancies exist within various social situations (eg. Goffman 1959; Schank & Abelson 1977). When entering a restaurant, for example, there is a particular sequence of events that is expected to occur in a given order (Schank & Abelson 1977). One could thus violate these expectancies and examine their effect upon judged duration. Actually, the makers of "Candid Camera" have already prepared this sort of experimental stimuli - it simply needs to be used in a laboratory situation. Regardless, experiments using other kinds of stimuli could offer greater generalizability of the present set of results.

In summary, it's acknowledged that the current development of the Expectancy Model may be founded upon experiments reflecting response or task bias. Although there are indications that these sorts of effects were absent here, it is nevertheless essential to seek converging operations. Apart from the issue of response bias, however, there is another potential deficiency within the Expectancy Model. It concerns the issue of remembered time.

Remembered Duration

In a previous section, we cited several reasons why the Expectancy Model seemed superior to existing models of judged duration. One advantage involved the concept of future time - situations where a perceiver can anticipate when an event will end. We saw how the Expectancy Model could explain these activities through the notions of synchrony and expectancy. On the other hand, it is true that the Expectancy Model encounters some difficulty with the concept of "past time". That is, "What processes are involved in the remembering of some time interval and when will perceived duration differ from remembered duration?"

These questions are easily answered within the Information-Processing Approach. The experience of nowness, namely perceived time, is associated with the contents of short-term memory while remembered time is associated with long-term memory. Further, perceived and remembered duration may not always correspond because elaboration processes can occur within long-term memory. For example, some have noted that a "fun" activity seems short in passing but long in memory. Conversely, a boring activity seems long in passing but short in retrospect. Presumably the reason for these discrepancies in past time is that fun experiences have a more enriched memorial representation than boring experiences and hence contain more information on which to construct a time judgment. In short, the information-processing approach encounters no difficulties with the concept of past time.

According to the Expectancy Model, however, it is not clear how the remembering of an event's duration occurs. Before I make an attempt to explain this, let me first point out some methodological problems that exist within the current literature on remembered time. It seems to me that one should be aware of these problems before speculating about the nature of "past time".

While reviewing the various methodological procedures in current use, we noted that "perceived time" is studied with the prospective paradigm while "remembered time" is typically studied with the retrospective paradigm. In the former, subjects are informed <u>before</u> the experiment that time judgments will be required, while in the latter time judgments are obtained <u>after</u> subjects have performed some sort of incidental task. In the retrospective case then only one time judgment per subject can be obtained, which obviously creates problems concerning statistical realiability of results. Apart from this however, there is a potential problem in equating these two paradigms with present and past time. That is, the retrospective paradigm is confounded with questionable effects of incidental instructions. Although the nature and demands of the incidental task are considered to be independent of the duration judgments, this claim is an experimental question that has never been addressed. It may in fact be the case that an incidental task requiring active subject involvement (eg. tracking) versus more passive involvement (eg. pleasantness ratings) will produce a very different sort of time judgment. Further, how do we know that the memory for a past event is the same for subjects who either know or don't know that such a memory judgment will be later required? This again is an experimental issue that needs to be investigated. In short, I think there are a variety of experiments that need to be done before one can assume that past time can be studied with the retrospective paradigm.

Assuming that these problems can be resolved, how might the concepts of synchrony and expectancy schemes apply to remembered duration? In her theory of Rhythmic Attending, Jones (1981b) has suggested that remembering is an activity that involves "attending backward in time". Although she has never really developed this idea, the main thrust is that the structural invariants of events are internalized within expeactancy schemes. Just as these schemes can guide attending forward in time for perceiving, they can also guide remembering in past time. According to this view then, perceiving and remembering are very similar activities - remembering is simply a recapitulation of the original act of attending. Given that an event's structure affords effective synchrony during perceiving, the event's structure should also be accurately remembered. Similarly, an event structure which misguides attending should create deficits in both perception and memory performance.

In general, then, the Expectancy Model might predict that the pickup of temporal structure during perceiving will also be used in remembering. For example, a pattern whose structure confirms our expectancies during perceiving has been predicted to yield accurate duration estimates. If so, then the duration of this melody should also be accurately remembered.

Suppose, however, that we are asked to remember the duration of melodies which end before or after they are expected (ie. melodies of Experiments 3 - 5). Although these patterns were under or overestimated in duration at the time of perception, will these same judgments be revealed in the remembering of some time interval? They may but another possibility exists. Specifically, if one is given feedback that the event was in fact over or underestimated at the time of perceiving, then one may incorporate this feedback knowledge into the expectancy scheme. Thus at the time of remembering, the pattern's actual duration may be remembered and not the error (ie. over or underestimation). In this case, one would expect a memory judgment that is opposite to the perceptual judgment (ie. If a pattern seems perceptually shorter, then it will seem longer in past time because of the feedback correction).

The sorts of hypotheses that are offered here are admittedly underdeveloped and in need of experimental support. In general, the Expectancy Model is deficient on the topic of memory largely because the theories on which this model is founded is also weak on this issue. Both Direct and Rhythmic Attending Theory, for example, have essentially ignored the activity of remembering. It is recognized, however, that any alternative theory of judged duration must have some means for addressing this topic.

