PHYSIOLOGICAL INFLUENCES ON INTERNAL TEMPO AFTER EXERCISE

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CHAPTER I

INTRODUCTION

In spite of the agreement among individuals regarding the existence of time, there is no one simple way to explain everyone's individual experience with time. For example, if two people are both in a car accident, their subjective experience of that event may be quite different from each other. One person may describe the events occurring within that time frame as taking place so quickly that they seemed to happen instantaneously or before the person was even aware of what was happening. The other individual may describe time as having slowed down to such a degree that he or she was able to perceive events that he or she normally would not. It is this type of subjective experience of time that makes research into time perception so important.

The necessity of this research stems from the fact that time perception and the judgment of the duration of the passage of time are indeed everyday, shared experiences. In many ways, time can be equated with the building blocks upon which all events are constructed. If we do not fully comprehend even the most basic aspect of time perception and duration judgment, how is it that people are able to take time for granted and function in a collaborative manner?

Despite the fact that time can be a subjective experience, many societies would cease to function in the way they were accustomed to if there were not some agreed upon method for everyone to mark the passage of time. Because whether they are aware of it or not, the individuals who make up any given society either willingly or are forced to acquiesce to the view of time held by the majority and surrender a personal sense of time. In the scientific literature, one aspect of this "personal" time is referred to as internal tempo.

Kir-Stimon (1977) provides a description of just what internal tempo, or personal tempo, is. According to Kir-Stimon, all people have a personal rhythm that affects the way that they think, behave, and interact with the world around them (as cited by Boltz, 1994). Boltz (1994) goes on to describe how this personal rhythm can be influenced by a variety of different sources. Not surprisingly, these factors include each person's environment, his or her physiology, as well as psychological state. Since there are probably as many different internal tempos as there are individuals, a way to determine exactly each person's personal tempo had to be devised.

To measure a person's rate of internal tempo, various researchers and authors have used a method referred to as "finger tapping" (e.g., Denner, Wapner, & Werner, 1964; Tiffin-Richards, Hasselhorn, Richards, Banaschewski, & Rothenberger, 2004; and Vanneste, Pouthas, & Wearden, 2001). Finger tapping is a simple technique in which a participant taps his or her finger on a surface at whatever rate is comfortable. Even though this method is a relatively simple way of getting some idea as to the participant's rate of internal tempo, the question of what other factors might be influencing that tempo remain complex issues.

Environment appears to have a great deal to do with how a person perceives time. It is reasonable, therefore, to expect that environment might influence the way in which people express that perception of time. If a person is surrounded by chaotic activities and sound, how is his or her internal tempo different than in a situation where things are much more calm and peaceful? Even a factor such as room temperature could influence the rate at which a person taps his or her finger as an indicator of internal tempo. Certainly, most people have had an experience when time seemed to pass at a different rate when they were confined to a situation in which the temperature was either too hot or too cold. Changes in environment are significant because one can assume that they have an impact on an individual on many different levels. The irritation a person feels if his or her surroundings are loud or disruptive might lead to changes in internal tempo based either on psychological and/or physiological alterations. Changes in external temperature definitely influence someone's bodily processes. Evidence of this is seen in perspiration, facial flushing, goose bumps, and shivering. If these processes can change the way a person expresses his or her subjective feelings regarding the passage of time, what effect does a change in something as simple as heart rate have on internal tempo? Hormonal changes, presence of brain tumors, and introduction of substances like alcohol, caffeine, and other drugs in the body also need to be considered when talking about internal tempo. This discussion leads directly into an examination of how physiological factors influence time perception as expressed through measurement of finger tapping.

The range of physiologically based influences is quite wide. It includes not only those factors such as disease, but also substances that can be introduced in the body. In a study by Zeitlhofer, Saletu, Stary, and Ahmadi (1984), people suffering from an endocrine-based condition known as hyperthyroidism were studied to see if their perception of time differed significantly from participants not suffering from hyperthyroidism. The same patients with hyperthyroidism were also studied after they received medication to treat their condition. The internal tempos of participants with hyperthyroidism was compared to the internal tempos of participants without the disease and was found to be significantly faster. Once treatment for hyperthyroidism was received, all the participants' internal tempos were measured again. This time, the participants with hyperthyroidism had internal tempos that more closely matched those of the healthy participants. This study provides a clear example of how biological factors can play a role in internal tempo. Evidence provided by this study suggests that other diseases may also change a person's internal tempo. If something as common as a hormone can play this large of a role, how might internal tempo be affected by changes in brain chemistry and structure in the presence of things like epilepsy, a stroke, or Alzheimer's disease? Impressive as it might be to think that something as mundane as a hormone that is normally present in the human body can substantially affect a person's internal tempo and thereby his or her expression of time in general, the list of exogenous, physiology-affecting agents goes on, however. Alcohol, caffeine, and marijuana also have specific effects on biological systems and therefore have the potential to influence internal tempo in their own way.

There are just as many ways in which psychological state can play a role in how a person experiences time as manifest in personal tempo. There are a number of disorders that can do this. It has long been documented that depression (Schwartz, Friedman, Lindsay, & Narrol, 1982; Steinberg & Raith, 1985), as well as anxiety (Barrat, 1983); can change a person's perception of time. This might be seen in a depressed person tapping very slowly, while an anxious person may tap at a much faster rate than either the depressed person or a person suffering from neither psychopathology. These two diagnoses are just the tip of the iceberg when it comes to the numerous mental health issues that hold some sway over internal tempo.

The goal of the present study is to fill in gaps that exist in literature regarding the way in which internal tempo interacts with both physiological and psychological states. While there is a great deal of research in the area of time and time perception, and even internal tempo, there seems to be very little information regarding a clear distinction between physical and psychological effects on a person's internal tempo. Part of the limitation in the current research comes from the fact that much of it focuses more incidentally on internal tempo, forcing other researchers to infer conclusions about this phenomenon, versus addressing internal tempo directly. There is a wide variety of literature that attempts to elaborate on the idea of each individual having his or her own inner speed and how this personal tempo affects various aspects of his or her life. There are numerous studies that look at ideas such as the effects of task complexity and processing speed. There are also many studies seeking to explain how time is estimated and whether it relies on aspects of cognition like memory and attention. Even though there is a range of research in this area, there is a lack of specific focus on how internal tempo itself can be affected by very simple physiological and emotional states.

In a review of the literature in this area, there are few studies that seem to manipulate the physiological state to determine how internal tempo might be affected. An example of one study that does do this is by Dosseville, Moussay, Larue, Gauthier, and Davenne (2002). In this study, the investigators increased participants' heart rates by having them ride a stationary bicycle and then measuring their internal tempo through finger tapping. Their findings suggested that an increase in heart rate may also have the effect of increasing an individual's internal tempo.

One possible confound of this study is that Dosseville et al. (2002) did nothing to assess their participants' emotional states. While they did have significant findings that an increase in heart rate coincided with an increase in finger tapping, which suggests an increase in internal tempo, the results of Dosseville et al. might also be influenced by the participants' emotional arousal and not physiological arousal. Angrilli, Cherubini, Pavese, and Manfredini (1997) found evidence based on research by Damasio (1994) that there is a great deal of "neuropsychological evidence supporting the assumption that emotions are involved in most, if not all, cognitive processes," (Angrilli, Cherubini, Pavese, & Manfredini, 1997, p. 972). If this is in fact the case, it would seem that a vital piece of the explanation of Dosseville et al.'s results was absent. Not taking into account the participants' emotional states basically prevents making a clear statement about the true effect an increased heart rate had on internal tempo.

Angrilli et al. (1997) examined how affective factors might influence time perception. Participants were shown slides that were associated with a certain degree of emotional arousal. The participants then gave a time judgment on a provided duration. Even though the heart rates of the participants in the study were monitored, the information was not used to make a determination of physiological arousal, but instead was used as a "measure of attention" (Angrilli et al., 1997, p. 974). While the results pertaining to level of emotional arousal and its effect on the judgment of duration did not reach significance, this study was important because it did take into account the possible effects that emotional state can have on the perception of time.

Even though this study touches on an important and neglected aspect of many experiments in time perception, it is still lacking. In addition to not measuring internal tempo, the article by Angrilli et al. (1997) does not take into account how the increases and decreases in heart rate might also be affecting their results. So in this instance, there is an inability to definitively point to either emotional or physiological arousal as having an influence on time perception and internal tempo.

The present study will attempt to disentangle how physiological and emotional arousal influence internal tempo and time perception. As with any similar endeavor, an in-depth literature review is the first step. The review will include specific examples of studies that examined the nature of internal tempo, the effects of physiological states on time perception, and the effects of emotional or psychological states on time perception. Finally, an experiment will be proposed that will attempt to tease apart the effects of emotional arousal from the effects of physiological arousal on internal tempo. To accomplish this, emotional arousal will be controlled for while an increase in heart rate will serve to address the physiological requirements.

CHAPTER II

REVIEW OF LITERATURE

Time perception is an important area of research because of the shared nature of it. It also has clinical relevance due to the way in which it ties to psychological state. Physiological state and environmental factors can affect time perception as well. The majority of this research has found inconsistent results regardless of the state (physiological of psychological) or the environment of the individual being studied. This could be due to the fact that when research in this area is undertaken, one or both of the states that can affect time perception is left unaccounted for. Additionally, many of the studies suffer from methodological problems that also bring the conclusions into question. For these reasons, research that addresses these problems is necessary to better understand how time perception is affected by physiological and psychological states.

Internal tempo and time perception are inextricably connected. Time perception can be influenced by internal tempo, the results of which are then seen in estimates of time. Internal tempo itself can be affected by physiological state, psychological state, and the environment. These are three important areas of focus in time perception and internal tempo research. Each of these three areas will be discussed.

Pertinent Definitions in Temporal Research

Despite the fact that the study of time has been going on for many decades, it seems that there is still some disparity in the definitions of some terms and ideas. To clarify this inconsistency, terms that are key to understanding the ways in which previous research has measured and defined time will be discussed first.

Time perception studies typically ask participants to judge durations that are very brief, typically less than a minute in length. Bindra and Waksberg (1956) describe the three main methods used in the research for time perception. These methods include verbal estimation, production, and reproduction (Table 4). Verbal estimation requires the participant to estimate verbally a provided duration. Production asks the participant to generate a specified duration that is likely given verbally. The production method often relies upon the use of some apparatus, like a button-press, for the participant to activate at the beginning of the estimate and deactivate when he or she judges the duration to have ended. This is different from the reproduction method only in the way the duration to be estimated is presented. Like verbal estimation, reproduction provides the participant with an interval, for example, a light is turned on for 2 seconds. The participant is then asked to reproduce the interval, perhaps again with a device similar to a button-press. This is perhaps the most complicated of the three methods due to the fact that there are two intervals that are part of this process. The first time frame is during the interval when, as in the example, the light is turned on. The second span of time is when the participant is reproducing the first interval. Though these methods were first discussed as early as 1956, they are still measures that are used in more current studies (Angrilli et al., 1997; Hancock, 1993; Wearden, Philpott, & Win, 1999) to assess time perception.

With these methods elaborated upon, two more important ideas regarding time research need to be addressed. These are the ideas of prospective and retrospective time estimation. These concepts are usually described in connection with the notion that attention is the mediating factor when it comes to a person’s ability to accurately estimate how much time has passed during any given interval.

Retrospective duration estimation is used when individuals are given a certain time interval, during which they may or may not be involved in another temporally-related task. Then, after the interval has ended, they are asked to estimate how long they believe that preceding interval to have been. With this type of estimation, the participants have no foreknowledge that they are going to be questioned about the interval once it has ended. It is this lack of advanced warning that defines retrospective time estimation. In theory, the participants have to rely on the information they receive from memory that was processed during the interval.

Prospective duration estimation is usually measured in a situation in which participants are asked to perform a certain task or tasks. The distinguishing feature of prospective estimation is that the participants are told before they begin their tasks that they will be asked to estimate the length of time that has passed once the interval has ended. Assuming participants have a finite "pool" of attention, every task takes resources from this "pool". The greater the complexity of the non-temporal task, the more attention is needed to effectively complete the task, so even though the participants know they are going to have to estimate the duration of the interval later, the resources left over may or may not be enough to accurately approximate the interval's duration (Zakay & Block, 1997). This dual-test idea does not define all prospective studies. In many, the only task is to pay attention to the time interval. Discussing the key methods (i.e. verbal estimation, production, and reproduction) used to study time perception is vital because there needs to be some familiarity with the terms in relation to the measuring techniques used in this particular arena of study.

Internal Tempo

There exist numerous studies (Mishima, 1968; Penton-Voak, Edwards, Percival & Wearden, 1996; Temperley, 1963; Treisman 1984; Treisman, Faulkner, Naish, & Brogan 1990) that examine the phenomenon of internal tempo, sometimes referred to in these studies as mental tempo, personal rhythm, or internal clock. A definition for internal tempo that Boltz (1994) includes in her research comes from Kir-Stimon (1977). This definition states that all people have a personal rhythm that affects the way that they think, behave, and interact with the world around them (as cited by Boltz, 1994). This internal tempo manifests itself in the speed at which a person walks, the rate at which a person speaks, and a general feeling of how fast or slow time passes. The laboratory measure of internal tempo is the rate at which a person taps his or her finger (Temperley, 1963), which is discussed in more detail below. Mishima (1968) also discussed how the people of a particular culture or geographical area might share similar mental tempos. This suggests that internal tempo does not exist removed from external influence. Environment, physiology, and psychological state all play a role in each person’s own internal rhythms.

The working model of the present proposal is that one's perception of time is strongly influenced by the speed of an internal time-keeping mechanism such as that proposed by Treisman et al., 1990. Treisman et al. discuss earlier work by Treisman (1963) in which he described how information processing plays a role in the functioning of this internal clock. He suggested that this clock generates regular pulses that are received and then measured. The rate at which these pulses are produced, according to Treisman et al., is determined by the arousal state of the pacemaker, or internal clock. Based on this model, a temporal processing mechanism that is being sped up by outside influences would result in faster pulses. Because the temporal pacemaker determines how much time has passed by "counting" the number of pulses received within a given interval, the consequence of the quicker rate of pulses would be that time would be gauged to be moving at a faster rate than it actually is.

While Treisman's work focuses mainly on examination of arousal as seen in electroencephalograms (EEG), his suggestion that level of arousal affects internal tempo in a correlational manner remains a provocative one. This idea implies that changes in the speed at which this internal mechanism operates will result in predictable changes in temporal perception. To say this more succinctly, physical arousal can alter the speed of internal tempo, which then proceeds to change the way an individual experiences the passage of time. Since internal tempo can be measured by ad hoc finger tapping, the result of a change in physiological state could be observed as a change in rate of finger tapping, as well as a change in the estimation of a sample interval.

