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Ph.D. THESIS SUMMARY

COGNITIVE MECHANISMS INVOLVED IN THE SUBJECTIVE TIME PERCEPTION

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Key words: time perception, cognitive mechanisms, interval length, subjective time passage.

CHAPTER I. THEORETICAL BACKGROUND[1]

1.1. Introduction and Research Problem

The perception of time is an area of fascination and study for various disciplines, from philosophy to biology and psychology. In the course of its scientific research history, time perception has raised a number of intriguing questions, ranging from what are the stimuli or the sensorial mechanisms involved in this type of perception, to what are the biological or cognitive bases for our temporal experiences.

Although this topic has received a great deal of attention in the field of psychology and a wide variety of factors that affect time perception are already known, the field still needs further clarification in terms of the theoretical models used to explain the various and sometimes inconsistent findings. From a methodological point of view, as a general remark, most of the studies were conducted in laboratory settings, investigating the perception of short duration (e.g., up to a few seconds) so it is difficult to infer that the findings could be generalized to real life situations. As for the practical implications of the research in this field, so far, the abundant literature on time perception lacks a systematic approach for the investigation of the factors that can be manipulated in order to control our perceived pace of life.

1.2. Relevance of the Research in the Field of Time Perception

The perception of time has been an investigation topic for more than a century, having a long history of research (Roeckelin, 2000). Psychologists have soon begun to acknowledge that the capacity to perceive time is crucial for optimal functioning (Block, Hancock, & Zakay, 1998; Buhusi & Meck, 2005). Numerous studies showed that, indeed, many aspects of our cognitive and behavioral functioning are based, at least in part, on processing temporal information (Poppel, 2004).

There is a vast amount of literature investigating the factors that distort time perception, with a focus on topics such as time management or time perspective (Caruso, Gilbert, & Wilson, 2008; Grondin, 2010; Zimbardo & Boyd, 1999). Once the research findings have begun to offer hints into the mechanisms upon which time perception relies on, researchers started to be preoccupied with the idea that we can control our temporal perception and our time related behavior.

Indeed, a thorough approach on identifying the factors which can lead to systematic time distortions, like the lengthening of subjective time perception, is even more relevant in the context of the general findings showing that as we grow older, time seem to pass faster (Bruss & Rüschendorf, 2010).

Although at the global level chronological longevity is increasing, studies show that as we grow older, we evaluate time as passing faster. There are studies which show that when older people are asked to estimate temporal intervals, they make shorter time estimates than younger people do (Craik & Hay, 1999). One of the first explanatory hypotheses for this finding is that each time period constitutes a smaller fraction of our life as a whole. Paul Janet, in 1877, wrote that the apparent length of an interval at a certain age is proportional to the total length of the person's life. A child of 5 feels a year as 1/5 of his whole life, while a man of 60 as 1/60 (James, 1890).

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At the same time, considering the increasingly fast-paced and more hectic ways of living in most of the developed countries (Levine, 1997), finding the factors that can be manipulated or the techniques that can be used in order to slow down the speed of time can represent a mean to gain a better sense of control over our life (Gruber, Wagner, & Block, 2004).

1.3. State of the Art in the Literature

The term *subjective time perception* is used interchangeably with *psychological time*, *temporal experience* or *temporal perception* (Roeckelin, 2000). The perception of time is characterized by the ability to estimate duration (Fraisse, 1978) or speed of time (Wearden, 2005). Other researchers defined time in a more general manner, stating that psychological time refers to an organism's time related experiences, behaviors and judgments (Block & Zakay, 2001).

An intriguing element of this topic is that, as opposed to other types of perception, temporal perception does not involve a specific sensorial modality and it is formed, at least in part, by integrating the information related to stimuli or events. Gibson and Lawrence (1975) described time perception as process of integration of external stimuli that provide a flow of change, which is perceived as the flow of time.

This particular feature of time perception has led researchers to explain the different types of temporal experiences and the impact of diverse factors on them in terms of cognitive and/or biological mechanisms (Block & Zakay, 1997).

1.3.1. Types of Temporal Experiences

The term *time perception* encompasses several types of temporal experiences, or fundamental aspects of our experience of time (Block, 1990; Poppel, 1978; Wearden, 2005), like:

(1) *Subjective time passage (the perception of the speed with which time passes);*

(2) *Interval length (duration) estimates;*

(3) *Simultaneity and succession.*

The focus of the current research is on the first two of these temporal experiences, (1) *subjective time passage judgments* and (2) *interval length judgments.*

1.3.1.1. Subjective time passage

This temporal experience refers to the perception of the speed with which time passes, or the perceived speed of time passage (Wearden, 2005).

Although important for our temporal behavior (e.g., planning), this specific kind of time experience has been rarely investigated, with most of the studies focusing on the impact of different factors on the ability to judge the length of a time interval and not necessarily on how people perceive the speed with which time passes during that interval or on the variables that can have an impact upon it (Wearden, 2005).

As for the methodological factors that can have relevance for this variable, there is only one study that started to shed some light on this matter (Wearden, 2005). The study procedure was the following one: one group of participants watched 9 minutes of the film "Armageddon" and another group of participants waited for 9 minutes in a simulated "waiting room" condition. At the end of the 9 minutes, they were asked to judge how quickly time seemed to pass. The participants in the "Armageddon" group rated the passage of time as faster than normal, and those in the "waiting room" judged time as passing slower than normal. Next, both groups read a novel for 10 minutes, and then they were asked to make a retrospective time judgment. The "waiting" condition was judged as shorter that the "Armageddon" one. The period of time

seemed to drag for the participants in the waiting condition while they judged it "on-line", although the interval was judged as being short.

Variables with impact on the subjective time passage.

Studies on variables affecting the subjective passage of time have suggested that this type of judgment is affected by the hedonic value of the task. More specifically, if people perceive a task or an event as being pleasant, they perceive time as passing quickly. Conversely, during a boring task, time is perceived as passing slowly (Watt, 1991). While these findings match the naïve theory "time flies when you are having fun", the cognitive mechanisms that can explain them are still unclear.

Except for the few mentioned studies, this particular type of time experience has rarely been investigated, although it contributes to our time management behaviors.

Also, since the subjective time passage judgments and interval length judgments have rarely been investigated in the same study, under the same methodological conditions, it is difficult to infer whether they are affected by the same variables or to explain the nature of their relationship.

1.3.1.2. Interval length estimates.

Researchers agree that if an event lasts longer than a few milliseconds, people are able to experience, remember and estimate its duration (Block, 1989). The term *interval length judgments* is used interchangeably with *duration judgments* or *duration estimates* (Block & Zakay, 1997*)* and it refers to the estimation of a temporal interval length.

This type of subjective time perception is the most frequently studied in the literature (Block, 1990) and the factors that have an impact on it and the cognitive mechanisms on which it relies on are better understood.

Researchers agree that the impact of these factors on this subjective temporal experience is contingent upon several methodological factors (Block, 1990).

Variables with impact on interval length estimates.

The following methodological variables were found to be relevant for research conducted in the field of temporal perception for the study of interval length estimates (Block, 1990; Wearden, 2005):

(1) Study paradigm;

(2) Method of assessment;

(3) Duration range.

(1) Study paradigms in the study of interval length estimates.

Researchers agree that a crucial distinction in any study focused on time perception is that between (a) the retrospective paradigm and (b) the prospective paradigm (Block & Zakay, 1997; Wearden, 2005).

(a) Retrospective paradigm.

The retrospective paradigm is defined by the fact that study participants are not aware in advance that they will have the task to estimate interval length (Block, 1989; Block & Zakay, 1997; Helfrich, 1996; Wearden, 2005). In this study paradigm, the participants are exposed to specific stimuli or events and then asked to estimate the duration of the time interval that contained those stimuli or events. This type of judgment is often called in the literature "remembered duration" (Block, 1990).

Researchers suggest that, since we do not pay attention to time clues very often, when asked to make a retrospective judgment, we use the amount of information processed, or the

amount of processed stimuli, as a basis for making inferences about the duration of an experienced event (Block, 1990; Ornstein, 1969; Zakay & Block, 1996).

Indeed, the research findings using this paradigm suggest that people remember duration as shorter if there is little information to process (Ornstein, 1969). On the other hand, when people are exposed to complex tasks and there is a large amount of stored and retrieved information, they remember the duration as longer. Research shows that retrospective duration judgments increase as a function of the available information from a specific time interval (Block & Reed, 1978; Brown, 1985; Ornstein, 1969; Zakay, 1993; Zakay & Block, 1996), thus offering memory-based models for the retrospective paradigm.

Therefore, if a person can retrieve a greater amount of contextual information, he/she remembers the duration of a time period as being longer (Ornstein, 1969). Researchers suggest that people rely on availability heuristic, remembering duration as being longer if they can retrieve more of the events that occurred during the time period (Block, 1990; Zakay & Block, 2004).

(b) Prospective paradigm.

The prospective paradigm is defined by the fact that the study participants are told in advance that the task will involve estimating the length of a temporal interval, being aware that they will need to estimate the duration of a task or event, estimation called, for clarity, "experienced duration" (Block, 1990; Brown, 1985).

According to the cognitive models of time perception (Thomas & Weaver, 1975; Zakay, 1998; Zakay & Block, 1996), in the prospective paradigm, a person divides attentional resources between non-temporal information (e.g., stimulus or task to be solved) and temporal information. In a study which used this paradigm, Zakay (1992) asked children to estimate the duration of a lamp staying lit. The study showed that, if their attention was distracted by a toy, they estimated time as being shorter than if their attention had not been distracted away from that lamp. An earlier study performed by the same author (Zakay, 1989) indicated that when the participants were told that the estimation of time was the primary task, they estimated time as longer than when they were told that the estimation of time is the secondary task. Other studies suggest that during a novel, difficult or complex task, people experience time to be shorter (Eagleman, 2008), whereas during a simple task, they have more resources available to process temporal information and they perceive time to be longer.

Prospective duration timing depends therefore on attention demanding processes that occur at the same time with the processing of non-temporal information (Pouthas & Perbal, 2004; Zakay & Block, 1997) and it is considered to be a dual-task condition (attention must be divided between temporal and non-temporal information processing) (Zakay & Block, 2004). For this reason, researchers have offered attention-based models for the prospective paradigm (Block & Zakay, 1996; Block & Zakay, 2001; Brown, 1985; Brown & Block, 1980; Macar, Grondin, & Casini, 1994; Zakay, 1992).

Overall, the researchers agree that experienced duration decreases as the difficulty of the non-temporal information-processing task increases, an idea that was supported by several experiments (Block & Zakay, 1997; Block, Zakay, & Hancock, 1998). In other words, if the person has to solve a more difficult task during the time period, experienced duration decreases (Macar, Grondin, & Casini, 1994).

(2) Methods of assessment in the study of interval length estimates.

Another relevant methodological variable in time perception studies is the method of assessment. The most frequently used methods of assessment are presented below.

(a) Temporal generalization.

When using the temporal generalization method, the participant receives a few presentations of a "standard" period that he/she has to remember. Next, when comparison durations are presented, the participant has to decide whether the comparison durations have the same duration as the standard ones (Wearden, 2005).

(b) Bisection.

Bisection is similar to the temporal generalization model. Two standard intervals are presented to the participants, one short and one long. After this procedure, when they receive a range of stimulus durations, they have to classify each presented duration in terms of similarity to the short or long standards, with a SHORT or LONG response being produced (Allan & Gibbon, 1991; Droit-Volet, 2003; Wearden & Ferrara, 1995).

(c) Verbal estimation.

For the verbal estimation method, the participant has to estimate (e.g. ''estimate the length of that duration in minutes or/and seconds'') a certain duration (Block, 1989; Wearden, 2005).

(d) Production and reproduction.

For the production method, the participant has to produce a specific duration (e.g. by pushing a button at the beginning and at the end of what he/she estimates to be the required duration). For the reproduction method, after being exposed to a standard duration, the participant has to reproduce it by the production method described above (Wearden, 2005).

(3) Duration range.

