Role of Sleep in Affect Regulated Decision Making under Risk: An ERP Study

A

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DECLARATION

I hereby declare that the thesis entitled **"Role of Sleep in Affect Regulated Decision Making under Risk: An ERP Study"** is the result of investigation carried out by me at the Sleep and Cognition Laboratory, Department of Humanities and Social Sciences, Indian Institute of Technology Guwahati, under the supervision of **Dr Naveen Kashyap**. The work has not been submitted either in whole or in part to any other university / institution for a research degree.

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CERTIFICATE

This is to certify that Ms Suman Dhaka has prepared the thesis entitled **"Role of Sleep in Affect Regulated Decision Making under Risk: An ERP Study"** for the degree of Doctor of Philosophy at the Indian Institute of Technology Guwahati. The work was carried out under my supervision and in strict conformity with the rules laid down for the purpose. It is the result of her investigation and has not been submitted either in whole or in part to any other university / institution for a research degree.

IIT Guwahati

April, 2017

Naveen Kashyap

Supervisor

Dedication

To my parents, who have always loved me unconditionally and taught me to work hard to achieve the goals that I aspire.

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ABSTRACT

Human beings are complex in nature. They live in an equally complex world around them. Their survival requires a constant interaction with both humans and the environment. Such interactions involve decisions that are made with certain or uncertain probabilities of consequences. Among the various factors that affect human decision making, emotions holds a major place. Previous research suggest that the emotions have an impact in the decision making process by influencing risk perception and consequence predictions. This effect of emotion on decisions can be down regulated by using specified behavioral responses that regulate the emotion effects. Besides the extrinsic emotion regulation strategies, sleep naturally lower the tone of emotions through the process of cathartic releases. Thus, sleep acts as a natural emotion regulating mechanism.

The present thesis is an attempt to study how behavioral modification of responses after emotions (regulation strategies) influence decision-making ability under risk and with known probabilities of consequences. Further, the study also evaluates the role of sleep on affect-regulated decision making under risk. The present thesis uses both behavioral and electrophysiological data to arrive at its conclusions. Experiment 1 tested the effectiveness of emotion regulation strategies across varied emotion induction methods and valence on decision making under risk. Distraction and cognitive reappraisal strategies significantly downregulated the emotion effect and led to less risk aversive behavior, particularly in negative pictorial stimuli. Other emotion regulation strategies no longer affected risk taking, suggesting these strategies are best suited to minimize carry over effect of emotion on risky decision-making. Experiment 2 and 3 investigated the effect of sleep over deprivation on negative effect regulated risky decision-making, using the reappraisal and distraction strategies. Electrophysiological data during the decision making task was collected in addition to behavioral data to supplement the overall effect. Sleep as compared to deprivation provides a better opportunity for downregulation of negative effect. Further, only reappraisal strategy successfully downregulated emotion effect and led to optimal decision making with maximum gains or minimum loses. The behavioral results were supported by the presence of error related negative and P300 waveforms over the front-central sites. The presence of FRN and P300 signal that subjects were sensitive to losses and were able to effectively evaluate the outcomes of the decision task on reappraisal trails across sleep nights. This leads to optimal decisions with calculated risks and beneficial outcomes for the decision maker. The present thesis reports that, reappraisal behavioral response (regulation strategy) is the most effective in downregulating emotion effects on risky decision-making and lead to maximally beneficial outcomes. This effect is further enhanced by sleep nights as sleep due to its inherent property of catharsis provided an optimal medium for effective downregulation of incidental emotion effects. Overall, the potential significance of these studies lies in understanding that how individual can employ regulation strategies to their benefit by altering their subjective experiences of emotion to maximize beneficial outcomes under risky situations.

Keywords: Emotion regulation, Distraction, Cognitive reappraisal, Risk, Decision-Making, EEG, FRN, P300.

List of Publications

Refereed Journals

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"Sometimes, all you can do is lie in bed, and hope to fall asleep
Before you fall apart......... (William C Hanna)"

Our everyday lives are complex entities, requiring us to make choices under risk or uncertainty. The choice making behaviour is termed as "*Decision Making*", and it involves an information-processing activity that begins with the recognition of a choice situation and ends with the implementation of the choice and the monitoring of its effects. Decision process requires the processing of large chunks of data making the process venerable to a large number of external and internal factors (Anderson and Dickinson, 2010; Güroglu et al., 2010; Henrich et al., 2005; Symmonds et al., 2010). Studies evaluating factors affecting decision-making suggest '*emotional bias*' as a key factor modulating decisions. Economic theory, '*the primate theory of decision making',* suggest that emotions lead to irrational decision making. Research from the last few years has shown that besides expected emotions (generated via ongoing decisions), incidental emotions (unrelated to the decision at hand) can also have a significant impact on judgment and choice (Clore, 1992; Forgas, 1995; Lerner and Kelther, 2000; Schwatz, 1990). When faced with an emotional situation, decision systems try to modulate the emotions (up / down regulate affect) in order to achieve the required goal (maximize pleasure / minimize pain). The process through which decision systems modulate emotions is called '*Emotion regulation - the ability to modify our emotions*' (whether innate or experimentally induced) which as the end product, upgrades the quality of decisions. The ability to regulate the appropriateness of emotional responses to circumstances is a major component of healthy, adaptive social behaviour and well-being. A major focus of research in affective neuroscience over the past decade has been to understand how emotions can be modified and how we can utilize this flexibility of emotion to develop more effective clinical interventions for more satisfying and healthy lives (Hartley and Phelps, 2010; Davidson and Begley, 2012). An important issue while exploring emotion regulation and decision making is to consider the effectiveness of various emotion regulation strategies. It is important to consider not only the effectiveness of various strategy but also the conditions under which strategies are effective (Aldao et al., 2010; Augustine and Hemenover, 2009). Studies investigating the influence of emotions on decisions often use affect manipulation to control and systematically change the current emotional state of the participants. Usually, this is done via video clips, pictures, and/or sounds (Ciarrochi and Forgas, 2000; Ellard, Farchione, and Barlow, 2012; Haase and Silbereisen, 2011; Winkielman et al., 2007). However, even though there are many theoretical arguments in favour of films, very little empirical evidence can be found. The inefficient regulation of emotions can lead to several difficulties that can lead to severe psychopathological states (Kring and Sloan, 2010). Interestingly, sleep disorders also lead to the occurrence of psychopathological states similar to once shown by deficient emotion regulation (Harvey, Murray, Chandler, and Soehner, 2011). This is lead scientists to study the process affecting sleep and emotional experience.

In today's modern society, drastic changes in living conditions such as prolonged work time, increased shift working, and various socio-psychological stresses have led to increasing number of sleep-related problems (sleep loss and chronic insomnia) and emotional dysfunctionality in humans. Sleep loss cause not only daytime sleepiness and psychomotor impairment, but also emotional instability, anxiety, and confusion, and chronic insomnia increases vulnerability to mood and anxiety disorders. In recent years, there has been an upsurge of evidence that sleep plays a vital role in the processing of emotions. Moreover, REM sleep in particular has been implicated in the consolidation of negative emotional episodic experiences (Wagner et al., 2001, 2006; Nishida et al., 2009), whereas manipulations of REM have been shown to alter the evaluation of affective stimuli, particularly those of negative valence (Wagner et al., 2007; Lara-Carrasco et al., 2009). Theory suggested that REM may offer an ideal neurobiological medium by reduction in aminergic neurochemistry and reactivated limbic anatomy (Hobson and Pace-Schott, 2002) which depotentiate prior negative experiences, restoring optimal post sleep affective reactivity (Levin and Nielsen, 2009; Walker, 2009a, 2009b; Walker and van der Helm, 2009). Thus, two events take place in REM that are crucial to daytime emotional regulation: 1) reactivity of the amygdala is down regulated due to suppression of central noradrenergic tone and 2) emotional memories are re-activated in amygdalar-hippocampal networks during REM. The deprivation of sleep affects several cognitive domains. It increases preservation error leading to rigid thinking, which in turn lowers our capacity to utilize new information in complex tasks built around the ideas involving innovative decision-making (Harrison and Horne, 1999). Deteriorated decision-making is primarily responsible for varied performance and applied strategies (Linde et al., 1999), further leading to increased risk taking behaviour (Killgore et al., 2006).

The present thesis aims to examine the effectiveness of emotion regulation strategies on risky decision making by modulating the stimuli, affect and sleep. To conduct these examinations, the study was categorized into two sections where - section one deals with behavioral experiments where the effect of emotion regulation of risky decision making is evaluated by manipulating stimuli (picture/video) and emotion regulation strategies and section two examines the role of sleep in emotion regulation guided risky decision making. In our initial experiments, we attempt to examine the effect of emotion regulation strategy on risky choice behavior. In experiment one, the effect of different types of emotion regulation strategy (situation selection, distraction, distraction, cognitive reappraisal, and suppression) on risk taking behavior were examined. As most of the studies in the area of emotion regulation examine only cognitive reappraisal and suppression and few examine distraction, we incorporated the situation selection and distraction strategy also in experimental paradigm, which is based on the concept of initial modulation of emotions. These type of emotion regulation strategy and their effect on risk taking behavior is a recent addition and are less studied compared to another type of emotion regulation strategy. The results of the experiments revealed the significant main effect of distraction and cognitive reappraisal on risk taking behavior. Based on these finding we eliminated situation selection, and suppression strategy in our further studies, as difference we found in our experiment clearly indicates that in comparison to situation selection and suppression, distraction and cognitive reappraisal are most effective to modulate risk-taking behavior. The next experiment of the thesis explored the effectiveness of emotion regulation strategy by manipulating stimuli affect (Positive/Negative) measured across two dimensions (arousal and valence) on risky choices. Since the main object of interest in the present thesis was to study the effectiveness of emotion regulation on risky choice behavior by manipulating the variable of emotion regulation, we decided to test how affect and type of stimuli effect affect regulated decision-making. In our third behavioral experiment, we manipulated the stimuli type (picture/film). Previous research on emotion regulation effect on risky choice behavior suggests that the type of emotional stimuli has a major role to play on such interactions. Since experiments in the thesis until this point used only pictorial stimuli, we decided to vary stimuli format/type in terms of pictures and films/videos. We, therefore, designed an experiment to investigate the effect of emotion regulation across two stimuli type (pictures and words) on affect regulated decision making. Results of the experiment clearly indicated picture superiority effect over film stimuli, as expected participants performed better for picture stimuli compared to film.

To extend our findings, same experiments were repeated to investigate the effect of emotion regulation on risk taking behavior by varying the sleep duration. The sleep duration was: a) resting state (sleep) which not only have optimal neural states that support emotion but also hinder emotional reactivity; b) non-resting state (sleep deprivation) with increased global and local neural depression that increase emotional reactivity c) second-half sleep deprived d) first-half sleep deprived. Our objective was to examine the effect of sleep duration on affect-regulated decision making in particular on risky choice behavior.

The overall objective of the thesis was to study the impact of emotion regulation effectiveness on risk taking behavior by manipulating stimuli and sleep duration. It is the well-established role of emotion in decision making but there are very few studies which examined the effect of emotion regulation on risk taking behavior and its condition under which it most effective. So the study of the interaction of emotion regulation and risk taking behavior in depth is essentially required to come across emotion dysregulation and their clinical pathological impact. In addition, to study not only the type of emotion regulation strategy but their effectiveness (in what condition) on risk taking behavior also a much-needed topic in emotion regulation and decision making.

Theoretical Foundation and Review of the Literature

1.1 Emotions

Researchers differ in their view of on the definition of emotions because; there exists no clear definition of the term "emotion" (Cunningham and Kirkland, 2012; Russell, 2003). However, most researchers agree that emotions consist of several essential components, namely cognitive, behavioral, physiological, and experiential components (Winkielman, Knutson, Paulus, and Trujillo, 2007). One feasible way of visualizing emotions is by breaking them into their basic dimensions of valence and arousal. Valence of emotions means pleasantness (how positively or negatively someone think or feels about something), and arousal of emotions refer to bodily activations (how physiologically alert, awake, and attentive someone feels about something) (Rothermund and Eder, 2011; Russell, 2003; Suri, Sheppes, and Gross, 2013; Winkielman et al., 2007). Valence and arousal can be demonstrated graphically in a two-dimensional coordinate system (see Figure 1). This model can explain most of the self-reported variance in ratings of emotions (Rothermund and Eder, 2011; Suri et al., 2013), considering all possible emotions from neutral (which is presented by the centre of the coordinate system), across moderate emotions up to extreme emotions (which is in the periphery of the coordinate system; Russell, 2003).

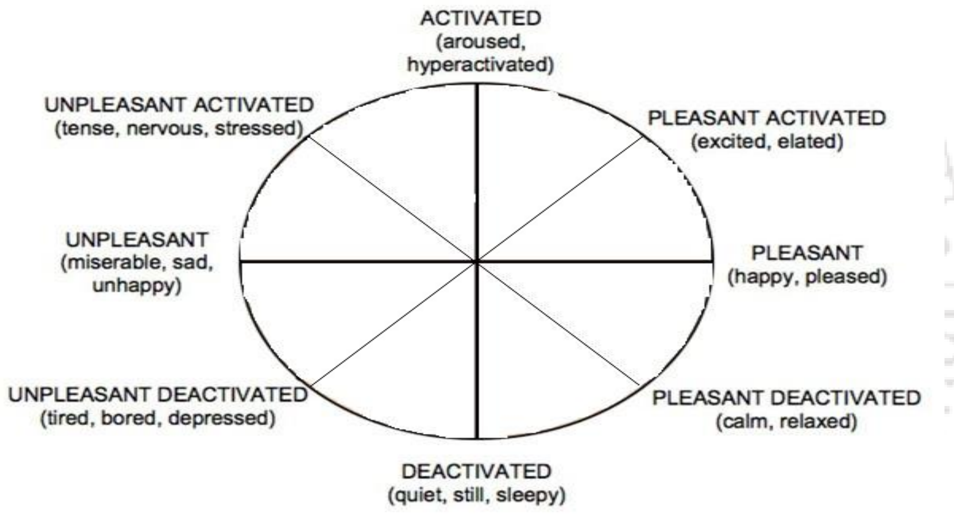


***Figure 1* |** Two-dimensional circumplex model of emotions. (Based on Russell, J.A. 2003)

Emotion can be defined via their functions, as done by Izard (2010). He shows how multifaceted emotional influences and processes play role in various fields, such as attention, motivation, behavior regulation, and communication. He defined one important function of emotions especially in the context of decision-making is - that emotion has an impact on associations between context and response through increasing or decreasing the salience or value of an event. However, the construct of "emotion" is still not very clear apart from the functions of emotions (Izard, 2010; Russell, 2003).