Because the way in which time perception changes based on the method of measurement used, the exact nature of these predictable changes is described with regard to each of the methods of temporal perception measurement reviewed previously. With the verbal estimation method (Gupta & Cummings, 1986; Stine, O'Connor, Yatko, Grunberg, & Klein, 2002; and von Kirchenheim & Persinger 1991) if the participant verbally provides an estimate (e.g., 1200 ms) that is greater than the duration given (e.g., 1000 ms), this is an overestimation of the standard time, the standard time being what the experimenter provided to the participant. This indicates that the internal clock, and thus internal tempo, is moving at a faster rate than the objective clock time. Conversely, if a participant gives a verbal estimate that is smaller than the given interval, this is an underestimation. In this instance, the participant might state that the 1000 ms sample duration was 800 ms. Based on the theoretical model, if the person experiences larger time units to be passing compared to those units of objective clock time, then his or her internal clock is going at a slower pace than the external clock.

With the production method (Adam, Rosner, Hosick, & Clark, 1971; Hancock, 1993; Hicks, Gualtieri, Mayo, Jr., & Perez-Reyes, 1984), if overestimation takes place when a participant is asked to produce a stated duration of time, 10 seconds for example, this implies that his or her internal tempo is moving at a slower rate than the outside objective clock would be. This is due to the person expressing temporal units that are larger than those of the objective clock. This individual would perhaps estimate a 10 second interval to be closer to 15 seconds depending on how slowly his or her internal clock was moving.

An underestimation that occurs with the production method translates into the individual providing an interval that is shorter than the sample interval. In this case, a person would produce a 50-second interval when asked to produce a 60-second duration. The production of an underestimation of the sample time would then suggest that the person's internal clock is moving at a faster rate than an outside clock. This could stem from the person perceiving time is passing in smaller units than external clock time. Baudouin, Vanneste, Isingrini, and Pouthas (2006) posit that when time is estimated using the production method the individual's internal clock speed is the determining factor of how fast or slow the interval produced will be.

If an experimenter is using the reproduction method (Angrilli et al., 1997; Stern, 1959) and a participant reproduces an interval that is longer than the interval he or she was exposed to, this implies that his or her internal clock is moving more quickly than any objective time keeping measures. This suggests that subjective units of time are judged to be larger than the objective clock time during the experiment when the participant is actually reproducing the time interval. For example, if a light is presented to the participant for 5 seconds, an overestimation of the time that the light was lit would mean that he or she would reproduce an interval closer to 8 seconds.

Underestimation due to a quicker moving internal clock would mean that he or she would reproduce a shorter interval of time than 5 seconds. An underestimation during reproduction means that the participant is reproducing a duration of time that is smaller than the one that he or she was exposed to initially. Baudouin et al. (2006) also comment on reproduction by saying that where production is dependent on an internal clock speed, reproduction of intervals relies upon the individual's working memory. Baudouin et al. cite the work of Gibbon, Church, and Meck (1984) who developed the scalar expectancy theory (SET). This theory postulates that there is an internal mechanism that estimates time using three stages. The first stage is the clock stage. At this stage, pulses are delivered to a cell during the duration of time that is to be estimated. At the second stage, the memory stage, the individual’s working memory actively stores the pulses that were accumulated during the clock stage. In the final stage, the decision stage, working memory compares the time interval to previously stored time intervals in reference memory in order to determine the accurate response to the estimation of a time interval. Thus, according to Baudouin et al., production is merely a counting mechanism that results in an estimation of a test interval. Reproduction, however, is dependent on gathering information on the test interval, holding that information in working memory, and then holding it up for comparison against previously encountered intervals, so that the current period of time can be estimated.

Measurement of Internal Tempo Through Finger Tapping

In the field of temporal related research, there are numerous authors who have used the finger tapping method to measure internal tempo (Boltz, 1994; Collyer, Broadbent, & Church, 1994; Denner, Wapner, McFarland, & Werner, 1963; Denner, Wapner, & Werner, 1964; Dosseville, Moussay, Larue, Gauthier, & Davenne, 2002; Kirby, Gupta, & Carr, 1991; Miyaoka, Sato, Takahashi, & Shimada, 1987; Vanneste, Pouthas, & Wearden, 2001). The authors of these studies may call internal tempo by different names (personal tempo, internal rhythm, cardiac and locomotor rhythm), but in the end their definitions still match that of internal tempo.

It is internal tempo that the researchers are hoping to access and measure by using the very simple method of having participants in their studies tap out a rhythm that is comfortable for them. The participant is asked to rest his or her hand on a flat surface. Then the person is asked to tap his or her finger, usually the index finger, at a pace that feels comfortable for him or her. It is that rate that is assumed to be the outward expression of the individual's internal tempo.

While this is the customary and accepted way to measure internal tempo throughout the literature, it should be pointed out that since internal tempo itself is in fact a theoretical mechanism, the method of measuring this mechanism is also theoretical. However, there is evidence from various studies that support finger tapping as a valid measure of internal tempo. Boltz (1994) conducted a study in which one measure that was taken was internal tempo. To gather data on her participants' internal tempos, Boltz asked that they tap out a rhythm that was comfortable for them at pre- and posttest. What she found was that after subtracting the pre-test scores from the posttest scores, the participants in the condition that was intended to induce relaxation had finger tapping scores that were significantly decreased from the rates they tapped prior to the manipulation. Conversely, the participants in the stress condition had finger tapping scores that were significantly faster from their own pre-test tapping rate. Boltz used the data she gathered on finger tapping rates to infer the rate of her participants' internal tempos.

Further evidence for the support of finger tapping as a valid measure of internal tempo comes from a study by Zeitlhofer et al. (1984). For their study, they asked hyperthyroid patients to tap at a rate that was comfortable for them. After the patients had received treatment for hyperthyroidism, they were again asked to tap at whatever rate was most comfortable for them. Zeitlhofer et al. found that there was a significant difference between the rates of tapping pre- and post-administration of medication. Tapping was fastest prior to medication. As in the previous study by Boltz (1994), Zeitlhofer et al. used the data they gathered on finger tapping to draw conclusions about internal tempo. Even though there are studies that lend support to finger tapping as being a valid and reliable measure of internal tempo, there are some gaps in the research in this area. For instance, there is a lack of evidence that internal tempo coincides with reaction time. No research has demonstrated that an individual's reaction time increases or becomes more accurate with a faster internal tempo, as exhibited externally by a fast rate of finger tapping.

Research on the Physiological Impact on Internal Tempo

The research on the physiological impact on internal tempo has shown that changes in the endocrine system (Zeitlhofer et al., 1984), brain (Binkofski & Block, 1996), and body temperature (Hancock, 1993) can alter how time is perceived. Changes in the physiology brought about by stimulants (Bonnet & Arand, 1994) and sedatives (Rammsayer, 1993) have also affected time perception. Because internal tempo is so enmeshed with time perception, it follows that internal tempo would be altered by these changes in physiology as well. One study where this effect is evident was conducted by Binkofski and Block (1996).

Binkofski and Block (1996) studied an individual with damage to his left frontal cortex. In this single-subject examination they reported on the experience of BW, who was admitted to the hospital after complaints of experiencing time as passing much more quickly than had been his previous experience. The patient was given a variety of neurological and neuropsychological assessments and it was determined that BW was suffering from “a left prefrontal cystic lesion surrounded by extensive perifocal edema” (Binkofski & Block, 1996, p. 488). BW was asked to give evidence of his perception of the passage of time. Despite having complained of perceiving time as passing incredibly fast, the subject was appropriately oriented to the date and the day of the week. It was reported that he felt that it was 60 minutes earlier than it actually was. The production method was used on five different days to see if BW could accurately produce an interval of 60 seconds. The mean of these five productions was 286 seconds.

The authors propose a number of explanations as to why BW was having the temporal experiences that he was. They stated that it was possible that BW’s experience was simply a “non-specific effect of brain damage” (Binkofski & Block, 1996, p. 490). They, however, discarded this explanation in the face of evidence by Benton et al. (1964) that other patients with damage to similar areas of the brain had temporal productions that were unlike those given by BW. The participants in the study by Benton et al. had much smaller estimation errors than BW. The patients in the Benton et al. study estimated a 60-second interval and their errors ranged from 21 to 28 seconds. An inappropriate dispersion of attentional resources was also used to explain why BW could not accurately produce a 60-second interval and why he was experiencing time as passing incredibly quickly. This explanation was undermined by the fact that BW had no problem having a conversation with someone. The only explanation that did not suffer from these problems was one that included an internal clock. Binkofski and Block proposed that BW had an internal clock that was producing pulses at a much slower rate than it had previously. Therefore, BW's productions were overestimates because his internal clock was slower than external measures of time.

One weakness of this study is that it uses information obtained from only one individual. The strengths include the identification of specific areas of the brain that can be attributed to the perception of time and that when these areas are damaged, time perception is also altered. This study also lends credence to the idea that an internal clock is present and can be modified by biological means or changes in anatomy. From this we can also surmise that time perception is in some way tied to anatomical and biological factors.

Zeitlhofer et al. (1984) conducted a study with people who were suffering from an endocrine-based condition known as hyperthyroidism. They were studied to see if their perception of time differed significantly from participants not suffering from hyperthyroidism. Hyperthyroidism occurs when too much of the hormones triiodothyronine (T3) and thyroxine (T4) are produced by the thyroid glands. An excessive amount of these hormones speeds up metabolism, which can lead to increased heart rate, breathlessness, and insomnia. The patients with hyperthyroidism were later studied after they received medication to treat their condition.

A comparison between participants' internal tempo, as measured by the finger tapping method, both before and after treatment for hyperthyroidism, showed that the participants' internal tempo was faster before they received treatment and slower after treatment. Before treatment, there were significant differences between the hyperthyroid group's rate of tapping versus the rate of tapping of a healthy control group, the clinical group tapping faster than the controls. Once treatment was administered, the individuals suffering from hyperthyroidism tapped at a rate that was similar enough to that of the control group to the extent that there were no longer any significant differences between the two groups.

Time perception was also measured in both groups using the production method. People in both groups were asked to produce intervals of time that equaled 10 seconds, 20 seconds, and 40 seconds. These findings paralleled those of the finger tapping tests. Before treatment the hyperthyroid patients all produced intervals that were shorter than those produced by the healthy controls. This study provides a clear example of how physiological factors can play a role in internal tempo and as a result in time perception. The results of this study strongly support the working model of the present proposal.

Hyperthyroidism caused definitive, clearly, measured changes in physiology, such as the speeding up of metabolism. By testing for levels of T3 and T4 hormones, hyperthyroidism can also be accurately diagnosed. These two objective measures leave little room to debate whether or not the physiology of the patient is affected. They also can make a statement to the degree to which changes in physiology have taken place. Because this study includes the use of finger tapping, the impact of hyperthyroidism can readily be seen in the rate of tapping. Since the participants who tapped the fastest were the ones who were pre-treatment hyperthyroid patients, it would appear that an increase in the speed of bodily processes speeds up the internal clock.

Because rate of finger tapping of the hyperthyroid patients dropped to rates similar to the rate of tapping of healthy individuals after treatment was administered, it is clear that physiology alone can account for the changes in internal tempo seen in this study. Whether or not the participants were experiencing emotional arousal or depression was not discussed as part of this study. However, even without any psychological interventions, the hyperthyroid patients' rates of tapping matched the rates of the healthy participants after treatment.

Another way to affect the physiological state is through changes in heart rate. Several studies (Hancock, 1993; Hawkes, Joy, & Evans, 1962; Marum, Macintyre, & Armstrong, 1972; Surwillo, 1982) examine how these changes in heart rate are connected to changes in internal tempo. One such study is by Dosseville et al. (2002). The researchers had ten participants tap out a comfortable tempo prior to riding a stationary bicycle for fifteen minutes. Once the exercise session ended, the participants again tapped out a tempo that felt natural. What researchers found was that there were significant differences between pretest and posttest with regards to the participants' heart rates, as well as preferred tapping rates, with both heart rate and tapping speed increasing.

Like the study by Zeitlhofer et al. (1984), the study by Dosseville et al. (2002) provided a clear connection between increased physiological rate and internal tempo. The present model suggests that internal tempo will increase when heart rate increases and this is something that is apparent in the Dosseville et al. study. The heart rates of the participants increased. When internal tempo was assessed by means of finger tapping, it too had increased. Though this study does provide evidence that a measurable physiological change like heart rate can have an equally measurable change on internal tempo, there are two criticisms of this study that most evident.

The first is that because the authors did not control for psychological discomfort that might have been present as a result of engaging in a strenuous physical activity, it is impossible to determine where the emotional influences end and the physical ones begin. A much more minor comment pertains to the lack of a measure of time perception. Once again, this is not a glaring flaw, but an omission that might have provided beneficial information to those interested in how internal tempo affects the judgment of duration.

Another study that looks at how heart rate influences time perception is by Marum, Macintyre, and Armstrong (1972). In this study heart rate was increased, decreased, and maintained by having participants use feedback to match their heart rates to an electronic metronome. Marum et al. found that an increased heart rate contributed to an underestimation of intervals when using the production method. This suggests that when heart rate increases, the internal clock rate increases as well and as has been mentioned before, a fast internal clock leads to shorter estimates of a standard time when participants attempt to produce intervals.

Another study that found underestimations of productions was conducted by Surwillo (1982). Surwillo had participants use the production method to estimate 30-, 60-, and 180-second intervals. What might be considered atypical about this technique is that pulse rates were not recorded during the time estimation tasks themselves. The results showed that individuals who took part in the study who had naturally-occurring “high pulse rates” (Surwillo, 1982, p. 105) consistently underestimated the amount of time they were supposed to produce. This can be interpreted to mean that their internal clocks were moving at a faster rate than those of the participants whose heart rates and internal tempos were slower.

One criticism of this study might be that it was not made clear what quantitative factors defined what constituted a “high pulse rate” (Surwillo, 1982, p. 105). The results are most brought into question by the fact that even though there was a correlation between an increased heart rate and a tendency for overestimation of time, significance was only obtained for the 30 second interval. Finally, these are also ambiguous results due to the fact that participants were allowed to count mentally during the production task. The main reason for this concern is that fact that research on time perception typically focuses on the subjective experience of the passage of time versus the counting of units of the passage of time just like what could be done simply by reading a clock. Though this study did focus on increased heart rate, it actually did not manipulate heart rate itself in order examine what effects these changes had.

A study that does rely on manipulation of physiology was one conducted by Hancock (1993). This study examined how body temperature affected personal tempo. By using a helmet made for the experiment, Hancock was able to warm certain parts of the participants’ scalps, thereby increasing their body temperature. He separated the participants into four different groups. He used a control group who did not have to wear a helmet and were not exposed to heat. A placebo group wore the helmet, but also was not exposed to any heat. The Heat 1 group wore the helmet and experienced mild heat. The final group, Heat 2, experienced the greatest heat.

After the heating took place, participants were asked to produce intervals of 1, 11, and 14 seconds. Hancock found that the control, placebo, and mild heat groups all produced overestimations of the intervals. Once the heat was increased into a more severe range, Heat 2, the participants then underestimated the duration of the intervals they were asked to produce. The author of this study surmised that body temperature does have some effect on internal tempo. If this is the case, it suggests that no heat and mild heat conditions led to internal clocks that were moving more slowly that an external measure of time, which led to their judgments of temporal units to be greater than the objective segments of time. The participants who experienced a greater degree of heat might have had internal clocks that were going at a faster rate than the standard clock time. This was exhibited in their underestimations of the duration of the intervals they were asked to produce. Based on the results of this study, it is evident that increases in body temperature can lead to changes in time perception in the same way that increases in heart rate and changes in hormone levels can affect time perception.