Another relevant methodological variable in time perception studies is the duration to which the participants are exposed to. Researchers have emphasized a clear distinction between intervals above and below 1 second. Most authors agree on the fact that processing intervals smaller than 1 second is an automatic, sensory based mechanism, whereas processing longer intervals is based on cognitive mechanisms (Hellstrom & Rammsayer, 2004; Lewis & Miall, 2003; Penney & Vaitilingam, 2008).

1.3.2. Factors that Influence Time Perception

Findings from the time perception literature highlight numerous factors as being relevant for time perception. However, the role of these variables mostly refers to interval length estimates and should be considered in relationship with the previously mentioned methodological factors.

Temporal relevance and temporal uncertainty.

Zakay (1992) introduced the concepts of *temporal relevance* and *temporal uncertainty*.

Temporal relevance is defined as the importance of time for performing an optimal behavior in a certain situation. Temporal uncertainty refers to the degree to which the duration of a future task is known or can be estimated. The author indicates that when we perform a routine task, temporal uncertainty will be low because the task is well known and we can estimate its length based on previous experiences with it. However, when the task is new, temporal uncertainty will be high (Zakay, 1992).

When temporal relevance and temporal uncertainty have higher levels, most available attentional resources will be allocated for temporal information processing and the prospective estimates will be long. When both temporal relevance and temporal uncertainty are low, few of our attentional resources will be allocated for temporal information processing and the prospective duration will be judged as being short (Block & Zakay, 1996).

However, it is not clear whether the impact of these variables, temporal uncertainty and temporal relevance, remains significant in the presence of other variables, like task difficulty or affective factors.

Affective factors.

There is a relatively rapidly flourishing avenue of research on the impact of emotion on time judgments (Angrilli, Cherubini, Pavese, & Manfredini, 1997). Langer, Wapner, and Werner (1961) found shorter time estimates for subjects experiencing fear than for subjects in a neutral condition. In another study, Thayer and Schiff (1975) asked subjects to retrospectively estimate the time interval spent in an eye-contact task while manipulating the facial expression of the subject's partner. Time estimates were longer for the time intervals filled with making eye contact with a person that had a negative-unpleasant expression than for the time intervals filled with making eye contact with a person that had positive-pleasant facial expression (Angrilli et al., 1997).

Although offering valuable insight, most of the studies focused on investigating the affective factors do not always specifically elucidate both the role of valence and arousal and it would be important for future studies to further investigate the composite impact of these two elements.

Arousal.

Several studies have shown that arousal, which refers to a state of physical activation (Schacter & Singer, 1962), can affect time evaluation. Activation levels have been manipulated in a number of ways, such as increase or decrease of body temperature (Angrilli et al., 1997; Fox, Bradbury, & Hampton, 1967), manipulation of circadian rhythms and administration of drugs (Gupta & Cummings, 1986). Studies showed that incrementing physical activation levels leads to an overestimation of the remembered temporal interval. However, Curton and Lordahl (1974) found that different activating methods (e.g., physical activity versus threat of shock) have different effects on time perception. The findings are integrated and accommodated by the attentional models of time (Gibbon, Church, & Meck, 1984; Tipples, 2010), which state that an arousal-sensitive peacemaker sends ticks, or pulses, to an accumulator that stores this pulses which later form the basis for the duration judgments. The proponents of these models suggest that an increased arousal accelerates the rate of the pacemaker, leading to a greater number of stored pulses (or time units) and, as a consequence, it leads to an overestimated interval length.

The large diversity of methodological variables (in terms of assessment methods, research paradigms or objective interval length) contributes to the variability of results and leading to a need to investigate more thoroughly the role of arousal in time perception.

One of the difficulties in further investigating the role of arousal is that there are ethical constraints related to exposing participants to stressful situations or administering several drugs and it would be important to find methodological settings in which the arousal state can be modified in conditions that offer both total safety and ecological validity (Campbell & Bryant, 2007).

Task complexity.

Research shows that the characteristics of the events in a time period influence duration judgment differently, depending on the study paradigm.

In the prospective paradigm, if an interval is filled with complex stimuli, it is regularly perceived as being longer than an equal time interval that has fewer events (Block, 1989). Under this paradigm, subjects experience a temporal interval (e.g., minutes, hours) that is filled by more complex events as shorter than an empty one. At the same time, when there is less stimulation

from the external environment than desired, the time in passing can seem very long (Block, 1989). These findings are interpreted according to the attentional models of time perception (Thomas & Weaver, 1975; Zakay & Block, 1996), which state that in the prospective paradigm, a person has to allocate his/her attentional resources both to temporal and to task processing.

In the retrospective condition, if the person is exposed to more complex information, the person remembers the duration as being longer. A common experimental finding is that subjective time perception is dilated when the task involves larger, brighter, novel, higher numerosity stimuli or moving stimuli (Eagleman, 2008). Results obtained in this paradigm show that when people are exposed to complex tasks, they remember the duration as longer. Also, from a similar line of research, there are studies that investigated the role of stimulus novelty, indicating that when a stimulus is presented repeatedly, the first appearance is judged to have a longer duration than successive stimuli (Pariyadath & Eagleman, 2007). The majority of the studies concerning the effect of stimulus familiarity/novelty used the "oddball" method, in which a different stimulus is included in a series of repetitive stimuli (e.g., 1111g111); in this situation, the different stimulus in a repeated series will be judged to have lasted longer than others of equal physical duration. To summarize, in the retrospective paradigm, people usually make longer duration estimates for complex stimuli (Zakay & Block, 1997). These findings are generally accommodated by the memory based models of time perception (Block, 1990; Block & Reed, 1978; Ornstein, 1969).

Temporal expectancies.

The expected length of an interval also determines an extension of the perceived time. Temporal expectancies can be formed as a function of previous experiences with an event, or by the influence of anchors (Thomas & Handley, 2008). Jones and Boltz (1989), in their expectancy/contrast model, suggest that, when one attends in an anticipatory fashion, the confirmation or violation of expected ending times exerts a systematic influence on duration judgments (Boltz, 1993). Expectancies are anticipatory beliefs that reflect prior information about the forthcoming perceptive environment (Summerfield & Egner, 2009). The expectancy effect is explained as a *top-down* process, in which prior information about a stimulus modulates perceptual processes, an explanation that relates with the concept of top-down attentional biasing. Expectancies guide the sensorial information by allowing the aspects of the sensory environment that are constant (previously processed) not to be processed in depth repeatedly. Also, they facilitate the interpretation of temporal input (Summerfield & Egner, 2009).

Cognitive absorption and attentional deployment: mindfulness meditation techniques.

As research findings suggest, the focus of attention (whether we focus on processing the non-temporal characteristics of an event or on the time cues during the same event) has an important role in time perception. Glicksohn, Mourad, and Pavell (1991–1992) suggest that there are individual differences in the extent of the attentional deployment oriented for the non-temporal characteristics of a task, or in the cognitive absorption in the task, with clear effects on the estimated duration. Cognitive absorption was first studied as a personality trait related to the capacity for imaginative involvement (Roche & McConkey, 1990; Tellegen, 1992; Tellegen & Atkinson, 1974). However, later studies have defined this construct as a state of absorbed or focused attention (Glicksohn, Mourad, & Pavell, 1991–1992). The same author highlighted the idea that the extent of attentional deployment, or cognitive absorption, is not necessarily a direct function of the task difficulty, as previously suggested by other authors. He suggested that, although the nature of the task can set a required level of attentional deployment for its

successful completion, the absorbed involvement is rather attitudinally based (Crawford, Brown, & Moon, 1993; Wild, Kuiken, & Schopflocher, 1995). Indeed, Tellegen (1992) has classified the focus on the task as being either instrumental (task-related), attitudinal or experiential (cognitive absorption). Therefore, researchers suggested that turning the focus on meditation could be a useful endeavor in the pursuit of finding techniques that can affect time perception (Glicksohn, 2001). So far researchers investigated the role of concentrative meditation which entails an experimental manipulation of the attentional level (Naranjo & Ornstein, 1971). Block (1979) indicated that during concentrative meditation the temporal interval was estimated as being shorter that the actual physical time, a result which he suggested that was due to the fact that concentrative meditation involves attending to a single stimulus (e.g., like a mantra). While concentrative meditation involves the focus of attention on a single stimulus, there are other types of meditation that involve other kinds of attentional deployment, like mindfulness meditation.

Mindfulness meditation is considered to be different from concentrative meditation (Dunn, Hartigan, & Mikulas, 1999; Holroyd, 2003) in that while concentrative meditation focuses attention on a single stimulus in order to let go of thoughts, mindfulness meditation is based on training the participants to focus and observe all the sensations, emotions and thoughts and to be able to describe them in detail (Shear & Jevning, 1999; Wallace, 1999). Mindfulness is defined as "the awareness that emerges through paying attention on purpose, in the present moment, and non-judgmentally to things as they are" (Williams, Teasdale, Segal, & Kabat-Zin, 2007, p. 47). Mindfulness means therefore to pay attention to the external and internal stimuli as they are in any given moment. A key element of mindfulness meditation is that it focuses on the unfolding of the present moment experience (Williams et al., 2007).

This particular feature of mindfulness meditation, that it involves both attention to the stimuli array and to the temporal cues by constantly keeping temporal orientation to the present moment, could represent a starting point for further investigating the effects of mindfulness meditation practice on time perception.

1. 4. Critical Remarks and Further Advances in the Field of Time Perception

In summary, research points to a wide variety of factors that affect time perception, factors that are related with both the contents of the time interval to be perceived and with individual characteristics.

From a theoretical perspective, although interval length estimates have received a great deal of attention in the time perception literature, the variability of study methods make it difficult to have a clear, systematic view of the factors that distort it one way or another. Also, some of the studies that report effects of specific variables on time perception do not compare the estimated duration with the objective duration or they use methods of assessing perceived duration that do not allow a clear investigation of the time overestimates (e.g., like bisection, in which case a time overestimate can be found, but it is not possible to ascertain the length of the reported overestimates). Therefore, pursuing a systematic investigation of the factors that affect interval length would have important theoretical benefits.

While on the interval length estimates numerous studies can be found, less is known about the subjective time passage, about the factors that affect it or about the mechanisms that support it. Like in the case of interval length estimates, finding the factors that affect this type of temporal experience and clarifying its underlying mechanisms would represent important theoretical contributions.

From a methodological point of view, as a general remark, most of the studies were conducted in laboratory settings, investigating the perception of short durations (e.g., up to a few seconds) so that is difficult to infer that the findings could be generalized to real life situations. This state of the current literature points to the importance of finding a research methodology that could allow both an increased internal validity (thus an increased control of study variables) and an increased external validity (thus conducting the research in a methodological setting that mimics real-life situations).

One such methodological setting could be the use of virtual reality systems. Virtual reality is being increasingly used in the field of psychology (Glanz, Rizzo, & Graap, 2003). One of the important features of virtual reality is that it delivers environments that allow a dynamic, multidimensional stimulus presentation, while in the same time offering a precise control of the experimental setting (Rizzo, Bowerly, Buckwalter, Klimchick, Mitura, & Parson, 2006). Usually, the virtual environments can be used for a multiple array of experimental situations that are otherwise not easily deliverable or controllable in "real-life" situations (Anton, Opris, Dobrean, & David, 2009).

Virtual reality settings allow users to see in full three dimensions, with vivid details, allowing the feeling of presence (e.g., the participants feel as if they are in the real represented environment). Also, the new immersive virtual settings allow users to interact with the environment, as well as to perform novel functions such as walking in the represented environment or performing other behaviors (Fox, Arena, & Bailenson, 2009).

For example, one of the difficulties in further investigating the role of arousal in time perception was that there are ethical constraints related to exposing participants to stressful situations or administering several drugs (Campbell & Bryant, 2007). The use of virtual reality could overcome these difficulties, allowing a further investigation of this variable. There are already studies which indicated that the virtual reality can provide effective environments for manipulating physiological arousal (Calvert & Tan, 1994).