In summary, we have noted that despite its advantages, the current development of the Expectancy Model is deficient in two areas. One concerns its inadequate treatment of the "past time" issue and the other involves its lack of converging operations. Neither problem is insurmountable, however, and can be resolved with future experimentation.

Now that we've considered some of the achievements and shortcomings of the Expectancy Approach, let us turn to a final issue that I wish to address. In the closing section of this discussion, I'd like to consider how the Expectancy Model that I've developed here may apply to other areas of time experience. These areas exist on the periphery of current research and have not yet been incorporated into one encompassing theory of judged duration. Here, however, it will be shown that the concepts of synchrony and expectancy can successfully explain the sorts of time errors that appear with boredom, drug usage, and personality disturbances. Let us now examine how this is so.

Applications of the Expectancy Model to Other Areas of Time Research

According to the assumptions of the Expectancy Model, the pickup of temporal structure involves a process of synchronization where a perceiver's internal rhythms lock into phase with the rhythmic structure of an event. Duration estimates are predicted to be quite accurate whenever an event's structure confirms a perceiver's expectancies. From this perspective, then, duration estimates depend upon the relationship between an organism and her environment and the relative degree of synchronization. Since synchronization does involve an interlocking of organismic and environmental rhythms, it therefore follows that errors of judged duration should arise from two general sources: a) alterations in the structure of an environmental event and, b) alterations in the organism's internal rhythms.

The experiments that were conducted for this dissertation have all addressed the first category of errors. Here we attempted to identify some structural invariants that specify a melody's end. These were revealed to include: properties of the final note; beat invariance of accent periods; and the temporal accenting of certain melodic relationships. By systematically violating these structures, we found that an event's duration was correspondingly over or underestimated. The primary contribution of this research was to show that structural relationships within the environment do have a major impact upon judged duration. The following section considers how over and underestimations of duration may also result from changes in a perceiver's internal rhythms.

Time Errors Arising From Changes in Organismic Rhythms

In this category of time experience, the structure of environmental events hasn't necessarily changed to create violations of expectancies. Instead, certain psychological or pharmacological agents have served to speed up or slow down the velocity of an organism's internal rhythms. Thus relative to the velocity of environmental events, an organism's rhythms will be moving faster or slower - thus resulting in over and underestimations of duration. For example, consider a melody whose actual duration is ten minutes. Assuming that this melody conforms to musical convention and contains the sort of invariants we discussed earlier (ie. beat invariance, resolution, etc), one should accurately perceive this melody's duration during states of "normal" consciousness. However, suppose that one's internal rhythms are speeded up by drugs or certain personality disturbances. Here, one is anticipating the melody's end before it actually occurs. Relative to one's expectations, then, the melody ends later than it should and thus seems longer in duration. In short, the environment seems to be moving slower than you are. The opposite effect should be obtained if one's internal rhythms are slowed down. One is now anticipating the melody's end after it really occurs and since the melody ends before expected, its duration is underestimated. In this situation then, the environment appears to be moving faster than you are.

There actually is a substantial body of research to support these claims. Stimulant and psychedelic drugs (ie. marijuana, LSD, caffeine, and amphetamines) have all been found to produce overestimations of duration (eg. Fischer 1966; Frankenhauser 1959). Depressant drugs (ie. nitrous oxide, alcohol, barbituates), on the other hand, all produce underestimations of an event's duration (eg. Frankenhauser 1959; Goldstone, Broadman & Lhamon 1958). In addition to drugs, there are a variety of personality disturbances which also serve to alter an organism's rhythms and to produce corresponding effects upon judged duration. Pain, stress, and anxiety, for example, may all act to accelerate one's internal rhythms to produce overestimations of time (eg. Hare 1963; Bokander 1965). Similarly, patients diagnosed as manic are more apt to overestimate duration than depressives who tend to display underestimations (Orme 1964; Lhamon, Goldstone & Goldfarb 1965). Studies investigating judged duration as a function of mood or emotional changes show converging results. When one is sad, the experiential dragging of time produces underestimations of time while overestimations are revealed in situations of fear, happiness, and excitement (Melges & Fougerousse 1966; Kastenbaum 1965). Lastly, alterations of internal rhythms may also account for the changes in temporal experience that seem to occur as a function of aging (LeBlanc 1969; McGrath & O'Hanlon 1968). Children commonly report that (clock) time seems relatively slow, perhaps because their level of internal activity is at its peak within the life span. Elderly individuals, on the other hand, frequently claim that "time seems to fly". Again, it's quite possible that their level of internal activity is increasingly decelerating relative to the environment, thus producing underestimations of judged duration.

In sum, there is a variety of time experiences that can all be incorporated within the Expectancy Model. Over and underestimations of duration can result from factors within the organism or environment, but in either case, judged duration is determined as a function of synchronization and expected endings. Thus, there seems to be a number of criterion on which the Expectancy Model has emerged superior to those models generating from the information-processing approach. It has been demonstrated that this alternative approach is not only more parsimonious and ecologically valid, but in addition, can apply to a wide realm of time experience.