These studies have focused on changes in physiology that occur because of brain tumors, endocrine disorders, various alternations in heart rate, body temperature. Binkofski and Block (1996) found that a brain tumor caused a patient to greatly overestimate a 60-second interval. Zeitlhofer et al. (1984) found that the rate of finger tapping of patients who had hyperthyroidism was significantly faster than the rates of healthy participants, and that once the hyperthyroidism was treated, the rates of tapping of both groups was no longer significantly different. Dosseville et al. (2002) demonstrated that increases in heart rates resulted in parallel increases in finger tapping rates of participants who rode a stationary bike. Hancock (1993) increased the body temperature of his participants and found that those who had the highest temperatures were also those who underestimated time by the production, implying a faster internal clock. These results all demonstrate that changes in physiology have a discernable impact on internal tempo.

Because drugs can also alter physiology, it is important to discuss how they can impact internal tempo and time perception. Hawkes, Joy, and Evans (1962) examined the effects of drugs (methamphetamine HCL, D-amphetamine SO_4, phenylpropanolamine HCL, chloropromazine HCL, mecamylamine HCL, and lactose) on participants' judgment of short durations of time. It was predicted that these drugs would have an effect on the participants' physiological responses, including respiration and heart rate. What they found was that increases in these two physiological functions correlated significantly with changes in the participants' estimation of time.

The participant's heart rates and respiration rates were increased. When participants produced these intervals that ranged from 0.5 seconds to 4 seconds they underestimated the intervals. As previously stated, when an interval is produced that underestimates the stated time provided to the participant, the working model states that his or her internal clock is going faster than the external clock. These data support a model of an internal clock that is moving at a faster rate than the standard clock time. This study does suggest changes in internal tempo are a direct result of the administration of drugs.

Rammsayer (1993) focused on how sedative drugs affected internal tempo and time perception. Rammsayer discussed arousal in terms of what occurs in the brain versus how heart rate and respiration rates change due to physiological arousal. Rammsayer administered 15 milligrams of the benzodiazepine midazolam to participants. He then had them perform an auditory discrimination of intervals to measure both time perception and estimation. For testing time perception, the duration of the intervals was in milliseconds. For time estimation, the intervals were in seconds.

The results of time perception portion of Rammsayer's experiment, which is defined in his study as the processing of information in the millisecond range, was not affected by the presence of benzodiazepines in the participants' systems. Conversely, there was a difference in the way that participants performed in the time estimation task. The results showed that individuals who received the midazolam overestimated the amount of time that the experimental interval actually was. Because their estimates of that interval got longer, within the frame of reference of internal tempo, the suggestion is that the participants' internal clocks were going more slowly once the sedative agent was administered and was therefore having an effect on their ability to correctly gauge how much time was truly passing during the experimental interval. A final measure was taken to determine participants' self-rated level of alertness, energy, and concentration. Both energy and alertness were subjectively rated as being negatively affected, whereas concentration was not.

Rammsayer was very thorough in his examination of how the body reacts to drugs in its system. Not all studies go into such extensive detail; however they still adequately address the issue of how drugs affect time perception. Bonnet and Arand (1994) do this in the book *Sleep Onset: Normal and Abnormal Processes*. In one chapter, Bonnet and Arand discuss perceived and actual sleep latency and how these were affected by sedatives and stimulants. The chapter states that a typical problem for individuals suffering from insomnia is that their perception of how long it takes them to fall asleep is very different from the perceptions of those who are normal sleepers. Two studies reviewed by Bonnet and Arand found that when participants were given benzodiazepines, the ratio between their subjective and objective sleep latency ratios went down. This means that the length of time that the participants felt that it took them to fall asleep was closer to the actual amount of time that it took them to finally fall asleep. This suggests that an internal time keeping mechanism was more closely approximating the objective clock time. So with an internal tempo that was moving faster than the standard clock time, participants might previously have felt that it took them ten minutes to fall asleep, when in fact it only took five minutes. This is due to the individuals overestimating time. Sleep deprivation also brought down the ratio between subjective and objective sleep latency.

Caffeine increased participants' sleep latency ratios (Bonnet & Arand, 1992), as would be anticipated after the administration of a stimulant. In terms of internal tempo, this suggests that individuals who consumed caffeine had an internal clock that was even more discrepant than people who took a sedative like a benzodiazepine. Their internal tempos were moving at an even faster rate, as evidenced by the estimation of even larger units of time which have the effect of making it seem as though time is passing even more quickly. So in the case of caffeine, verbal overestimation of sleep latency occurs and with sedatives the estimation of time was closer to the actual amount of time that it took them to fall asleep, overall reducing or eliminating the overestimation of sleep latency.

Though it is reasonable to assume that if a stimulant can cause an increase in heart rate, and consequently, verbal overestimations of time, suggesting that the internal clock is moving faster than the outward clock, this is not always a safe, straightforward assumption, as is demonstrated in a study by Engle and Graney (2000). Engle and Graney dealt with the physiological and psychological effects of therapeutic touch (TT). They found that after the participants had received TT, their heart rates and blood pressures were both anticipated to be reduced. What actually happened though was that the participants' heart rates decreased, while their blood pressure increased. The participants produced a measure of 40 seconds both at pre- and posttest. The results showed that participants significantly underestimated the interval after TT was administered. This lends credence to the hypothesis that heart rate has a significant impact on internal tempo, even regardless of other bodily processes. The increase in heart rate seen in the participants in this study could have resulted in a faster moving internal clock compared to the objective measure of time. Because of this speeding up of internal tempo, time seemed to be moving at a faster pace for the participants in this study.

So it is apparent from the array of studies reviewed in this section that physiology can have an impact on an individual's internal tempo. The route that is taken to affect physiology may be different in many of these studies, but the result was often the same. An individual's own personal rhythm can be made to speed up or to slow down generally in accord with increased or decreased rates of physiological processes, the result of which is that his or her perception of time changes. Though not all studies included a "direct" measure of internal tempo by measuring rate of finger tapping, the conclusion can be drawn that changes expressed in time perception through verbal estimation, production, and reproduction occur as the result of changes in internal tempo.

As these studies demonstrate, physiology can have a definitive impact on internal tempo as demonstrated either through time estimation methods or through finger tapping. Though an increase in heart rate was a factor in several of the studies, changes in brain structure caused by a tumor had similar effects as changes in heart rate. Based on these findings, it is possible to draw the conclusion that physiology does have some effect on internal tempo and to go a step farther, it might be possible to conclude that an increase in heart rate leads to an increase in internal tempo.

The studies that follow came to conclusions that run counter to the results found by the majority of authors presented here. Though there is not typically a straightforward explanation as to why these investigators found the results that they did, they must at least be discussed. Perhaps it is even more important that these sorts of studies are brought to light due to the fact that they make obvious the need for further research into this area of study.

In 1959, M.H. Stern examined how the thyroid might be affecting the participants' performance and speed on certain activities. Hypothyroid patients would be expected to perform more slowly than healthy controls. Researchers tested patients with hypothyroidism both before and after treatment on four tasks (speed of tapping, reaction time, time estimation, and leg lift persistence). In addition, hyperthyroid patients, clinic patients, and normal controls provided comparison groups. Hypothyroid patients had a faster speed of tapping, greater reaction times, and underestimated time on a reproduction of a 15-second interval before treatment of their hypothyroidism was administered. Once treatment was given, the patients' performances in all areas more closely mirrored that of the control group. This is unusual given that the expectation would be that the hyperthyroid patients would have these results instead, as was found by Zeitlhofer et al. (1984). Furthermore, the performances of normal controls were faster than that of both hypothyroid and hyperthyroid patients.

Another way to likely influence an individual's physiological state is through the administration of sedative medications. In a 1971 study, Adam, Rosner, Hosick, and Clark had participants inhale an anesthetic to determine if this altered their perception of time, implying that changes in production of brief time intervals also changes, or is the result of alterations in, internal tempo. While the anesthetic gas was being administered, the participants’ heart rates, body temperature, and respiration rates were being monitored.

Adam et al. (1971) found that while the participants were attempting to produce intervals equal to 20, 40, and 60 seconds, their productions were too long. In other words, they overestimated the amount of time in the intervals that they were supposed to be producing. With regards to internal tempo, this implies that the participants' internal clocks were moving at a slower rate than the external standard clock was moving. As previously stated, several physiological measures were taken during the delivery of the anesthetic. No significant changes in physiology were recorded in any of the participants during the inhalation of the anesthetic and the subsequent overestimation of duration.

Ague (1974) also attempted to alter physiology by using nicotine to increase his participants' heart rates. Ague tested how inhalation of nicotine would affect his participants' heart rates, skin temperature, forearm blood flow (FABF), skin conductance, and time estimation. What he found was that after nicotine was administered, heart rate, FABF, and skin conductance all increased significantly, mostly during the first ten minutes after nicotine inhalation and slowly returning to normal within the hour. Skin temperature was the only variable to decrease significantly. Estimates of time were also affected. Ague found that his participants significantly overestimated the 3-minute intervals they were supposed to produce, implying that their internal clocks had slowed down. This of course runs counter to the expectation that a stimulant like nicotine would speed up a person's internal clock. However, because the effects on non-smoking controls were not tested, no direct connection could be established between the participants' tendency to overestimate and nicotine exposure. It could be that any one of the dependant variables alone, or in any combination, could be influencing the perception of time.

In this study, the participants smoked four cigarettes with varying amounts of nicotine in them. One of the cigarettes actually contained no nicotine at all. The participants who did smoke cigarettes containing nicotine all experienced overestimations of a 5-second interval, however the same participants also overestimated a 5-second interval during pre-testing. Even though these two time periods were both significant, they were not compared to each other to determine if there were a significant change. Additionally, because the subjects were all accustomed to smoking at least five cigarettes a day, the absence of nicotine for the eight hours preceding the study may have had some unforeseen effect on the results.

Curton and Lordahl (1974) performed an experiment in which they manipulated the heart rates and attentional levels of their participants, with physical exercise, and with the threat of shock. They further divided these two groups into two more subgroups. One subgroup was to accurately connect lettered dots in alphabetical order. The other subgroup connected numbered dots in their appropriate numerical order.

Curton and Lordahl cited several authors, including Cahoon (1969), Hawkes, Joy, and Evans, (1962), and Marum, MacIntyre, and Armstrong (1972) as examples of studies that found that an increase in heart rate corresponded with increases in verbal estimates of time. Because of these findings, the researchers expected to find that in their study, as heart rate increased, the participants' written estimation of the time it took them to complete the alphabetical or numerical connect-the-dot task would also increase. They also predicted that the numerical task would lead to more accurate estimations of time because it would simulate counting.

Some of the expectations of this study were not met when the results were analyzed. The authors found that the effects of increased arousal, whether due to exercise or threat of shock, when combined with complex or simple tasks could not reliably predict their participants' estimates of time. However, the results did show that exercise increased heart rate more effectively than threat of shock, but there were no time estimates taken post-exercise that did not include the distracter tasks.

Finally, the goal of a 2002 study by Stine, O'Connor, Yatko, Grunberg, and Klein was to examine the effects of caffeine on the estimation of time. Stine et al. (2002) suggested that various levels of caffeine would produce different effects on the accuracy of judgment of durations. Their theory was that there would be an inverted U-shaped figure that would result from none, low, and high doses of caffeine, with accuracy being best at the peak of the U where caffeine consumption was moderate. There were no significant effects of caffeine consumption on time estimation.

As previously stated, these particular studies do not neatly fall into categories that clearly support the hypothesis put forth by the present study. It is important, however, to know where there are discrepancies and gaps in the literature. Though this study may not fill in all those gaps and clarify inconclusive results, it is still helpful to know what ground has already been covered by other studies and what results have emerged from them. At the very least, these studies serve to help other investigators aware of possible confounds, alternate findings, and diverse interpretations of results. This can only serve to improve current studies.

Research on the Psychological Impact on Internal Tempo

Because the working model of this proposal is that physiological arousal can account for the effects of an increase in internal tempo independently from emotional arousal, it is important to review exactly how emotional arousal can affect internal tempo. Research in the area of psychological factors that influence time perception has found that stress (Edmonds, Cahoon & Bridges, 1981; Greenberg & Kurz, 1968; Harton, 1939; Schiff & Thayer, 1968), relaxation (Boltz, 1994; Gupta & Cummings, 1968), boredom (Troutwine & O'Neal, 1981), anxiety and depression (Falk & Bindra, 1954; Hawkins, French, Crawford, & Enzle, 1988; Langer, Wapner, & Werner, 1961), and environmental factors (Boltz, 1994; Ozel, Larue, & Dosseville, 2004; Rai, 1975) also impact time perception. Angrilli et al. (1997) examined the impact of emotional arousal on time perception. In this experiment, the researchers examined how affective factors, specifically valence and arousal, might influence time perception. Participants were shown slides that were associated with a certain degree of emotional arousal. While they were viewing the slides, their heart rates and skin conductance responses (SCR) were monitored. Even though the heart rates of the participants in the study were monitored, the information was not used to make a determination of physiological arousal. The participants then judged how long they were exposed to the slides by reproducing the amount of time they believed to have passed.

Based on the results, the authors conclude that there are "two different patterns of time estimation, one activated in low-arousal situations, and the other in high-arousal ones that show an opposite behavior at positive and negative valence levels" (Angrilli et al., 1997, p. 978). This is noteworthy because the authors cite literature that suggests that when participants view negative/low and high arousal slides, which would be considered threatening and therefore allotted more attention, participants would normally underestimate the given intervals. What the experimenters found was that underestimation of the intervals took place when negative/low arousal slides were presented. However, this same effect occurred when positive/high arousal slides were viewed by participants. In addition to this finding, the results showed that overestimation occurred under negative/high arousal and positive/low arousal viewing conditions.

This discovery is what led to the assertion that there are perhaps two different paths for the estimation of time with regards to emotional factors. It is possible that the negative/low arousal slides were not distressing and that the positive/high arousal slides had a soothing effect. That could explain why their presentation resulted in underestimations, which suggests a slow internal tempo. The negative/high arousal slides could have caused a greater level of distress than any other combination of factors, leading to an increase in heart rate and a faster internal tempo. The positive/low arousal slides may have increased heart rate simply piqued the participants' interest as opposed to being calming like the positive/high arousal slides. In this instance, there is an inability to definitively point to either emotional or physiological arousal as having an influence on time perception and internal tempo. As a result, the emotional and physiological factors are intertwined and lack a clear delineation of which parts influence the end result of the expression of time perception.