Also, from the same methodological perspective, the findings from the studies investigating the subjective passage of time, point to the importance of elucidating the role of study paradigm for this temporal experience.

As for the practical implications, so far, the abundant literature on time perception has not been concretized in a systematic approach for the investigation of the factors that can be manipulated in order to control our perceived pace of life. Research indicates the possible role of mindfulness meditation as such a technique.

However, research is still needed in order to investigate the impact of mindfulness meditation on both interval length estimates and on subjective time passage.

To summarize, time perception has received a great deal of attention in psychology and there is a wide variety of factors that affect time perception, factors that are related with both the contents of the time interval to be perceived and with individual characteristics. However, the field still needs clarification and several important lines of research were identified throughout this chapter, lines of research that will be further described in the following chapters.

CHAPTER II. RESEARCH AIMS AND OVERALL METHODOLOGY

Although this topic has received a great deal of attention in the field of psychology and a wide variety of factors that affect time perception are already known, the field still needs further clarification in terms of the theoretical models used to explain the various and sometimes inconsistent findings. From a methodological point of view, as a general remark, most of the studies were conducted in laboratory settings, investigating the perception of short duration (e.g., up to a few seconds), so it is it is difficult to infer that the findings could be generalized to real life situations. At the same time, as described in the first chapter, there is still a need to clarify the role of methodological factors, like the study paradigm, for subjective time passage. As for the practical implications of research in this field, so far, the abundant literature on time perception has not been concretized in a systematic approach for the investigation of the factors that can be manipulated in order to control our perceived pace of life.

Theoretical Advances

Although the previous studies have provided valuable insight into the variables that can affect time perception, the research findings are sometimes contradictory, due to the great variability concerning the research paradigms and the study methodology.

At the same time, the theoretical models used in the field make various and sometimes inconsistent proposals about the mechanisms of subjective time perception and are frequently disconnected from the general findings in the cognitive psychology domain.

Given the current state of the literature, the general objective of this research is to investigate, in a systematic manner, the factors that affect time perception (both as interval length judgments and as subjective passage of time judgments), bringing also clarification in the matter of cognitive mechanisms that support this subjective phenomenon.

Although interval length perception has received a great deal of attention in the time perception literature and the factors that affect this subjective temporal experience are better understood, so far there has been no systematic approach on identifying the factors that can lead to a lengthening of the subjective time. Also, some of the studies that report effects of specific variables on time perception do not compare the estimated duration with the objective duration or they use methods of assessing perceived duration that do not allow a clear investigation of the time overestimates (e.g., like bisection, in which case a time overestimate can be found, but it is not possible to ascertain the length of the reported overestimates).

(1) The first objective of this study was therefore to identify the factors that can be manipulated in order to induce temporal dilation (as interval length estimates) and to evaluate the magnitude of such temporal dilations for each identified factor. In order to reach this objective, the method of quantitative meta-analysis was used (Study 1).

After identifying the factors that can be manipulated in order to lengthen interval estimates and bringing clarification in the matter of the cognitive models that support these findings, the aim of this research was to investigate the factors that have an impact on the subjective passage of time and the mechanisms on which this type of temporal experience relies on.

(2) The second objective was therefore to clarify the role of specific cognitive factors (temporal expectancies) on the subjective time passage. Whereas most of the studies in the time perception literature are focused on investigating the variables that affect interval length estimates, Study 2 (an experimental study) aimed to clarify the role of temporal beliefs in the perception of time passage

(3) Stepping forward after identifying the factors that lengthen interval length estimates and highlighting some of the factors that affect subjective time judgment, the research had a specific objective related to the investigation of the relation between these two separate temporal experiences. Study 3 (an experimental study) was conducted in order to reach this objective, while also clarifying the impact of task difficulty, temporal relevance and hedonic interest on both interval length judgments and subjective time passage judgments.

Methodological Developments

The findings summarized in Chapter I suggest the importance of elucidating the role of the paradigm in the study of subjective time passage, this being a fruitful endeavor in the pursuit of investigating the cognitive mechanisms on which this type of subjective phenomenon relies on.

(4) Another specific objective was to investigate the role of the study paradigm on the subjective time passage. An experimental study (Study 4) was conducted in order to reach this objective.

Another objective of this research was to increase the extent to which the findings can be generalized to "real-life" situations, with the use of the implemented research methodology, namely, the use of virtual reality systems in the study of time perception. Using such a research methodology could allow both an increased internal validity (thus an increased control of study variables) and an increased external validity (thus conducting the research in a methodological setting that mimics real-life situations).

Practical Implications

After systematically investigating and clarifying the factors that affect both interval length judgments and passage of time judgments, and after bringing important methodological developments, the ground was set for the next specific objective of this research, which was to find specific techniques for controlling time perception, both subjective time passage and as estimation of interval length.

Research findings described in Chapter I indicate the possible role of mindfulness meditation as such a technique for manipulating time perception.

(5) Therefore, the specific goal of Study 5 was to investigate the impact of mindfulness practice on 1) the subjective time passage and 2) the interval (duration) estimates.

(6) After highlighting the role of mindfulness exercise as a tool for manipulating time perception, the last objective was to investigate the effects of mindfulness practice, while clarifying the effects of emotional factors (arousal and emotional valence) on the perception of the speed with which time passes (Study 6).

CHAPTER III. ORIGINAL RESEARCH

The empirical studies presented in this chapter follow the specific aims previously described.

Study 1 is a quantitative meta-analysis conducted in order to identify the factors that can be manipulated in order to induce temporal dilation (as interval length estimates) and to evaluate the magnitude of such temporal dilations for each identified factor.

After bringing theoretical clarifications in the matter of factors with impact on interval length estimates, study 2 (experimental study) was focused on investigating the role of temporal beliefs in the perception of time passage.

Stepping forward after identifying the factors that lengthen interval length estimates and highlighting some of the cognitive factors that affect subjective time passage, the research had a specific objective related to the investigation of the relation between these two separate temporal experiences. Study 3 (experimental study) was conducted in order to reach this objective, while also clarifying the impact of task difficulty, temporal relevance and hedonic interest on both interval length judgments and subjective time passage judgments.

Study 4 (experimental study) was conducted in order to investigate the role of the study paradigm on subjective time passage, bringing thus clarification in the matter of methodological variables with impact on this subjective temporal experience.

After systematically investigating and clarifying the factors that affect both interval length judgments and passage of time judgments, and after bringing important methodological developments, the ground was set for the next specific objective of this research, which was to find specific techniques for controlling time perception, both as subjective time passage and as estimation of interval length.

Therefore, the aim of Study 5 (experimental study) was to investigate the impact of mindfulness practice on subjective time passage and interval (duration) estimates, offering thus practical advances in this field.

After highlighting the role of mindfulness exercise as a tool for manipulating time perception, Study 6 (experimental study) had the aim to clarify the effects of this technique, while also clarifying the effects of emotional factors (arousal and emotional valence) on subjective time passage.

Study 1. A Quantitative Meta-analytical Review of Experimental Studies Investigating Psychological Time Dilation

Overview of the Present Study

Although time perception literature has numerous studies investigating these distortions, there has been no systematic approach on identifying the factors that can lead to a lengthening of the subjective time. Also, some of the studies that report effects of specific variables on time perception do not compare the estimated duration with the objective duration or they use methods of assessing perceived duration that do not allow a clear investigation of the time overestimates (e.g., like bisection, in which case a time overestimate can be found, but it is not possible to ascertain the length of the reported overestimates).

Most of the data on subjective time dilation comes from studies that have investigated non-specific time distortions.

The aim of this meta-analytical review is to investigate the factors that can be manipulated in order to induce a subjective time dilation, and for the variables found to have an impact on the subjective time dilation, to assess the magnitude of the effect sizes and the magnitude of the obtained time dilation.

Method

Sample of Studies

In the current meta-analysis we included experimental studies in which time dilation was obtained by manipulating one or more independent variables. We conducted a computer-assisted literature search using PsychINFO (1960-2009) database using the following search terms: *subjective time*, *time perception* and *time estimation,* and MEDLINE using the search terms*: time perception*. We also searched references from the relevant articles, books (e.g. Helfrich, 1996) and book chapters (e.g. Block, 2003).

The inclusion criteria were as follows: (a) experimental studies in which time dilation was obtained by manipulating one or more variables; (b) experiments involving normal human participants judging durations greater than 1 second; (c) studies that reported the ratio of subjective time to objective time or enough statistics in order to cumpute that (d) studies that used a duration judgement that allowed to compute the ratio of subjective to objective time (verbal estimates, reproductions). These criteria excluded: (a) experiments using durations shorter than 1 second (e.g. Aubry, Guillaume, Mogicato, Bergeret, & Celsis, 2008), animals (e.g., Miki & Santi, 2005), participants showing psychopathology (e.g., Rueda & Schmitter-Edgecombe, 2009), or participants experiencing an unusual physical condition (e.g., Cheng, Ali, & Meck, 2007) or an altered state of consciousness (e.g., Bowers & Brenneman, 1979), (b) studies that used bisection and temporal generalisation as a measure or experiments in which participants made qualitative judgments (e.g., Grondin & McAuley, 2009), (c) studies that did not report enough statistics to compute the effects sizes or the the subjective/objective ratio (e.g., Block & Reed, 1978) and (d) studies in which researchers did not obtain and report an extension of the subjective time perception (e.g., Hellström & Carlsson, 1997).

The 12 remaining articles (see Table 1) represented 22 distinct experimental studies, using a total of 2904 study participants.

Coded Variables

As in previous meta-analyses of the duration judgment literature, for each experiment we coded the following variables:

(1) the type of the variable that was manipulated;
(2) study paradigm;
(3) duration length: short—3.0–14.9s, moderate—15.0–59.9s, or long—60.0s or longer (Block, Hancock, & Zakay, 2010);
(4) duration judgment method (verbal estimation, production or reproduction);
(5) number of subjects;
(6) publication year.

Effect Size Analyses

Data were analyzed using Comprehensive Meta-analysis v.2.2 software, with supplemental analyses conducted using SPSS v.16. Cohen's *d* (1977) was used as a measure of the effect size. A *d* value of 0.00 indicates no difference between experimental group and control group; conventionally, 0.2, 0.5, and 0.8 are taken to represent small, medium and large effects, respectively (Cohen, 1988). The 95% confidence interval (*CI*) and statistical significance (*p*) was calculated for each effect size estimate.

Duration Judgment Ratio Analyses (Directional Errors)

In order to directly evaluate and compare the length of duration overestimates for different intervals, the data of each study were converted into ratios of subjective duration to objective duration. Ratio values of 1.00 show perfect accuracy, ratios below 1.00 represent underestimation of the actual duration of the interval, and those above 1.00 indicate overestimation of the actual duration of the interval (Block, Hancock, & Zakay, 2010; Hornstein & Rotter, 1969).

Results

Table 1 presents the study characteristics, the effects sizes and the mean ratios obtained.

Overall Analyses of Effect Sizes

The overall effect size estimates were computed fallowing the methods proposed by Hunter and Schmidt (2004). We included one effect per study and the overall effect size estimate (*d*) was .91, *SD* = .49. Because the studies varied widely in sample sizes, we corrected the overall d value for sample size, and the obtained a weighted mean value (*D*) was .71, *VarD* = .11, thus indicating a medium effect size; the 95% confidence interval about the mean was .24 to 1.18, $p <$ .05, and that shows that the overall effect size is statistically different from zero (see Table 1 and Table 2).

The overall effect size estimate indicates that time dilation can be obtained by manipulating different variables. Still, the studies included in the current meta-analysis are heterogeneous in several respects: independent variables, study paradigm, time judgment method, and objective duration. Therefore, we conducted several analyses to capture these differences.