Another way of describing emotions is by dividing emotions based on the object they are connected. Schlösser, Dunning, and Fetchenhauer (2013) distinguish between anticipated emotions - which are directed on the consequence of a decision, and immediate emotions - which are directed on what is felt in the special moment one is experiencing. Anticipated (or expected) emotions are not experienced directly but are expectations of how the person will feel once gains or losses associated with that decision are experienced (Loewenstein and Lerner, 2003). Anticipated emotions, on the one hand, are important when talking about decision making because they are connected to the selection between alternative options. People are supposed to choose the option that will cause most positive emotions and least negative emotions (Loewenstein and Lerner, 2003). Immediate emotions, on the other hand, have an impact on decisions, too, by changing processes of recall, attention, and interpretation (Ciarrochi and Forgas, 2000).

1.2 Emotion Regulation: General Overview

Imagine standing in a slow moving queue at a supermarket the delay further enhanced on account of the slow moving counter clerk. The situation leads to feelings of anger that can be easily noticed as manifestations in thoughts, feelings, and behaviours. At this moment, we are all prepared to deliver a sarcastic comment on the clerk but soon realize that such a comment will worsen thinks and thus refrain from the verbal abuse. This refrain from the verbal abuse can be explained partly in terms of our ability to regulate our emotions in response to situational stimuli. Emotional regulation refers to the heterogeneous set of processes by which the brain influences which emotions we have, when we have them, and how we experience and express these emotions (Gross, 2002). The ability to regulate emotions is important for adoption and helps us to act functionally. The importance of regulating emotional impulses has an old history starting with the works of Sigmund Freud where the regulation of anxiety is the centrepiece of his psychodynamic theory of mental life (S. Freud, 1926). Freud's work was extended in the fields of stress and coping where exploration of the cognitive and behavioural strategies of managing specific external and/or internal demands that are appraised as stressful and taxing or exceeding the resources of a person were studied (Lazarus and Folkman, 1984). In the past decade or so, the field of emotion regulation has grown as an independent field (Gross, 1998a). Researchers interested in emotion regulation have generally viewed emotions as whole-body responses that signal personally relevant, motivationally significant events (Frijda, 1987; Levenson, 1999). From this perspective, emotion regulation corresponds to a goal directed processes functioning to influence the intensity, duration and type of emotion experienced (Gross and Thompson, 2007). Emotion regulation permits flexibility in emotional responding in accord with peoples momentary as well as one's longer-term goals in any given situation. A variety of classification systems exist for emotion regulatory processes. For example, Gross's (Gross, 1998a) process model of emotion regulation highlights the time course of emotion regulation. By contrast, Koole (2009) has emphasized motivational-functional dimensions in organizing the literature. Gyurak, A., Gross, J. J., and Etkin, A. (2011) define two theoretical and empirical spheres that organize different areas of emotion regulation and label these as "explicit" and "implicit." Furthermore, they define explicit emotion regulation as those processes that require conscious effort for initiation and demand some level of monitoring during implementation and are associated with some level of insight and awareness. It is believed that implicit processes are evoked automatically by the stimulus itself and run to completion without monitoring and can happen without insight and awareness.

1.3 Explicit Emotion Regulation

James Gross and colleagues report a paradigmatic case of explicit emotion regulation in their works on emotion regulation (Gross and Levenson, 1993; McRae et al., 2010; Ochsner, Bunge, Gross, and Gabrieli, 2002). According to their paradigm, a typical test of explicit emotion regulation starts by presenting the participants with a task that involves processing stimuli under two different conditions – one in which participants are instructed to react naturally (reactivity trial), and another in which participants are instructed to regulate their emotional responses (regulation trial) using a strategy specified by the researcher. This basic paradigm has been widely adopted, and the body of evidence from these studies suggests that explicit emotion regulation strategies can reliably influence emotional responding. Typically, negative or aversive images are used to elicit emotional responses including negative photographs depicting threat-related images such as accident scenes (McRae et al., 2010; Ochsner et al., 2002; Ray et al., 2005; Urry, 2010), or disgust-eliciting film excerpts (Goldin, McRae, Ramel, and Gross, 2008). Other researchers have used positive stimuli in the form of erotica (Beauregard, Lévesque, and Bourgouin, 2001) or pictures of cute pets and sporting events (Kim and Hamann, 2007). Most commonly, researchers have studied the effects of down-regulation instructions, using a wide range of strategies, but emotion amplification through up-regulation instructions has also been examined (Demaree et al., 2006; Eippert et al., 2007; Kunzmann, Kupperbusch, and Levenson, 2005).

1.4 Process Model of Emotion Regulation

The process model of emotion regulation is based on the appraisal theories of emotion (Gross and Barrett, 2011). The key element of these theories is that - faced with an event (be it external or internal), one‘s emotional responses are mediated by the cognitive evaluations (appraisals) that he or she makes to that event. This assumption applies to positive and negative events, as well as positive and negative emotions, but the research in the appraisal tradition has been more focused on the negative side. One such theory of appraisal is Lazarus‘theory (Lazarus, 1991; Lazarus and Folkman, 1984) which identifies two primary components of cognitive evaluations: primary and secondary appraisals. The primary appraisal is related to the motivational relevance (―Is this event important for me?), motivational congruence (―Is this event in accordance to my goals?) as well as to the ego-involvement (―Is this event menacing my personal identity?) of a particular event. The secondary appraisal is related to the responsibility for the event (―Am I or others to blame for what happened?), coping resources (―If there‘s a threat, can I respond to it?), and the expectations about the future (―What are the consequences of this event?"; Lazarus, 1991).

Facing an event that is triggering an emotional response, an individual has several ways through which he could alter the unfolding emotion (Gross, 1998b; Gross and Thompson, 2007; see Figure 2).

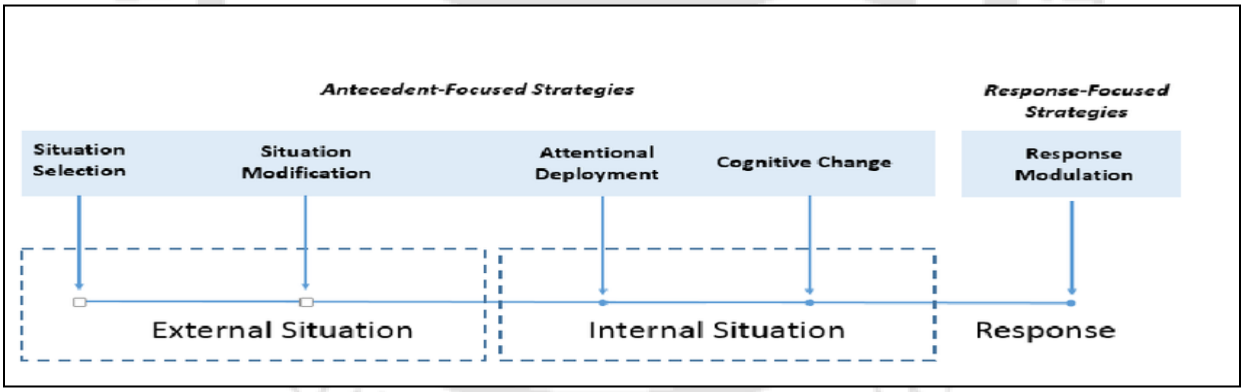


Figure 2 | Process model of emotion regulation (Based on Gross, 2000)

A process model of emotion regulation shows, how specific strategies can be differentiated along the timeline of the emotional response (Gross, 1998b; 2001). The fundamental theme of this model is that emotion regulation strategies differ on the time point at which they have their primary impact on the emotion-generative process. Based on the time of occurrence, process model describes mainly two type of emotion regulation strategy. Antecedent focused strategies that refer to things we do before the emotion response tendencies have become fully activated and have changed our behaviour and peripheral physiological responding (e.g., a job interview is taken as an opportunity to learn more about the company, rather than as a pass fail test). Response focused strategies refer to things we do once an emotion is already underway, after the response tendencies have been generated. These strategies are further divided into five subtypes. The first of these strategies is situation selection - refers to approaching or avoiding certain people, places, or things to regulate emotion. For example, you may like to have dinner with a friend who always makes you laugh the night before a big exam rather than going to the last-minute study session with other nervous students. Often, situation selection involves short-term emotional benefits and long-term cost. For example, shy person’s efforts to decrease anxiety by avoiding social situations may provide short-term relief at the cost of longer-term social isolation (Leafy, 1986). Second, distraction – involves making efforts to modify the situation directly to alter its emotional impact. For example, continuing with the example of the exam, if you are talking with your friend the night before a big exam, and he asks whether you are ready for the exam, you can make it clear that you would rather talk about something else. Third, attentional deployment - is used to select which of the many aspects of the situation you focus on. An example is distracting yourself from a conversation that has taken an upsetting turn by counting ceiling tiles (Nix, Watson, Pyszczynski, and Greenberg, 1995). Attentional deployment also includes efforts to concentrate particularly intensely on a particular topic or task (Csikszentmihalyi, 1975), or to find the underlying cause of a problem by ruminating about it (Nolen-Hoeksema, 1993). Once you have focused on a particular aspect of the situation, cognitive change refers to selecting which of the many possible meanings you will attach to that aspect. For example, you might remind yourself “it’s only a test”, rather than seeing the exam as a measure of your value as a human being. Cognitive change is often used to decrease the emotional response. However, it may be used to magnify the emotional response and even to change the emotion itself (e.g., transforming anger at a bully into pity). Finally, response modulation refers to attempts to influence emotion response tendencies once they already have been elicited. Response modulation is implemented by decreasing expressive behaviour. In our example of the exam, response modulation might take the form of hiding your embarrassment after miserably failing the exam. Other targets of response modulation include the experiential and physiological components of emotion.

1.5 Decision Making - Definition and Function of Decision Making

Decision-making is defined as the cognitive process of selecting an outcome out of many alternatives (Coricelli et al., 2007). Every decision that we make results in a choice that either has a mental representation or is an actual action. The function of decision-making is to help us adjust rapidly to new environments as we are constantly exposed to external information (Gospic et al., 2011).

1.6 Role of Emotion in Decision Making

Most cognitive processes are affected by emotional states (Blanchette and Richards, 2010). Decision-making process also is influenced by emotions and it can be safely concluded that decisions are rarely based on objective truths (Forgas, 1995; Gasper and Clore, 2000; Russell, 2003). Emotions can improve the quality of decisions, and people with emotional deficits often make worse decisions than those without such deficits. Emotions can lead to biased judgments when they are used as a shortcut in the decision-making process (Loewenstein and Lerner, 2003). Thus, emotions can generally lead to better or worse decisions and these connections are important. Among these decisions, risky decisions and subsequent risky behaviour are an especially noteworthy research topic. The predominant opinion about the role of emotion in decision making in economics, psychology, and, more recently, neuroscience is the dual systems approach. This approach suggested that there are two dominant systems people use to understand and assess risk: the “analytic system” and the "experiential system." In psychology, the terms "hot" versus "cool" have been used to describe decisions driven by affect or lack of affect (Figner et al., 2009).The "analytic system" involves conscious and deliberate cognitive processes that employ various algorithms and normative rules to produce logical, reason-oriented, behaviour. In contrast, the "experiential system" uses past experiences, emotion-related associations, and intuitions when making decisions. The experiential system relies more on unconscious rather than conscious processes.

Most models of decision-making assume it be a rational process, which would exclude the possibility of emotion playing a role. Other models take the valence-based approach and evaluate negative and positive affect on behaviour, without specifying the emotion. This has led to a limited understanding of how specific emotions, especially those present in an individual in risky and uncertain situations, contribute to the decision-making process. Risky behaviour contains an inherent emotional component that cannot be ignored but must be integrated into a more dynamic model of decision-making. Current theory by Loewenstein and Lerner (2003) identifies two kinds of emotions that influence decisions a) expected emotions, which are expectations about future emotional consequences of a decision, and b) immediate emotions, which are emotions felt while making a decision. Immediate emotions are experienced at the moment of choice and fall into one of two categories. "Integral" emotions, like expected emotions, arise from thinking about the consequences of one's decision, but integral emotions, unlike expected emotions, are experienced at the moment of choice. "Incidental" emotions are also experienced at the moment of choice, but arise from dispositional or situational sources objectively unrelated to the task at hand'. Researchers have found that incidental emotions extensively carry over from one situation to the next, affecting decisions (Han et al., 2007; Keltner and Lerner, 2010; Lerner and Keltner, 2000;

Lerner and Tiedens, 2006; Loewenstein and Lerner, 2003), a process known as the carryover of incidental emotions (Bodenhausen, 1993; Loewenstein and Lerner, 2003).

In previous studies, different effects of emotions on decisions have been investigated. Emotions can act as primers for cognition in the way that they selectively influence the recall of information. When in a positive emotional state, it is easier to recall positive information. Moreover, positive details get more attention, learning of positive things is easier, and interpretations of ambiguous information are biased in a positive way (Ciarrochi and Forgas, 2000). Additionally, the perception of an object depends on the emotional state. People in a positive emotional state perceive an object in a more pleasant way than people in a negative emotional state would do. This usage of emotions as a shortcut to judgment is described in the affect-as-information model (Winkielman et al., 2007).