As has been demonstrated by several studies, one way to look at how judgment of duration is affected is to look at anticipation. Certainly there are many different sorts of emotions that can go hand in hand with anticipation. Anxiety and fear most definitely fall into this category, but these are specific emotional responses that will be explored in more depth in the discussion to follow. Strict anticipation is the current focus, specifically the expectation of success or failure (Harton, 1939), pleasant or unpleasant sensory occurrences (Schiff & Thayer, 1968), and positive or negative experiences (Edmonds, Cahoon, & Bridges, 1981).

In a study by Harton (1939), participants were either led to believe that their performance on a series of mazes would end in success or failure. The results demonstrated that those individuals who expected that they were going to succeed at the tasks verbally underestimated the amount of time they spent working on the mazes. The opposite was found in the group that was anticipating failure on the task. Their verbal estimates were judged to be longer (i.e. overestimation) than the duration of the actual time spent working on the mazes.

The author did not discuss these results in terms of internal tempo, but his results might suggest that the internal clocks of those in the success category were moving slower than those in the failure category.

A study by Schiff and Thayer (1968) had participants both reproducing and verbally estimating an interval during which they were anticipating smelling a pleasant, unpleasant, or neutral-smelling substance. In their results, Schiff and Thayer discovered that the particular smell made no significant impact on the participants' estimation of time. What they did find was that waiting, in general, seemed to produce overestimates of verbal estimations and reproductions. With both verbal estimation and reproduction, overestimation of a stated interval could suggest that the participants' internal clocks had been sped up. The results that were found with verbal estimation and reproduction might be the consequence of both, or either, emotional or physiological arousal.

In the study conducted by Edmonds, Cahoon, and Bridges in 1981, participants were told that they were going to experience either a positive, negative, or neutral emotional event during the course of the study. The significant results were associated with the shorter of the two intervals measured, an interval of 60 seconds, versus the longer interval of 240 seconds. Participants who were anticipating a positive emotional experience judged the interval during which they waited for the experiment to commence to be longer than it actually was. Their verbal overestimation suggested that their personal rhythms were going at a faster rate than objective time. The participants who were anticipating a negative or a neutral situation judged the 60-second interval to be shorter than it actually was. This underestimate might mean that their internal tempos were slower than the external measure of time.

There were also several studies that looked specifically at how boredom affects judgment of duration. In the first study under discussion, Geiwitz (1964) attempted to determine the effects of how hypnotically induced states of boredom affected judgment of 5-second and 10-second intervals in a single male participant. Geiwitz found that the more bored the participant was, the more time he felt had passed. When he was the most bored, his productions of the intervals were significantly overestimated. The suggestion is that his internal tempo was moving slower once boredom was initiated through post-hypnotic suggestions.

Gupta and Cummings (1968) looked at state of mind to see if that might have an influence on internal tempo. The study examined the differences in time perception of individuals who underwent hypnosis to induce relaxation versus those who used progressive muscle relaxation. A control group was also added for comparison purposes. Verbal estimation was the method used for measuring time perception in this study. The results of the study found that the group that received hypnosis underestimated the sample intervals. Another way of describing this phenomenon would be to say that their participants' internal tempos were moving slowly when compared to an external clock. Neither the progressive muscle relaxation group nor the control group experienced any significant distortion in time judgment.

Troutwine and O'Neal (1981) sought to moderate boredom by offering the participants a choice in what task they were to perform. All participants initially heard the same audiotaped information. Then the group was broken into two separate groups. The participants in one group could choose to continue listening to an audiotape after they were told they had already fulfilled the requirements of the study or they were given the choice to leave immediately. This was the volitional group. The participants in the other experimental group were simply told that they would be hearing another audiotape and were not given a choice whether or not to continue. This was the non-volitional group. The volition and non-volition groups were then broken into two more groups. One of the new subgroups listened to a boring tape, while the other listened to an interesting one. All participants were asked to produce a five-minute interval. Participants who were in the boring condition of the group that had no choice but to stay and listen (non-volition) produced longer intervals than those in the interesting condition within the non-volition group. The overestimation of the elapsed five minutes in the non-volition/boring condition suggests a slower internal tempo than the internal tempos of participants in the non-volition/interesting group. There were no discernable differences between the volition/interesting and volition/boring groups, perhaps suggesting that participants who chose to stay might have convinced themselves that the boring audiotape was not as boring since they had chosen to stay, making their estimates of time more like those of the participants who listened to the interesting audiotape.

While Troutwine and O'Neal (1981) observed the effects of low-arousal, boring situations, Greenberg and Kurz (1968) examined what would happen under more high-arousal conditions such as stress. This study looked at how stress and the sex of the participant might influence the judgment of how long a card sorting task took. Both men and women were asked to engage in sorting cards from the Wisconsin Card Sorting Task. The hypothesis was that males would be more responsive to failure in a timed task. What the authors found was that men, when compared to women under the same experimental condition, in the timed condition who were led to believe they were failing the task verbally estimated the duration of the task to be shorter than it actually was. This underestimate might mean that their internal clocks moved more slowly than objective clocks. The authors suggested that the stress of the time constraints on the task as well as the men's desire to achieve was responsible for the results. In this instance, the men who were led to believe they were failing the task were the ones to verbally underestimate the interval, and as previously stated, this could mean that their internal tempos were moving at a slower pace than objective clock measures.

Not only stress, but other mental states can influence physiology. Though depression and anxiety are psychological disorders and not simply mood states, their effect on physiology and on time estimation could be significant. One study that discusses the effects of a depressed mood is by Hawkins, French, Crawford, and Enzle (1988). Participants looked at cards that were supposed to generate happy, sad, or neutral moods. Then the participants engaged in a card sorting task and were left alone in the room to continue the task for either thirteen minutes or four minutes. Once the session was over, they were asked to rate how long they objectively and subjectively felt they were left alone in the testing room while they were sorting the cards. The objective measure was accomplished by asking participants to “indicate” how much time they felt they spent on the card-sorting task. The participants were then presented with the subjective assessment, which was a 9-point scale. They were asked to choose a number between one and nine that best described how quickly or slowly time seemed to pass while they were sorting the cards. Point one was labeled “very slowly” and point nine was labeled “very quickly.” When they compared the two groups of scores, they found that the participants' objective measures of time were not significantly affected by their mood state. The experimenters found that when comparing the three groups (happy, sad, or neutral mood groups) for a subjective estimation of time, the depressed affect group significantly underestimated the intervals when compared to both the happy and neutral mood groups. The authors suggested that subjective estimates of time are influenced by different factors than objective estimates. This could be one explanation for the results. The end result is that an internal clock could be moving more slowly than external measures of time. In this study, the participants’ subjective estimates that time passed “very quickly” or “very slowly” might have more reliably corresponded to internal tempo than did their objective estimates because the intervals they were asked to estimate were so long. The length of the test intervals (thirteen or four minutes) may have been allowed participants enough time to cognitively separate their subjective feelings of how much time passed from their objective estimates of time. If this is the case, the length of the test intervals could be seen as a confound to this study.

Another area of research that pertains to time perception has to do with examining situations where fear is the main factor influencing time perception. Langer, Wapner, and Werner (1961) induced anxiety in their subjects by having participants stand on a motorized cart that took them toward the edge of a stairwell or took them away from the same stairs. Those participants in the perceived dangerous situation produced five second intervals that were shorter than the actual intervals. Though no measure of heart rates were taken by the experimenters, it is likely that when the individuals felt that it was possible that they might fall into the stairwell, their heart rates increased. This would be a logical assumption based on the human fear response of fight or flight. This increase in heart rate could have led directly to an increase in internal tempo as evidenced by the fact that they produced underestimations of the time interval. It was possible that the results were the consequence of the participants in the dangerous situation having an internal tempo that was moving faster than objective measures as a direct result of an increased heart rate due to fear or anxiety for their safety.

Another study that might have made participants question their safety was a study in 1963 by Hare. He sought to address the possibility that previous studies' results where there was a threat of shock to create an anxious state was due to anticipatory anxiety and not just the fear of actually being shocked. To this end, the electrodes were removed from the participants' fingers during the nonanxiety conditions where no shock was received after participants verbally estimated 5-second and 20-second intervals. An anxiety condition was included where participants did wear the electrodes that delivered the shock once the intervals were estimated. The results showed that those in the shock condition verbally judged the intervals to be longer than they actually were, meaning perhaps that their internal clocks were running faster than those who did not receive shocks. Again, this overestimation could be attributed to physiological changes that came about as the result of the circumstances of the study. Since the participants in the shock condition did not receive a shock until after their estimation of the 5- and 20-second intervals, it is apparent that merely the threat of shock was enough to increase their internal tempos. As a person anticipates a painful event occurring, their heart rates are likely to increase. This could be a plausible explanation for the verbal overestimations due to fast paced internal time keeping mechanisms seen in the results. Hare was able to effectively create anxiety in his participants with the threat of potential for harm.

Falk and Bindra (1954) also created anticipation of a harmful event in their participants, but the manner in which they created a fear for safety differed. Falk and Bindra attempted to create an effect on their participants' production of a fifteen second interval when they were either anticipating an electrical shock or not anticipating one. What they found was that anticipation of the shock did not have a significant effect on the participants' produced amounts of time.

Lundberg, Ekman, and Frankenhaeuser (1971) designed a similar study where participants anticipated an electric shock. The participants were first given a mild shock and then told that in forty-five minutes they would receive a shock that was five times the intensity of the one they just received. As part of the study, heart rate, emotional intensity, and subjective estimates of the passage of time from the first shock administration to the end of the forty-five minutes when the next shock was anticipated were measured. What the authors found was that some participants overestimated the interval between when they first received a shock and when they anticipated the next shock. They also found that other participants underestimated the same interval.

Emotional intensity and heart rates followed a similar trend. Emotional intensity and heart rates both increased as the time for the second shock came closer. The forty-five minute period was both over- and underestimated by the participants. This study is included because it demonstrates both that emotional intensity and heart rate can be affected by an induced anxious state and that these two factors can influence time perception, even if at the end of the study it is indeterminate as to how this perception is affected.

Rao and Mythili (1979) set out to determine if manifest anxiety in their participants had any relationship between rate of finger tapping and/or time estimation. Their anticipated results were that participants who scored highest on a measure of manifest anxiety would verbally overestimate 10-, 20-, and 50-second intervals. The participants who were most anxious were also predicted to tap at a faster rate than those who were less anxious. What they found was that there was no difference between the individuals who were experiencing high, medium, and low levels of anxiety and their rate of finger tapping. Significant results did occur when the verbal estimates of the three intervals was examined for the high anxiety group. These participants estimated the intervals as being longer than they actually were. This could mean that their internal clocks were moving faster than those of the other two groups, even though the finger tapping measure did not demonstrate any significant difference between these groups, so in this instance, time estimates and finger tapping did not correlate. The authors provided no theory as to why this discrepancy existed. However, one explanation might be that emotional arousal was acting independently from physiological arousal and was acting in a way that was not able to be measured by finger tapping.

Finally, Watts and Sharrock (1984) investigated the effect of having participants who experienced spider phobia estimate the amount of time they spent in the presence of a spider during the experimental condition. There were two conditions in this test. The first had the spider in a container that was deemed a "safe" distance away by the participant. In the second condition, the spider was moved closer to the participant, but still in a range that was considered "safe" by the participant. During each trial, participants were in the presence of the spider for forty-five seconds and then asked to verbally estimate how long the trial had lasted. Significant results were found only in the second condition where participants gave longer verbal estimates of how long they looked at the spider. Again this sort of overestimate suggests an internal tempo that is moving faster than the external clock, and this could be because the closer the spider was, despite still being a "safe" distance away, might have increased participants' heart rates. Since the experimenters only used verbal estimations in their study, there is no information on how finger tapping might have been affected and what that data might say about internal tempo.

Rai (1975) investigated how employees in quiet versus noisy working conditions and length of time each spent in these conditions (one year to twelve years) affected their ability to accurately verbally estimate a 60-second interval. The participants were shown a lamp that was lit for 60 seconds and were then asked how long they felt the light had been lit. What he found was that those who worked in noisy conditions and had worked under those conditions the longest had the longest durations. This result indicates that the participants who had worked in the noisy conditions the longest had internal tempos that were going faster than the objective clock time. He suggested that his results could be explained by the association between the internal tempo and the metabolisms of the workers in these environments had changed due to the greater level of and exposure to noise. Those who worked in noisy environments were thought to have experienced changes in metabolisms which led to parallel changes in internal tempo. Because the participants expressed time estimates that were longer than the 60-second interval provided, it is assumed that their internal clocks were moving faster than the external clock. This would account for their verbal estimates of the interval being so much longer than it actually was.

Boltz (1994) subjected her participants to situations in which they heard incoherent, coherent, or continuous noises. Incoherent noises were ones that had very little predictability in their nature, e.g., the random screeching of monkeys or the sound of a person crying. Coherent sounds were of a more repetitive, therefore more predictable, type, e.g., a person running or chewing cornflakes. Continuous sounds did not change pitch during the time that it was presented, e.g., an electric saw being operated.

In between the presentation of the incoherent, coherent, and continuous auditory conditions, the participants were exposed to one of two types of sounds. One was of a calm and peaceful beach where waves were washing on the shore. The other was of a car horn honked intermittently in the background. While participants listened to sounds of the beach, they were to imagine that they were relaxing on a calm, serene beach. This was obviously intended to induce a state of relaxation in the participants. While the other group, who were listening to the sound of a car horn honking, was asked to imagine that they were in a library attempting to work on a paper due the next day.

The point of exposing participants to the three types of noise and then either inducing relaxation or agitation was to determine if arousal state had an effect on how accurately they remembered the durations from first exposure to the second. The participants were then asked to accurately recall the duration of a sound (incoherent, coherent, and continuous) they heard when they were exposed to the same sound after the initial trial session. This was made even more difficult because the previously heard sound was presented along with two distracter sounds that were either 20% shorter or 20% longer in duration than the sound they heard originally. What Boltz found was that participants remembered durations best when the sounds were coherent and that the incoherent sounds were remembered the least well. The participants' ability to remember continuous sounds fell between their memory performances with coherent and incoherent sounds. Participants' memory of all coherent and continuous durations was the worst under stressful conditions, but did not vary significantly when they attempted to remember the duration of the incoherent noises, nor was performance affected under relaxation conditions. Additional results demonstrated that by using the finger tapping method to assess her participants' internal tempos, Boltz found that internal tempos were significantly decreased under the “beach” condition and increased under the “honking horn” condition. As the results of these studies demonstrate, certain environmental conditions such as noisy working environments, stressful working conditions, and relaxing conditions are factors that can have a significant influence on judgments of duration by affecting physiology. Changes in physiological state typically cause parallel changes in internal tempo, either speeding up or decreasing internal tempo as physiological arousal decreases or increases.

Ozel, Larue, and Dosseville (2004) examined how a stressful auditory environment would affect their participants' arousal and consequently, their production of a 10-second interval. In their study, all participants did specified tasks under a "noisy "condition as well as a "non-noisy" condition. The authors reported that they had their participants listen to the sounds of gunfire, fighting, and motocross for 20 minutes in the "noisy" condition. During that time, the participants' first task was to use a stopwatch to produce a 10-second interval. Their second job was to walk at a pace that was comfortable for them toward a traffic cone that was 10 meters away from their starting position. When they took their first step, they started a stopwatch and stopped it with their last step. For the final task, the participants imagined themselves walking toward the same target, but did not actually do any walking. Again, they pressed the stopwatch when they took their first imaginary step and stopped the stopwatch with their last imaginary step.