Effect Sizes and Independent Variables

Presenting all the effect sizes associated with the independent variables would not be particularly conclusive, so we clustered the independent variables into four categories, following relevant findings in the field literature: affective factors, time related expectancies, task complexity and motivation for the outcome (see Table 2). The affective factors category was comprised in experiments in which the researchers manipulated the emotional state of the participants during the time interval to be judged (Noulhiane, Mella, Samson, Ragot, & Pouthas, 2007). Time related expectancies category was comprised in experiments in which the researchers manipulated the predicted ending time of the event to be judged. That is, the ability to anticipate when in time an event will come to an end, a temporal cognition that can stem from previous experience with that event, from consensual agreement about how much time will be spent in a task (Boltz, 1993; Konig, 2005; Thomas & Handley, 2008).Task complexity category was comprised in experiments in which the participants had to process numerous, diverse or difficult stimuli (Schiffman & Bobko, 1974).

Table 1

Study Characteristics, Effect Sizes (Cohen's d) and Mean Directional Errors

Study	*N*	Independent variable	Study paradigm	Study method	Mean dirrectional errors	Cohen's *d*	Number of effect sizes per study
Filer&Meals (1949)[1]	131	Motivation for outcome	Retrospective	Verbal estimates	1.17	0.34	1
Filer&Meals (1949)[2]	127	Motivation for outcome	Retrospective	Verbal estimates	1.19	0.39	1
Meade (1959)	120	Motivation for outcome	Retrospective	Verbal estimates	1.72	0.92	6
Meade (1966)	80	Motivation for outcome	Retrospective	Verbal estimates	1.19	0.58	3
Schiffman & Bobko (1974)	63	Task complexity	Retrospective	Verbal estimates	1.21	0.70	3
Sarason & Stoops(1978) [1]	96	Affective factors	Retrospective	Verbal estimates	1.30	0.42	1
Sarason & Stoops(1978) [2]	120	Affective factors	Retrospective	Verbal estimates	1.32	0.43	4
Sarason & Stoops(1978) [3]	60	Affective factors	Retrospective	Verbal estimates	1.30	0.56	4
Block et al. (1980)[1]	48	Task complexity	Prospective	Reproductions	1.02	1.04	1
Block et al. (1980)[2]	48	Task complexity	Prospective	Reproductions/Verbal estimates	1.17	0.70	2
Block et al. (1980)[3]	96	Task complexity	Prospective	Reproductions/Verbal estimates	1.07	0.93	3
Boltz (1993)	48	Expectancies for stimulus duration	Retrospective	Verbal estimates	1.15	1.23	1
Boltz (1993)[1]	48	Expectancies for stimulus duration	Retrospective	Verbal estimates	1.48	1.28	1
Vohs & Schmeichel (2003)[1]	47	Task complexity	Retrospective	Verbal estimates	1.34	0.69	1
Vohs & Schmeichel (2003) [2]	39	Affective factors	Retrospective	Verbal estimates	1.17	1.26	2
Vohs & Schmeichel (2003) [3]	50	Affective factors	Retrospective	Verbal estimates	1.27	0.73	2
Vohs & Schmeichel (2003)	47	Affective factors	Retrospective	Verbal estimates	2.01	1.16	1
Conway (2004)	38	Task complexity	Retrospective	Verbal estimates	1.06	0.52	1
Noulhiane et al.(2007)	24	Affective factors	Retrospective	Verbal estimates	1.08	1.25	6
Thomas & Handley (2008) [1]	75	Expectancies for stimulus duration	Retrospective	Verbal estimates	1.42	0.53	1
Thomas & Handley (2008)[2]	61	Expectancies for stimulus duration	Retrospective	Verbal estimates	1.13	0.89	1

Baldauf et al. (2009)	16	Task complexity	Retrospective	Verbal estimates	1.32	2.17	1

Table 2

Independent Measures and Mean Effect Sizes

Independent variable	Number of studies	*N*	Average weighted effect size *(D)*	*VarD*	95% Confidence interval of *D*
Affective factors	6	436	0.68	0.14	0.14-1.22
Time related expectancies	4	232	0.92	0.13	0.40-1.44
Task complexity	7	356	0.96	0.19	0.62-1.30
Motivation for theoutcome	6	508	0.53	0.10	1.29-1.23

The motivation for the outcome category was comprised in experiments in which the participants can reach a desirable outcome at the end of the task, with each unit of the task regarded as a significant advance toward that outcome (Meade, 1963).

The ANOVA analysis did not reveal any significant differences among the four categories, $F(3, 37) = .10$, $p > .05$, showing that the independent variables, at least coded by using these cathegories, do not obtain different effect sizes. The effect sizes associated with the four categories of independent variables are individually presented in Table 2.

Moderator Effects

In order to see whether effect sizes differed as a function of study paradigm (e.g. prospective or retrospective) we conducted a one-way ANOVA analysis. The results showed that effects sizes did not differ significantly in what the employment of prospective or retrospective study paradigm is concerned, $F(1, 39) = 2.79$, $p < .05$. Since the study paradigm is one of the most important factors in time perception studies, triggering different cognitive mechanisms that support the time judgment (Block & Zakay, 1997), for the classes of variables that comprised a sufficient number of effect size in order to investigate the moderator role of the study paradigm, we checked for differences in effect sizes as a function of the paradigm. The only class of variables that allowed a comparison between paradigms was the class of affective factors. However, we did not find a difference in the effect sizes, all *p*s > .05.

The results of the ANOVA analysis indicated that effects sizes differ significantly as a function of the objective duration, $F(2, 38) = 4.35$, $p < .05$. Post-hoc tests showed that long duration produce significantly larger effect sizes than medium durations.

All the experiments included in this meta-analytical study have used either the verbal estimates method or the reproduction method for assessing time estimates. The ANOVA analysis did not reveal any significant differences between the two methods (verbal estimates and reproductions), $F(1, 39) = 1.01$, $p > .05$.

Overall Analyses of Dirrectional Errors

The mean time duration judgment ratio for the selected studies was 1.31, with $SD = .24$.

Dirrectional Errors and Independent Variables

In order to check whether the length of time overestimation differs significantly as a function of the independent variables, we conducted one-way ANOVA analyses. The results indicated that the length of time overestimation was affected differently by the independent

variables, $F(3, 37) = 3.34$, $p < .05$. Motivation for the outcome had the largest duration judgment ratio ($M = 1.51$, $SD = .28$), while affective factors ($M = 1.25$, $SD = .22$), time related expectancies ($M = 1.25$, $SD = .16$) and task complexity ($M = 1.25$, $SD = .18$) had similar results.

Discussion

The overall mean effect size estimate ($D = .71$) indicates a medium effect size and shows that the manipulation of different variables in order to obtain a subjective time dilation can be effective.

Although the ANOVA analyses did not reveal significant differences in terms of effect size among all the independent measures, larger effect sizes appear to be associated with manipulating temporal expectancies and with manipulating task complexity. Manipulating the affective factors and the motivation for the outcome are associated with moderate effect sizes. The results indicated that effects sizes do not differ significantly when it comes to using prospective or retrospective study paradigm. Also, there were no significant differences between the two methods (verbal estimates and reproductions). However, we found that effect sizes differ significantly as a function of task duration, with larger effect sizes obtained for tasks that are longer than one minute.

The results show that a larger time overestimation is obtained when motivation for a desired outcome is aroused experimentally. If at the end of a time interval the participants can reach a desired outcome, they tend to overestimate the period of time. The existence of the desired outcome can make the information about time more relevant (e.g., how much time until one gets in the possession of the outcome). Zakay (1992) suggests that when time relevance is high, the temporal awareness is also high, and the person processes a large amount of temporal cues, which can lead to time overestimates. Affective factors are another class of variables that can induce an overestimation of time perception. The activation induced by emotional stimuli makes time to appear longer. The expected length of an interval also determines an extension of the perceived time. Results also show that we can also manipulate time estimates by manipulating task complexity.

This was, to our knowledge, the first attempt to systematically investigate the factors that induce a subjective time dilation. Examining the variables that can be manipulated in order to obtain time dilation and the factors that moderate this effect brings theoretical clarification in this matter.

Study 2. An Experimental Investigation of the Relationship Between Expectancies and the Subjective Time Passage Using a Virtual Reality System [2]

Overview of the Present Study

After systematically investigating the factors that affect interval length estimates, this research turned its attention to the investigation of the subjective time passage.

In which the experience of time is concerned, research results match such naïve theories about time perception as: time flies during pleasant activities and drags during boring or stressful activities (Flaherty, 1999; Vohs & Schmeichel, 2003).

Sackett et al. (2009) suggested that people use their temporal schemas as a metacognitive attribution for their experience.

Whereas most of the studies in the time perception literature are focused on investigating the variables that affect duration judgment in the prospective or retrospective paradigm, this study aims to clarify the role of temporal beliefs in the perception of subjective time passage.

Our first objective was to investigate the effects of temporal expectancies on the subjective time passage (Experiment 1). The second objective was to examine the impact of the discrepancy between expected and actual duration on hedonic judgments (Experiment 2) in order to test the bidirectional association contained in the temporal expectancy that "time flies when you are having fun".

Experiment 1

This experiment was designed to test the hypothesis that the subjective time passage is affected by the expectancies that people have about time. We manipulated hedonic expectancies for participating in a task that involved the immersion in a virtual reality environment.

We chose the virtual environment because the system allows a more controlled experimental setting, offering at the same time an increased degree of realism (Kalawsky, 1993).

We also investigated the impact of temporal expectancies on the retrospective duration judgments and the relationship between the two types of temporal experiences (the perception of the speed with which time passes and the perception of interval length) in order to asses if they are affected by the same cognitive variables.

We expected that manipulating hedonic expectancies would affect passage of time judgments, so that people who are led to believe that their experience will be enjoyable will evaluate time as passing faster than the people who expect to feel bored.

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[2] This study was published.

Sucala, M., Stefan, S., Szentagotai-Tatar, A., & David, D. (2010). Time flies when you expect to have fun. An experimental investigation of the relationship between expectancies and the perception of time progression. *Cognition, Brain, Behavior. An Interdisciplinary Journal, 14*(3), 231-241.

The authors have contributed to the article as follows:

- Sucala, M.: study design, conducting the study, analyses and results interpretation, writing the manuscript
- Stefan, S.: results interpretation, writing the manuscript
- Szentagotai-Tatar, A.: results interpretation, consultation for writing the manuscript
- David, D.: study design, analyses and results interpretation, consultation for the exposition of the manuscript.

Method

Participants

To be eligible, participants had to be at least 18 years of age and with no uncontrolled major physical or psychiatric illness. Thirty-seven (34 female and 3 male) undergraduate students participated, in exchange for course credit. The mean age was 21.18, *SD* = .96. Informed consent was obtained prior to participation.

Design and Procedure

An univariate between-groups design was used ("*enjoyment expectancies*" – *positive expectations*, versus "*boredom expectancies*" – *negative expectations*).

Participants were randomly assigned to one of the two experimental conditions. After being told that the experiment was related to cognitive mechanisms involved in the perception of virtual reality, they were asked to remove their watches and phones and place them out of sight; they were explained that this was the regular procedure when participating in a virtual reality task. A volunteer, confederate in the study, gave the instructions to the participants, according to the group they were randomized in.

Participants in the *positive expectations* group (n = 18) were told that the virtual environment they were about to enter was an "exciting and interesting one, and no matter how engaging it will be, you should remain focused".

Participants in the *negative expectations* group (n = 19) were told that the virtual environment they were about to enter was a "generally uninteresting one, but no matter how boring it will be, you should remain focused". These instructions were intended to manipulate their expectancies and to mask the objective of the experiment.

After being given the instructions, the participant was fully immersed in the virtual environment for 300 seconds. Duration was measured using a digital stopwatch and a technical assistant stopped the virtual reality program at the end of the specified time period. The virtual reality program was a Cave Automatic Virtual Environment (CAVE), which is an immersive virtual reality environment where projectors are directed to three, four, five or six of the walls of a room-sized cube.

The selected virtual environment was the 3D Solar System Application, an environment in which the participant can navigate through the planets of the solar system. For this application, the motion tracker systems calculates the 3D perspective view in real-time, both for the head and the Xbox 360, a controller that is used as a navigation device. The Xbox 360 controller is trackable device in six degrees of freedom which allows the observer to attend to any target in the scene and to interact totally immersed in the application (see Appendix 3).