1.7 Expected Emotions and Immediate Emotions

As mentioned above, emotions can be described on account of the object they are connected with (Schlösser et al., 2013). On one hand, research shows immediate emotions cause an influence of affective stimuli on following behaviour, which is called affective priming and is independent of conscious experience of changes in the emotional state (Winkielman et al., 2007). On the contrary, anticipated emotions influence the process of decision making as they are connected to the outcome of a decision (Loewenstein and Lerner, 2003). In uncertain situations, emotions are used as a source of information (Payne, Cheng, Govorun, and Stewart, 2005). In this manner, both anticipated and immediate emotions have the same effect on risk behaviour; positive emotions increase the likelihood of risky behaviour, whereas negative emotions decrease the likelihood of risky behaviour (Knutson et al., 2008). This could also be explained by emotional benefits and losses. If a certain option entails more emotional benefits and fewer costs than other given options, it is likely that this option will be chosen (Suri et al., 2013). This effect is independent of the source of the emotions. Anticipated emotions can be changed by a general positive state, and thus, can influence a decision (Haase and Silbereisen, 2011). This is called affective misattribution; an attribution is done, but it is directed at the wrong source (Russell, 2003). Apart from the effect of anticipated emotions, there is an immediate effect of emotions (Knutson et al., 2008; Schlösser et al., 2013). Immediate positive emotions (e.g., happiness) induce lower risk perception (Haase and Silbereisen, 2011) and increases the likelihood of risky behaviour (Knutson, Wimmer, Kuhnen, and Winkielman, 2008). This effect is mediated by positive cognitions which are activated by positive emotions (Gasper and Clore, 2000; Haase and Silbereisen, 2011; Winkielman et al., 2007). The mediation can be explained via a change in salience. Positive emotions point attention to potential gains and increase their salience, resulting in the increase of risky behaviour (Knutson et al., 2008). Furthermore, positive emotions lead to positive interpretations of ambiguous information and, as a result, increase the likelihood of optimistic evaluations of risk (Winkielman et al., 2007). In contrast, immediate negative emotions (e.g., fear) decrease the probability of risky behaviour (Gasper and Clore, 2000; Winkielman et al., 2007). This effect is mediated by cognition. Negative emotions lead attention to potential losses and thus increase their salience, and reduce the probability of risky behaviour (Knutson et al., 2008).

In summary, there are different indications for relations between emotions and decision making in general and decision making under risk in particular. These relations can be explained via direct influences (e.g., the perception of objects) or indirect influences (e.g., change of recall processes) and emotions can differ in the object they are connected with (as described by immediate and anticipated emotions).

1.8 Neural Mechanisms of Decision Making

All decisions are associated with an uncertainty, an expected value, and short versus long - term reward (Rushworth and Behrens, 2008; Tobler et al., 2009). The neural mechanisms of uncertainty, expected value and reward, involve emotional processing. Hsu et al., (2005) showed that the level of ambiguity correlated positively with amygdala and OFC activity, and negatively with the striatum and expected value is guided by the striatum to ensure maximal gain (Hsu et al., 2005). Many studies have shown the importance of emotional processes in decision-making. Damasio and colleagues studied patients with lesions of the amygdala, OFC and vmPFC and found these patients have increased risk seeing behaviour further establishing that these areas are necessary for risk behaviour (Bechara et al., 2003). De Martino and colleagues demonstrated that amygdala participates in the framing effect, previously described by Tversky et al., (1981) (De Martino et al., 2010; De Martino et al., 2006; Tversky and Kahneman, 1981). Interestingly, DeMartino et al. (2010) also demonstrated that patients with amygdala lesions are not affected by the framing effect as amygdala damage eliminates monetary loss aversion (De Martino et al., 2010). Neural reward circuits are also important for decision-making, as we prefer the choices that maximize our gain (reward). For example, observing products that we like activates subcortical brain regions like nucleus accumbens (Knutson et al., 2008) and cortical regions such as vmPFC cortex (Paulus and Frank, 2003), both related to emotional reward processing in terms of wanting and liking (Berridge and Kringelbach, 2008; Kringelbach and Berridge, 2009).

1.9 Rationality

Aristotle was probably the first thinker to provide meaning to the topic of rationality (Travesky and Hutchinson, 1986) and since then a sea of definitions floating around explaining rationality. Colman, (2003) elegantly defines rationality as "…it involves thinking and behaving reasonably or logically. Rational beliefs are those that are internally consistent and rational arguments are those that obey the rules of logic" (Colman, 2003). In terms of economics rationality translates as "the recommendation always to behave to maximize the expected time utility per time unit" (Good, 1952)". Classical game theory defining economic rationality of utility predicts that maximizing payoff should be the aim of player participating in experimental economic games (Von Neumann et al., 1953). In real life, however, this effect can only be achieved in autistic (Sally and Hill, 2006) and brain lesion populations (Shiv et al., 2005). Studies on healthy controls show that economic rationality of utility predication cannot be validated through experimentations since decision-making processes are influenced by varied factors like emotions (Bechara et al., 2003; De Martino et al., 2006; Tversky and Kahneman, 1981). The debate over whether subjective experiences of emotion are functional or maladaptive is open-ended (Gohm and Clore, 2002). Feeling are regarded by some researchers as a source of unwanted bias (Shiv, Loewenstein, Bechara, and Damasio, 2005; Slovic, Finucane, Peters, and MacGregor, 2002) which needs to be controlled (Gross and John, 2003).

Others maintain that feelings play a significant role in decision-making (Damasio, 1994) and benefit personal well-being (Aspinwall and Taylor, 1997). Two contrasting perceptive define affect and decision-making relationship. The *feeling-as-bias inducer*, view holds feeling as the source of bias in decision processes and can lead to skewed decision making. Feeling related bias can affect the content of information retrieved from memory (Erber, 1991; LeDoux, 1993; Meyer, Gayle, Meeham, and Harman, 1990). An example of feeling dependent bias is the "mood congruence recall effect," which refers to people's tendency to recall materials from memory that are consistent with their affective state at the time of recall (Mayer et al., 1990). Feelings can also colour cognitive judgments required for decision-making. An example to support the view is the "mood congruence judgment effect," where people tend to make judgments that are consistent with their affective states at the time of judgment (Johnson and Tversky, 1983; Mayer et al., 1992). Another way in which feelings can affect decisions is by directly biasing individual choices (Gray, 1999; Shah, Friedman, and Kruglanski, 2002). For example, studies have shown that intense unpleasant feelings often lead people to favour short-term enhancements, focusing on what is best in the moment, regardless of possibly negative long-term consequences (Gray, 1999). Other researchers have proposed a *feeling-as-decision-facilitator* view. In this approach, affective feelings facilitate and enable decision-making process. The facilitation can occur through several ways. The affective reaction is a core driver of conscious attention and allocation of working memory, both of which are necessary for the extensive cognitive processes involved in decision-making (Damasio, 1994; Kitayama, 1997; Wells and Matthews, 1994). For example, Damasio (1994) asserted that feelings boost the conscious attention and continued working memory required for any reasoning or decision-making. Ketelaar and Clore (1997) also suggested that an important function of momentary feelings is to shift attention from less-pressing goals to ones that are more urgent.

In the present study, we suggest that the functional or dysfunctional aspect of affect feelings is dependent to a large degree on how people experience those feelings and how they use it in the decision-making process. Accounting for individual differences in affect information processing we suggest that individuals while making decisions can experience intense feelings and regulate the possible biases induced by those feelings (Gohm, 2003; Gohm and Clore, 2000).

1.10 Emotion Regulation and Decision-Making

Historically psychological research made distinctions between emotion and cognition, however, recent research suggest that these domains largely overlap (Blair, Smith, Mitchell, Morton, Vythilingam, and Pessoa et al., 2007; Gray, 2004), and the emotions we experience can have considerable influence on our decisions (Bechara, Damasio, and Damasio, 2000).

A recent laboratory study (Sokol-Hessner, Hsu, Curley, Delgado, Camerer, and Phelps, 2009) showed loss aversion to be reduced by adopting an intentional cognitive approach to emotion regulation. Directing subjects to adopt such a strategy resulted in lower arousal relative to losses (as measured by skin conductance) and in lower behavioural loss aversion compared to a control group. Another recent laboratory study (Heilman, Crisan, Houser, Miclea, and Miu, 2010) showed an (instructed) intentional cognitive approach to emotion regulation to reduce the impact of induced emotions on risk aversion and on performance in the pre-hunch/hunch stage of the Iowa Gambling Task such that risk aversion was reduced and performance in the gambling task was greater relative to a control group. Winkielman, et al., (2005) reported that thirsty participants were willing to pay greater money for a sugary beverage when they were unconsciously exposed to subliminally present happy faces and an opposite effect when exposed to angry faces. They inferred that subliminal emotion induction influences the valuation process in decision-making (Winkielman, Berridge, and Wilbarger, 2005). Learner, (2004) reported that participants who viewed emotional video clips made more disrupted economic decisions like endowment effect where sellers assign higher prices to owned items (Lerner, Small, and Loewenstein, 2004). Specifically, disgust video inductions were associated with an absence of the endowment effect and sadness video inductions with a reversal of it. Besides emotion inductions, the negative emotional state like acute stress can influence cognition at the behavioural (Patil, Apfelbaum, and Zacny, 1995) and neural levels (Arnsten and Goldman-Rakic, 1998). Further, acute stress modulates financial decision-making (Porcelli and Delgado, 2009) and may put those who cannot cope with stress at risk of poor decision making, as illustrated by addiction relapse (Sinha, 2007). It is true that employing cognitive emotion regulation strategies to control these emotions may foster better, more goal-directed decision-making. Few self-control studies outline the mechanisms of cognitive control of decision-making. Depletion of self-control resources was shown to increase the impulsive buying behaviour leading to less advantageous decisions (Vohs and Faber, 2007). Similarly, Hare (2009) reported that the use of self-control by dieters in food consumptions could be expressed as cortical mechanisms (Hare, Camerer, and Rangel, 2009). Activity in vmPFC in successful dieters reflected both taste and health information of displayed food items, while non-self-controllers activity in this region reflects only taste information. These studies suggest that self-control promotes decision-making towards long-term goals like saving money and losing weight. A recent study directly tested the effect of emotion regulation on financial decision-making in which participants faced choices between a gamble and guaranteed amount (Sokol-Hessner, Hsu, Curley, Delgado, Camerer, and Phelps, 2009). For the emotion regulation strategy, participants were instructed to reappraise (think like trades assembling portfolios) so as to lessen the importance of each decision. As controls participants thought of each decision in isolation. A recent behavioural study examined regulation of craving in cigarette smokers in which smokers were presented with cigarette-related images cued either to regulate their feelings (by focusing on the long term consequences of smoking) or no regulation (focus on the immediate sensory experience of smoking) (Kober, Kross, Mischel, Hart, and Ochsner, 2010). Regulation reduced self-reported feelings of craving that was related to increased activity in prefrontal regions and decreased activity in the ventral striatum and ACC (Kober, Mende-Siedlecki, Kross, Weber, Mischel, and Hart et al., 2010). Early works on emotion regulation and decision-making focussed on negative emotion regulation. Newer studies are now focussing on the regulation of positive emotions and how they affect decision process. This shift is likely due to the crucial role of positive emotions in approach behaviours that can become maladaptive, such as the compulsive drug seeking exhibited in addiction.

1.11 Sleep

A conscious brain state with reduced responsiveness towards external stimuli that provides for baseline neural levels is termed as sleep. Sleep is measured using polysomnography, which measures a host of bodily functions like brain wave activity, eye movements, muscle movements, heart and respiration rates which can then be represented using a visual hypnogram that provides for a useful cross-section of sleep architecture. There are two main types of sleep the non-rapid eye movement sleep (NREM) and rapid eye movement sleep (REM). These stages have their own distinct physiological, neurological and psychological features. Non-REM sleep comprises of high amplitude slow oscillations (with the frequency gradually slowing and the amplitude increasing as sleep deepens), while REM sleep consists of lower amplitude fast oscillations that are similar to normal waking activity (see Figure 3).

NREM and REM sleep Cycles

The whole sleep cycle undergoes NREM and REM sleep alternatively. The sleep episode starts with stage 1 of NREM sleep continuing to stage 2 and then going through stage 3 and 4, ending up at REM sleep. This whole cycle is repeated throughout the night. Nocturnal sleep comprises of 75-80% NREM and 20-25% REM episodes. According to Carskadon, et al., (2005), the average length of the first NREM-REM sleep cycle is 70-100 minutes. The second, and later, cycles last for about 90-120 minutes (Figure 3). In normal adults, REM sleep increases as the night progress and in the last one-third of the sleep episode, it is the longest.