Chapter Summary

This chapter has summarized the major contrasts between the traditional information-processing models of judged duration and the Expectancy Model that has been developed within this dissertation. By focussing on the relationship between an organism and her structured environment, the Expectancy Approach has been shown to offer a number of advantages on both a philosophical and experimental level. Despite these advantages, however, it is also acknowledged that this novel perspective is deficient on two important issues. First, there is a lack of converging operations for experimental hypotheses and second, the issue of remembered time has not been adequately addressed. Some ways in which these problems may be rectified were suggested. The final section of this chapter discussed how the Expectancy Model may be applied to other sorts of time experience that have not previously been encompassed by one theoretical framework.

LIST OF REFERENCES

Adams, R.D. (1977). Intervening stimulus effects of category judgments of duration. Perception & Psychophysics, 21, 527-534.

Allan, L. (1979). The perception of time. Perception & Psychophysics, 26, 340-354.

Allan, L. & Kristofferson, A.B. (1974). Psychophysical theories of duration discrimination. Perception & Psychophysics, 16, 26-34.

Atkinson, R. & Shiffrin, R. (1968). Human memory: A proposed system and its control processes. In K.W. Spence & J.T. Spence (Eds) Advances in the psychology of learning and motivation research and theory. Vol. 2. New York: Academic Press.

Avant, L. & Lyman, P. (1975). Stimulus familiarity modifies perceived duration in prerecognition visual processing. Journal of Experimental Psychology: Human Perception and Performance, 1, 205-213.

Barclay, C., Cutting, J. & Kozlowski, L. (1978). Spatial factors in gait perception that influence gender recognition. Perception & Psychophysics, 23, 145-152.

Benjamin, W. (1984). A theory of musical meter. Music Perception, 1, 255-413.

Berry, W. (1976). Structural functions in music. Englewood Cliffs: Prentice Hall.

Bharucha, J. (1984). Anchoring effects in music: The resolution of dissonance. Cognitive Psychology, 16, 485-518.

Bharucha, J. & Krumhansl, C. (1983). The representation of harmonic structure in music: Hierarchies of stability as a function of context. Cognition, 13, 63-102.

Block, R. (1974). Memory and the experience of duration in retrospect. Memory & Cognition, 2, 153-160.

Block, R. (1978). Remembered duration: Effects of event and sequence complexity. Memory & Cognition, 6, 320-326.

Block, R. (1982). Temporal judgments and contextual change. Journal of Experimental Psychology: Human Learning and Memory. 8, 530-544.

Block, R. (1984). Contextual coding in memory: Studies of remembered duration. In J. Michon & J. Jackson-Roy (Eds) Time, mind, and behavior. Heidelberg: Springer-Verlag.

Block, R. & Reed, M. (1978). Remembered duration: Evidence for a contextual-change hypothesis. Journal of Experimental Psychology: Human Learning and Memory, 4, 656-665.

Block, R., George, E. & Reed, M. (1980). A watched pot sometimes boils: A study of duration experience. Acta Psychologica, 46, 81-94.

Bokander, I. (1965). Time estimation as an indicator of attention-arousal when perceiving complex and meaningful stimulus material. Perceptual and Motor Skills, 21, 323-328.

Bower, G. & Winsenz, D. (1969). Group structure, coding, and memory for digit series. Journal of Experimental Psychology Monograph Supplement, 80, 1-17.

Broadbent, D. (1958). Perception and communication. London: Pergamon Press.

Brown, H. & Butler, D. (1981). Diatonic trichord as minimal tonal cue-cells. In Theory Only, 5, 39-55.

Brown, D. & Hitchcock, L. (1965). Time estimation: Dependence and interdependence of modality-specific effects. Perceptual and Motor Skills, 21, 727-734.

Buffardi, L. (1971). Factors affecting the filled-duration illusion in the auditory, tactual, and visual modalities. Perception & Psychophysics, 10, 292-294.

Burnside, W. (1971). Judgment of short time intervals while performing mathematical tasks. Perception & Psychophysics, 9, 404-406.

Butler, D. & Brown, H. (1984). Tonal structure versus function: Studies of the recognition of harmonic motion. Music Perception, 2, 6-24.

Creelman, C. (1962). Human discrimination of auditory duration. Journal of the Acoustical Society of America, 34, 582-593.

Cutting, J., Proffitt, D. & Kozlowski, L. (1978). A biomechanical invariant for gait perception. Journal of Experimental Psychology: Human Perception and Performance, 4, 357-372.

Deutsch, D. (1980). The processing of structured and unstructured tonal sequences. Perception & Psychophysics, 28, 381-389.

Devane, J. (1974). Word characteristics and judged duration for two response sequences. Perceptual and Motor Skills, 38, 525-526.

Dooling, J. (1974). Rhythm and syntax in sentence perception. Journal of Verbal Learning and Verbal Behavior, 13, 255-264.

Dowling, J. (1978). Scale and contour: Two components of a theory of memory for melodies. Psychological Review, 85, 341-354.

Fischer, R. (1966). Biological time. In J.T. Fraser (Ed) The voices of time. N.Y.:Brazillier Press.