Measures

Subjective time passage judgments. At the end of the 300 seconds, participants were asked to indicate how time seemed to progress while in the virtual reality environment, a method used to assess the subjective experience of the passage of time (Wearden, 2005). We used a 5-point Likert-type scale, with endpoints labeled "time flew" and "time dragged" and a midpoint labeled "normal", where low ratings indicated an accelerated time passage and high ratings indicated slower time passage.

Interval length estimates. Also, participants were asked to estimate retrospectively the duration of the task (in seconds). Data from each participant were converted into ratios of subjective duration to objective duration. Ratio values of 1.00 show perfect accuracy, ratios below 1.00 represent underestimation of the actual duration of the interval, and those above 1.00

indicate overestimation of the actual duration of the interval (Block, Hancock, & Zakay, 2010; Hornstein & Rotter, 1969).

Manipulation check. As a manipulation check, participants had to rate the task on a Likert-type scale, with respect to the degree of (a) enjoyment, (b) engagement, (c) excitement, (d) fun and (e) boredom that they felt during the task, a method used to obtain hedonic task judgments (Sackett et al., 2009). Endpoints of the scale were labeled "not at all" and "extremely" and the midpoint was labeled "medium".

Results

We first checked the effects of the manipulation. In the case of enjoyment measures, because ratings for enjoyment, engagement, excitement and fun were highly related ($\alpha = .80$) we combined them in order to create a composite measure and, as anticipated, participants in the "enjoyment expectancies" group rated the task as being more enjoyable than those in the "boredom expectancies" condition, $t(35) = -3.07$, $p = .004$, $d = 1.03$. They also rated it as being less boring than the other group, $t(35) = 3.52$, $p < .001$, $d = -1.1$.

For the measures of time perception, results indicated that time seems to pass with 35% faster in the "enjoyment expectancies" condition than in the "boredom expectancies" one, $t(35) = 3.84$, $p < .001$, $d = -1.63$. As for the duration judgment, we did not find significant differences between the two groups ($p > .05$). Also, we did not find a significant relation between the two experiences of time ($p > .05$).

The results are discussed in the general discussion section.

Experiment 2

This experiment was designed to test the hypothesis that manipulating external time cues will have an impact on the hedonic judgments people make about the events contained in that specific time period and to replicate the findings of Sackett et al. (2009).

We expected that participants would evaluate a task as being more enjoyable when time seemed to have passed faster than when time seemed to have passed slowly.

Method

Participants

To be eligible, participants had to be at least 18 years of age and with no uncontrolled major physical or psychiatric illness. Thirty-eight (36 female and 2 male) undergraduate students participated, in exchange for course credit. Mean age was 21.26, $SD = 1.17$. Informed consent was obtained prior to participation.

Design and Procedure

An univariate between-groups design was used ("*time flies*" condition versus "*time drags*" condition).

The procedure follows the model used by Sackett et al. (2009). Participants were randomly assigned to one of the two conditions. After being told that the experiment looked at cognitive mechanisms involved in the perception of virtual reality, participants were asked to remove their watches and phones and place them out of sight; they were explained that this was the regular procedure when participating in a virtual reality task. They were told that they would be immersed in the virtual reality environment for exactly 10 minutes.

Participants in the "*time flies*" condition ($n = 19$) were exposed to the virtual reality and, after 5 minutes, the experimenter re-entered the room and told the participants that time had elapsed.

Participants in the "*time drags*" condition ($n = 19$) were exposed to the virtual reality and, after 20 minutes, the experimenter re-entered the room and told them that the time had elapsed.

The virtual environment used was the 3D Solar System Application (technical details explained in Experiment 1). Duration was measured using a digital stopwatch.

Measures

Hedonic judgments. Following virtual reality exposure, participants were asked to rate their degree of (a) enjoyment, (b) engagement, (c) excitement, (d) fun and (e) boredom during the task. We used a 5-point Likert-type scale (Dawes, 2008) with endpoints labeled "not at all" and "extremely" and a midpoint labeled "medium".

Manipulation check. As a manipulation check, participants were also asked to indicate how time seemed to progress while in the virtual reality environment (Wearden, 2005), using Likert-type scale with endpoints labeled "time flew" and "time dragged" and a midpoint labeled "normal". Low ratings indicate an accelerated time passage and high ratings indicated slower time passage.

Results

We first checked the effects of the manipulation. Participants in the "time flies" condition indicated that time seemed to pass with 26% faster than did participants in the "time drags" condition, $t(36)= -3.17$, $p = .008$, $d = -1.03$. Participants in the "time flies" condition rated the task as being more enjoyable, $t\ (36) = 3.37$, $p = .002$, $d = 1.05$, and less boring, $t(36) = -2.87$, $p = .008$, $d = -.93$, than the participants in the "time drags" condition.

General Conclusions and Discussion

The first study revealed that when people expect to have an enjoyable experience, they perceive time as passing more quickly, applying a heuristic based on their naïve theory that time passes faster when you are having fun (Sacket et al., 2009). However, to our knowledge, this is the first study that specifically investigated the impact of temporal expectancies on the perception of the speed with which time passes, not only on the ability to correctly estimate the length of a specific time interval. Our results do not indicate an effect of this expectancy on duration judgments, suggesting that this form of temporal experience is less affected by temporal expectancies and probably, as the literature suggests, is a function of the amount of information processing, or the amount of processed stimuli (Ornstein, 1969). When someone is asked to make a retrospective duration judgment, he/she uses the amount of "memory storage" or "contextual change" during that specific time interval so that greater amounts of "storage" result in longer time judgments (Wearden, 2005).

The second experiment revealed that people seem to enjoy their experiences more if they think time passed quickly, inferring, as Sackett et al. (2009) proposed, that their subjective perception of the speed with which time passes contains information about the hedonic value of the event, with the perception of the speed with which time passes serving as an input for metacognitive judgments.

These findings indicate that the popular belief that "time flies when you are having fun" functions both ways, as a heuristic for judging time as running faster while enjoying an event, and enjoying an event more while experiencing an accelerated perception of the speed with which time passes, therefore bringing important theoretical developments in terms of the factors that affect subjective time passage.

Study 3. Psychological Time: Interval Length Judgments and Subjective Time Passage Judgments[3]

Overview of the Present Study

After clarifying some of the cognitive factors with impact on subjective time judgments in the previous study, this study takes further the investigation of the factors that affect this temporal experience.

Research findings indicate that task complexity (e.g., how cognitively demanding a task is) is one of the influential variables that determine the interval length estimates.

Zakay (1992) introduced the idea that there are other variables, aside from the task difficulty (or cognitive load), that can have an impact on the amount of attention allocated to temporal information. He suggested that attention to time increases whenever timing becomes important for adaptation to an event (for example, while facing a deadline). He defined the concept of *temporal relevance* as the "level of relevancy and importance of time dimension in a specific state required for the optimal adaptation to the external environment" (Zakay, 1992, p.110), stating that when temporal relevance is high, the interval length is perceived as longer because we pay more attention to time.

However, it is not clear whether temporal relevance has the same impact on interval length estimates regardless of the task difficulty and it would be important to investigate the possible interaction effects between these two variables (task difficulty and temporal relevance) on interval length estimates in order to understand the conditions in which temporal relevance affects temporal judgments.

Since the subjective time passage judgments and interval length judgments have rarely been investigated in the same study, under the same methodological conditions, it is difficult to infer whether they are affected by the same variables or the nature of their relationship. The previous attempts to clarify the factors that affect subjective time passage judgments have used the retrospective paradigm, and it would be important to also understand the factors that impact the subjective passage of time judgments under the prospective paradigm as well.

Therefore, one objective of this study is to investigate, in the prospective paradigm, the impact of temporal relevance and task difficulty on both interval length judgments and subjective time passage judgments. Also, another objective was to clarify the possible interaction effects between these two variables (task difficulty and temporal relevance) in their impact on interval length judgments and subjective passage of time judgments. We also wanted to investigate the relationship between interval length judgments and subjective passage of time judgments, expecting a positive correlation between the two variables. Based on the literature, we expect that when the temporal relevance is high, the interval length will be perceived as longer than when the temporal relevance is low. Also, when the temporal relevance is high, time will be

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[3] This study was published:
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The authors have contributed to the article as follows:

- Sucala, M.: study design, conducting the study, analyses and results interpretation, writing the manuscript
- Scheckner, B.: results interpretation, writing the manuscript
- David, D.: study design, analyses and results interpretation, consultation for the exposition of the manuscript.

perceived as passing slower than when the temporal relevance is low. As for the impact of task complexity, we expect that while performing an easy task, interval length will be perceived as longer than while performing a difficult task. Also, we expect that while performing an easy task time will be perceived as passing slower than while performing a difficult task.

Another objective of this study was to investigate the impact that the hedonic value of the task has on both interval length judgments and on subjective passage of time judgments. Based on previous findings, we expect that while performing a task evaluated as being pleasant, interval length will be evaluated as shorter. Also, during a task evaluated as being pleasant, time will seem to pass faster.

Method

Participants

To be eligible, participants had to be at least 18 years of age and with no uncontrolled major physical or psychiatric illness. Seventy-eight undergraduate students (71 women and 7 men) participated in the experiment in exchange for course credit. The mean age was 21.88, *SD* = 3.80. The study had IRB approval and informed consent was obtained prior to participation.

Design and Procedure

A two-factor design was used. The first factor was task difficulty, which had two levels - *shallow/structural processing* and *deep/semantic processing* (Craik & Lockhart, 1972).

In the *shallow/structural level* group, the participants were asked to read a text and identify all the words that started with the letter S. The text was printed, written in Times New Roman font, sized 12.

In the *deep/semantic level* group, participants were told to read the same text, to identify all the words that started with the letter S, and to find a synonym for them (Dixon & Eye, 1984).

The second factor is temporal relevance, which had two levels – *high temporal relevance* and *low temporal relevance*.

In the *high temporal relevance* group the participants were told that they have a time limit and they should work as fast as possible, starting and stopping the task when they heard the START and STOP words, respectively.

In the *low temporal relevance* group, participants were simply told to start when they heard the word START.

Participants were randomly assigned to the four experimental conditions. After telling them the instructions mentioned above, all participants were told that they would have to estimate the length of the task after completion. All the participants were told to stop working after 4 minutes (240 seconds). Duration was measured using a digital stopwatch.

Measures

Interval length judgments. After the participants heard the word STOP, they were asked to make verbal estimates (in minutes and seconds) for the temporal length of the task. Following standard practice, in order to evaluate the direction of the temporal distortion, estimated times were transformed into measures representing Directional Errors (Khan, Sharma, & Dixit, 2006). When participants are required to give verbal estimates of various interval durations, the standard procedure is to convert the data into ratio scores by dividing the estimated duration by the actual duration (Brown, 1985). In the transformed data set, a value of less than 1.00 represents a temporal duration underestimate, whereas a value greater than 1.00 represents a temporal overestimate. A directional error of 1.00 represents an accurate estimation (Wahl & Sieg, 1980).

Subjective time passage judgments. The participants were also asked to indicate how quickly time seemed to pass during the task (Wearden, 2005). We used a 5-point Likert scale where 1= "time flew", 3= "normal", and 5= "time dragged". Lower ratings indicated an accelerated subjective time passage and higher ratings indicated a slower subjective time passage.

Ratings of hedonic interest. Ratings of hedonic interest were also assessed using a 5 point Likert scale where 1="boring", 3="medium", and 5="very interesting" (Sackett et al., 2009).

Results

An analysis of variance (ANOVA) was computed for each dependent variable: interval length judgments (directional error), subjective time passage judgments, and ratings of hedonic interest.