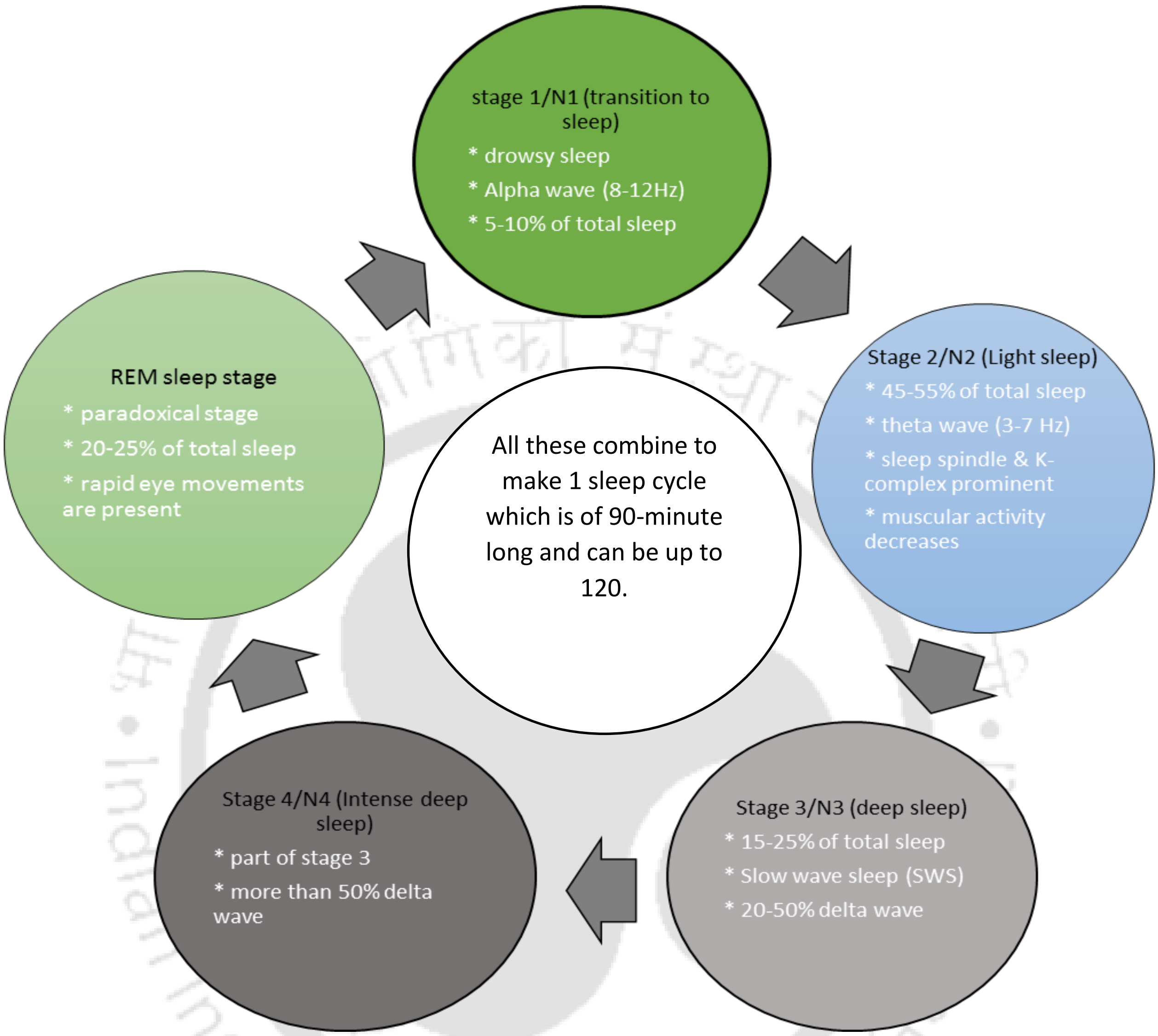


Figure 3| Represents whole sleep cycle with stage specification of sleep.

1.12 Sleep and Emotion

Research on sleep and cognition has memory as the most studied cognitive systems (Rauchs, Desgranges, Foret and Eustache, 2005; Walker and Stickgold, 2010) and very few attempts have been made to study the effects of sleep and sleep loss on emotion regulation. Authors working in the area of sleep report that sleep loss lowers emotional intelligence (Killgore et al., 2008), impairs emotional regulation by increasing irritability (Kahn-Greene et al., 2006) and emotional lability (Horne, 1985) and worsens mood in children (Berger et al., 2012; Vriend et al., 2013) and adults (Dinges et al., 1997; Lingenfelser et al., 1994; Rose et al., 2008). Deprivation of sleep also increases self-reported feelings of depression, frustration, and anxiety (Caldwell et al., 2004; Durmer and Dinges, 2005; James and Gregg, 2004; Pilcher and Huffcutt, 1996; Scott et al., 2006; Kahn-Greene et al., 2007) which causes severe deficits on daily activities in addition to cognitive and behavioural changes (Vandekerckhove and Cluydts, 2010). Sleep deprived medical residents evaluate disruptive daytime events (e.g., when being disrupted during a scheduled activity) more negatively which in turn reduces the positive effect of goal-enhancing experiences (e.g., an opportunity to perform a medically challenging task; Zohar et al. 2005). Minkel et al., (2012) used cognitive tests with low-stress level and found subjective stress, anxiety and anger peaked in sleep-deprived subjects as compared to rested controls. By contrast, increased negative mood and stress levels were reported following high-stress cognitive testing in both normal sleep and sleep-deprived conditions. The authors suggested that the psychological threshold for the perception of stress from cognitive demands lowered after sleep deprivation, whereas negative effects in response to high-stress performance demands are not increased. This lack of effect of sleep in the latter case might be due to a ceiling effect in stress responses. Poor sleep quality akin to sleep deprivation is associated with decreased ability in cognitive reappraisal (Baglioni et al., 2010; Bower et al., 2010; Mauss et al., 2013). Mauss et al., (2013) concluded that a lack of sleep or poor sleep quality alters cognitive reappraisal by impairing higher cognitive functions (Goel et al., 2009; Tucker et al., 2010). In an fMRI study emotional reactivity for aversive stimuli after sleep deprivation was found to correlate with amplified amygdala responses and decreased connectivity with medial prefrontal cortex (mPFC) (Yoo et al., 2007). Decreased mPFC activity suggests that deregulation of emotion after sleep deprivation (Yoo et al., 2007) or restricted sleep (Motomura et al., 2013) signals degraded top-down inhibitory control. Increased autonomic reactivity following sleep deprivation also supports the disinhibition hypothesis (Franzen et al., 2009). Gujar et al., (2011) found heightened activity throughout mesolimbic brain networks (reward areas) in response to pleasant stimuli after sleep deprivation, with high connectivity in early primary visual processing regions and limbic areas and loss in functional connectivity with medial frontal and orbitofrontal brain regions. One night of sleep deprivation led to an overestimation of positive emotional stimuli, correlated with activity in mesolimbic regions (Gujar et al., 2010), Zohar et al., (2005) found that goal-enhancing experiences were less positively perceived by medical residents in lack of sleep. Discrepancies between these studies may be due to different amounts of sleep deprivation (Motomura et al., 2013). Sleep debt alters the processing of negative emotional stimuli more than positive stimuli. Total sleep deprivation impairs emotional reactivity for aversive stimuli and by its antidepressant effect (Gillin et al., 2001) amplifies reactivity throughout limbic regions in response to positive emotional stimuli. Rosales-Lagarde et al., (2012) scanned participants twice during a visual emotional reactivity task, before (baseline condition and 24 h following REM/NREM deprivation) and reported that emotional reactivity increased for REM deprived group as compared to baseline. Similarly, functional MRI revealed increased activity in regions involved in emotional processing in the REM sleep-deprived group during the second test period (relative to the baseline), whereas cerebral activity was similar before and after an experimental night with NREM sleep interruptions. These results suggest that REM sleep may contribute to reset emotional brain reactivity to cope with next day's disruptive events. Research evidence from 5-year-old children shows that they display a high rate of NREM stage 2 spindle which is linked with current and future positive emotional and behavioural functioning (Mikoteit et al., 2013). This suggests that REM sleep may not be the only stage involved with emotional processing

1.13 Sleep and Emotion Regulation

Sleep plays a critical role in mental health and psychosocial adjustment across the lifespan. Research suggests inadequate sleep worsens neurocognitive functioning, increase the experience of negative emotions, reduce the occurrence of positive emotions, and alter the ways in which individuals understand, express, and modify these emotions. Inability to experience and control emotions in context-appropriate ways is a prominent feature of various forms of psychopathology. Sleep related emotional reactivity has been the subject of many studies, as it is believed to represent the actual regulation. In these studies, subjective sleep problems, partial sleep restrictions, and their effect on emotional regulation were studied using self-reported questionnaires. Studies on children employed parental reports. These methods suffered from possible reporter bias and lack of differentiation among regulatory processes. Neurobiological reports revealed sleep deprivation related decreased connectivity between medial prefrontal cortex (PFC) and ventral ACC with the amygdala. This can be translated in terms of problems related to monitoring and regulatory control. Other regions of the striatum (e.g., the caudate, putamen) implicated in motivation and emotion regulation also are highly sensitive to sleep. To understand the precise impact of sleep on the ability to regulate emotions would require the use of experimental paradigms that explicitly ask participants to regulate their emotions thereby making it possible to detangle reactivity from emotion regulation processes. Our literature mainly focuses on sleep and emotion regulation within a process model framework by distinguishing how sleep may impact emotion regulation at each stage of the process model of emotion regulation and its effect on goal directed behaviour (risky decision making).

Situation selection

Research exploring the extent to which behavioural changes reflect emotion regulatory efforts using sleep paradigm are few in number. However, few studies have tried to illustrate how poor sleep may alter emotion at situation selection level. Insufficient sleep can weaken motivation to seek out and participate in rewarding social activities, in turn, harming positive social relationships. Poor sleeper's exhibit lower frequencies and less regularity of social activities along with poor social well-being than good sleepers. One study using sleep deprivation (72 h) reported lower motivation towards social and leisurely activities varying with hours spent in wakefulness. Less sleep also increases the likelihood of experiencing negative emotions via situational decisions. To summarize, sleep loss significantly alters behaviour in ways that decrease the likelihood of situating oneself in positive emotional contexts. Prioritizing sleep over other important waking activities, reduced energy for and motivation to seek out enjoyable social activities, and low overall anticipation of reward for one's efforts might contribute to selecting situations that meet current emotional needs but ultimately undermine the likelihood of positive emotional experiences over a longer term.

Attentional deployment (Distraction)

Impaired decision-making and poor impulse control after sleep deprivation might point the fact that sleep deprivation may lead to inappropriate modification of various situations surrounding the decision task. The ability to self-monitor, appropriately interact with others, notice others' nonverbal cues, and accurately identify others' emotions are diminished when sleep is disrupted. Dyadic research among couples suggests that individuals are less understanding and empathic of their partner in the face of inadequate sleep and that after extended periods of sleep loss (55 h). Impaired decision making, poor impulse control, and daytime sleepiness have additional implications for distraction strategies in work settings. One experimental study reported sleep deprivation to enhance deviate behaviours and decrease in self-control at the workplace. The latter finding suggests that delay in gratification is a consequence of poor sleep. Together, these collective results suggest individuals manage the feelings of frustration and devaluation at the workplace by modifying the work environments through maladaptive rather than adaptive strategies. Impulses restrain create heightened physical and increase in workplace accidents and injuries when sleep is inadequate. Distraction regulates emotion without changing the aspects of the actual environment, unlike situation selection where considerable change is made to the external situation. In spite of a variety of distraction strategies, distraction (i.e., diverting attention away from something negative) is perhaps the most commonly studied attentional strategy because it attenuates neurobiological activity in emotional brain regions in response to negative emotional content. Sleep deprivation produces an opposing effect on these same structures suggesting that distraction ability/efficacy may be thwarted when sleep is inadequate. Although no study has examined the use of distraction as an explicit means of regulating emotional responses in the context of sleep, sleep-related alteration of attention for emotional stimuli is a common finding. In particular, sleep deprivation may increase vigilance to negative or threat-related information. Chuah et al., (2010) found that negative pictures were more distracting than neutral pictures during a delayed response working memory task, evidenced by impaired working memory and subjective reports of distractibility. In line with other findings, distraction in response to negative images corresponded with increased amygdala activation and reduced functional connectivity with frontal cognitive control brain regions. Several recent studies have utilized event related potentials (ERP) following sleep deprivation as a sensitive measure of attention to emotional stimuli. In one study, both positive and negative IAPS images produced significantly larger late positive potential amplitude than neutral images when participants were rested, whereas sleep deprivation diminished differences among the picture types (i.e., late positive potential responses to neutral pictures were as large as those evoked by emotional pictures). Gujar et al., (2011) reported that wakefulness enhanced rating of anger and fear while nap weakens the ratings. It was found the post nap changes in fear and happiness ratings were more noticeable in subjects showing enhanced REM periods during nap. Available research examining attention to emotion content after sleep loss suggests a failure to use attentional strategies can effectively regulate emotional responses. Inadequate sleep weakens the use of distinction as emotional regulation mechanisms by the employment of different neural structures and processes. Specifically, disrupted sleep impairs attention to emotional information and may increase the salience of negative, threatening information

Cognitive reappraisal

Another method of emotion regulation involving cognitive mechanisms is reappraisal where emotional events are reinterpreted or reframed leading to weakening of emotional experience through down regulation of subjective and physiological components of emotions. Cognitive behavioural treatment (CBT) programs for affective disorders often make use of reappraisal during which they teach patients the art of utilizing reappraisal techniques as a means of decreasing negative emotion. Participants who watched sad movie clips after poor sleep quality for more than a week reported decreased feelings suggesting a notable decrease in the cognitive reappraisal ability. Another study found that individuals who tend to utilize cognitive reappraisal as an emotional regulation strategy (as measured by self-reports) were less vulnerable to effects of sleep deprivation on late positive potential responses (using ERP) to negative emotional stimuli. Although enough neurobiological evidence exists that support the view that sleep disruption negatively effects cognitive control centres of the brain little research has examined direct links between sleep and explicit attempts at cognitive reappraisal or actual cognitive reappraisal ability using experimental methods. One study found that sleep deprivation significantly reduces the tendency to think positively. In a study, utilizing two nights of partial sleep restriction (6.5 h followed by 2 h), adults and adolescents engaged in catastrophizing (a maladaptive form of cognitive appraisal) reported a greater likelihood of catastrophes coming true. Only one study has examined the use of explicit cognitive reappraisal in relation to sleep. Healthy adolescents (13-17 y) were randomized to either one night of restricted (4 h) or idealized (9.5 h) sleep following a week of normal sleep (Reddy, R. M., 2014). The following day, participants were provided training in cognitive reappraisal techniques and were asked to simply view and to reappraise IAPS images. The restricted and idealized sleep groups generated a similar number and type of reappraisal statements. Moreover, in both groups, ratings of reappraised as compared to viewed negative images were more positive, suggesting a similar degree of emotion regulation ability between the groups. Although preliminary and specifically focused on adolescents, these results suggest that cognitive reappraisal ability may be somewhat resistant to sleep loss effects.