Fodor, J. & Pylyshyn, W. (1981). How direct is visual perception? Some reflections on Gibson's ecological approach. Cognition, 9, 63-110.

Frankenhauser, M. (1959). Estimation of time: An experimental study. Stockholm: Almquist and Wiksell.

Garner, W. (1962). Uncertainity and structure as psychological concepts. New York: Wiley.

Gettys, D. (1975). Discrimination of short temporal intervals: A comparison of two models. Perception & Psychophysics, 18, 1-8.

Gibson, J. (1966). The senses considered as perceptual systems. Boston: Houghton Mifflin.

Gibson, J. (1975). Events are perceivable but time is not. In J.T. Fraser and N. Lawrence (Eds) The study of time II. New York: Springer-Verlag.

Gibson, J. (1979). The ecological approach to visual perception. Boston: Houghton Mifflin.

Goffman, E. (1959). The presentation of self in everyday life. New York: Doubleday.

Goldstone, S., Broadman, W. & Lhamon, W. (1958). Effect of quinal barbitone, dextro-amphetamine and placebo on apparent time. British Journal of Psychology, 49, 324-328.

Goldstone, S. & Goldfarb, J. (1963). Judgment of filled and unfilled durations: Intersensory factors. Perceptual and Motor Skills, 17, 763-774.

Goldstone, S. & Goldfarb, J. (1964). Auditory and visual time judgment. Journal of General Psychology, 70, 369-387.

Goldstone, S. & Lhamon, W. (1974). Studies of the auditory and visual differences in human time judgments: Sounds are judged longer than lights. Perceptual and Motor Skills, 39, 63-82.

Goodman, G. (1980). Picture memory: How the action schema affects retention. Cognitive Psychology, 12, 473-495.

Gregory, R. (1966). Eye and brain. New York: McGraw Hill.

Hahn, J. & Jones, M.R. (1981). Invariance in auditory frequency relation. Scandinavian Journal of Psychology, 22, 1-16.

Handel, S. (1973). Temporal segmentation of repeating auditory patterns. Journal of Experimental Psychology, 101, 46-54.

Hare, R. (1963). Anxiety, temporal estimation and rate of counting. Perceptual and Motor Skills, 16, 441.

Harton, J. (1938). The influence of the difficulty of activity of the estimation of time. Journal of Experimental Psychology, 23, 270.

Harton, J. (1939). An investigation of the influence of success and failure on the estimation of time. Journal of General Psychology, 21, 51-62.

Hicks, R., Miller, G. & Kinsbourne, M. (1976). Prospective and retrospective judgments of time as a function of amount of information processed. American Journal of Psychology, 89, 719-730.

Hicks, R., Miller, G., Gaes, J. & Bierman, K. (1977). Concurrent processing demands and the experience of time-in-passing. American Journal of Psychology, 90, 431-446.

Hogan, H. (1975). Time perception and stimulus preference as a function of stimulus complexity. Journal of Personality and Social Psychology, 31, 32-35.

Jones, M.R. (1976). Time, our lost dimension: Toward a new theory of perception, attention, and memoroy. Psychological Review, 83, 323-355.

Jones, M.R. (1981a). Only time can tell: On the topology of mental space and time. Critical Inquiry, 7, 557-576.

Jones, M.R. (1981b. A tutorial on some issues and methods in serial pattern research. Perception & Psychophysics, /30,/ 492-504.

Jones, M.R. (1981c). Music as a stimulus for psychological motion: Part I. Some determinants of expectancies. Psychomusicology, 1, 34-51.

Jones, M.R. (1982). Music as a stimulus for psychological motion: Part II. An expectancy model. Psychomusicology, 2, 1-13.

Jones, M.R. (1984). Structural organization of events in time. In J. Michon & J. Jackson-Roy (Eds) Time, mind, and behavior. Heidelberg: Springer-Verlag.

Kastenbaum, R. (1965). The direction of time perspective: The influence of affective set. Journal of General Psychology, 73, 189-201.

Kaufman, W. (1974). Sight and mind. New York: Oxford University Press.

Krumhansl, C. (1979). The psychological respresentation of musical pitch in a tonal context. Cognitive Psychology, 11, 346-374.

Krumhansl, C. & Shepard, R. (1979). Quantification of the hierarchy of tonal functions within a diatonic context. Journal of Experimental Psychology: Human Perception and Performance, 5, 579-594.

Krumhansl, C., Bharucha, J. & Castellano, M. (1982). Key distance effects on perceived harmonic structure in music. Perception & Psychophysics, 32, 96-108.

Kuhn, T. (1962). The structure of scientific revolutions. Chicago: University of Chicago Press.

LeBlanc, A. (1969). Time orientation and time estimation: A function of age. Journal of Genetic Psychology, 115, 187-194.

Lehiste, I. (1975). The perception of duration within sequences of four intervals. Paper presented at the 8th. International Congress of Phonetic Sciences, Leeds, August 21.

Lerdahl, F. & Jackendoff, R. (1983). A generative theory of tonal music. Cambridge: MIT Press.

Lhamon, W., Goldstone, S. & Goldfarb, J. (1965). The psychopathology of time judgment. In P. Hoch & J. Zubin (Eds) Psychopathology of perception. New York: Grune and Stratton.