Ozel et al. (2004) found that participants significantly underestimated the interval in the noisy condition. The presumption made by the authors was that the noise level caused a change in arousal level, which led to the speeding up of their participants' internal clock, which would account for the underestimation of the produced intervals. The only drawback with these results is that the authors did not attempt to address specifically what they meant by "arousal." Because the sounds the participants were exposed to were considered stressful, psychological arousal might be the cause of the changes in estimation. Physiological arousal could easily be the explanation as well though. Since the authors did not use any mechanisms to measure changes in heart rate or instruments to determine if emotional changes occurred as well, it is impossible to tease these two factors apart. What also might have been helpful for the interpretation of the study would have been an inclusion of a measure of internal tempo such as finger tapping, as Boltz (1994) did in her study.

These studies demonstrate numerous ways that psychological state can be influenced. What was found was that feelings of success or failure, boredom, stress, relaxation, anxiety, and depression can all have some effect on estimation of time. What is noteworthy about these studies is that their results can be interpreted in physiological terms. Even though the goal of the studies was to examine how a psychological state influences estimations of time, plausible explanations for changes in estimations of intervals can be found based on increases or decreases in heart rates of the participants. Most studies (Boltz, 1994; Hare, 1963; Langer et al., 1961) that examined psychological impact supported the working model of this proposal. There were other studies that were unable to provide similar support (Falk & Bindra, 1954; Hawkins et al., 1988). The results in the studies that focus on the effects of psychological arousal have more variability than the results in the studies that focus on physiological arousal. With the physiological arousal studies (Zeitlhofer et al., 1984), there are clear changes that occur that can be easily measured. How these changes affect internal tempo and time perception are straightforward. This is not a trend seen in the results of studies related to psychological arousal (Angrilli et al., 1997). Because fewer definitive studies exist on how psychology affects internal tempo and time estimation, more research needs to be done to account for the effects of psychological, while at the same time taking into account the effect of physiological state. This is an important issue considering both can have an effect on the estimation of time.

CHAPTER III

THE PRESENT STUDY

Literature Summary and Current Study

It is evident that there are indeed areas in this field of study that require further investigation. For instance, in much of the research that has been done to determine how psychological states, such as general anxiety or the anticipation of an unpleasant event, affect internal tempo and thereby, time perception, it is sometimes difficult to know where the influences of emotional arousal end and those of physiology begin. In these studies, changes may be seen in participants' expressions of time; however it is difficult to know where these changes originate. This is because any means of examining changes in perceptions of time relies on some outward expression of internal tempo, and as can be seen in the literature previously outlined, there are a number of variables that can affect internal tempo. Clearly, there are psychological states that can instigate changes in this personal rhythm (Boltz, 1994; Edmonds et al., 1981; Harton, 1939; Schiff & Thayer, 1968; Troutwine & O'Neal, 1981). Just as clearly though, there are physiological states that can change these rhythms equally well. Examples of both these manipulations can be seen in Angrilli et al. (1997), Binkofski and Block (1996), Watts and Sharrock (1984), and Zeitlhofer et al. (1984).

Watts and Sharrock (1984) did indeed produce differences in expressions of the passage of time in their participants by inducing phobic responses. Angrilli et al. (1997) were also successful in changing participants' judgments of the passage of time based on emotionally laden pictures. The authors even added another layer to their study by examining participants' heart rates as they viewed the pictures. What these authors were able to do was to manipulate their participants' emotional states, leading to a change in the judged duration of brief intervals, which leads to the conclusion that somehow internal tempo must also have been affected. This could lead the casual reader to believe that emotion is the guiding force behind most people's own individual rhythm.

Though Binkofski and Block (1996) and Zeitlhofer et al. (1984) did not focus on psychological state at all, they definitely saw changes in expression of time perception in their studies. By looking at how time perception changed based on hyperthyroidism as Zeitlhofer et al. did, or by the presence of a brain tumor like Binkofski and Block, these authors demonstrated that there is definitely some physical component that affects internal tempo. Several other authors found similar results. Dosseville et al. (2002) increased participants' heart rates by having them ride a stationary bicycle. Afterwards, they found that the participants' rate of finger tapping had increased. This implies a parallel increase in internal tempo. Marum et al. (1972) had their participants attempt to match their heart rates to the sound of an electronic metronome. They found that after the participants' heart rates were increased, they underestimated sample intervals when using the production method. Again, this suggests that internal tempo was sped up and thereby had an influence on time estimation. Though Hancock (1993) did not measure changes in heart rate, he manipulated physiology by increasing the body temperature of his participants. His results were that production underestimations occurred in participants who were exposed to the greatest amount of heat. Though this study did not look at heart rate specifically, there is still a physiological component that suggests that physiological arousal will lead to increases in internal tempo, which then affects time estimation.

These studies demonstrate that though emotional arousal does seem to play a role in increasing internal tempo, altering an individual's physiology, specifically increasing arousal, has a more predictable effect. This effect is that the person experiences a faster moving internal tempo than the external clock, so that when he or she attempts to accurately estimate that passage of time the fast internal clock is manifested with fast finger tapping and can also be observed in the three methods of time estimation. With verbal estimation, a fast internal clock would manifest as verbal overestimations. Overestimations in reproduction also suggest a faster moving internal tempo, whereas underestimations of productions typically mean a fast internal tempo. Increasing a person's physiological arousal is also a much more reliable way of changing arousal level. As previously stated, level of emotional arousal is typically measured by subjective self-reports.

Because self-reports are very subjective, it could be difficult to determine level of emotional arousal since one person's level of distress may be much greater than another individual's. However, their self-reports may reflect a similar emotional state. Physiological arousal can be measured by objective, external means. This also suggests that by measuring level of physiological arousal researchers can more accurately predict how internal tempo will be affected.

There are a large number of significant results to be found in the experiments outlined here and elsewhere, but what is lacking is a study that controls for the effects of physiology and mental state on internal tempo. As can be seen in studies like those by Binkofski and Block (1996), Zeitlhofer et al. (1984), Dosseville et al. (2002), Hancock (1993), and Marum et al. (1972), physiology alone can change a person's internal tempo. However, there are also studies that focus on emotional arousal (Angrilli et al. 1997; Greenberg & Kurz, 1968; Langer, Wapner, & Warner, 1961; Lundberg, Ekman, & Frankenhaeuser, 1971). The problem with studies like these is that if participants are anxious about the potential for injury (Langer, Wapner, & Warner, 1961) or the threat of shock (Lundberg, Ekman, & Frankenhaeuser, 1971), it is likely that their physiological states have been altered. Presumably their arousal levels would increase, which could mean that their heart rates, respiration, and blood pressure all might have increased. Because studies like these typically focus on either physiological or emotional arousal, it is necessary to design a study that will address both of these issues because studies continue to have one or the other uncontrolled for and act as a confound. Does internal tempo stem from psychological or physiological state? These are questions that have remained unanswered. These are also questions that the current study endeavored to address. To determine whether or not physiological arousal can account for the effects on internal tempo and time estimation independently from emotional arousal, the proposed study attempted to increase physiological arousal alone, increase emotional arousal independent of physiological arousal, and combine the effects of physiological and emotional arousal. With the inclusion of these three groups, as well as a group that did not have either their physiological or emotional state manipulated, it was possible to determine what effects physiological and emotional arousal have on internal tempo and time perception when these two arousal states are independent from one another. This design also facilitated determining what effect an interaction between physiological and emotional arousal will have.

To address the issue of increasing physiological arousal, participants were asked to engage in a "step test." The step test is discussed in an article by Brouha (1943 as a means to activate the respiratory and cardiac systems. This manipulation served to increase heart rates. To accomplish the task of raising the participants' emotional state, a segment from the movie "Marathon Man" was shown. This particular portion of the movie has been described as being sufficient to increase emotional distress in a very short span of time (J. Chaney, personal communication, April 12, 2006).

For the present study, there were four groups, three experimental and one control. The participants in the control group were asked to stand for the duration of the testing session, an interval of 71 seconds. The control group (control) did not have either their emotional or physiological state influenced. The first experimental group, referred to as the physiological arousal group (PA), did the step test. They also watched a segment from "The Secret Life of the Brain" discussing language development in children. This was a neutral stimulus, which was not intended to influence the participants' emotional state. The second experimental group, also called the emotional arousal group (EA), only had their emotional state manipulated by watching a segment from the movie “Marathon Man.” The participants in this group did not do the stepping task, but instead stood while watching the movie segment. The third, and final, experimental group, which will is also called the combined arousal group (CA), engaged in both the step test to increase their physiological arousal and at the same time, they were shown the distressing movie segment from "Marathon Man.”

Prior to these manipulations, all participants had their heart rates, internal tempo, and emotional state and emotional intensity levels measured. Internal tempo was measured using the finger tapping method. The participants were asked to tap out their preferred tempo. Pretest emotional arousal levels were measured using the Self-Assessment-Manikin (SAM) which consists of "two 9-point visual scales representing cartoon-subjects ranging from sad to happy (emotional state) and from calm to activated (emotional intensity)" (Angrilli et al.,1997).

After these measures were taken, the participants performed the tasks commensurate with the group to which they belonged. All of the measures that were taken prior to the experimental manipulation, or participation in the control group, were again administered (i.e., measurement of heart rate, internal tempo, emotional state, and emotional intensity). In addition, two final measurements were taken. The participants were asked to produce a 13-second interval by pressing the space bar on a desktop computer. They were also asked to verbally estimate how long they believed the duration of the testing interval to have been. The first main hypothesis of this study was that increased heart rates, whether accomplished by physiological or emotional arousal, would lead to faster internal tempos, which would manifest as verbal overestimations of the passage of time. The second main hypothesis was whether physiological arousal could account for speeding up of the internal clock independently from emotional arousal.

Hypotheses

Hypothesis One: Stepping will increase heart rate.

Hypothesis Two: The distressing DVD segment will increase heart rate.

Hypothesis Three: Stepping will increase emotional arousal.

Hypothesis Four: The distressing DVD segment will increase emotional arousal.

Hypothesis Five: Stepping will increase internal tempo.

Hypothesis Six: The distressing DVD segment will increase internal tempo.

Hypothesis Seven: Stepping will lead to an underestimation in temporal production and a verbal overestimation of the temporal interval.

Hypothesis Eight: The distressing DVD segment will lead to an underestimation in temporal production and a verbal overestimation of the temporal interval.

It is important to remember that all of the following predictions are based on the experimental groups having been compared to the control group. Therefore, because each of the experimental groups and the control group manipulated physiological and emotional arousal differently, the expectation was that it would be apparent whether the greatest changes in heart rate, and therefore internal tempo and time estimation, occurred when physiology was manipulated, when emotional state was manipulated, or whether it was a combination of both of these factors. It was anticipated that the PA group, who engaged in the step test, but did not have their emotional state manipulated, would have a consistent increase in heart rate when evaluated against the comparison of the EA group to the control group. This increase in heart rate, due to physiological arousal, should also have led to increases in internal tempo and in the amount of verbal overestimations and underestimations in production. If physiology is better than emotion at increasing internal tempo and thereby affecting time perception, then significant results would only have been found with the PA group. If emotional and physiological changes are truly independent from one another, then significant changes would have been seen in internal tempo, production, and verbal estimations in the EA group when emotional arousal alone was manipulated. This observation would have established the separate nature of these two arousal states since participants in the EA group only had their emotional state manipulated, whereas participants in the PA group only had their physiological state altered.

CHAPTER IV

METHODS

Participants

Ninety-eight participants were recruited from Oklahoma State University (OSU) human subject pool using Experimetrix. In exchange for their participation in the study, they received credit for the class they were enrolled in. The age range for recruitment was 18 to 30. The age range for participants who actually took part in the study was from 18 to 25. The data from six participants was not used in this study, but was used only as part of a pilot study. The results included data from fifty women and forty-two men, for a total of 92 participants whose data was included in the analysis. The control group consisted of 15 women and 11 men. The PA group was made up of 9 women and 13 men. The EA group had 9 women and 12 men. The CA group consisted of 17 women and 6 men. Participants self-identified their ethnic background. Seventy-eight Caucasians, 7 African-Americans, 4 Native Americans, 2 Hispanics, and 1 Asian participated in the study. Because this study required the participants to engage in brief physical activity, with the goal being to increase heart rate, participants were asked that they be healthy enough to participate. Due to their impact on physiological arousal, participants were excluded from the study if they had a history of smoking, diabetes, hyperthyroidism, hypothyroidism, hypertension, hypotension, irregular heart rate, previous heart attack, or pregnancy. In addition, participants were excluded based on whether or not they were taking certain medications. These medications included heart, blood pressure, and asthma medications. Because one of the goals of this study was to examine emotional and psychological influences, participants were excluded based on whether or not they were receiving treatment for any mental health issues at the time of the study.

Apparatus

Heart Rate

Heart rate was measured by using an Omron HR100 heart rate monitor. The monitor is designed to be worn just below the pectoral muscles or the breasts. The monitor is composed of a flexible rubber transmitter that is attached to an adjustable elastic band. The information produced by the monitor is relayed to a wrist unit that displays a digital readout of the heart rate. The Omron HR100 monitor is reliable to within three beats per minute of the heart. A verbal report regarding the method the Omron HR100 uses to calculate heart rate stated that the monitor counts the number of beats of the heart that occur within a one minute time frame. That information is then transmitted to the wrist unit (Omron Represenative, personal communication, December 7, 2007). For the present study, the monitor took readings of the participants' heart rates prior to them engaging in the step test and immediately upon finishing the step test. The heart rates are recorded and reported in beats per minute (bpm).

Measures

Self-Assessment Manikin.

To assess the participants' emotional arousal level both before and after the initiation of the step test, the Self-Assessment Manikin was used. "The Self-Assessment Manikin (SAM) is a non-verbal pictorial assessment technique that directly measures the pleasure, arousal, and dominance associated with a person's affective reaction to a wide variety of stimuli" (Bradley & Lang, 1994, p. 49). The SAM uses "two 9-point visual scales representing a cartoon ranging from sad to happy (emotional state) and from calm to activated (emotional intensity)" (Angrilli et al., 1997).

The individual taking the SAM looks at five cartoon faces that indicate an emotion. There is one space between each of the faces for a total of five faces and four blank spaces. The person taking the SAM is then asked to circle any number, 1 through 9, on the scale below the face or blank space of the one that best represents their own emotional state. The same pattern is used for the emotional intensity scale, which is directly below the emotional state scale. On the emotional state scale, the number one is paired with a sad face and the number ten is paired with a very happy face. On the emotional intensity scale, the number one is paired with a sleepy face and the ten is paired with a figure that is very excited (Appendix C). The SAM has been found to have reliability that ranges from .63 to .82 for emotional state and .98 for emotional intensity with alpha at .88 (Backs, Silva, & Han, 2005). For the data analysis, the number that the participant circled at pretest and then again at posttest was used as a representative of their emotional state and intensity.