Response modulation

Response modulation involves the goal-directed alteration of an individual's experiential, behavioural, and/or physiological responses to an emotional stimulus. Response modulation occurs after an emotion has been fully generated; meaning that opportunities for alteration are likely to be fewer just as the modulatory effort required is likely to be greater. The most commonly studied form of response modulation is expressive suppression where attempts are made to hide visible signs of emotion. Although suppression of negative emotion has been found to have a large effect on self-reported emotions, it is also associated with the presence of psychopathological symptoms and increased activation in emotion-generative brain regions, indicating a general failure of this strategy to decrease the emotion that is actually experienced. Evidence from speech analyses suggests that adolescents and adults restricted to 2 h of sleep use less positive and more negative emotion words with changes in the acoustic properties of their voice suggesting increased sadness, low physiological activation, and stress/anxiety. After one night of total sleep deprivation, adults were less emotionally expressive in response to both positive and negative emotional video clips. However, neither study explicitly asked participants to modulate their expression. Thus, it is unclear whether differences in emotional expressiveness were a result of weakened regulatory ability, or were simply based on differences in reactivity (e.g., those who experienced less positive emotion displayed less positive emotion). In a novel study by Schwarz and colleagues, participants were instructed to respond to emotional stimuli with compatible or incompatible reactions after 8 h of sleep and after 4 h of sleep. Using facial electromyography, facial reactions to emotional stimuli were slower for the restricted group, but the inhibition of expressions themselves was not impaired. Thus, whereas global emotional expressiveness might be altered by sleep loss, the ability to intentionally modulate expressions may be more resistant to the effects of sleep loss. Future investigation of expressiveness in contexts that require explicit attempts to suppress emotion can provide greater information about the influence of sleep on this regulatory strategy.

1.14 Relevance and Potential Impact of Present Research Topic

The above research literature clearly suggests that emotion regulation has been a recent area of psychological research that is attracting the interest of many research groups around the world. This interest centres on profound implications of emotion regulation in understanding and treating a wide range of psychopathology symptoms. Emotion regulation as used in the present thesis focuses its effectiveness on modulating goal directed behaviour that in the present thesis is risky decision making.

Emotion plays a key role in human social and economic decision-making (Elster, 1998; Loewenstein, 2000; Peters, Va¨stfja¨ll, Ga¨rling, and Slovic, 2006). People while choosing between alternatives evaluate objective features (expected return) using subjective standards (Edwards, 1962; Kahneman and Tversky, 1979), which are influenced by emotional states (Loewenstein and O’Donoghue, 2004; Naqvi, Shiv, and Bechara, 2006; Slovic, Finucane, Peters, and MacGregor, 2007). Recent literature suggests that people use emotion regulation to weaken the influence of emotional states on choice behavior (Gross, 2002). This suggests the possibility that decision effects influenced by acute emotions, may be mediated by emotional regulation strategies. This raises the additional possibility that different regulation strategies could have different decision implications. In this present thesis, we use the process model of emotion regulation to study the differential effect of emotion regulation strategies on risky decision-making and how could this efficacy modulated by nature of stimuli and affect type.

Emotional regulation studies are regarded as controversial by some authors on the grounds of lack of theoretical and empirical validation. A look at the literature presented above is far from providing definitive conclusions on whether emotion regulation changes the behavioural responses beside physiological response modulation. In fact, in the experimental research section, we will approach some of the key gaps in this paradigm and try to offer relevant answers to questions still unanswered.

Sleep plays a critical role in mental health and psychosocial adjustment across the life span. Inadequate or disrupted sleep degrades several aspects of neurocognitive functioning and psychological health. Most studies do not explicitly examine regulatory processes related to emotion but rather focus on discrete emotions and/or overall emotional reactivity. These are additional arguments why the topic of this thesis is relevant in the current scientific context.

Despite widespread interest in the construct of emotion regulation within the sleep literature, emotion regulation, as defined by Gross lack concrete experimental validation. In reviewing available findings, we found only a few studies that have attempted to directly examine emotion regulation in relation to sleep. Several studies using self-reported emotion regulation questionnaires suggest that sleep disruption predicts poorer emotion regulation. The degree of correspondence between retrospective reports and real-time use of regulatory strategies is nonetheless unclear. Many of the studies cited refer to more implicit regulation strategies or behaviours and cognitions that impact emotion indirectly. Since little research has examined explicit attempts to modulate emotion, a primary question for future work is whether sleep affects regulation ability versus simply the tendency to engage in actions or thoughts that alter emotion responses. Studies differ vastly in their approaches to measuring sleep ranging from naturalistic (at-home) subjective sleep patterns, to one or several nights of sleep restriction, to total sleep deprivation protocols. Other studies have focused more specifically on restricted REM versus NREM sleep stages. A common naturally occurring form of sleep loss in the general population is characterized by irregular sleep-wake schedules including restricted sleep during the week and extended (i.e., recovery) sleep periods on weekends. This pattern of sleep notably results in sleep architecture alterations including 'rebound REM' sleep on weekend nights. In the evaluation of the development of emotional problems, sleep pattern could potentially provide more generalizable experimental findings regarding emotion generation and regulation. Similarly, there is some indication that sleep quality rather than quantity might better predict certain emotional outcomes including regulation.

As a conclusion of this short section, the topic of emotion regulation is expected to have a great impact on many cognitive functions and how it can modulate behaviour beyond physiology that would have a strong impact on psychological well-being, but this impact is still to be proved. This thesis is anchored in this hot-topic, but adopting an additional perspective using process model of emotion regulation and how sleep modulates this if indeed emotion regulation has a significance on decision making.

2. RESEARCH AIMS AND GENERAL METHODOLOGY

2.1 Research Aims

The last chapter reviewed the literature on how emotions effect risky decision making. The review brought forth several questions some of which will be answered through the present thesis.

1) Effectiveness of emotion regulation on risky decision making.

a) Whether the effects of emotion and emotion regulation on risky decision-making process vary across the type of affect (positive/negative)?

b) Whether the effects of emotion and emotion regulation on risky decision-making process vary across the type of affect stimuli used for inducing emotion (picture/video)?

c) Whether emotion as compared to emotion regulation has a differential effect on risky decision making process?

d) Whether varying the emotion regulation strategies have any significant effect on risky decision making process?

2) Role of Sleep on affect regulated risky Decision making.

a) To study the effect of sleep on affect regulated risky decision-making process.

b) To outline the electrophysiological markers for sleep induced and affect regulated risky decision-making process.

c) To ascertain the role played by first-half and second-half sleep deprivation on affect regulated risky decision-making.

2.2 General Methodology

In this section, we outline the various tools and equipment used in the present thesis. Each tool/equipment is defined in detail here. How these are used in the thesis is also mentioned here. This section has been written with the aim to minimize unnecessary repetitions and redundancies in the thesis.

2.2.1 Questionnaire-

2.2.1.1 Mini-Mental State Examination (MMSE) - The mini mental state examination (MMSE), the most commonly used instrument for screening cognitive function was developed by Folstein, et al., (1975). MMSE is an eleven item questionnaire that tests five areas of cognitive function namely - orientation, registration, attention and calculation, recall, and language. The maximum score achievable on this test is 30. A score of 23 or lower is indicative of cognitive impairment. The MMSE takes only 5-10 minutes to administer and is therefore practical to use repeatedly and routinely. The MMSE has been a valid method and extensively used in both clinic and research.

Use in present Thesis: In the present thesis, the MMSE is used to screen out the subject with mild to major cognitive impairments. It is thus an important part of our exclusion criteria.

For Experiment 1A and 1B- The mean score for MMSE is 28.64 ± 1.34 (range: 30.6 - 26) which is greater than 23, which indicates no cognitive impairment for participants (N=40).

For Experiment 2 and 3- The mean score for MMSE is 28.58 ± 1.17 (range: 24 - 30) which is greater than 23, which indicates no cognitive impairment for participants (N=17).

Note: In total, 17 subjects underwent one sleep and one deprivation night as a requirement for completing the experiment 2. The same participants completed additional first and second half night testing to complete the requirements of experiment 3. However, only 14 subjects from the original 17 completed both the partial nights and hence the total number of participants in experiment 3 remained 14. Thus, 17 subjects completed experiment 2 and 14 subjects completed experiment 3.

2.2.1.2 Positive and Negative Affective Schedule (PANAS) - Watson, D., and Clark, L. A. (1994) developed a scale to access the extreme positivity and negativity across among subjects volunteering across various conditions of psychological tests. PANAS consists of a set of emotional words that describe different feelings and emotions. In this thesis we used an expanded version of PANAS is called PANAS-X which comprises of 60 instead of 20 emotion words (items). Participants undertaking the PANAS are asked to rate the extent to which they experienced each emotion words on a five-point Likert Scale ranging from "very slightly" to "very much". Half of the presented emotion words represent negative affect (distressed, upset, guilty, ashamed, hostile, irritable, nervous, jittery, scared, afraid), and the other half positive affect (interested, alert, attentive, excited, enthusiastic, inspired, proud, determined, strong, active). The PANAS has been regarded as a highly reliable and valid measure for nonclinical populations. The extremity of scores obtained through this scale represents abnormal affect processing in the individual under test.

Use in present Thesis: In the present thesis, the PANAS is used for screening subjects with an extreme affective response. PANAS serves as an essential part of our exclusion criteria. The mean score for positivity and negativity on PANASX across various condition is (Positive scale = 3.1; Negative scale = 1.4) which indicate no extreme positivity and negativity across participants (N=40).

2.2.1.3 Mood Questionnaire – It's an in house developed questionnaire to measure the mood of the participants on the five-point scale from not at all to very much. They have to reports their present feelings on sleepy, active, tense, tired, bored, motivated and concentred domain.

Use in present Thesis: In the present thesis, the mood questionnaire scans for abnormal mood changes across conditions among volunteers participating in the various experiments.

For Experiment 1A and 1B- The mean score for Mood questionnaire is 17.62 ± 2.28 (range: 16 - 21) which is greater than 15, which indicates no mood discrepancy for all the participants (N=40).

For Experiment 2 and 3- The mean score for MMSE is 17.05 ± 1.80 (range: 17 - 20) which is greater than 15, which indicates no mood discrepancy for all the participants (N=17).

2.2.1.4 Memory and Attention Test – In memory test participants were asked to write the name of occupations in one minute. And in attention test, they, have to write the words start with “A” in one-minute time span, but that would not be any name or it shouldn’t be any compound word too.

Use in present Thesis: Memory and Attention test were performed in the sleep experiment (Experiment 2 and 3).

For Experiment 2- The mean score for memory and attention test (range: 6 - 20) are as follows:

Memory Test							
Sleep				Sleep Deprivation			
Before		After		Before		After	
Mean	SD	Mean	SD	Mean	SD	Mean	SD
8.52	2.06	9.26	3.03	9.78	2.55	8.52	2.54
Attention Test							
Sleep				Sleep Deprivation			
Before		After		Before		After	
Mean	SD	Mean	SD	Mean	SD	Mean	SD
9.42	3.90	11.94	4.51	12.05	3.71	11.36	3.00

Table 1: Represents mean and SD score for memory test

Which is greater than 5, which indicates no decrement in memory and attention for all the participants (N=17) and across condition too.

For Experiment 3- The mean score for memory and attention test (range: 7 - 25) are as follows:

Memory Test							
REMD				NREMD			
Before		After		Before		After	
Mean	SD	Mean	SD	Mean	SD	Mean	SD
9.28	1.70	9.71	1.79	8.00	2.00	9.00	2.58
Attention Test							
REMD				NREMD			
Before		After		Before		After	
Mean	SD	Mean	SD	Mean	SD	Mean	SD
12.14	3.13	11.42	2.07	11.42	3.30	12.42	4.50

Table 2: Represents mean and SD score for attention test

Which is greater than 5, which indicates no decrement in memory and attention for all the participants (N=14) and across condition too.

2.2.1.5 Pittsburgh Sleep Quality Index (PSQI) - The Pittsburgh Sleep Quality Index (PSQI) which was developed in 1988, by Buysse et al., (1989), is an effective instrument used to measure the quality and patterns of sleep in adults. It differentiates “poor” from “good” sleep quality by measuring seven areas (components) of sleep: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction over the last month. Questions on PSQI are related to individual usual sleep habits during the past month only. Answers should include the most accurate reply for the majority of days and nights during the last month. The items from the PSQI are summed to create a total score which represents overall sleep quality. A total score of “5” or greater is indicative of poor sleep quality. PSQI is a standardized sleep questionnaire for clinicians and researchers as well to use with ease.

Use in present Thesis: In this thesis, PSQI scale is used in experiment 2 and 3 to assess the quality of sleep during the past month of participants. The mean score for PSQI is 3.84 ± 0.34 which is less than 5, which indicates a good sleep quality impairment for all the participants.

We also find N=5 participants having a score greater than 5, so we excluded them from all the sleep study.

2.2.1.6 Drug questionnaire - DRUG USE QUESTIONNAIRE (DAST-20) is used to assess the information about participants' potential involvement with drugs excluding alcohol and tobacco during the past 12 months. The DAST is scored by summing the number of responses that indicate drug use problems. "No" responses to questions 4 and 5 indicate problems. For all other questions, a "Yes" response indicates drug use problems. Total DAST scores range from 0 to 20.