Loehlin, J. (1959). The influence of different activities on the apparent length of time. Psychological Monographs: General and Applied 73 (4, Whole No. 479).

Martin, J. (1972). Rhythmic (hierearchical) vs. serial structure in speech and other behavior. Psychological Review, 79, 487-509.

Martin, J. (1975). Rhythmic expectancy in continuous speech perception. In A. Cohen & S. Nooteboom (Eds) Structure and process in speech perception. New York: Springer-Verlag.

McGrath, J. & O'Hanlon, J. (1968). Relationship among chronological age, intelligence and rate of subjective time. Perceptual & Motor Skills, 26, 1083-1088.

McKay, G. & Timothy, D. (1977). Time estimation: Effects of attentional focus and of a comparison of internal conditions. Perception and Motor Skills, 45, 584-586.

Melges, F. & Fougerousse, C. (1966). Time sense, emotions, and acute mental illness. Journal of Psychiatric Research, 4, 127-140.

Meyers, L. (1956). Emotion and meaning in music. Chicago: University of Chicago Press.

Michaels, C. & Carello, C. (1981). Direct perception. Englewood Cliffs: Prentice Hall.

Miller, G., Galanter, E. & Pribram K. (1960). Plans and the structure of behavior. New York: Henry Holt & Co.

Orme, J. (1964). Personality, time estimation and time experience. Acta Psychologica, 22, 430.

Ornstein, R. (1969). On the experience of time. Baltimore: Penguin Books.

Neisser, U. (1967). Cognitive psychology. New York: Appleton-Century-Crofts.

Newell, A. & Simon, H. (1972). Human problem solving. Englewood Cliffs: Prentice Hall.

Pike, K. (1946). The intonation of American English. Ann Arbor: University of Michigan Press.

Posner, M. & Boies, S. (1971). Components of attention. Psychological Review, 78, 391-408.

Povel, D. (1984). Time,, rhythms, and tension: In search of the determinants of rhythmicity. In J. Michon & J. Jackson-Roy (Eds) Time, mind, and behavior. Heidelberg: Prentice Hall.

Poynter, W. (1983). Duration judgment and the segmentation of experience. Memory & Cognition, 11, 77-82.

Poynter, W. & Homa, D. (1983). Duration judgment and the experience of change. Perception & Psychophysics, 33, 548-560.

Priestly, R. (1968). Man and time. New York: Dell.

Purdy, J. & Gibson, J. (1955). Distance judgment by the method of fractionation. Journal of Experimental Psychology, 50, 374-380.

Rock, I. (1975). An introduction to perception. New York: Macmillan Publishing Co.

Restle, F. (1972). The role of phrase. Journal of Experimental Psychology, 92, 385-390.

Schank, R. & Ableson, R. (1977). Scripts, plans, goals, and understanding. Hillsdale, N.J.: Erlbaum.

Schiff, W. & Detwiler, M. (1979). Information used in judging impending collision. Perception, 8, 647-658.

Schiff, W. & Thayer, R. (1968). Cognitive and affective factors in temporal experience: Anticipated or experience pleasant and unpleasant sensory events. Perceptual and Motor Skills, 26, 799-808.

Schiffman, H. & Bobko, D. (1974). Effects of stimulus complexity on the perception of brief temporal intervals. Journal of Experimental Psychology, 103, 156-159.

Sedgewick, H. (1973). The visible horizon. Doctoral dissertation, Cornell University Library.

Shaw, R., McIntyre, M. & Mace, W. (1974). The role of symmetry in event perception. In R. MacLeod & H. Pick (Eds) Perception: Essays in honor of James Gibson. Ithaca, N.Y.: Cornell University Press.

Shepard, R. (1984). Ecological constraints on internal representation: Resonant kinematics of perceiving, imagining, thinking, and dreaming. Psychological Review, 91, 417-447.

Thomas, E. & Brown, I. (1974). Time perception and the filled duration illusion. Perception & Psychophysics, 16, 449-458.

Thomas, E. & Weaver, W. (1975). Cognitive processing and time perception. Perception & Psychophysics, 17, 363-367.

Todd, T. (1981). Visual information about moving objects. Journal of Experimental Psychology: Human Perception and Performance, 7, 795-810.

Triesman, M. (1963). Temporal discrimination and the indifference interval: Implications for a model of the "internal clock". Psychological Monographs, 77, Whole No. 576.

Treisman, A. (1964). Monitoring and storage of irrelevant messages in selective attention. Journal of Verbal Learning and Verbal Behavior, 3, 449-459.

Turvey, M. (1977). Contrasting orientations to the theory of visual information processing. Psychological Review, 84, 67-88.

Ulman, R. (1980). Against direct perception. The Behaviorial and Brain Sciences, 3, 373-416.

Underwood, G. & Swain, R. (1973). Selectivity of attention and the perception of duration. Perception, 2, 101-105.

Vitz, P. & Todd, T. (1969). A coded element model of the perceptual processing of sequential stimuli. Psychological Review, 76, 433-449.

Vroon, P. (1970). Effects of presented and processed information on duration experience. Acta Psychologica, 34, 115-121.