Interval Length Judgments

The main effect of Temporal relevance was significant, $F(1, 74) = 18.78$, $p < .001$, $d = .98$, indicating that in the High temporal relevance condition, participants perceived the interval length as longer. The effect of the Level of processing was also significant, $F(1, 74) = 15.20$, $p < .001$, $d = .88$, indicating that in the Shallow processing level condition, participants evaluated the temporal interval as being longer than in the Deep processing level condition. The Temporal relevance × Level of processing interaction was significant, $F(1, 74) = 7.71$, $p = .007$, $d = .62$. For the difficult task there was no difference between the interval length estimates given by the participants in the low temporal relevance group and the participants in the high temporal relevance group ($p > .05$). However, for the simple task, participants in the high temporal relevance group gave significantly longer interval length estimates than the participants in the low temporal relevance group, $t(40) = 5.29$, $p < .001$, $d = 1.67$.

Subjective Time Passage Judgments

Temporal relevance had a significant effect on subjective time passage judgments, $F(1, 74) = 11.01$, $p < .001$, $d = .75$, indicating that in the high temporal relevance condition, participants perceived time as passing with 10% more slowly. The effect of the level of processing was also significant, with a large effect size, $F(1, 74) = 19.50$, $p < .001$, $d = 1.00$, indicating that in the Shallow processing level condition, participants perceived time as passing slower than in the Deep processing level condition. The Temporal relevance × Level of processing interaction was significant, $F(1, 74) = 5.85$, $p < .001$, $d = .54$. For the difficult task, there was no difference between the high temporal relevance and the low temporal relevance groups. However, for the simple task, when participants were aware of the time passage (high temporal relevance) they perceived time as passing significantly slower than when they were not aware of the time passage (low temporal awareness group), $t(40) = 4.64$, $p < .001$, $d = 1.5$.

Ratings of Hedonic Interest

Overall mean ratings of hedonic interest were near the midpoint of the 5-point Likert scale. The ratings of hedonic interest did not differ significantly as a function of either task difficulty or temporal relevance (all ps $> .05$). The ratings of interest did not significantly correlate with either interval length estimates or with subjective passage of time judgments (all ps $> .05$).

Furthermore, we investigated the relationship between the prospective duration estimates and the subjective time passage judgments. We found a significant correlation between these two variables , $r(76) = .33$, $p < .001$, indicating that a longer prospective estimate is associated with a slower perceived time passage.

Discussion

The results of the present study indicate that when the time dimension becomes relevant (e.g., when having a time limit for completing a specific task), we allocate more of our attentional resources to temporal information, and give longer interval length estimates. If during an interval we pay close attention to time, constantly monitoring the time cues, we judge the interval to be longer (Zakay, 1998). We also found that simpler tasks tend to be perceived as longer. These results are consistent with the attentional models of time, which state that prospective duration timing depends on attention demanding processes that occur concurrently with the processing of non-temporal information (Thomas & Weaver, 1975; Zakay, 1998; Zakay & Block, 1997). Therefore, the more attentional demanding the task that fills the interval is, the shorter the estimates for the length of that interval will be. These models view interval length perception as a direct function of the amount of attention allocated for processing time related information (Zakay, 1992).

As researchers suggested (Zakay, 1992), the attention to time increases not only when the task that fills the interval is easy, but also when time becomes relevant (like having a deadline imposed for completing the task). By further investigating the interaction effect between task difficulty and temporal relevance, this study brings an important finding. When the task is difficult, the interval length estimates are shorter than for simple tasks, regardless of the level of temporal relevance. When the task is more demanding, although time might be relevant, as in the situation of having a deadline, the attentional resources are preferentially allocated for solving the task. However, when the task is simple, being aware of time passage (high temporal relevance) leads to temporal overestimates (the interval length is judged as being longer than it chronologically is) because, as Zakay (1992) suggested, when time becomes relevant, the perceptual system becomes sensitive to any internal or external time cues, and the non-demanding task allows more resources to be allocated for temporal processing.

A major finding of this study is that subjective time passage judgments seem to be affected by the same factors as interval length estimation. In other words, results indicate that both temporal relevance and level of task difficulty have a significant impact on subjective time passage judgments. Time is perceived as passing slowly when we are aware of its passage and when we are involved in solving tasks that are not difficult. It also appears that that the slowest time passage occurs when the person becomes aware of a time limit for resolving a simple task.

Based on the results, it seems possible that these two temporal experiences, interval length estimates and subjective time passage judgments, as assessed in the prospective paradigm, rely on the same attentional mechanisms. This idea is further supported by the significant correlation found between these two variables, showing that a longer interval length estimate is associated with a slower perceived time passage.

We did not find that the degree of interest is related to either subjective time passage judgments or interval length judgments, but it is possible that the results are due to the task we selected, which triggered mean ratings of interest near the midpoint of the Likert scale in all experimental conditions.

This study is the first to specifically investigate, under the same paradigm, the factors that affect both interval length judgments and subjective passage of time judgments. The study adds empirical data that could clarify the cognitive mechanisms on which the two temporal experiences are based on.

To our knowledge, this study is the first to investigate both interval length estimates and subjective time passage judgments under the same methodological conditions. The results have

both theoretical and practical implications that are likely to benefit the field, as well as individuals' efforts to better manage temporal resources. If we want to control our temporal behavior in order to obtain a better management of our time resources it is crucial to know which variables predict the way we perceive time.

Study 4. The Role of the Paradigm on the Subjective Time Passage

Overview of the Present Study

This study had the aim to bring methodological developments in the field of time perception. The purpose of the present research was to investigate the role of the paradigm on the perception of the subjective time passage. Based on previous findings, we expect that in the prospective condition participants will perceive time as passing slower than in the retrospective condition. The results of this study might have an important implication for the study of subjective time passage, setting its methodological base.

Method

Participants

Eligible participants were at least 18 years of age and had no uncontrolled major physical or psychiatric illness. Eighty-two undergraduate students (74 were women, 8 were men) participated in exchange for course credit. Mean age was 22.29, *SD* = 2.62. The study had IRB approval and informed consent was obtained from each participant prior to the study.

Design and Procedure

The independent variable had two modalities: (1) prospective paradigm and (2) retrospective paradigm.

When arriving at the scheduled day for the experiment, all the participants were told that the experiment will involve watching a video sequence. All of them were asked to remove their watches or phones and place them out of sight with the explanation that every distracter should be removed. Participants were randomized in the following conditions.

Participants in the prospective paradigm (n = 41) were told that they will have to watch a video sequence and, at the end of it, they will have the task to evaluate how time seemed to pass during this video sequence and how long the video sequence lasted.

Participants in the retrospective paradigm (n = 41) were told only that their task will involve watching a video sequence and responding to questions related with cognitive processes at the end of the task.

All the participants watched a 4 minutes video containing a sequence from a BBC Blue Planet Series (BBC, 2007).

Duration was measured using a digital stopwatch and an assistant stopped the video sequence at the end of the 4 minutes.

Measures

Subjective time passage judgments. At the end of the 4 minutes, all the participants were asked to indicate how time seemed to progress while watching the video sequence, a method used to assess the subjective experience of the passage of time (Wearden, 2005). We used a 5-point Likert scale with endpoints labeled "time flew" (1) and "time dragged" (5) and a midpoint labeled "normal" (3), where low ratings indicating an accelerated time passage and high ratings indicating a slower time passage.

Interval length estimation. We also included interval length estimates in order to check if the effects of our experimental manipulation will replicate the findings in the literature. The participants were also asked to verbally estimate the duration of the video sequence. The data from each participant was converted into ratios of subjective duration to objective duration. Ratio values of 1.00 show perfect accuracy, ratios below 1.00 represent underestimation of the actual duration of the interval, and those above 1.00 indicate overestimation of the actual duration of the interval (Block, Hancock, & Zakay, 2010; Hornstein & Rotter, 1969).

Results

Subjective Time Passage Judgments

We obtained a significant effect of the paradigm on perception of the speed with which time passes, $t(80) = 3.40$, $p < .001$, $d = .76$, indicating that in the prospective group, participants perceived time as passing with 19% slower than in the retrospective group.

Interval Length Estimation

The main effect of the paradigm was also significant for the interval length estimates, $t(80) = 3.93$, $p < .001$, $d = .88$. Results indicated that in the prospective paradigm, interval duration was estimated as being longer than in the prospective paradigm. In the prospective paradigm, the subjective duration was with 30% longer than the objective time.

Discussion

The results of this study showed that the paradigm is an important methodological variable for the subjective time passage, indicating that when the participants were aware that they will have to evaluate time passage, they perceived time as passing slower. Also, when they were aware of the time relevance for the task, they perceived interval length to be longer, a result that is consisted with the main findings in the time perception literature (Block, Hancock, & Zakay, 2010; Zakay & Block, 2004).

These results suggest that the perception of the speed with which time passes relies on the same cognitive mechanisms as interval length estimation does and they offer an important methodological development in the field, setting the basis for conducting future studies.

Study 5. The Effects of Mindfulness Exercise on Time Perception

Overview of the Present Study

The literature on time perception has not been concretized yet in a systematic approach for the investigation of factors that can be manipulated in order to control our perceived pace of life. The theoretical and methodological developments brought by the previous studies of this research made possible the pursuit of this line of research.

Most of the studies investigating time perception suggest that the most relevant factors that affect time perception are stimulus-related, focusing on investigating the characteristics of the tasks and events that fill a temporal interval in order to assess their impact on either subjective time passage or interval length judgments (Block, 1990; Wearden, 2005). Therefore, one way of manipulating time perception would be to manipulate stimulus characteristics. However, there could be other ways to manipulate time perception without manipulating the stimulus characteristics. Ornstein (1969) suggested that the attentional focus could be changed by other means in order to attend more or less to the task at hand. One such technique could be mindfulness meditation. Mindfulness is defined as “the awareness that emerges through paying

attention on purpose, in the present moment, and non-judgmentally to things as they are" (Williams et al., 2007, p. 47).

Therefore, a key element of mindfulness meditation is that it focuses on the unfolding of the present moment experience (Williams et al., 2007). This particular feature of mindfulness meditation, that it involves both attention to the stimuli array and to the temporal cues by constantly keeping temporal orientation to the present moment, could represent a starting point for further investigating the effects of this technique on time perception.

Therefore, the goal of the present study was to investigate the impact of mindfulness practice, with varying degrees of external stimulation, on both of the mentioned temporal experiences: 1) subjective time passage judgments and 2) interval length judgments. This is the first study in the literature that investigates the role of mindfulness practice on time perception. From a practical perspective, results might provide relevant insight related to the techniques that can be used in order to control subjective time perception.

Method

Participants

To be eligible, participants had to be at least 18 years of age and with no uncontrolled major physical or psychiatric illness. Eighty-three undergraduate students (75 women and 8 men) participated in the experiment in exchange for course credit. The mean age was 23.36, SD = 4.39. The study had IRB approval and informed consent was obtained prior to participation.

Design and Procedure

A two-factor design was used. The first factor was the mindfulness meditation practice, with two conditions: (1) mindfulness meditation practice condition and (2) control condition. The second factor was the type of stimulation, with two conditions: (1) a complex stimulation condition during which participants viewed a video sequence and (2) a reduced stimulation sequence during which participants remained in the waiting room. Participants were randomized in the four study conditions.

Mindfulness group participants completed one of two identical mindfulness training course sessions, during which the same instructor introduced them to the concept of mindfulness, meditation practice, group discussion, and interactive mindfulness-based exercises (Hayes, Follette, & Linehan, 2004). Initially, the meditation exercises emphasized proper breathing and focus, but later they required participants to extend their attention to the present moment and to the unfolding of moment-to-moment experiences. Participants were told to practice mindfulness meditation on a daily basis for 30 minutes at a time. They were given a specific mindfulness exercise for their daily practice (Kabat-Zinn, 1994). None had any prior experience with mindfulness techniques. Following a week of practice, participants were officially scheduled to participate in the experiment. They were asked to keep a record of their daily mindfulness practice.

Control group participants received no type of training. None had any prior experience with meditation or mindfulness techniques.

The participants in the video sequence condition proceeded to watch a 5 minute BBC Blue Planet Series compilation (BBC, 2007), while those participants in the waiting room condition waited for 5 minutes before an assistant brought them into the experiment room.

The mindfulness group was instructed to use their mindfulness techniques—exactly as practiced—during the video viewing (when in the video sequence condition) and while sitting in the waiting room (when in the waiting room condition).