Use in present Thesis: In the present thesis, the DAST-20 is used to screening out participants' involvement with drugs. It is thus an important part of our exclusion criteria. The total score for DAST-20 is less than 5, which indicate no drug use problems among all the participants (N=40).

2.2.1.7 Cognitive Emotion Regulation Questionnaire (CERQ) - Is a multidimensional questionnaire developed by Garnefski, Kraaij, and Spinhoven (2001) to identify the cognitive emotion regulation strategies (or cognitive coping strategies) that individual use after having experienced negative events or situations. The CERQ makes it possible to identify individual cognitive strategies and compare them to norm scores from various population groups. This thesis uses the short version of CERQ which contain 18 items. Participants were asked to rate on a seven-point scale ranging from "very slightly" to "very much. The CERQ identifies nine regulation strategies and in the short version CESQ two items in combination represent a cognitive strategy. Participants summed up scores indicates which emotion regulation strategies they usually prefer after experienced negative events.

Use in present Thesis: In the present thesis, the CERQ is used to identify subjective preference of cognitive affective regulation strategies. When completing the questions subjects themselves indicate on a five-point scale to which extent –'(almost) never' (1), 'sometimes' (2), 'regularly' (3), 'often' (4), or '(almost) always' (5) – they make use of certain cognitive coping strategies. Of the 4 items included in a scale a sum score is made (simple straight count), which can range from 4 (never used) to 20 (often used cognitive coping strategy).

For Experiment 1A and 1B- The mean score on CERQ revealed that participants prefer all the strategy equally, we didn't find any significant difference across strategies. [Emotion regulation Strategies: Self-blame = 11.66 ± 3.60, Acceptance = 13.5 ± 3.82, Rumination = 12.33 ± 5.24, Positive Refocusing = 10.66 ± 3.22, Refocus on planning = 14.66 ± 2.60, Positive reappraisal = 16.66 ± 2.99, Putting into perspective = 12.60 ± 3.22, Catastrophizing = 9.5 ± 3.08, and Other-blame = 8.5 ± 1.73]. One-way analysis of variance across all dimensions of the CERQ report no significant difference in the choice of strategies among participants. $F(8, 351) = 1.43$; $p > 0.05$.

For Experiment 2 and 3- The mean score on CERQ revealed that participants prefer all the strategy equally, we didn't find any significant difference across strategies. [Emotion regulation Strategies: Self-blame = 8.45 ± 3.62, Acceptance = 9.41 ± 3.69, Rumination = 10.48 ± 4.29, Positive Refocusing = 10.50 ± 3.95, Refocus on planning = 12.48 ± 4.32, Positive reappraisal = 10.50 ± 3.95, Putting into perspective = 9.25 ± 3.75, Catastrophizing = 8.67 ± 3.65, and Other-blame = 7.12 ± 2.69]. One-way analysis of variance across all dimensions of the CERQ report no significant difference in the choice of strategies among participants. $F(8, 144) = 1.25$; $p > 0.05$.

2.2.1.8 Domain-Specific Risk Taking (Adult) Scale (DOSPERT) - Domain-Specific Risk-Taking (DOSPERT) scale Blais, and Weber (2006) is a psychometric scale that assesses risk taking in five content domains: financial decisions (separately for investing versus gambling), health/safety, recreational, ethical, and social decisions. Participants rate the likelihood that they would engage in domain-specific risky activities. This thesis used a short version of the scale with 30 items that would be interpretable by a wider range of respondents in different cultures (Blais, and Weber, 2006).

Use in present Thesis: DOSPERT scale was used to assess the risk taking behaviour of participants before they performed the BART in order to gauge their risk taking preference across domains.

For Experiment 1A and 1B- The mean score on DOSPERT revealed that participants risk taking were approximately similar [Domain: Ethical = 16.92 ± 6.59, Financial = 19.61 ± 7.73, Health/ Safety = 20.63 ± 7.43, Recreational = 22.43 ± 9.14, and Social = 32.58 ± 5.69]. Further statistics analysis using one-way analysis of variance among all risk domains suggest that participants did were not show greater riskiness towards one domain. This would mean there no significant difference among riskiness across domains of DOSPERT. $F (4, 195) = 2.10; p > 0.05$.

For Experiment 2 and 3- The mean score on DPSPERT revealed that participants risk taking in five content domain were equally, we didn't find any significant difference across the domain. [Domain: Ethical = 20.06 ± 4.53, Financial = 23.8 ± 5.72, Health/ Safety = 31.29 ± 6.36, Recreational = 25.29 ± 8.42, and Social = 27.4.58 ± 4.89]. Further statistics analysis using one-way analysis of variance among all risk domains suggest that participants did were not show greater riskiness towards one domain. This would mean there no significant difference among riskiness across domains of DOSPERT. $F(4, 80) = 1.93$; $p > 0.05$.

2.2.2 Stimuli

I) Pictures: Pictorial stimuli used by behavioural tasks in the present thesis were extracted from the International Affective Picture System (IAPS: Lang, and Bradley, 2008). In total 60 pictures (20 neutral scenes, 20 positive scenes, and 20 negative scenes) were used. We used the following criteria from extracting pictures from IAPS. The three categories of pictures differed significantly from each other with regard to IAPS normative valence ratings (negative: M = 2.62, SD= 1.04; neutral: M= 5.25, SD = 1.41; positive: M = 7.58, SD = 0.38. Positive pictures did not differ from negative pictures on arousal ratings (negative: M= 5.81, SD= 2.06; neutral: M= 2.01, SD = 1.23; positive: M= 5.81, SD= 2.28). The mean difference for valance ratings (or arousal ratings) between positive and neutral pictures was the same as the mean difference valance ratings (or arousal ratings) between negative and neutral pictures. Each picture was displayed at a resolution of 600 x 800 pixel on a computer screen at a viewing distance of 60 cm using E-Prime ver.2.0.11 presentation software.

II) Videos: Video stimuli used in the experiments were selected from Rottenberg, J., and Ray, R. D., and Gross, J. J. (2007) a standardised method for reliably eliciting emotion states. We used three emotion inducing film clips: happy, sad and a neutral film to serve as a baseline. The sad film clip (170 s) from the "The Champ" film depicted a sad scene of father's death who is a champ and his son is crying in that clip and from film " The Lion King" (131 s) depicted one lion throws another lion off of a cliff. At this point, the lion is falling off of a cliff backwards into the stampede. The lion's son has just crawled under his paw and lies down by his father. The happy film (153 s) depicted figure skater Sarah Hughes winning the Olympic gold medal and (161 s) comedy scene from the stand-up comedy, TV shows. The neutral film (70 S) showed "Non-commercial Screen Saver" and coastal landscape scenery.

2.2.3 Task:

2.2.3.1 Emotion Regulation Task - The emotion regulation task was designed using E-Prime ver.2.0.11. A total of 300 pictures, with an equal number of emotional (positive and negative) and neutral pictures, were selected from IAPS (International Affective Picture System using the criteria described above (General methodology section 2.2.2). The task was divided into three blocks. In the first block (practice) the subjects were trained on emotion regulation strategies. They were also made familiar with the task operations in this block. The second block consisted of the emotion view condition - *during with the subjects passively viewed the emotional stimuli presented on the screen*, and the third, emotion regulation condition – *where the participants view the affective stimuli with standard instruction (in Gross, 2002) corresponding to emotion regulation strategies they are required to follow to minimize emotions*. Each subject was subjected to the view as well as all the regulation conditions. After each stimuli presentation and following viewing/regulation, subject rated the valence and arousal of each affective stimulus on seven-point self-assessment manikin (Self-Assessment Manikin; Lang, 1980). Detailed procedure enlisting presentation of stimuli and instructions given to participants before experimental task performance is explained below:

Presentation of stimuli

Practice Trial:

Pictorial Stimuli- 15 pictures (5 positive, 5 negative, 5 neutral) were selected from IAPS (International Affective Picture System.

Video stimuli- video clips depicting emotions (1 positive, 1 Negative and 1 neutral) were presented to participants as video stimuli. Video stimuli used in the training session and in the practice trials were different from those used in the experimental session.

During the practice, participants were made familiar with the design of the experiment and the procedure for SAM ratings. Additionally, participants also learnt how to use the emotion regulation strategies. The experimenter provided detailed standardized instructions concerning the administration of different regulation strategies (situation selection, distraction, cognitive reappraisal, and suppression). Following this, subjects took the practice trials where they viewed wither picture or video clips on screen. Subjects were required either to passively view or regulate their emotions using prompted strategies followed by providing ratings about their emotional state on arousal and valence dimensions of SAM. Stimuli used during the practice sessions were not repeated on the main task.

Main Task-

Pictorial stimuli: 300 pictures, with an equal number of emotional (positive and negative) and neutral pictures IAPS (International Affective Picture System), extracted using the criteria described above (General methodology section 2.2.2) served as test stimuli. These images further formed five blocks of stimuli (view, situation selection, distraction, cognitive reappraisal and suppression). Subjects attended the view block first followed by the regulation blocks (random order). Subjects passively attended the images and then provided SAM ratings (arousal and valence) of their emotional state in the view block. Within the regulation blocks, subject attended pictures and then regulated their emotional state using the regulation instruction provided at the start of each picture. Subjects logged SAM ratings (arousal and valence) of their emotional state following regulation for each picture. Within subject regulation, block presentation was randomized, while between subjects it was counterbalanced.

Video stimuli: We used thirty emotion inducing film clips (ten happy, ten sad, ten neutral).

Picture and video stimuli presentation formed different trials. Within any trail blocks of stimuli appeared in pre-defined order. Trail presentation was counterbalanced across subjects. Both the trials were separated from each other by a 5 minutes time gap. [Please see the Figure 9 for task design using E-Prime ver.2.0.11].

The standard instructions corresponding to each emotion regulation strategies are described below:

I) Emotion view: in this condition, participants after completing the mood questionnaire were asked to view affective stimuli containing pleasant and unpleasant pictures/ videos (as described in general methodology section 2.2.2) and rate their emotions how they are feeling on a seven point Self-Assessment Manikin scale.

II) Situation Selection Strategy: In this emotion regulation strategy participants viewed the combination of three pictorial stimuli on a single slide and were asked to select a picture. While selecting the picture participants were instructed to minimize their emotions in which participants either avoid or approach the particular type of emotion to regulate their emotional response. Same way of presentation was followed for video stimuli. After that participants were asked to rate their emotion on Self-Assessment Manikin scale on the basis of picture/video they selected out of four affective stimuli.

III) Distraction: This time participants were asked to minimize their emotion by using distraction strategy, in which participant had the choice to alter elements within the situation to decrease stimuli ability to elicit an emotional response. Participants were advised to focus on a non-emotion aspect of the situation. This decreases stimuli ability to elicit an emotional response. After following these instructions in every affective stimulus they were asked to rate their emotion on Self-Assessment Manikin scale.

IV) Cognitive Reappraisal strategy: In this emotion regulation strategy participants were instructed to use standard emotion regulation instruction of reappraisal, in which participants alter the specific meaning of a situation to alter its emotional impact. For minimizing the relative emotion, participants are encouraged to rethink about the situation or think in terms of third person perspective about the situation. After following these instructions in every affective stimulus they were asked to rate their emotion on Self-Assessment Manikin scale.

V) Suppression Strategy: This is a response focused emotion regulation strategy in which participants are required to minimize their experiential, physiological and behavioural states that are elicited by attending the stimuli. After altering their emotion by using this strategy they were asked to rate their emotions for each affective stimuli on Self-Assessment Manikin scale.

2.2.3.2 Risky Decision Making Task (Balloon Analogue Risk Task **-** BART; Lejuez et al., 2002) – Balloon Analogue Risk Task was presented as a computer-based measure of risk-taking tendency. During the task, the computer screen showed a small simulated balloon accompanied by a balloon pump, a reset button labelled "Collect", a permanent money earned display labelled "Total Earned", and a second display listing the money earned on the last balloon and labelled "Last Balloon." With each pump, 10 cents get added in a temporary reserve. When a balloon explodes, all money in the temporary bank gets lost**.** At any point during each trial, the participant has two choices; he could either stop pumping the balloon and click the Collect button or keep pumping the balloon until it explodes. Clicking Collect button transferred all the money collected in that particular trial from the temporary bank to the permanent bank, where the new total earned would be incrementally updated cent by cent. After a particular balloon is exploded or the money is collected, the participant is exposed to a new balloon until he completes all the 30 trials (i.e. balloons inflation). All balloons had a different explosion point with the weakest balloon exploding on the first pump and the strongest balloon exploding after 128 pumps and average explosion point was on pump number 64. A balloon that did not explode was encoded as a "positive feedback" trial; a balloon that exploded was encoded as a "negative feedback" trial. The dependent measure on the BART was the adjusted number of pumps across balloons (the average number of pumps on successfully collected trials) (Lejuez et al., 2002). Additionally, a mean number of desired pump (described as initial decision of participants) and the number of explosions (i.e. the number of balloons that could not be redeemed because they exploded). In the thesis Balloon Analogue Risk Task was used for assessing risky decision making.

2.2.4 Participants:

Undergraduate students (mean age= 22.8 ± 3.5 years) from Indian Institute of Technology Guwahati volunteered for the experiments in exchange of partial credit toward a course requirement or equivalent monetary benefit. Each participant was tested individually in sessions that lasted approximately one hour for behaviour experiments and three hours for electrophysiological experiments. All the participants completed the following set of questionnaires: a personal data form including questions about age, gender eyesight etc. along with inform consent form, a mood questionnaire, and positive and negative affect schedule (PANAS; Watson et al., 1988), DOSPERT scale (Weber, 2002; Blais, 2006)., CERQ and PSQI scale in sleep experiments (experiment 4 and 5).