Wiemann, J. & Knapp, M. (1975). Turn-taking in conversation. Journal of Communication, 25, 75-92.

Wingfield, A. & Klein, J. (1971). Syntactic structure and acoustic pattern in speech perception. Perception & Psychophysics, 9, 23-25.

Zakay, D., Nitzan, D. & Glicksjohn, J. (1983). The influence of task difficulty and external tempo on subjective time estimation. *Perception & Psychophysics, 34,* 451-456.

<u>Statistical Results for Simplicity Dimension</u>

Main Effect for Rhythm (1,32 = 53.76, p<.0001, MSe = 1.754)

Main Effect for Pattern (F1,32 = 95.89, p<.0001, MSe = .581)

Pattern x Rhythm Interaction (F1,32 = 9.39, p<.004, MSe = .192)

Rhythm x Instance Group Interaction (F1,32 = 4.58, p<.046, MSe = 1.754)

<u>Statistical Results for Musicality Dimension</u>

Main Effect for Pattern (F1,32 = 42.11, p<.0001, MSe = .995)

Pattern x Rhythm Interaction (F1,32 = 14.72, p<.0006, MSe = .185)

Pattern x Instance Group Interaction (F1,32 = 13.13, p<.0001, MSe = .995)

APPENDIX A

SECONDARY RESULTS OF EXPERIMENT 1A

APPENDIX B

RESULTS OF RECOGNITION MEMORY EXPERIMENTS

EXPERIMENT 1C

The primary purpose of this recognition memory experiment was to motivate subjects to optimally attend to all patterns within the judged duration task. Since this data was available, however, a secondary purpose was to determine whether prototypes and nonprototypes are differentially remembered.

Previous research by Goodman (1980) and Dowling has reported that nonprototypical stimuli are better recognized than prototypical items but that prototypes are better recalled than nonprototypes. Their explanation for this phenomenom is that prototypes are incorporated into a common cognitive schema while nonprototypes receive a more isolated and differentiated representation. Hence prototypes are better recalled but poorly recognized because their structure overlaps and interferes with that of other members in a schema. If this is true, then a similar finding should be obtained in the present experiment. In addition, the nature of distractor items should exert a differential effect. If distractors contain an identical contour to their original patterns, these should be incorporated into the schema and should thus be more poorly recognized as NEW items. Nonprototypes should not be differentially affected by distractor type since they presumably are represented in a more isolated format. To test these claims, subjects from the judged duration experiment (1b) were asked to return a second day for a recognition memory test.

Method

Design and Subjects

The design was 2 x 2 x 2 x 2 x 2 x 3 mixed factorial. Two levels of total duration (long, short) were crossed with two levels of rhythm (Four and Five Beat), two levels of pattern type (Rules, Norules), and three levels of memory probe (Old; New with same contour; New with different contour). The two between-subjects variables were counterbalance order (I, II) and melodic instance group (A, B).

The forty-four subjects who participated in Experiment 1b (of the time estimation task) returned the following day for the present experiment. Eleven subjects were assigned to one of the four between-subjects conditions.

Stimulus Materials

The two groups of melodies (Group A, B) from Experiments 1a and 1b were designated as the sets of "OLD" stimulus items. Each group contained 8 melodic patterns, four rule and four norule melodies, under the four rhythm x duration conditions as described previously.

For each of the eight melodic patterns in each "OLD" stimulus group, two types of "NEW" distractor items were created. One distractor contained the same contour as its OLD counterpart and the other contained a different contour. Such distractors were created by preserving the same initial argument and end rules of its counterpart, but changing the middle rule such that it yielded a same or different contour.

These distractor patterns were then crossed with the two rhythms at each of the two durations, yielding a total of 96 experimental trials for each group (A, B). Within a group, then, there were 32 "OLD" items and 64 "NEW" items. The 96 trials were randomized and divided into two blocks of 48 trials for presentation. The apparatus used for presentation was the same as before.

Procedure

Recorded instructions informed subjects of task requirements and experimental details. On each trial, a one sec. warning tone (5000 hz) preceded a pattern by two secs. Two seconds later, this same pattern was repeated for the benefit of the listener. During a 7 sec. response interval, subjects were then required to decide whether this pattern was OLD or NEW and to circle the appropriate judgment on their response sheet. Subjects were also asked to indicate the certainity of this judgment on a confidence scale ranging from 1 to 7: 1 meaning very certain and 7 meaning very uncertain.

Each experimental session was approximately 45 minutes in duration with a brief 3 min. rest period provided after 48 trials.

Results

This experiment hoped to converge on previous research showing that prototypes are more poorly recognized than nonprototypes. Although there was some suppport for this hypothesis, results were not consistent with both measures of recognition accuracy (ie. percent correct and Ag) nor uniformly applied to all pattern instances. It therefore seems more reasonable to merely provide a succinct summary of the overall findings. Results of statistical analyses are presented in the following tables of this Appendix.