Procedure

All testing was conducted in the Developmental and Psychophysiology laboratory at OSU. Testing of one participant at a time took approximately fifteen minutes. Participants were provided with a copy of the consent form, which was thoroughly reviewed by the researcher prior to the beginning of the testing session. Participants were given a physical health, mental health, and medication screener (Appendix A), as well as a demographic form (Appendix B).

Some participants who failed to meet criteria were provided with credit for participation, but still continued with testing. The data from these individuals as well as data from other participants used as pilot data. As previously stated, there were six participants' whose data was included in the pilot study, but was not used in the analysis of the data. For those participants who met criteria whose data was used, baseline measures of heart rate, internal tempo, and emotional state and intensity were taken. Participants were then asked to engage in a "step test". The step test is discussed in an article by Brouha (1943), in which he described it as a means to activate the respiratory and cardiac systems. In this test, the participant steps up onto a platform with one foot. The second foot then joins the first on the platform. The participant then steps down one foot at a time back onto the ground. This is a very straightforward way of increasing the participants' heart rates, which was monitored during the test. For this study, the participants engaged in the step test for 71 seconds.

Regardless of experimental conditions, all participants' heart rates, internal tempo, emotional state, and emotional intensity were measured at pretest and at posttest. Internal tempo was measured using the finger tapping method. The participants were asked to tap out their preferred tempo for 30 seconds on the space bar of the keyboard on a desktop computer.

Immediately after the group-determined tasks, all of the measures that were taken prior to the instigation of the step test, were once again administered (i.e., measurement of heart rate, internal tempo, emotional state, and emotional intensity) at the end of the 71-second interval. After these measures were taken, the participants were asked to produce a 13-second interval by pressing the space bar on a desktop computer. The duration in seconds that the participant pressed the space bar was used in the data analysis. Finally, the participants were asked to verbally estimate in seconds how long they believed the duration of the step test to have been.

Analysis

The purpose of this study was to determine whether or not increased heart rates, accomplished by either physiological or emotional arousal, led to faster internal tempos, which were expected to manifest as verbal overestimations and production underestimations of the passage of time.

The design was a 2 (Emotional Arousal: Distressing DVD versus Neutral DVD) X 2 (Physiological Arousal: Stepping versus Standing) mixed-subjects factorial design, which is a between groups measure, with six dependent variables. A one-way analysis of variance (ANOVA) was performed on each of the dependent variables (heart rate, internal tempo, emotional state, emotional intensity, verbal estimation, and production). Heart rate, internal tempo, emotional state, and emotional intensity were measured both at pre- and posttest. They were converted to pretest and posttest change scores. Post hoc Tukey tests were also performed.

CHAPTER V

RESULTS

Hypothesis One and Hypothesis Two

The first hypothesis was that stepping would increase heart rate from pre-test to post-test. It was expected that the PA group and the CA group would show increases in heart rate when compared to the control group. The second hypothesis was that the distressing DVD segment will increase heart rate. Thus, the EA group should show a significant increase relative to the control group. The dependent variable manipulated for both hypothesis one and hypothesis two is the change in heart rate from pre-test to post-test. A one-way ANOVA was conducted between the PA, EA, CA, and control groups on the dependent variable change in heart rate from pre-test to post-test There was a significant main effect for group, $F(3, 88) = 22.776$, $p < .001$, eta-squared = .44, power = 1.00;

A follow-up Tukey analysis was conducted between the control and CA groups ($p < .001$), control and PA groups ($p < .001$), control and EA groups ($p = .989$), CA and PA groups ($p = 1.000$), CA and EA groups ($p < .001$), and PA and EA groups ($p < .001$). This represents every combination of comparison groups. These are the comparisons relevant to both hypothesis one and hypothesis two.

These are the comparisons relevant to both hypothesis one and hypothesis two. The results of the Tukey test were that a comparison between the control group and the CA group, between the control group and the PA group, between the EA and CA groups, and between the EA and PA groups was significant at $p < 0.001$. The comparison between the EA and control groups was not significant, $p = .989$.

These results demonstrated that participants' heart rates in both of the stepping condition groups increased significantly when compared to the control and EA groups; the EA group did not show a significant heart rate increase. A summary of means and standard deviations for these groups can be viewed in Table 1. The first hypothesis was supported. Based on the results of the data analyses, the stepping manipulation worked in the way it was intended, namely, to significantly increase the heart rates of the participants. Hypothesis two was not supported by the data.

Hypothesis Three and Hypothesis Four

The third hypothesis was that stepping would increase emotional arousal. It is important to note that in this case, arousal can mean either an increase or a decrease in emotional state. The direction of a shift in emotional state is not as relevant as the fact of whether or not arousal took place at all. However, it was anticipated that the distressing DVD would bring about a decrease in emotional state. Emotional intensity signifies how strongly the emotional state is affected, or how intensely participants experience a given emotional state. Increases in emotional arousal were expected to have been seen in the PA, CA, and EA groups, if stepping did have a measurable effect on emotional arousal. The fourth hypothesis was that the distressing DVD segment would increase emotional arousal. If this was the case, then emotional arousal would have been seen in the EA and CA groups. The dependent variable manipulated for both hypothesis three and hypothesis four is the dependent variable emotional arousal, as seen in emotional state and emotional intensity.

A one-way ANOVA was conducted between the PA, EA, CA, and control groups on the dependent variable of emotional state change from pre- to post-test using the Self-Assessment Manikin (SAM). There was a significant main effect for group, $F(3, 88) = 3.781$, $p < 0.013$, eta-squared = .11, power = .80. A one-way ANOVA was conducted between the same groups on the dependent variable of emotional intensity. There were no significant main effects for this variable $F(3, 88) = 0.82$, $p = 0.488$, eta-squared = .03, power = .22.

A follow-up Tukey analysis was conducted between the control and CA groups ($p = .600$), control and PA groups ($p = 1.000$), control and EA groups ($p = .017$), CA and PA groups ($p = .686$), CA and EA groups ($p = .298$), and PA and EA groups ($p = .029$). This represents every combination of comparison groups for emotional state. These are the pertinent comparisons for hypotheses three and four. The results of the Tukey test were that there was a significant difference ($p = .02$) between the control and EA groups for emotional state. A comparison between the EA and PA groups for emotional state also revealed that these two groups were significantly different from one another at $p = .03$. A comparison between the control group and the PA group was not significant for emotional state, $p = 1.000$, or for emotional intensity, $p = .971$. Within the EA group, emotional state moved in the negative direction, while emotional intensity moved in a positive direction. This means that participants felt strong negative emotions in the EA groups. In the PA group, emotional state moved in a positive direction and emotional intensity moved in a negative direction. To say this differently, participants felt positive emotions, but the intensity was weak and was not statistically significant.

These results, in addition to the means and standard deviations, showed that the emotional state of the participants in the EA group was significantly affected when compared to the PA groups. The PA group did not show a significant change in emotional state. There were no significant differences between groups for emotional intensity. Hypothesis three was not supported by the data; however, hypothesis four was supported. What this means is that the participants' moods were significantly changed by the distressing DVD, but that the level and intensity of the moods they were feeling was not significantly changed.

Hypothesis Five and Hypothesis Six

The fifth hypothesis was that stepping would increase internal tempo. If stepping did have an effect on internal tempo, then increases in internal tempo would have been seen in the PA and CA groups in comparison to the control group. The sixth hypothesis was that the distressing DVD segment would increase internal tempo. If this was the case, the EA and CA groups would have demonstrated increases in internal tempo when compared to the control group. The dependent variable manipulated for both hypothesis five and hypothesis six is the change from pre- to post-test in internal tempo. A one-way ANOVA was conducted between the PA, EA, CA, and control groups on the dependent variable of internal tempo, as measured with the finger tapping method. There were no significant main effects for group $F(3, 88) = 0.86$, $p = 0.468$, eta-squared = .03, power = .23. This data for internal tempo do not support hypotheses five or six. Neither stepping nor the distressing DVD increased internal tempo.

Hypothesis Seven and Hypothesis Eight

The seventh hypothesis was that stepping would lead to an underestimation in temporal production and a verbal overestimation of the temporal interval. Verbal overestimations of a 71-second interval and production underestimations of a 13-second interval would have been seen in the PA and CA groups when compared to the control group. The eighth hypothesis was that the distressing DVD segment would lead to an underestimation in temporal production and a verbal overestimation of the temporal interval. This would have been seen when the EA and CA groups were compared to the control group. The dependent variables manipulated for both hypothesis seven and hypothesis eight are the changes from pre- to post-test in production and verbal estimation. A one-way ANOVA was conducted between the PA, EA, CA, and control groups on the dependent variable of production. There were no significant main effects for group $F(3, 88) = 0.55$, $p = 0.653$, eta-squared = .02, power = .16. A one-way ANOVA was also conducted between the same groups on the dependent variable of verbal estimation. Again, there were no significant main effects for group $F(3, 88) = 1.36$, $p = 0.271$, eta-squared = .04, power = .34.

These results, the means, and standard deviations all showed that participants' production and verbal estimation in all of the testing conditions was not significantly affected when compared to the control group. Based on the results of the analysis of the data, neither stepping nor the distressing DVD had an effect on production or verbal estimation. Therefore, hypotheses seven and eight were not supported by the data.

CHAPTER VI

DISCUSSION

The goal of the present study was to fill gaps that exist in literature regarding the way in which internal tempo interacts with both physiological and psychological states. While there is a great deal of research in the area of time, time perception, and internal tempo, there seems to be very little information regarding a readily apparent way to distinguish between physiological and psychological effects on a person's internal tempo. Even though there is a broad range of research in the area of time perception, there is a lack of specific focus on how internal tempo can be affected by physiological and emotional states.

There are some studies, however, that manipulate the physiological state to determine how internal tempo might be affected. A study by Dosseville et al. (2002) suggested that heart rate might influence internal tempo. When rate of finger tapping was compared at pre- and posttest, the results showed that after riding a stationary bike, which resulted in an increase in heart rate, their participants' rates of tapping had also increased, demonstrating an increase in internal tempo. One major limitation of this study, however, was that their participants' emotional states were not measured.

In a study that did take into account how emotional state might affect time perception, Angrilli et al. (1997) found evidence based on research by Damasio (1997) that emotion is an indispensable part of mental processes (Angrilli, Cherubini, Pavese, & Manfredini, 1997, p. 972). To address the idea that emotions and mental processes go hand in hand, Angrilli et al. examined how affective factors might influence time perception by exposing their participants to emotionally arousing visual slides. Next, participants were asked to give a time estimate for a duration of time that they were exposed to after the emotional arousal manipulation. The results that pertained to the estimation of time did not reach significance. One piece of information that might have been useful in determining why the estimates were not significant was information on the participants' physiological state. This could have been a physiological measure such as participants' heart rate, blood pressure, or respiratory rate. Because the study by Angrilli et al. did not address this issue, it was difficult to determine what effect, if any, physiological arousal had on time perception. Additionally, in the study by Angrilli et al., internal tempo was not measured.

What can be seen in both the Angrilli et al. (1997) and the Dosseville et al. (2002) studies is the gap that is left by the literature. Not taking into account participants' emotional states or their physiological states prevents making a clear statement about the true effect an increased emotional state or heart rate can have on internal tempo. With the aforementioned study and others like them, leaving out a measure of internal tempo also limits the conclusions that can be drawn about data on time perception and how physiology and emotion can affect internal tempo.

The present study attempted to disentangle how physiological and emotional arousal, either independently or in combination, influenced internal tempo and time perception. If emotional and physiological arousal states affect internal tempo and time perception independently from one another, then significant production underestimations and verbal overestimations would coincide with an increase in internal tempo. To determine what is influencing internal tempo; one experimental group would have their heart rates, alone, increased. Another group would only have their emotional state aroused.

If internal tempo, and thereby time perception, relies upon emotion via activation of physiological processes, such as increased heart rate, then a group that is manipulated both emotionally and physiologically would have significant increases in heart rate, internal tempo, production underestimations, and verbal overestimations. These results would indicate an interdependence between emotional arousal and physiological arousal in how they affect internal tempo and time perception. In an attempt to tease apart the effects of emotional arousal from the effects of physiological arousal on internal tempo, several hypotheses were proposed in this study.

Hypothesis One: Stepping will increase heart rate.

Hypothesis one, that stepping would increase heart rate, was supported by the analyses. When the dependent variable of heart rate was analyzed using a one-way ANOVA between the PA, EA, CA, and control groups, a significant main effect was found for group. When a post-hoc Tukey test was conducted between all the experimental groups, the results were that a comparison between the control group and the CA group, between the control group and the PA group, between the EA and CA groups, and between the EA and PA groups was significant. These results showed that the heart rates of the participants in both of the stepping manipulation groups (PA and CA) were significantly different from the control and EA groups. Since both hypotheses one and two are manipulating the dependent variable of heart rate, the results of the ANOVA and Tukey tests are the relevant analyses for hypothesis two as well. An examination of the means of the EA and control groups revealed that the heart rates in these two groups were similar enough to make them nearly identical. As expected, the PA and CA groups had greater increases in heart rate than the control or EA groups.

Hypothesis Two: The distressing DVD segment will increase heart rate.

This hypothesis was not supported by the analysis of the data. The same one-way ANOVA that was described as the analysis for hypothesis one was conducted on the dependent variable of heart rate. As stated above, a significant main effect was found for group and a Tukey test revealed that only the groups that stepped, the PA and the CA groups, experienced a significant change in heart rate. This did not coincide with the expectation of hypothesis two that an increase in heart rate would be observed in the EA, as well as the CA groups.

The analyses demonstrated that heart rates were increased by the manipulation of having groups engage in the step-test. Heart rate was significantly increased by having the participants engage in physical exercise in both the present study and in the study by Dosseville et al. (2002). The groups that stepped (PA and CA groups), regardless of what DVD they watched, had the greatest increase in heart rates. The distressing video, however, did not increase heart rate.

Hypothesis Three: Stepping will increase emotional arousal.

The hypothesis that stepping will increase emotional arousal was not supported. A one-way ANOVA was conducted on the dependent variable of emotional state, and there was a significant main effect for this variable. The results of a follow-up Tukey test demonstrated that there was a significant difference between the control and the EA groups. There was also a significant difference between the EA and PA groups. These results show that the emotional states of the participants were affected by the distressing DVD and not by stepping. If stepping had increased emotional arousal, then the groups that would have been affected would have been the PA and the CA groups. Because the statistical power was equal to .80, it is not likely that an increase in sample size would produce different results.