Inclusion Criteria: Average academic performance, Adaptation of sleep laboratory conditions, young adults in the age group described, corrected to normal vision and no known history of any physical abnormalities in the last six months.

Exclusion Criteria: Mild to moderate neurological/psychiatric conditions, abnormal sleep wake cycle, Mild to moderate addiction in any form.

2.2.5 Tools

a) ***10 channel sleep polysomnography*** **Nihon-Khoden:** This will be used for recording and staging sleep. Recordings will be obtained from scalp site A1, A2 (linked earlobes), C3, C4 (scalp electrodes), EOG V, EOG H (eye movements), EMG 1, EMG 2 (for chin EMG) and Fpz (Ground).

b) ***28 channel Brain Vision ActiChamp with Analyzer 2.0 for EEG/ERP*****:** Timed locked Event Related Potentials (ERP) will be recorded from 28 scalp sites (AF3, AF4, F7, F3, Fz, F4, F8, FC5, FC1, FC2, FC6, T7, C3, Cz, C4, T8, CP5, CP1, CP2, CP6, P7, P3, Pz, P4, P8, PO3, PO4, Oz), A1, A2 (linked earlobe), EOG V, EOG H (eye movements), Fpz as ground and Fcz for online reference.

c) ***E-prime ver 2.0.11:*** was used for designing and executing the emotion regulation task, BART task and as well as for trigger generation during the event related potential task.

2.2.6 General Design

2.2.6.1 Behavioural Experiments – First part of the thesis consisted of behavioural experiments done to test the differential affect processing by emotion regulation. Most subjects in these experiments arrived at the laboratory during day time. The subjects were briefed about the nature of the experiment to be performed. After they provided informed consent they were made to undergo preliminary tests (demographic information, MMSE, Drug questionnaire, mood, PANAS, CERQ and DOSPERT). Once the subjects have successfully completed the instructions of the preliminary test (relating the task to be performed) was provide and it was ensured that the subjects have understood all aspects of the experiment. Questions and doubts were answered to facilitate the subject briefing. Practice blocks followed in which subject familiarized themselves with the experimental requirements. When the subject reports their willingness to take the actual experiments, they were seated comfortably in the laboratory testing area and the actual testing begins. At any point, if the subjects report inability to complete the task they were allowed to do so with the cancellation of the experimental task. All subjects were debriefed after successfully completing of the experimental session.

Experiment 1A and Experiment 1B were conducted on the same number of participants where N = 40.

Experiment 2 had N = 17, and it follows a within-subject design where A condition (sleep, deprivation) X B affect (positive, negative, neutral) and BART score as a dependent variable

For Experiment 3 has N = 14 subjects. The 17 subjects of experiment 2 took part in experiment 3 with the exception of 3 subjects who failed to follow experiment procedure and were excluded.

2.2.6.2 Electrophysiological Experiments: - The second part of the thesis consists of sleep and well as event related potential testing. Subjects for these set of experiments arrived at the laboratory at 09:00 hrs on experimental nights. They were handed the Actiwatch and advised to wear it till they arrived for the experimental sessions starting 20:00 hrs the same day. They were encouraged to not take naps during the day and also abstain from alcoholic beverage and smoking throughout the day. After arriving at the sleep laboratory the subjects were briefed in the manner described above. The sleep group subjects were attached electrodes for monitoring sleep. After completion of the behavioural task subjects were either allowed to sleep or remain awake with the experimenters in the laboratory. At 07:00 am the next morning the subjects were awakened from sleep, the sleep sensors were removed and they were allowed a quick shower with light breakfast following it. After an addition 03 hours following waking, which they spent in the laboratory, they were prepared for ERP recording using 32 electrode setup. Upon finishing the session, the subjects were debriefed, thanked and allowed to leave the laboratory.

Behavioral Studies

2.3 Experiment 1A: Effectiveness of Affect Regulation in Terms of Stimuli Type and Affect

Background – One challenge in psychological research dealing with affect processing is to generate emotional states in the laboratory setup through the use of external stimuli (picture, video, text etc.). One widely used and accepted method that can be easily standardized, is the use of pictures. The International Affective Picture System (IAPS; Lang et. al., 2008), provides such a set of standardized photographs also it has the advantage of being an internationally known method. IAPS pictures have been used in a wide range of research topics and are typically shown for a duration of six seconds (Vrana et al., 1988; Bernat et al., 2006; Codispoti et al., 2006; Rhudy et al., 2007). In addition to the IAPS, video clips have also been widely used and accepted as stimuli in the field of emotion research (McHugo et al., 1982; Gross and Levenson, 1995; Bartolini, 2011). As our present thesis deals with the effectiveness of emotion regulation in the context of risky decision making we incorporated the guidelines recommended by Webb et al, 2012 concerning factors effecting emotion regulation. Webb et al., (2012) propose (a) nature of emotion induction and (b) nature of to be regulated emotion as important factors in emotion regulation. The nature of the focal emotion (i.e., what feeling is being regulated) is likely to influence the effectiveness of emotion regulation and it also varies in term of the dimension of affect. Till date studies have emphasized the effectiveness of emotion regulation strategies and their impact on cognition. The present study also incorporates the condition under which strategies are more effective (i.e. nature of emotion induction and type of affect to be regulated). So we decided to test the emotion regulation effectiveness across affect type and nature of stimuli. In this experiment, we try to compare the emotion regulation effectiveness across emotion induction method by using picture and video stimuli. Compared to static pictures and sound, video is more powerful format for elicitation of emotional states because it can effortlessly and simultaneously stimulate visual and auditory senses thereby multiplying their individual impacts through psychophysiological and neurological underlying mechanisms. Films share most of the advantages that pictures offer, like their capability of being standardized and have been argued to be even more advantageous (Gross and Levenson, 1995).

2.3.1 Objective

To test whether affect regulation strategies differ on processing affect generated through pictures / videos and to confirm whether the differences extend over processing positive and negative affect.

2.3.2 Hypothesis

a) Affect regulation strategies will differentially modulate processing of stimuli (picture/video).

b) Positive and negative valance stimuli will be differentially processed by emotion regulation strategies.

2.3.3 Variables: Independent variables- Affect (positive, negative); Strategies (view / situation selection / Distraction / cognitive reappraisal and suppression) and Stimuli (picture/video).

Dependent variables- Self-Assessment Manikin ratings

2.3.4 Design:

The experiment is based on 2 Affect (positive, negative) x 2 Stimuli (picture, video) x 5 Strategies (view/ situation selection/distraction/cognitive reappraisal/ suppression) complete repeated measure design. The dependent variable is Self-Assessment Manikin rating. [See Figure 4].

2.3.5 Methodology

Participants (N = 40) were trained using standard emotion regulation instructions (Gross, 2002) on practise sessions for performing the emotion regulation task. The main task comprised on two primary level picture / video stimuli. Each primary level was further divided into five experimental treatment arms: view, situation selection, distraction, cognitive reappraisal and suppression. Once the subjects have satisfactorily learned every regulation strategy, they were introduced to the main task. The main task required each subject to participate across all treatment arms within both the primary levels. The main task started by inducing subjects to - view treatment arm. The experiment begins by showing subjects affective pictures which the subject was required to passively view for 6000 milliseconds followed by rating each displayed picture on Self-assessment manikin scales of arousal and valence. Once the subjects had completed all trials within the picture block the experiment was repeated for the second level consisting video clips as stimuli. The subjects were given rest for five minutes while switching from picture level to video level. Picture and video stimuli used in the task were of positive / negative and neutral content. After the experimental session was completed. The Self-assessment manikin scorings were blocked into positive / negative and neutral content type. Experimental task paradigm showed in Figure 9.

2.3.6 Results

2.3.6.1 Emotion regulation effectiveness across nature of stimuli (picture/video):

Four separate repeated measure ANOVA were performed to check if the participant followed the instructions for emotion regulation we measured the subjective rating for valance and arousal both for positive and negative valence stimuli.

2.3.6.2 Positive Affect -

a) Arousal rating of positive affect:

I) Situation selection Strategy: ANOVA with 2 stimuli (picture, video) x 2 affect (view, situation selection) as within subject factor and Self-assessment manikin rating for arousal as dependent variable was performed. There was no significant main effect of stimuli [(F (1, 39) = 0.06, p > 0.05)], and affect [F (1, 39) = .007, p > 0.05]. The mean difference for pictorial stimuli in emotion group is 5.28 ± 0.92 and in emotion regulation group is 4.85 ± 0.25. Similarly, mean difference for movie stimuli in emotion group is 6.12 ± 0.94 and in emotion regulation group is 5.94 ± 0.84 (Figure 11A). Thus, arousal levels for positive stimuli in the view group were no different than the situation selection group. This indicates that situation selection did not significantly regulate the positive emotions generated through picture stimuli. Non-significant interaction effects were reported.

II) Distraction: ANOVA with 2 stimuli (picture, video) x 2 affect (view/ distraction) as within subject factor and Self-assessment manikin rating for arousal as dependent variable was performed. There was no significant main effect of stimuli [(F (1, 39) = 0.12, p > 0.05)] and affect [F (1, 39) = .07, p > 0.05]. The mean difference for pictorial stimuli in emotion group is 5.28 ± 0.92 and in emotion regulation group is 4.85 ± 1.07 similarly mean difference for movie stimuli in emotion group is 6.12 ± 0.94 and in emotion regulation group is 5.2 ± 0.84 (Figure 11B). It can thus be inferred that arousal levels were not significantly modulated by distraction when compared with view condition. No interaction effect was found significant.

III) Cognitive reappraisal strategy: ANOVA with 2 stimuli (picture, video) x 2 affect (view, cognitive reappraisal) as within subject factor and Self-assessment manikin rating for arousal as dependent variable was performed. There was no significant main effect of stimuli

[(F (1, 39) = 0.08, $p > 0.05$)], and affect [F (1, 39) = 0.7, $p > 0.05$]. The mean difference for pictorial stimuli in emotion group is 5.28 ± 0.92 and in emotion regulation group is 4.18 ± 0.48 similarly mean difference for movie stimuli in emotion group is $6.12 \pm .94$ and in emotion regulation group is 4.89 ± 0.47 (Figure 11C). It can thus be inferred that arousal levels were not significantly modulated by cognitive reappraisal when compared with view condition No interaction effect was found significant.

IV) Suppression strategy: ANOVA with 2 stimuli (picture, video) x 2 affect (view, suppression) as within subject factor and Self-assessment manikin rating for arousal as dependent variable was performed. There was no significant main effect for stimuli [(F (1, 39) = 0.9, $p > 0.05$)], and affect [F (1, 39) = .09, $p > 0.05$]. The mean difference for pictorial stimuli in emotion group is 5.28 ± 0.92 and in emotion regulation group is 4.85 ± 0.47 similarly mean difference for movie stimuli in emotion group is $6.12 \pm .94$ and in emotion regulation group is 5.79 ± 0.38 (Figure 11D). No interaction effect was found significant. It can thus be inferred that arousal levels were not significantly modulated by suppression when compared with view condition.

b) Valance rating for positive affect:

I) Situation selection Strategy: ANOVA with 2 stimuli (picture, video) x 2 affect (view, situation selection) as within subject factor and Self-assessment manikin rating for arousal as dependent variable was performed. The mean difference for pictorial stimuli in emotion group is 4.82 ± 0.93 and in emotion regulation group is 5.05 ± 0.78 similarly mean difference for movie stimuli in emotion group is $6.01 \pm .29$ and in emotion regulation group is 5.79 ± 0.73 (Figure 12A). There was no main effect of stimuli [(F (1, 39) = 0.4, $p > 0.05$)] or affect [F (1, 39) = .05, $p > 0.05$] which tells us that situation selection as emotion regulation strategy does not significantly regulate stimuli valence as compared to emotion view conditions. No interaction effect was found significant.

II) Distraction: ANOVA with 2 stimuli (picture, video) x 2 affect (view, distraction) as within subject factor and Self-assessment manikin rating for arousal as dependent variable was performed. The mean difference for pictorial stimuli in emotion group is 4.82 ± 0.93 and in emotion regulation group is 4.98 ± 0.97 similarly mean difference for movie stimuli in emotion group is $6.01 \pm .29$ and in emotion regulation group is 5.89 ± 0.79 (Figure 12B).There was no significant differences [($F (1, 39) = 0.18$, $p > 0.05$)] for Self-Assessment Manikin rating as a function of stimuli type. F value [$F (1, 39) = .03$, $p > 0.05$] which shows no significant main effect across emotion vs emotion regulation. No interaction effect was found significant.

III) Cognitive reappraisal strategy: ANOVA with 2 stimuli (picture, video) x 2 affect (view/ cognitive reappraisal) as within subject factor and Self-assessment manikin rating for arousal as dependent variable was performed. The mean difference for pictorial stimuli in emotion group is 4.82 ± 0.93 and in emotion regulation group is 4.05 ± 0.73 similarly mean difference for movie stimuli in emotion group is $6.01 \pm .29$ and in emotion regulation group is 5.79 ± 0.88 (Figure 12C).There was no significant differences [($F (1, 39) = 0.13$, $p > 0.05$)] for Self-Assessment Manikin rating as a function of stimuli type. F value [$F (1, 39) = .02$, $p > 0.05$] which shows no significant main effect across emotion vs emotion regulation. No interaction effect was found significant.

IV) Suppression strategy: ANOVA with 2 stimuli (picture, video) x 2 affect (view/ suppression) as within subject factor and Self-assessment manikin rating for arousal as dependent variable was performed. The mean difference for pictorial stimuli in emotion group is 4.82 ± 0.93 and in emotion regulation group is 5.08 ± 0.75 similarly mean difference for movie stimuli in emotion group is 6.01 ± .29 and in emotion regulation group is 5.49 ± 0.85 (Figure 12D).There was no significant differences [($F (1, 39) = 0.01$, $p > 0.05$)] for Self-Assessment Manikin rating as a function of stimuli type. F value [$F (1, 39) = .10$, $p > 0.05$] which shows no significant main effect across emotion vs emotion regulation. No interaction effect was significant.