When data was analyzed in terms of percent correct, results did in fact reveal that prototypical patterns, containing rule structure and a compatible Four Beat rhythm, yielded lower recognition. In contrast, nonprototypes containing a Five Beat rhythm and no rules were recognized at a more superior level. In addition, distractors containing the same contour as the original patterns were more disruptive to prototypes than nonprototoypes. The more sensitive measure of Ag, however, revealed that these effects only occur within one of the two melodic instance groups (Group A). The second group produced anomalous results that are not immediately explicable.

TABLE 27

MEAN PERCENT CORRECTLY RECOGNIZED AS A FUNCTION OF RHYTHM AND MEMORY PROBE. ($F_{2,80} = 22.71$, $P < .0001$, MSE = .029) MAIN EFFECT FOR RHYTHM ($F_{1,40} = 18.6$, $P < .0001$, MSE = .025).

	FOUR BEAT	FIVE BEAT	MEANS
OLD	.837	.757	.797
NEW SAME CONTOUR	.511	.625	.568
NEW DIFFERENT CONTOUR	.697	.842	.770
MEANS	.682	.741	

TABLE 28

MEAN PERCENT CORRECTLY RECOGNIZED AS A FUNCTION OF RHYTHM, MEMORY PROBE, AND MELODIC INSTANCE GROUP.
($F_{2,80} = 5.97$, $P < .004$, $MSE = .029$)

		OLD	NEW SAME CONTOUR	NEW DIFFERENT CONTOUR	MEANS
FOUR BEAT	GROUP A	.784	.543	.648	.658
	GROUP B	.889	.480	.747	.705
FIVE BEAT	GROUP A	.756	.591	.824	.724
	GROUP B	.759	.659	.861	.760
	MEANS	.797	.568	.770	

TABLE 29

MEAN PERCENT CORRECTLY RECOGNIZED AS A FUNCTION OF PATTERN TYPE AND MEMORY PROBE. ($F2,80 = 16.38$, $P<.0001$, MSE = .03)

MAIN EFFECT FOR PATTERN ($F1,40 = 11.04$, $P<.002$, MSE = .032)

MAIN EFFECT FOR PROBE ($F2,80 = 37.53$, $P<.0001$, MSE = .07)

	RULE	NORULE	MEANS
OLD	.827	.767	.797
NEW SAME CONTOUR	.493	.643	.568
NEW DIFFERENT CONTOUR	.737	.803	.770
MEANS	.686	.738	

TABLE 30

MEAN PERCENT CORRECTLY RECOGNIZED AS A FUNCTION OF PATTERN TYPE, MEMORY PROBE, AND MELODIC INSTANCE GROUP.
($F_{2,80}$ = 7.49, $P < .001$, MSE = .03)

		OLD	NEW SAME CONTOUR	NEW DIFFERENT CONTOUR	MEANS
RULES	GROUP A	.770	.457	.733	.658
	GROUP B	.884	.528	.741	.705
NO RULES	GROUP A	.770	.676	.739	.724
	GROUP B	.764	.611	.866	.760
	MEANS	.797	.568	.770	

TABLE 31

MEAN A_g AS A FUNCTION OF PATTERN TYPE, MEMORY PROBE, AND MELODIC INSTANCE GROUP. ($F_{1,40}$ = 13.54, P<.0007, MSE = .005)

	SAME CONTOUR		DIFFERENT CONTOUR		
	RULES	NORULES	RULES	NORULES	MEANS
GROUP A	.691	.776	.818	.828	.778
GROUP B	.819	.770	.900	.888	.844
MEANS	.755	.773	.859	.858	

TABLE 32

MEAN A_g AS A FUNCTION OF RHYTHM, MEMORY PROBE, PATTERN TYPE AND MELODIC INSTANCE. ($F1,40 = 9.31$, $P < .004$, $MSE = .003$)

MAIN EFFECT FOR GROUP ($F1,40 = 6.46$, $P < .015$, $MSE = .059$)

MAIN EFFECT FOR PROBE IS ($F1,40 = 87.46$, $P < .0001$, $MSE = .009$)

		SAME CONTOUR		DIFFERENT CONTOUR		
		RULES	NORULES	RULES	NORULES	MEANS
FOUR BEAT	GROUP A	.723	.764	.816	.799	.776
	GROUP B	.822	.794	.928	.886	.858
FIVE BEAT	GROUP A	.659	.787	.820	.857	.781
	GROUP B	.816	.745	.871	.890	.831
	MEANS	.755	.773	.859	.858	

EXPERIMENT 2B

One reason why the prototypicality hypothesis was not supported by the previous experiment may involve the nature of distractor items. There, distractor melodies always preserved the rhythm of the old items but varied in terms of same or different contour. It may be the case, however, that musical patterns are either differentiated from or incorporated into a common scheme on the basis of rhythm (and not contour) and how well that rhythm corresponds to a pattern's melodic accent structure. In the present experiment, then, subjects were always presented with those same melodies used in the judged duration task but with an "old" or "new" rhythm. The temporal accents of these New rhythms were designed to be compatible with one type of prototype and incompatible with the other. If prototypes really are represented in a common scheme on the basis of rhythm, then melodies containing compatible rhythms should be more poorly recognized than those containing incompatible rhythms.