A one-way ANOVA was also conducted on the dependent variable of emotional intensity. This time, there were no significant main effects. After a visual examination of the means, it appears that none of the manipulations had an impact on emotional intensity. Thus, data for emotional intensity also did not support hypothesis three. The statistical power of this analysis was equal to .22. This suggests that greater sample size would yield different results. However, since the emotional state scale did have power that reached the .80 level, it is also possible that a larger sample size would have no effect on the emotional intensity scale. Angrilli et al. (1997) had much higher significant effect of emotional state $F(1,49) = 1058.528$, $p < 0.0001$ (p. 976). They also obtained very high significant effect for emotional intensity $F(1,49) = 138.91$, $p < 0.0001$ (pp. 976-977). It is possible that they found these results because the slides that they exposed their participants to were better at eliciting stronger emotional responses. For example, one slide was of a body of a dead human being. Another slide was of two naked individuals.

Hypothesis Four: The distressing DVD segment will increase emotional arousal.

The hypothesis that the distressing DVD segment would increase emotional arousal was supported by one scale on the SAM, but not on both scales. A one-way ANOVA was conducted on the dependent variable of emotional state and a significant main effect was found. The post-hoc Tukey tests showed that there was a significant difference between the control group and the EA group. This is what would be expected if the distressing DVD did increase emotional arousal. This was further confirmed by the significant difference between the EA and PA groups. A one-way ANOVA was conducted on the dependent variable of emotional intensity. There were no significant main effects for this variable. The means for the groups implied that none of the manipulations had an effect on the groups for emotional intensity. This means that hypothesis four was not supported by the data for emotional intensity. Since emotional arousal was increased in a negative direction, as seen in the emotional state data, this means that the level of distress the participants were feeling when their mood was changed by the “Marathon Man” DVD was not significantly changed. The results seen in the discussion regarding hypotheses one, two, three and four demonstrated that the manipulations worked in the way they were intended. Stepping alone did not decrease emotional state. Stepping did not negatively affect emotional state. In both cases of physiological and emotional arousal, both manipulations worked in the way they were intended to. They also did not have a negative impact on the other.

Hypothesis Five: Stepping will increase internal tempo.

The hypothesis that stepping would increase internal tempo was not supported. A one-way ANOVA was conducted on the dependent variable of internal tempo. There were no significant main effects for this variable. The PA and CA groups would be expected to have means that revealed an increase in internal tempo. This was not the case however. The control group and the PA group have means that are very similar. Statistical power was equal to .23, so it is possible that if the sample size were increased that stepping would then be found to increase internal tempo. It was anticipated that stepping would have the effect of increasing internal tempo similar to what was seen in Dosseville et al. (2002). However, their results may stem from the fact that their participants rode a stationary bicycle for a total of 15 minutes in between the times that their internal tempos were measured. Since the participants in the present study only stepped for a total of 71 seconds, it is likely that if they were asked to step for a longer duration of time, internal tempo would be increased, as was found in Dosseville et al.

Hypothesis Six: The distressing DVD segment will increase internal tempo.

The hypothesis that the distressing DVD segment would increase internal tempo was not supported. A one-way ANOVA was conducted on the dependent variable of internal tempo. As in the discussion of hypothesis five, there were no significant main effects for internal tempo and the means across the groups were all similar.

Despite the fact that both manipulations did what they were designed to do, they still did not significantly affect internal tempo. An increase in heart rate did not result in faster internal tempo. Since there were no significant effects on internal tempo with significant increases in heart rate, which represents physiological arousal, and significant decreases in emotional state brought about by watching the distressing DVD, which is emotional arousal, neither physiological arousal nor emotional arousal or a combination of these two factors significantly affects internal tempo. These results were puzzling, considering other studies found that internal tempo was changed by both physiological means (Zeitlhofer, Saletu, Stary, & Ahmadi, 1984; Hancock, 1993; & Dosseville, Moussay, Larue, Gauthier, & Davenne, 2002) and by emotional state changes (Boltz, 1994).

Since the statistical power was so low (power = .23), the lack of significance found in these results could potentially be the result of a small sample of participants. Similar to the explanation regarding the lack of increase in internal tempo with the stepping manipulation, the absence of an increase in internal tempo with the distressing DVD might be the result of too brief of an exposure to the material. Boltz (1994) was able to achieve changes in internal tempo based on emotional arousal. However, her participants were subjected to the sound of a car horn honking or the sound of waves on a beach for a duration of 5 minutes. Again, since participants in the present study were only exposed to the emotionally laden material for 71 seconds, it is possible that this duration was not long enough to initiate a change in internal tempo and that it would have occurred had the testing interval been longer.

Hypothesis Seven: Stepping will lead to an underestimation in temporal production and a verbal overestimation of the temporal interval.

This hypothesis was not supported. Stepping did not lead to production underestimations or to verbal overestimations. A one-way ANOVA was conducted on the dependent variable of production and on the dependent variable of verbal estimation. Neither of these variables had significant main effects. With both production and verbal estimation, if hypothesis seven had been supported, then evidence of this would have been seen in the PA and the CA groups. Statistical power in both cases was very low (verbal estimation power = .34, production power = 16). The natural assumption is that increasing sample size would be the best way to solve this problem. Just as in the previous hypotheses, another explanation for the lack of supportive results could be the fact that the participants simply did not engage in the step test long enough to have an effect on internal tempo or either of the time estimation methods.

Hypothesis Eight: The distressing DVD segment will lead to an underestimation in temporal production and a verbal overestimation of the temporal interval.

This hypothesis was not supported. Stepping did not lead to production underestimations or to verbal overestimations. As stated above, a one-way ANOVA was conducted on the dependent variables of production and of verbal estimation. Since there were no main effects for either variable, it was evident that the distressing DVD segment did not lead to production underestimates or to verbal overestimates. A larger sample size (verbal estimation power = .34, production power = 16), longer exposure to the distressing material (Angrilli et al., 1997, Boltz, 1994), and a higher degree of distressing material (Angrilli et al.) might provoke production underestimates and verbal overestimates.

Strengths and Weaknesses

It must be noted that the manipulations in the present study are much narrower compared to those in other studies. This does not need to represent a weakness in this study however. For example, Angrilli et al. (1997) exposed their participants to several different time intervals (2, 4, and 6 seconds). The participants were asked to rate how long each interval was on two different scales (analog time scale and button press). Five different slides were presented that were described as pleasant, high arousal slides; pleasant, low arousal slides; neutral slides; unpleasant, high arousal slides; and unpleasant, low arousal slides. Two different rating of emotional state and intensity were gathered using the Self Assessment Manikin (SAM) at two separate points in the study. Participants also wore electrocardiogram lead electrodes to measure heart rate and electrodes on two fingers to gather data on skin conductance responses (SCR’s). At the conclusion of the study, participants then filled out a debriefing questionnaire to determine if they had understood the experiment instructions. The present study might seem simplistic in comparison to the study by Angrilli et al. given all the factors that were taken into consideration. While the greater number of variables in Angrilli et al. study might make it appear to be more complete, this might not, in fact, be the case.

As previously stated, participants were asked to report the duration of a testing interval on an analog time scale and with a button press by means of reproduction. Again, though they did obtain significant main effects for time estimation and the present study did not reveal significant main effects for production or for verbal estimation. Angrilli et al's. results might not be as conclusive as they first appear, however. The present study used the retrospective method of time estimation. This means that participants were unaware that they would be required to estimate temporal intervals until those intervals were over. Two criticisms arise from the study by Angrilli et al. with regards to their time estimation results. First, their study was prospective in design, which means that participants knew from the beginning of the experiment that they would be asked to estimate certain time intervals. Additionally, the analog scale began at zero seconds and ended at ten seconds. It would not take an astute observer to deduct from the starting and ending points on the scale that the interval to be estimated was less than eleven seconds. This, in addition to the prospective design, could have led to greater accuracy of the estimates, which resulted in significant main effects for time estimation. Another point of contention is the results of SAM.

While the results of the SAM in the present study only reached significance for emotional state ($F(3, 88) = 3.781$, $p < 0.013$) and not for emotional intensity ($F(3, 88) = 0.82$, $p = 0.488$) it is possible that the methodology that produced these results was the more appropriate when compared to the manipulations used by Angrilli et al. For instance they might have arrived at the results they did because of the repeated exposure to the different kinds of slides. If a participant was exposed to slides of a naked couple, an erotic couple, a kissing couple, a baby with an eye tumor, a smashed face, a dead cut body, a spider on bananas, a rat, and a dead cow, it is possible that emotional state and emotional intensity would eventually be affected simply because of the nature of the slides and the anticipation of what the next slide might be. Finally, the results could simply have been the due to the cumbersome nature of dealing with the electrocardiogram lead electrodes and finger electrodes that the participants were required to wear.

Another dependent variable that did not reach significance in the present study was that of internal tempo. This was surprising, considering Zeitlhofer et al. (1984), Boltz (1994), and Dosseville et al. (2002) all found an increase in internal tempo based either on physiological or emotional manipulation. Zeitlhofer et al. measured internal tempo in hyperthyroid patients both prior to administration of medication for treatment of the disorder and after treatment had been received. One component that was absent from their study was a measure of emotional state. While it is true that anxiety can be a result of the hormonal changes that occur with hyperthyroidism, the participants in their study may have been anxious, and therefore had an increase in internal tempo, because they had recently been diagnosed with an illness that could potentially require them to take medications every day for the rest of their lives. Because there is no measure of emotional state prior to treatment and once treatment had been administered, it is difficult to attribute the increase in internal tempo simply to physiological change.

The study by Boltz (1994) could also lead to questions regarding the results. Boltz reported that she was able to significantly increase her participants' internal tempo after inducing stress through exposure to a car horn honking and guided imagery where the participants were asked to visualize that they were in a library trying to complete an important school paper. She also stated that she was able to decrease participants' internal tempo by having them listen to the sound of gentle waves on a beach and imagining that they were relaxing alone on that beach. It is possible that even though Boltz was able to affect internal tempo it may have been through means other than stress or relaxation.

Instead of stress, Boltz could have been measuring the level of frustration, irritation, or anger that she created in her participants because of the sound of the horn honking and the imagery involved in that manipulation. A related effect may have been seen in the relaxation group. Perhaps, Boltz induced boredom in participants instead of relaxation and therefore internal tempo was influenced by a different emotion than the one intended. Additionally, frustration, irritation, anger, and boredom may all have affected the results since Boltz exposed her participants to 48 trials of coherent, continuous, and incoherent sounds. As previously mentioned, even though the present study might appear simple in nature, perhaps it is comprised of more appropriate manipulations that reduce the chance of measuring and being influenced by factors that were not anticipated.

Dosseville et al. (2002) also found increases in internal tempo, however, this was after physiological manipulation as opposed to induced emotional arousal, as Boltz (1994) did. Because Dosseville et al. were interested in the influence of circadian rhythms, they had ten participants engage in a 15-minute cycling exercise five times a day for five consecutive days. The earliest testing session was at 6:00 AM. The last testing session was at 10:00 PM. One factor that could have influenced that heart rates and internal tempos of the participants was that they could have been upset at having to engage in the experiment so many times over a short span of time. They might have been excited to have the day's testing completed at 10:00 PM. They might also have been angry to be required to be at the testing location at 6:00 AM. One strength that the present study can claim is its brevity. Participants were never engaged in the testing session for more than 15 minutes. Also, the current study's narrower scope may have led to more accurate results than might have been found in similar studies.

The present study has several other strengths. The main strength pertains to the physiological and emotional manipulations. The step-test did exactly what it was intended to do. It increased the heart rates of the participants. In using the Self-Assessment Manikin to measure the emotional states of the participants, it was found that the groups who watched the distressing DVD, “Marathon Man”, did experience a significant decrease in emotional state. Again, the distressing DVD had the effect that it was anticipated to have on the participants. Both of these results suggest that it was not either manipulation that failed, but some other factor. Even though this is a comment about a weakness in the study within a statement about strengths, it is important to note that pointing out a gap in research, pointing out an area that had previously gone undetected, is one major strength of the present study.

Unfortunately, there are also many limitations in this study. The lack of significant results could be attributed to the small sample size. It might be possible to achieve results that make a statement regarding internal tempo if more subjects were included. It is possible that another test of emotional state would yield results that would give different or more information about emotional arousal and internal tempo. Also, it is apparent that in order to achieve results that were similar to some of the reviewed literature, a longer duration of exposure to both physiological and emotional manipulations would be helpful in achieving the results that were anticipated. Having participants view material that is more emotionally provocative would also likely result in significant results for emotional intensity.

Future Directions

Future studies could address some of the limitations previously discussed A larger sample size and a different test for emotional state could prove useful in future research. It would be useful to have participants engage in some physical activity for a greater length of time in order to see an effect on internal tempo and time perception tasks. Increasing the physical activity to five minutes might achieve the desired result without having the effect of provoking a negative response in participants in reaction to the greater length of the exercise. Also, to see more effects as the result of emotional arousal, different materials could be used to stimulate an emotional response. It would be difficult to determine what would achieve a stronger emotional response without disturbing the participants.

Finally, in the area of neuropsychology, if studies conclude that it is physiology that is the determining factor for internal tempo and time perception, then it might be interesting to conduct fMRI or PET scan studies that focus on finding out if there is a particular region of the brain that is responsible for time perception. With this sort of concrete evidence, it might even be possible when examining the results of fMRI's or PET scans to visually observe why individuals from different cultures experience time differently from other cultures.

In conclusion, this study demonstrates a clear need for further research into the area of internal tempo and time perception. Even though the present study was unable to find conclusive results regarding the impact physiological and emotional arousal have on internal tempo, the very lack of evidence points to other factors that remained unaccounted for within the realm of time perception and internal tempo.

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APPENDICES

Appendix A

Demographic Form

Subject ID#:_______

Gender: M F Age: ____________

Ethnic Background: ________________

Do you currently smoke? Y N

Has a medical doctor ever treated you for or diagnosed you with:

Diabetes	Y	N
Hyperthyroidism	Y	N
Hypothyroidism	Y	N
Hypertension	Y	N
Hypotension	Y	N
Irregular Heart Beat	Y	N
Heart Attack	Y	N

Are you currently taking medications to treat any of the previously listed conditions? Y N

Current Medications (Including over the counter medications and/or herbal supplements)

Medication Purpose

____

____

____

Are you currently pregnant? Y N

Are you currently receiving treatment from a mental health professional? Y N

Appendix B

Exclusion Criteria

DIABETES

People with type 2 diabetes produce insulin; however, the insulin their pancreas secretes is either not enough or the body is unable to recognize the insulin and use it properly. Individuals with type 1 diabetes do not produce insulin in their pancreases.

- Frequent urination
- Excessive thirst
- Extreme hunger
- Unusual weight loss
- Increased fatigue
- Irritability
- Blurry vision

HYPERTHYROIDISM

Hyperthyroidism means your thyroid makes too much thyroid hormone. It controls your metabolism, which is how your body turns food into energy. Having too much thyroid hormone can make a lot of things in your body speed up or you may have no symptoms at all.

Symptoms

- Feel nervous, moody, weak, or tired.
- Have hand tremors; have a fast or irregular heartbeat; or have trouble breathing, even when you are resting.
- Sweat a lot, and have warm, red skin that may be itchy.
- Have frequent and sometimes loose bowel movements.
- Have fine, soft hair that is falling out.
- Lose weight even though you are eating normally or more than usual.