Upon arriving to the experiment site, all participants were asked to remove their watches and place all phones and/or other time devices out of sight.

Duration was measured using a digital stopwatch. After 5 minutes, an assistant either stopped the video sequence or retrieved the participant from the waiting room.

This estimation was made according to the retrospective paradigm in that participants were not told in advance that they would be asked to estimate time. Literature often refers to such retrospective judgment as "remembered duration" (Block, 1990).

Measures

Subjective time passage judgments. As a means of assessing the subjective experience of time passage, participants were asked to indicate how fast or how slow time seemed to progress while watching the video sequence and while sitting in the waiting room (Wearden, 2005). We used a 5-point Likert scale ranging from "time flew" to "normal" to "time dragged." Low ratings indicated accelerated time passage, whereas high ratings indicated decelerated time passage.

Interval length estimates. Participants were also asked to retrospectively estimate the duration of the task (in seconds). Data from each participant were converted into ratios of subjective duration to objective duration. Ratio values of 1.00 reflected perfect accuracy. Ratios below 1.00 reflected an underestimation of the actual duration of the interval, whereas those above 1.00 reflected an overestimation (Block, Hancock, & Zakay, 2010; Hornstein & Rotter, 1969).

Results

Mindfulness and the Subjective Time Passage

We found that mindfulness practice had a significant effect on participant perception of the speed with which time passes, $F(1, 79) = 20.52$, $p < .001$, $d = 1.08$. These results indicate that participants in the mindfulness group perceived time as having passed with 16% more slowly than did participants in the control group. The mindfulness × condition interaction did not reach statistical significance ($p > .05$). However, descriptive statistics indicate that those in the waiting room condition tended to perceive time as having passed more slowly than participants watching the video sequence.

Mindfulness and Interval Length Estimates

We found no significant main effect of mindfulness practice on interval length judgments ($p > .05$). However, the main effect of stimulation condition was found to be significant, $F(1, 79) = 30.13$, $p < .001$, $d = 1.30$, with post-hoc tests indicating that participants watching the video sequence gave longer interval length estimates than did those in the waiting room condition. Furthermore, we found the mindfulness × stimulation condition interaction to be significant, $F(1, 79) = 4.29$, $p = .040$, $d = .49$, with descriptive analyses indicating that those in the waiting, mindfulness group gave longer estimates than did those in those in the waiting, non-mindfulness (control) group.

We also found a negative, however not statistically significant ($p > .05$), correlation between participant perception of the speed with which time passes and participant estimation of interval length.

Discussion

An important finding of this study is the fact that mindfulness practice had a significant effect on the perceived speed with which time passes. Participants in the mindfulness group perceived time as having passed more slowly than participants in the control group, indicating

that an awareness of our present experience, on a moment-to-moment basis, may impact the way we perceive the passage of time.

Participants in the waiting room condition also perceived time as having passed slightly more slowly than did those watching the video sequence. This finding is consistent with the idea that when we have little information to process, we become more aware of temporal cues, we allocate more of our attentional resources to temporal information, and consequently we perceive time as having passed more slowly (Zakay, 1992; Zakay & Block, 1996).

Although mindfulness practice had no significant effect on estimations of interval length, it is interesting to note that while in the waiting room condition, those participants with mindfulness techniques at their disposal gave longer estimations of duration than did those lacking mindfulness training. Participants seemed to overestimate interval length in conditions involving more complex external stimuli (like watching a video sequence) and underestimate interval length in conditions involving less complex stimuli (like waiting).

Our findings provide significant empirical support for the ability of mindfulness meditation to slow down our perception of time passage. One practical implication of this finding is that mindfulness techniques could potentially help us gain a better sense of control over our increasingly faster and more hectic lives (Levine, 1997).

Study 6. The Role of Mindfulness Exercise on Time Perception. Further Investigation Using a Virtual Reality System

Overview of the Present Study

The previous study showed that mindfulness practice had a significant effect on the perceived speed with which time passes. Participants in the mindfulness group perceived time as having passed more slowly than participants in the control group, indicating that an awareness of our present experience, on a moment-to-moment basis, may impact the way we perceive the passage of time. However, it is not clear which are the mechanisms that can explain these findings.

Research suggests that one of the mechanisms by which meditation has an impact on time perception concerns the emotional factor (Glicksohn, 2001). More specifically, research suggests that mindfulness meditation practice can represent a mean for regulating emotional factors, like arousal and emotional valence (Chambers, Gullone, & Allen, 2009).

Arousal

The findings concerning the role of arousal in time perception have been sometimes contradictory, with studies pointing that high arousal stimuli were perceived as being shorter (especially in the prospective paradigm) (Noulhiane et al., 2007), while other studies have found that arousal has no effect unless in interaction with emotional valence (Angrilli et al., 1997), showing that participants overestimated negative valence, high arousal stimuli. In contrast, at high levels of arousal, positive stimuli were underestimated. In another study, Droit-Volet and Meck (2007) found similar results, showing that threatening high arousal stimuli were overestimated more than the non-threatening high arousal stimuli. However, so far, one of the difficulties in clarifying the specific role of arousal in time perception has been related to the ethical constraints that preclude inducing extreme stress in laboratory conditions.

Emotional Valence

Langer, Wapner, and Werner (1961) found that subjects who were experiencing fear of danger gave shorter time estimates than subjects in a neutral condition (Angrilli et al., 1997). In another study, Thayer and Schiff (1975) asked subjects to estimate the length of an interval spent in an eye-contact task while manipulating the facial expression of the subject's partner, a critical factor considered to influence the affective valence of an interpersonal contact (Angrilli et al., 1997). Time estimates where longer when combined with a negative-unpleasant than with a positive-pleasant facial expression.

The present study had the objective to investigate the effects of mindfulness practice, while also clarifying the effects of emotional factors (arousal and emotional valence) on the subjective time passage. Based on previous findings, we expect that mindfulness practice will lead to a slower subjective time passage.

Method

Participants

To be eligible, participants had to be at least 18 years of age and with no uncontrolled major physical or psychiatric illness. Ninety-one (79 female and 12 male) undergraduate students participated in the experiment, in exchange for course credits. Mean age was 21.13, SD = 1.42. The mean age was 20.92, *SD* = .88. The study had IRB approval and informed consent was obtained prior to participation.

Design and Procedure

A bivariate between-groups design was used; (1) Mindfulness, with two conditions: mindfulness exercise and control condition, and (2) Virtual reality, with two conditions: River City and Roller Coaster, both described below.

Participants were first randomly assigned to one of the two groups (mindfulness group and control group).

The participants in the mindfulness group were asked to participate in mindfulness exercise session training, in groups of 4-5, where they were introduced to the mindfulness concept. After the theoretical introduction, they practiced a mindfulness exercise (Kabat-Zin, 1994) and received feedback for it. They were told that in the following week, they should use that exercise as often as possible and were give written instructions for guidance. They also received an exercise diary, with the request to mark on the diary every time they did the exercise and also, to write any remarks that they had about the exercise. Every participant was scheduled for participating in the experiment after a week from this first meeting. They were told the purpose of the study is to investigate the role of mindfulness techniques on cognitive mechanisms.

The participants in the control group received no training and they had no prior exposure to mindfulness meditation.

In order to manipulate the emotional factors, the participants in each group, mindfulness and control, were further randomized in two experimental conditions - two virtual reality environments: the participants in the Low arousal condition were immersed in the "River city condition" (an application that allows the participant to take a walk in virtual city, with a relaxing scenery) and the participants in the high arousal group were immersed in a "Roller coaster" environment (an application that allows the participant to take a ride with a virtual roller coaster). We chose the virtual environment because the system allows a more controlled experimental setting, offering the possibility to fully control a multisensorial environment that

also has an increased degree of realism (for example, movement simulation, essential in virtual reality environments (Kalawsky, 1993), allowing thus to induce arousal without exposing the participant to real dangers or unethical environments (Campbell & Bryant, 2007). There are studies that already indicated the role of virtual environments in manipulating emotional factors (Calvert & Tan, 1994). The virtual reality system that was used is an EON Icube, a PC based multi-sided immersive environment in which participants are completely surrounded by virtual imagery and 3D sound. For the selected applications, the motion tracker systems calculate the 3D perspective view in real-time, both for the head and the Xbox 360, a controller that is used as a navigation device. The Xbox 360 controller is trackable device in six degrees of freedom which allows the participant to aim at any target in the scene and interact totally immersed inside the application.

When arriving at the scheduled day for the experiment, all the participants were told that the experiment involves cognitive mechanisms used in the perception of virtual reality. All of them were asked to remove their watches or phones and place them out of sight with the explanation that this is the regular procedure when participating in a virtual reality task.

After hearing the instructions, the participants were fully immersed in the virtual environment for 300 seconds. Duration was measured using a digital stopwatch and a technical assistant stopped the virtual reality program at the end of the specified time period.

Measures

Subjective time passage judgments. At the end of the 300 seconds, the participants were asked to indicate how time seemed to pass while in the virtual reality environment, a method used to assess the subjective experience of the passage of time (Wearden, 2005). We used a 5-point Likert scale with endpoints labeled "time flew" and "time dragged" and a midpoint labeled "normal", where low ratings indicating an accelerated time passage and high ratings indicating a slower time passage.

Self-reported arousal. Participants were asked to report the level of physical arousal that they felt during the task, on a Visual Analogue scale (0= "extreme calm", 10="extreme physical arousal"). Previous research has demonstrated that self-reported arousal reliably covariates with physiological reactions associated with emotional response (e.g., skin conductance response, heart rate), suggesting that this is a valid measure of emotional responding (Matthews, 1987, 1989).

Valence ratings.

Ratings for task valence were requested, using a Visual Analogue scale (0 = "extremely unpleasant", 10 = "extremely pleasant").

Results

An analysis of variance (ANOVA) was computed for each dependent variable.

Subjective Time Passage Judgments

The results showed that there was a significant effect of mindfulness $F(1, 87) = 7.37$, $p = .008$, $d = .57$, with results indicating that time seemed to pass with 16 % slower than in the control group. The main effects of the condition, or the interaction between mindfulness and condition did not reach statistical significance ($p > .05$).

Self-reported Arousal

There was a significant difference in arousal between the two virtual environments conditions, $F(1, 87) = 8.94$ $p = .004$, $d = .64$, with participants in the "Roller coaster" condition giving higher estimates for self-reported arousal. The main effects of Mindfulness did not reach statistical significance (all $ps > .05$).

Emotional Valence Ratings

The main effects of Condition and Mindfulness did not reach statistical significance (all *ps* > .05).

Arousal and Valence Effects on the Subjective Time Passage Judgments

Furthermore, we tested the effects of arousal and valence on the subjective passage of time. Participants were grouped in either Low arousal or High arousal group, as based on the group mean for this variable. In the same way, participants were grouped in either Positive valence group or Negative valence group as based on the group mean for this variable. Both arousal, $F(1, 87) = 9.07$, $p = .003$, $d = .63$, and valence had a significant effect, $F(1, 87) = 7.37$, $p < .001$, $d = .56$, with a slower time passage for low arousal and a faster time passage for positive valence. Also, the arousal × valence interaction had a highly significant effect, $F(1, 87) = 7.37$, $p < .001$, $d = .78$. In the high arousal condition, positive valence produced the faster perception of the speed with which time passes, while in negative valence produced the slowest perception of the speed with which time passes.

Discussion

A major finding of this study is that perception of the subjective time passage was affected by the mindfulness exercise, indicating that time is perceived as passing slow when we are aware of its passage.

A mindful stance, defined as present-time awareness, could be used in order to subjectively slow down our time perception. As opposed to other manipulations used to increase temporal awareness (directly, like the use of time limits, waiting conditions, or indirectly, by using different levels of task complexity) it has the advantage of allowing the focus on time perception without taking away the focus from the task because mindfulness practice aim toward awareness of moment to moment unfolding of stimuli, while being aware of the "here and now" dimension.