METHOD

Design and Subjects

The design was a 2 x 4 x 4 x 2 x 2 mixed factorial. Two levels of melodic argument size (Three vs. Four Tones) were crossed with four levels of melodic instance, four levels of rhythm (Five Beat, Seven Beat, Duple Meter, Sextuple Meter) and two levels of total duration

(Long, Short). Two levels of counterbalance order was the single between-subjects variable.

The same twenty-two subjects of Experiment 2 were required to return a second day for the present experiment. Eleven were randomly assigned to one of the two counterbalance orders.

<u>Stimulus Materials</u>

The eight melodies used in the judged duration task were crossed with four different rhythms. Two of these were "old" in that they were the same Five and Seven Beat rhythms as used in the judged duration task. The two "New" rhythms were constructed on the basis of a Duple or Sextuple meter. The Duple meter contains a pause after every other tone and like the Seven Beat rhythm, is compatible with melodies based on a four tone argument. The temporal accents of this rhythm, however, are incompatible with the melodic accents of melodies generated from a three tone argument. Conversely, the Sextuple meter contains a pause after a sixth tone of a melody. Like the Five Beat rhythm, it is therefore compatible with melodies based on a three tone argument and incompatible with those based on a four tone argument.

For actual pattern presentation, the eight melodies were crossed with the four rhythms at two total durations (Long, Short) to yield 64 experimental trials. Two randomized blocks of 32 trials were devised, resulting in one presentation of each pattern for a given subject.

<u>Apparatus</u>

Identical to previous experiment.

Procedure

Subjects were instructed to decide whether the pitch intervals of a melody were the same as a melody encountered on the previous day (Old) or whether they were unfamilar (New). Instructions emphasized that judgments of "old" and "new" should be made on the basis of melody and not on rhythm. In all other respects, the procedure was identical to that of Experiment 1b.

Results

In the memory task of the present experiment, subjects were always given the same melodies as used in the judged duration task but with either "Old" or "New" rhythms. Performance then can only be assessed in terms of Hits and Misses because there are no actual new melodies to correctly reject or falsely recognized. Since an Ag analysis is therefore inappropriate, an analogous measure of sensitivity was obtained through difference scores. Here, the percentage of misses for each Old rhythm was subtracted from the percentage of misses for its corresponding New rhythm. Since the Five Beat and Sextuple meter rhythms are both compatible with the melodic accents of patterns based on a Three Tone argument (and both are incompatible with melodies generated from a Four Tone argument), their respective error rates were subtracted from one another. Similarly, the error rates for the Seven Beat and Duple meter rhythms were subtracted from one another because their temporal accents were compatible with melodies generated from a Four Tone argument and incompatible with those based on a Three Tone argument.

Table 33 displays these mean difference scores as a function of melodic argument size and rhythm. The means displayed in each condition are collapsed over melodic instance, counterbalance order, and total pattern duration.

The results of an analysis of variance failed to reveal any significant main effects or interaction.

Table 33.

Mean difference scores as a function of melodic argument size and rhythm.

	Three Tone	Four Tone
Five Beat - Sextuple Meter	.30	.30
Seven Beat - Duple Meter	.28	.31

EXPERIMENT 3C

The task within this last memory experiment differs from that used in the two previous studies. Here a subject was signalled to perform one of two tasks before each experimental trial: a) to compare the relative duration of patterns or; b) to decide whether two patterns are the "same or different" in pitch relationships. If patterns ending on the tonic and major third are indeed representative of natural music, constituting prototypes, performance on both patterns should be lower than that on previous context endings (which should be more nonprototypical). Similarly, patterns ending on the tonic and major third should yield comparable performance. To investigate these various sets of predictions, the following experiment was conducted.

Method

As described in Experiment 3b.

Results

As before, the purpose of this recognition memory task was to test a hypothesis concerning the memorial representation of prototypes. Previous research by Goodman (1980) and Dowling (1978) has reported that nonprototypes are better recognized than prototypes. According to this rationale, the resolved patterns of the present experiment should have been more poorly recognized than unresolved patterns. However, when the data was analyzed both in terms of percent correct and Ag, results did not support these expectations. There were inconsistancies across both measures of recognition and, in general, results were not amenable to any logical intepretation. They are summarized in the following tables.

TABLE 34

MEAN PERCENT CORRECT RECOGNITION AS A FUNCTION OF THE HARMONIC ENDING OF THE FIRST AND SECOND PATTERN OF A PAIR. ($F_{8,112} = 7.42$, $P < .0001$, MSE= .04)

FIRST PATTERN	SECOND PATTERN: TONIC	MAJOR THIRD	PREVIOUS CONTEXT NOTE
TONIC	.76	.77	.87
MAJOR THIRD	.78	.70	.58
PREVIOUS CONTEXT NOTE	.75	.46	.59

TABLE 35

MEAN A_g AS A FUNCTION OF THE HARMONIC ENDING OF THE FIRST AND SECOND PATTERN OF A PAIR. ($F_{5,70}$ = 11.48, $P < .0001$, MSE = .01)

SECOND PATTERN

	TONIC	MAJOR THIRD	PREVIOUS CONTEXT NOTE
TONIC		.83	.80
MAJOR THIRD	.79		.65
PREVIOUS CONTEXT NOTE	.75	.59	