HYPOTHYROIDISM

Hypothyroidism is a lack of thyroid hormone. It develops when the thyroid gland does not produce enough of the hormone, which controls the way the body uses energy. A lack of thyroid hormone affects all body systems.

Symptoms

- Coarse and thinning hair.
- Brittle nails.
- Dry skin.
- A yellowish tint to the skin.
- Slow body movements and speech.

- Inability to tolerate cold.
- Feeling tired, sluggish, or weak.
- Memory problems, depression, or difficulty concentrating.
- Constipation.
- Heavy or irregular menstrual periods that may last longer than 5 to 7 days.

Other, less common symptoms may include an enlarged thyroid gland (goiter), modest weight gain, a hoarse voice, muscle aches and cramps, a puffy face, and swelling of the arms, hands, legs, and feet.

HYPERTENSION

What Is "Normal" Blood Pressure?

There are several categories of blood pressure, including:

- **Normal:** Less than 120/80
- **Prehypertension:** 120-139/80-89
- **Stage 1 hypertension:** 140-159/90-99

Symptoms

- Severe headache
- Fatigue or confusion
- Vision problems
- Chest pain
- Difficulty breathing
- Irregular heartbeat
- Blood in the urine

HYPOTENSION

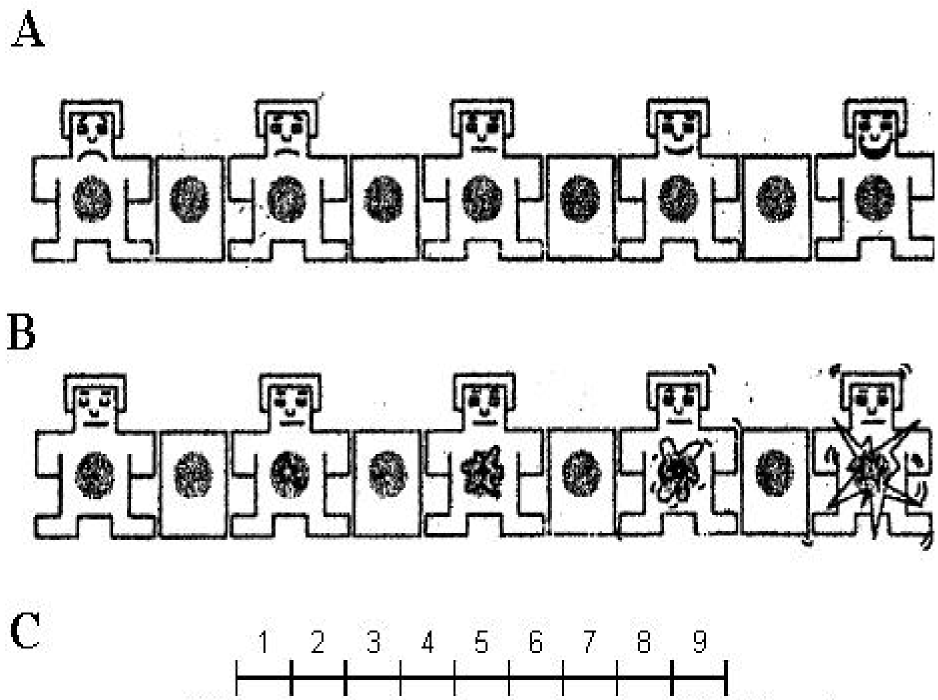
Hypotension is the medical term for low blood pressure (less than 90/60). Normal blood pressure is usually in the range of 120/80 (systolic/diastolic).

Symptoms

- Dizziness
- Lightheadedness
- Unsteadiness
- Dimming or blurring of vision
- Weakness
- Fatigue
- Cognitive impairment
- Nausea
- Head or neck discomfort
- Cold, clammy skin
- Headache

Appendix C

Self-Assessment Mankin



Appendix D

IRB Approval

Oklahoma State University Institutional Review Board

Date:	Friday, February 23, 2007
IRB Application No	AS071
Proposal Title:	Physiological Influences on Internal Tempo After Exercise
Reviewed and Processed as:	Expedited

Status Recommended by Reviewer(s): Approved Protocol Expires: 2/22/2008

Principal Investigator(s

Ruth Zephier
215 North Murray
Stillwater, OK 74078

David Thomas
215 N. Murray
Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☑ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Beth McTernan in 219 Cordell North (phone: 405-744-5700, beth.mcternan@okstate.edu).

Sincerely,

Sue C Jacobs

Sue C. Jacobs, Chair
Institutional Review Board

Appendix E

Informed Consent

Informed consent form for Research Participation
Department of Psychology, Oklahoma State University
Faculty Advisor: David Thomas, Ph.D.

I, _________________________, hereby agree to participate in a research project entitled: **Exploring Physiological and Emotional Arousal** being conducted by Ruth Zephier, graduate student in clinical psychology, under the supervision of David G. Thomas, Ph.D.

It is my understanding that:

1. I will be asked to engage in brief physical exercise and/or watch a DVD movie clip. There are four conditions to which I may be assigned. One condition would involve standing for a brief period of time. Another condition would require me to engage in brief physical exercise, equivalent to walking up two flights of stairs, while watching a short DVD clip of neurons in a child's brain. A third condition, would ask me to engage in brief physical exercise while watching a clip from the movie "Marathon Man" in which the lead character is having his teeth drilled. The fourth possible condition to which I may be assigned would only require me to stand while watching the segment from the movie "Marathon Man". Additionally, my heart rate will be measured before, during, and after the exercise. I will also be asked to rate my emotional state on a standardized questionnaire. These tasks will take no more than fifteen minutes to complete.

2. Because this study will require me to engage in brief physical activity, I should be healthy enough to participate. I will be excluded from the study if I have a history of smoking, diabetes, hyperthyroidism, hypothyroidism, hypertension, hypotension, irregular heart rate, previous heart attack, or current pregnancy. In addition, I may be excluded based on whether or not I am taking certain medications. These medications would include heart, blood pressure, or asthma medications. I will also be excluded based on whether or not I am currently receiving treatment for any mental health issues.

3. I will receive 1 unit of research participation credit for each hour of participation. The number of units I earn will be recorded in the Experimetrix system.

4. This research will provide me with the beneficial opportunity to reflect on myself in a unique way. Also, the results of this research will be beneficial to the scientific community because it will help researchers understand how individuals' are impacted by physiological and emotional states.

5. All of my responses and all of the information that I provide during this project will be coded anonymously and held in strict confidence. Furthermore, all of the research data will be coded and analyzed in a manner that protects by confidentiality.

6. I may ask questions of the researcher and expect pertinent responses. Also, the purpose of the study will be explained to me once I have completed all of the tasks.

7. I may refuse to participate in this study or may discontinue participation at any time without prejudice, question, or reprimand. If I do choose to discontinue my participation, I understand that I will still receive research credit.

8. As was explained to me when I signed up for this study, I understand that other methods of obtaining the same amount of research credit (e.g., writing research papers or attending colloquia) are available to me; hence, my participation in this research is completely voluntary.

9. It is possible that the consent process and data collection will be observed by research oversight staff responsible for safeguarding the rights and wellbeing of people who participate in research.

10. If I have any questions after I have concluded my participation, I may contact Ruth Zephier, B.A. at (405) 880-6861 (cyane9@yahoo.com) or 215 North Murray Hall, OSU, Stillwater, OK 74078. If I have any questions regarding the rights of research participants in this study, I may contact Dr. Sue Jacobs, chair of OSU's Institutional Review Board at (405) 744-5700 or 219 Cordell North, OSU, Stillwater, OK 74078.

11. A signed copy of this consent form will be given to me for my records.

I have read and fully understood the consent form. I have had a chance to ask questions about the study and my questions have been answered to my satisfaction. I sign this form freely and voluntarily.

________________________________ __________

Participant's signature Date

I certify that I have personally explained all of this form to the participant before requesting that he or she sign it.

________________________________ __________

Authorized Research Assistant Date

OSU
Institutional Review Board
Approved 2/23/07
Expires 2/22/08
Initials dj
AS-07-1

Table 1

Table of Means (and Standard Deviations)

	Control	Physiological Arousal (PA)	Combined Arousal (CA)	Emotional Arousal (EA)
Emotional State	.12(.65)	.09(.87)	-.22(1.17)	.71(1.01)
Emotional Intensity	.000(1.23)	-.18(1.47)	.09(1.68)	.48(1.29)
Internal Tempo	1.92(15.14)	1.50(14.17)	5.87(12.65)	6.57(11.33)
Production	11.68(8.25)	11.08(4.08)	10.02(3.28)	11.95(4.62)
Verbal Estimation	54.23(28.70)	68.00(41.76)	52.26(27.03)	51.76(26.10)

	Control	EA	CA	PA
Heart Rate	-.19(11.05)	1.00(13.46)	22.44(12.45)	22.77(14.81)

Note. The values with a continuous underline are not significantly different from one another. Emotional state is measured on a nine-point visual scale with the number one equated to a sad face and the number nine equated to a happy face. Emotional Intensity is also measured on a nine-point visual scale with the number one equaling a calm face and the number nine paired to a very happy face. Internal tempo was measured by how many taps the participant tapped in a 30-second interval. Production was measured by how many seconds that the participant pressed the space bar on a computer keyboard. Verbal estimation is measured in how many seconds the participant stated that they felt the step or standing task took. Heart rate is measured in beats per minute.

Table 2

Means and Standard Deviations of Dependent Variables by Condition

	Control	Physiological Arousal (PA)	Emotional Arousal (EA)	Combined Arousal (CA)
Pre Heart Rate (HR)	85.42(11.57)	82.13(13.96)	85.82(19.92)	83.78(10.80)
Post HR	85.96(13.88)	101.65(19.73)	88.55(22.40)	106.00(17.77)
Pre Internal Tempo (IT)	59.17(23.70)	77.22(36.05)	65.73(37.15)	67.00(25.60)
Post IT	61.00(25.90)	76.87(35.13)	72.77(39.51)	74.17(29.77)
Pre Emotional State (ES)	6.96(1.20)	6.65(1.11)	6.50(.91)	6.74(.86)
Post ES	6.96(1.00)	6.74(.96)	5.95(1.05)	6.52(1.24)
Pre Emotional Intensity (EI)	4.25(1.70)	4.30(1.85)	3.50(1.10)	4.04(1.49)
Post EI	4.29(1.63)	4.00(1.48)	4.05(1.50)	4.13(1.84)

Note. Emotional state is measured on a nine-point visual scale with the number one equated to a sad face and the number nine equated to a happy face. Emotional Intensity is also measured on a nine-point visual scale with the number one equaling a calm face and the number nine paired to a very happy face. Internal tempo was measured by how many taps the participant tapped in a 30-second interval. Production was measured by how many seconds that the participant pressed the space bar on a computer keyboard. Verbal estimation is measured in how many seconds the participant stated that they felt the step or standing task took. Heart rate is measured in beats per minute.

Table 3

Time Estimation Methods

	Methods	**Methods**	**Methods**
Relative magnitude of judgment and standard	***Verbal Estimation***	***Production***	***Reproduction***
Judgment **larger** than the standard	Overestimation of the standard	Overestimation of the standard	Overestimation of the standard
Judgment **larger** than the standard	Internal clock **faster** than external clock	Internal clock **slower** than external clock	Internal clock **faster** than external clock during reproduction
Judgment **larger** than the standard	Subjective temporal units **smaller** than objective temporal units	Subjective temporal unites **larger** than objective temporal units	Subjective temporal units **larger** than objective temporal units during reproduction

	Methods	**Methods**	**Methods**
Relative magnitude of judgment and standard	***Verbal Estimation***	***Production***	***Reproduction***
Judgment **smaller** than the standard	Underestimation of the standard	Underestimation of the standard	Underestimation of the standard
Judgment **smaller** than the standard	Internal clock **slower** than external clock	Internal clock **faster** than external clock	Internal clock **slower** than external clock during reproduction
Judgment **smaller** than the standard	Subjective temporal units **larger** than objective temporal units	Subjective temporal unites **smaller** than objective temporal units	Subjective temporal units **smaller** than objective temporal units during reproduction

VITA

Ruth Hotema Zephier

Candidate for the Degree of

Master of Science

Thesis: PHYSIOLOGICAL INFLUENCES ON INTERNAL TEMPO AFTER EXERCISE

Major Field: Clinical Psychology

Biographical:

Personal Data: 4200 Horizon North Parkway, #1115
Dallas, TX 75287

Education:

8/02 – 12/08 Graduate Studies, Stillwater, Oklahoma — Oklahoma State University, Major: Clinical Psychology
Completed the requirements for the Master of Science in clinical psychology at Oklahoma State University, Stillwater, Oklahoma in December, 2008.

9/96 – 5/97 Post-baccalaureate Studies, Vermillion, South Dakota — University of South Dakota, Major: Psychology

9/93 – 6/96 Bachelor of Arts, Minneapolis, Minnesota — University of Minnesota, Major: Speech

Experience:

August 2002 – May 2007 Graduate Research Assistant: Psychology Department at Oklahoma State University, Stillwater, Oklahoma
Worked on data collection for a study on stereotyped threat. Completed thesis titled "Internal Tempo and the Perception of Time After Exercise". Project supervised by David Thomas, Ph.D.

Honors and Memberships:

American Psychological Association – Student Affiliate
Southwestern Psychological Association
Oklahoma Psychological Society
Psi Chi National honor Society in Psychology

Name: Ruth Hotema Zephier Date of Degree: December, 2008

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: PHYSIOLOGICAL INFLUENCES ON INTERNAL TEMPO AFTER EXERCISE

Pages in Study: 108 Candidate for the Degree of Master of Science

Major Field: Clinical Psychology

Scope and Method of Study: The goal of the present study is to fill in gaps that exist in literature regarding the way in which internal tempo interacts with both physiological and psychological states. Participants were 98 students enrolled in introductory psychology classes at Oklahoma State University. Each participant had their heart rates, emotional state, emotional intensity, and internal tempos measured as pretest and posttest. Time estimation was measured by production and by verbal estimation at posttest. A univariate analysis of variance was conducted to determine what impact emotional arousal versus physiological arousal had on three experimental groups and one control group with regards to internal tempo and time estimation.

Findings and Conclusions: Hypothesis one, that stepping would increase heart rate, was supported by the analyses. The second hypothesis, that the distressing DVD segment would increase heart rate, was not supported by the analysis of the data. Stepping did not increase emotional arousal as anticipated by hypothesis three. The hypothesis that the distressing DVD segment would increase emotional arousal was supported by one scale on the SAM, but not on both scales. The fifth hypothesis was that stepping would increase internal tempo, but this was not supported by the analysis. The sixth hypothesis was that distressing DVD segment would increase internal tempo. Again, this hypothesis was not supported by the data analysis. The seventh hypothesis was that stepping would lead to an underestimation in temporal production and a verbal overestimation of the temporal interval. This hypothesis was not supported. The final hypothesis was that the distressing DVD segment would lead to an underestimation in temporal production and a verbal overestimation of the temporal interval. This was not supported by the evidence either.

ADVISER'S APPROVAL: Dr. David G. Thomas