Mindfulness meditation practice did not have a significant effect on emotional factors, therefore we cannot draw an inference that its impact on subjective time passage could be related to emotional factors, as suggested in the literature.

However, we decided to separately investigate the effects of arousal and valence on the perception of the speed with which time passes. The results show that we perceive time as passing slower for low arousal stimuli and faster for positive valence stimuli. In the high arousal condition, positive valence produced the faster perception of the speed with which time passes, while negative valence produced the slowest perception of the speed with which time passes.

A theoretical implication is that the study brings clarification on the role of emotional factors.

The findings further provide significant empirical support for the ability of mindfulness meditation to slow down our perception of time passage. One practical implication of this finding is that mindfulness techniques could potentially help us gain a better sense of control over our increasingly faster and more hectic lives (Levine, 1997).

CHAPTER IV. GENERAL CONCLUSIONS AND DISCUSSION

This research brought important theoretical contributions related to the factors that affect both the perception of duration and the perception of time passage. Also, another contribution was related to the methodological developments. After bringing theoretical clarification and highlighting some of the relevant methodological aspects in the field, the ground was set for bringing an important practical implication, namely, pointing a technique that can be used as a tool for controlling our temporal perception. These findings are discussed bellow.

4.1. Theoretical Advances

The critical review of the literature offered in the first chapter highlighted the fact that although interval length perception has received a great deal of attention in the time perception literature and the factors that affect this subjective temporal experience are better understood, so far there has been no systematic approach on identifying the factors that can lead to a lengthening of the subjective time.

Therefore study 1 was focused on specifically investigating the variables that can extend the perceived duration. This study showed that subjective time dilation can be experimentally achieved and it highlighted the variables that can be manipulated in order to do that.

The results of this study showed that the largest effect sizes seem to be associated with manipulating temporal expectancies and task complexity. Manipulating affective factors and motivation for the outcome were associated only with moderate effect sizes.

As for the magnitude of the overestimates, the results show that a larger time overestimation is obtained when motivation for a desired outcome is aroused experimentally. If at the end of a time interval the participants can reach a desired outcome, they tend to overestimate that period of time. The existence of the desired outcome can make the information about time more relevant (e.g. how much time until one attains the outcome).

Another class of variables that can induce an overestimation of time refers to affective factors. The activation induced by emotional stimuli makes time appear longer. The results are generally explained by the activation-based models of time perception (Treisman, 1963), which suggest that emotions generate an increase in the pacemaker rate, which leads to an extended subjective duration. This overestimation occurs for negative stimuli, indicating that negative stimuli induce greater physiological activation than positive ones (Noulhiane, Mella, Samson, Ragot, & Pouthas, 2007).

The expected length of an interval also determines an extension of the perceived time. Temporal expectancies can be formed as a function of previous experiences with an event, or by the influence of anchors (Thomas & Handley, 2008). When individuals do not have information about the duration of an event, they wrongly estimate the interval in an expected direction based upon previous experiences with the task. When they have information about an upcoming event and it lasts longer than expected, they tend to overestimate the actual duration.

Results show that we can also manipulate time estimates by manipulating task complexity. The idea is that a person bases the duration judgments on the amount of different contextual information that is retrieved, a process that relies on the availability of such information (Zakay & Block, 1996). The more complex the task and the more cognitive changes a person can process, the longer he/she will remember the duration (Block, 1990).

As the literature suggests, the length of time overestimation is differentially affected by the paradigm (prospective or retrospective) (Zakay & Block, 1997). Another interesting finding,

in line with other research findings, was that the type of study method affects the length of time overestimation (verbal estimates and reproductions), with the mean duration judgment ratio for verbal estimates being higher than for the reproductions.

This study was the first attempt to systematically investigate the factors that induce subjective time dilation.

The first chapter also pointed to the fact that there is another time perception phenomenon, the subjective passage of time (or the perception of the speed with which time passes), which was far less understood.

Study 2 pursued therefore an investigation of the factors that have an impact on the perception of the speed with which time passes.

This study revealed that when people expect to have an enjoyable experience, they perceive time as passing more quickly, applying an heuristic based on their naïve theory that is not necessarily incorrect (Sackett et al., 2009) and that matches the scientific results which indicate that in stressful situations people judge time intervals as being longer (Vohs & Schmeichel, 2003). However, this is, from our knowledge, the first study that specifically investigated the impact of temporal expectancies on the perception of the speed with which time passes, not only on the ability to correctly estimate the length of a specific time interval.

Also, study 2 revealed that people seem to enjoy their experiences more if they think time passed quickly, inferring, as Sackett et al. (2009) proposed, that their subjective perception of the speed with which time passes contains information about the hedonic value of the event.

These findings indicate that the popular belief that "time flies when you are having fun" functions both ways, as a heuristic for judging time as running faster while enjoying an event, and enjoying an event more while experiencing an accelerated perception of the speed with which time passes.

Whereas most of the studies in the time perception literature are focused on investigating the variables that affect duration judgment, this study added empirical data for clarifying the relationship between temporal beliefs and the subjective time passage.

Study 3 further pursued the investigation of the factors that affect subjective time passage, evaluating the relation between this temporal experience and interval length judgments. The study also investigated the impact of two important factors (temporal relevance and task complexity) on both the subjective time passage and on interval length estimates. The findings of this study indicate that when the time dimension becomes relevant (e.g., when having a time limit for completing a specific task), we allocate more of our attentional resources to temporal information, and give longer interval length estimates. If during an interval we pay close attention to time, constantly monitoring the time cues, we judge the interval to be longer. We also found that simpler tasks tend to be perceived as longer, a result that is consistent with previous studies investigating prospective judgments (Block & Zakay, 1996; Block & Zakay, 1997).

A major finding of this study is that subjective time passage judgments seem to be affected by the same factors as interval length estimation. In other words, results indicate that both temporal relevance and level of task difficulty have a significant impact on subjective time passage judgments. Time is perceived as passing slowly when we are aware of its passage and when we are involved in solving tasks that are not difficult. It also appears that the slowest time passage occurs when the person becomes aware of a time limit for resolving a simple task.

Another theoretical contribution was that of study 6, which, besides investigating the impact of mindfulness exercise on subjective time perception, also clarified the impact of

emotional factors on subjective time passage, showing that we perceive time as passing slower for low arousal stimuli and faster for positive valence stimuli. In the high arousal condition, positive valence produced the fastest perception of the speed with which time passes, while negative valence produced the slowest perception of the speed with which time passes.

4.2. Methodological Developments

Study 4 was focused on clarifying the role of methodological variables in the case of subjective time perception.

This study showed that the paradigm is an important methodological variable for perception of the speed with which time passes, indicating that when the participants were aware that they will have to evaluate time passage, they perceived time as passing more slowly. Also, when they were aware of time relevance for the task, they perceived interval length to be longer, a result that is consistent with the main findings in the time perception literature (Block, 1990; Block, Hancock, & Zakay, 2010).

These results further highlight the idea that it is possible that perception of the speed with which time passes relies on the same cognitive mechanisms as interval length estimation does.

In the retrospective paradigm, while not being aware of the time relevance, when asked to estimate the passage of time, participants use the amount of information processed, or the amount of contextual changes as a decisional heuristic for evaluating how time passed during that task (Block & Reed, 1978; Ornstein, 1969).

In the prospective paradigm, estimating the passage of time depends on attention demanding processes that occur concurrently with the processing of non-temporal information (Pouthas & Perbal, 2004; Zakay & Block, 2007). As the research findings indicate, if a person focuses more attention on temporal information processing, as in the prospective paradigm, more time signals are processed and time is perceived as passing slower.

Another methodological implication of this research was that two of the included studies (study 2 and study 6) used virtual reality environments in order to increase the extent to which the findings can be generalized to "real-life" situations. Using such a research methodology allowed both an increased internal validity (thus an increased control of study variables) and an increased external validity (thus conducting the research in a methodological setting that mimics real-life situations).

4.3. Practical Implications

After previous studies clarified the factors that affect both interval length judgments and passage of time judgments, a specific objective of the last studies was to find specific techniques for controlling time perception, both as perception of the speed of time and as estimation of interval length.

Chapter I summarized and offered a critical review of the literature, pointing that this abundant literature on time perception has not been concretized in a systematic approach on the investigation of factors that can be manipulated in order to control our perceived pace of life.

Research findings described in Chapter I indicated the possible role of mindfulness meditation as such a technique for manipulating time perception, therefore studies 5 and 6 investigated the impact of mindfulness meditation practice on time perception.

An innovative and major finding in study 5 is that perception of the speed with which time passes is affected by mindfulness exercise, a result indicating that mindfulness meditation practice could be a useful tool for controlling this type of temporal experience.

A mindful stance, defined as present-time awareness (Forsith & Eiffert, 2008), could be used in order to subjectively slow down our time perception. As opposed to other manipulations

used to increase temporal awareness (directly, like the use of time limits, waiting conditions, or indirectly, by using different levels of task complexity) it has the advantage that it allows the focus on time perception without taking away the focus from the task because mindfulness practice aim toward awareness of moment to moment unfolding of stimuli, while being aware of the "here and now" dimension (Kabat-Zin, 1994).

The results of the last empirical study, study 6, confirmed the finding that mindfulness exercises can be used in order to slower our perception of the speed with which time passes. Subjective time passage was affected by the mindfulness exercise, indicating that time is perceived as passing slowly when we are aware of its passage.

These are the first studies that addressed the role of mindfulness meditation practice in time perception, showing that it is a useful technique for controlling our time perception.

In summary, this research brought important theoretical contributions related to the factors that affect both the perception of duration and the perception of time passage. Also, another contribution was related to the methodological developments. After bringing theoretical clarification and highlighting some of the relevant methodological aspects in the field, the ground was set for bringing an important practical implication, namely, pointing a technique that can be used as a tool for controlling our temporal perception.

An important contribution of this research is that, once the factors and the mechanisms by which time perception can be controlled are found, these factors and mechanisms can be used in order to control temporal experiences in the desired direction, either by lengthening or slowing time perception, or by shortening or speeding the perceived time.

This means that once we have identified the factors that can be manipulated for controlling time perception, we could also use them in order to make time pass faster during unpleasant events, such as invasive medical procedures or as a technique for pain management. Therefore, the findings could have potential clinical applications as well.

Therefore, future studies should further investigate these clinical implications investigating the role of the identified factors and techniques for controlling temporal perception in clinical and /or elderly populations, with implications for the quality of life.

Also, future studies should further investigate the clinical implications of this research, investigating the role of the identified factors and techniques for controlling temporal perception in clinical and /or elderly populations, with implications for the quality of life.

In the same time, future studies should further investigate the mechanisms by which mindfulness meditation impacts subjective time passage. One of the fruitful avenues of research could be the investigation of time awareness and task awareness while practicing mindfulness meditation.

Also, another line of research, more specifically related to the subjective time passage, could be related to the investigation of the effect of affective factors while investigating the role of other variables like temporal relevance or task complexity since it is possible that, in real life situation, facing a deadline for a difficult task can trigger affective factors that might have relevance for subjective time passage judgments.

However, the results of the present research have important theoretical, methodological and practical implications that are likely to benefit the field, as well as individuals' efforts to better manage temporal resources.

If we want to control our temporal behavior in order to obtain a better management of our time resources, it is crucial to know which variables predict the way we perceive time.

Finding the factors that can be manipulated in order to slow down the speed of time can represent a mean for gaining a better sense of control over our increasingly faster and more hectic lives (Levine, 1997).

Limits

The present research is not without limits. First, only undergraduate students participated in the studies and most of the participants were women. Therefore, these results may not generalize to men, or individuals of different age groups.

Second, the research is limited in that participants' perceptions and estimations may have been affected by other confounding variables, such as the degree to which participants were prone to boredom. However, it is unlikely that other conditions significantly influenced the results of our studies in that randomization typically controls for potential confounding variables by increasing the chance that all groups are essentially equal.

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Note: Reference marked with an asterisk indicates studies included in the meta-analysis (Study 1). The in-text citations for studies selected for meta-analysis are not preceded by asterisks.

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