2.3.6.3 Negative Affect -

a) Arousal rating of negative affect:

I) Situation selection Strategy: ANOVA with 2 stimuli (picture, video) x 2 affect (view/ situation selection) as within subject factor and Self-assessment manikin rating for arousal as dependent variable was performed. There was no significant differences [($F (1, 39) = 0.18$, $p > 0.05$)] for Self-Assessment Manikin rating as a function of stimuli type. F value [$F (1, 39) = 0.5$, $p > 0.05$] which shows no significant main effect across emotion vs emotion regulation. The mean difference for pictorial stimuli in emotion group is 6.82 ± 0.74 and in emotion regulation group is 4.78 ± 1.03 similarly mean difference for movie stimuli in emotion group is 6.02 ± .59 and in emotion regulation group is 5.89 ± 0.74 (Figure 13A). No interaction effect was significant.

II) Distraction: ANOVA with 2 stimuli (picture, video) x 2 affect (view/ distraction) as within subject factor and Self-assessment manikin rating for arousal as dependent variable was performed. There was no significant differences [($F (1, 39) = 0.18$, $p > 0.05$)] for Self-assessment manikin rating as a function of stimuli type. F value [$F (1, 39) = 5.96$, $p < 0.05$] which shows significant main effect across emotion vs emotion regulation. The mean difference for pictorial stimuli in emotion group is 6.82 ± 0.74 and in emotion regulation group is 4.01 ± 0.63 similarly mean difference for movie stimuli in emotion group is 6.02 ±

.59 and in emotion regulation group is 4.58 ± 0.47 (Figure 13B). No interaction effect was found significant.

III) Cognitive reappraisal strategy: ANOVA with 2 stimuli (picture, video) x 2 affect (view/cognitive reappraisal) as within subject factor and Self-assessment manikin rating for arousal as dependent variable was performed. There was no significant differences [(F (1, 39) = 0.08, $p > 0.05$)] for Self-assessment manikin rating as a function of stimuli type. F value [F (1, 39) = 7.54, $p < 0.05$] which shows significant main effect across emotion vs emotion regulation. The mean difference for pictorial stimuli in emotion group is 6.82 ± 0.74 and in emotion regulation group is 4.08 ± 1.04 similarly mean difference for movie stimuli in emotion group is 6.02 ± .59 and in emotion regulation group is 5.09 ± 0.4 (Figure 13C). No interaction effect was significant.

IV) Suppression strategy: ANOVA with 2 stimuli (picture, video) x 2 affect (view/ suppression) as within subject factor and Self-assessment manikin rating for arousal as dependent variable was performed. There was no significant differences [(F (1, 39) = 0.046, $p > 0.05$)] for Self-assessment manikin rating as a function of stimuli type. F value [F (1, 39) = 0.55, $p > 0.05$] which shows no significant main effect across emotion vs emotion regulation. The mean difference for pictorial stimuli in emotion group is 6.82 ± 0.74 and in emotion regulation group is 4.78 ± 1.03 similarly mean difference for movie stimuli in emotion group is 6.02 ± 0.59 and in emotion regulation group is 4.98 ± 0.74 (Figure 13D). No interaction effect was found significant.

b) Valance rating for negative affect:

I) Situation selection Strategy: ANOVA with 2 stimuli (picture, video) x 2 affect (view/situation selection) as within subject factor and Self-assessment manikin rating for valance as dependent variable was performed. There was no significant differences [(F (1, 39) = 0.18, p > 0.05)] for Self-assessment manikin rating as a function of stimuli type. F value [F (1, 39) = 0.99, p > 0.05] which shows no significant main effect across emotion vs emotion regulation. The mean difference for pictorial stimuli in emotion group is 1.02 ± 0.24 and in emotion regulation group is 1.91 ± 0.63 similarly mean difference for movie stimuli in emotion group is 2.02 ± .59 and in emotion regulation group is 2.08 ± 0.47 (Figure 14A). No interaction effect was found significant.

II) Distraction: ANOVA with 2 stimuli (picture, video) x 2 affect (view/distraction) as within subject factor and Self-assessment manikin rating for valance as dependent variable was performed. There was a significant differences [(F (1, 39) = 4.86, p < 0.05)] for Self-assessment manikin rating as a function of stimuli type. F value [F (1, 39) = 5.85, p < 0.05] which shows significant main effect across emotion vs emotion regulation. The mean difference for pictorial stimuli in emotion group is 1.02 ± 0.24 and in emotion regulation group is 3.97 ± 0.24 similarly mean difference for movie stimuli in emotion group is 2.02 ± .59 and in emotion regulation group is 3.01 ± 0.4 (Figure 14B). No interaction effect was significant.

III) Cognitive reappraisal strategy: ANOVA with 2 stimuli (picture, video) x 2 affect (view/cognitive reappraisal) as within subject factor and Self-assessment manikin rating for valance as dependent variable was performed. There was a significant differences [(F (1, 39) = 7.38, p < 0.05)] for Self-assessment manikin rating as a function of stimuli type. F value [F (1, 39) = 5.45, p < 0.05] which shows significant main effect across emotion vs emotion regulation. The mean difference for pictorial stimuli in emotion group is 1.02 ± 0.24 and in emotion regulation group is 4.07 ± 0.14 similarly mean difference for movie stimuli in emotion group is 2.02 ± .59 and in emotion regulation group is 3.11 ± 0.40 (Figure 14C). No interaction effect was found significant.

IV) Suppression strategy: ANOVA with 2 stimuli (picture, video) x 2 affect (view/suppression) as within subject factor and Self-assessment manikin rating for valance as dependent variable was performed. There was no significant differences [($F(1, 39) = 0.29$, $p > 0.05$)] for Self-assessment manikin rating as a function of stimuli type. F value [$F(1, 39) = 0.17$, $p > 0.05$] which shows no significant main effect across emotion vs emotion regulation. The mean difference for pictorial stimuli in emotion group is 1.02 ± 0.24 and in emotion regulation group is 1.81 ± 0.63 similarly mean difference for movie stimuli in emotion group is 2.02 ± .59 and in emotion regulation group is 2.38 ± 0.47 (Figure 14D). No interaction effect was found significant.

2.3.7 Conclusion:

In conclusion, the data reported in this study suggests negative emotions are better regulated by extrinsic emotion regulation which is also supported by previous researchers. Further, our data indicate, better regulation of pictorial stimuli compared to video stimuli in emotion regulation task across all emotion regulation strategies, which shows that both stimuli type differ in their personalization of content to be regulated and in the method of emotion induction. The result of the present study also indicates that only two emotion regulation strategies (cognitive reappraisal and distraction) are more effective in comparison to other emotion regulation strategies of the process model of emotion regulation. In next experiment, we will compare the effect of all emotion regulation strategies of process model on risky decision making using Balloon Analogue Risk Task.

2.4 Experiment 1B: Effect of Emotion Regulation Strategies on Risky Decision Making

2.4.1. Objective

To test whether affect regulation strategies differentially modulate risky decision making on Balloon Analogue Risk Task scores.

2.4.2 Hypothesis

Emotion regulation will lead to changes in Risky choice behaviour (in terms of Balloon Analogue Risk Task scores).

2.4.3 Variables:

Independent variables- Strategies (view / situation selection / distraction / cognitive reappraisal and suppression) and Stimuli (picture/video)

Dependent variables- Risk Taking Behavior: - measured in terms of Mean adjusted pumps: the average number of pumps on balloons where money was collected before an explosion.

2.4.4 Design:

The experiment is based on 2 stimuli type (picture / video) x 5 emotion regulation (view/ situation selection/ distraction /cognitive reappraisal/ suppression) repeated measure design with emotion regulation, stimuli type (picture, video) as within subject factor and BART score as dependent variable measure. [See Figure 4].

2.4.5 Methodology

In this experiment, we compared the effectiveness of different emotion regulation strategies on decision making under risk. To achieve this objective N=40 participants were recruited and tested across all the five emotion regulation strategies. Participants were instructed to follow standard instruction for each strategy as described above (general methodology section 2.2.3.1). Immediately after completing emotion regulation task participants asked to perform BART. Experimental task paradigm showed in Figure 10.

Experiment 1 was conducted to evaluate the effectiveness of emotion regulation on risky decision making using behavioural analysis. The previous set of the experiment were exploratory in nature which were designed to specifically test the effectiveness of individual regulation strategies, the effectiveness of stimuli type and affect type that were most effective in producing significant changes in risk choices across BART.

2.4.6 Results

Risky choice behavior: Mean adjusted number of pumps defined as the average number of pumps on balloons (manually pressing the key “V” on keyboard) where money was collected before an explosion were calculated from the participants on the BART task across the conditions [view/ situation selection/distraction /cognitive reappraisal/ suppression].

2.4.6.1 Nature of stimuli (picture, video) and risky decision-making:

To calculate risk taking behaviour we calculate the mean no. of adjusted pumps on BART task both in emotion and emotion regulation group.

I) Situation selection Strategy: ANOVA was performed with 2 stimuli type (picture, video) x 2 emotion regulation (view/ situation selection) as within subject factor and mean no. of adjusted pumps on Balloon Analogue Risk Task as dependent variable. The mean difference of adjusted pumps for pictorial stimuli in emotion group is 42.75 ± 4.24, in emotion regulation group is 44.98 ± 5.38 and for video stimuli in emotion group is 38.45 ± 3.42, in emotion regulation group is 40.08 ± 6.28 (Figure 15A). F value [$F(1, 39) = 3.98$, $p > 0.05$] which shows no significant main effect across emotion vs emotion regulation. There was no significant differences (F (1, 39) = 0.08, $p > 0.05$, for risky decision making as a function of stimuli type. No significant interaction effects were found.

II) Distraction: ANOVA was performed with 2 stimuli type (picture, video) x 2 emotion regulation (view/ distraction) as within subject factor and mean no. of adjusted pumps on Balloon Analogue Risk Task as dependent variable. The mean difference of adjusted pumps for pictorial stimuli in emotion group is 48.57 ± 8.24, in emotion regulation group is 64.86 ± 7.84 and for video stimuli in emotion group is 39.04 ± 6.24, in emotion regulation group is 50.08 ± 4.07 (Figure 15B). F value [F (1, 39) = 22.53, $p < 0.05$] which shows significant main effect across emotion vs emotion regulation. There was a significant differences (F (1, 39) = 85.91, $p < 0.05$, for risky decision making as a function of stimuli type. No significant interaction effects were found.

III) Cognitive reappraisal strategy: ANOVA was performed with 2 stimuli type (picture, video) x 2 emotion regulation (view/ cognitive reappraisal) as within subject factor and mean no. of adjusted pumps on Balloon Analogue Risk Task as dependent variable. The mean difference of adjusted pumps for pictorial stimuli in emotion group is 44.15 ± 7.34, in emotion regulation group is 68.79 ± 9.18 and for video stimuli in emotion group is 40.45 ± 5.42, in emotion regulation group is 60.08 ± 5.08 (Figure 15C). F value [F (1, 39) = 27.61, $p < 0.05$] which shows a significant main effect across emotion vs emotion regulation. There was a significant differences (F (1, 39) = 87.98, $p < 0.05$, for risky decision making as a function of stimuli type. No significant interaction effects were found.

IV) Suppression strategy: ANOVA was performed with 2 stimuli type (picture, video) x 2 emotion regulation (view/ suppression) as within subject factor and mean no. of adjusted pumps on Balloon Analogue Risk Task as dependent variable. The mean difference of adjusted pumps for pictorial stimuli in emotion group is 41.37 ± 8.57, in emotion regulation group is 42.68 ± 9.08 and for video stimuli in emotion group is 36.06 ± 6.16, in emotion regulation group is 38.84 ± 5.09 (Figure 15D). F value [$F(1, 39) = 2.60$, $p > 0.05$] which shows no significant main effect across emotion vs emotion regulation. There was no significant differences ($F(1, 39) = 0.13$, $p > 0.05$, for risky decision making as a function of stimuli type. No significant interaction effects were found.

2.4.7 Conclusion:

By using the process model of emotion regulation, the present study aimed to investigate differential effect of emotion regulation strategies on risky decision making. Results suggest that under laboratory conditions, cognitive reappraisal and distraction are most effective on risky decision making. Which shows that these both emotion regulation strategies were able to modulate risk attitude by efficaciously downregulating an emotional experience. Reappraisal and distraction enables riskier decision making that does not occur either with other emotion regulation strategies or an absent emotion regulation strategy. Although according to Gross, 2002 each of the emotion regulation strategies has different social, cognitive and behavioral outcomes, but in our study we found cognitive reappraisal strategy and Distraction most effective on risk taking behavior in comparison of other emotion regulation strategies. A possible reason for the results could be that cognitive mechanisms of regulating affect are known to produce better results than behavioral outcomes. In our next set of experiment, we will be examining the role of sleep on affect regulated risky decision making with our selected variable (Pictorial stimuli, Negative affect and emotion regulation strategies (distraction, cognitive reappraisal)). In further experiments, on the basis of the findings of the previous set of behavioural experiments, we decide to use only two emotion regulation strategies (cognitive reappraisal and distraction), negative affect and only pictorial stimuli to examine the role of sleep in affect regulated risky decision making.

Electrophysiological studies

2.5 Experiment 2 – Effect of Emotion Regulation on Risky Decision Making After Sleep and Sleep Deprivation.

The previous sets of experiments were designed to evaluate the effectiveness of emotion regulation on risky decision making using behavioral analysis. In the present set of experiments, we will incorporate sleep as our main independent variable to explore its role in affect regulated risky decision making. According to physiological perspective, emotion regulation process includes interaction between prefrontal cortex which executes control process and subcortical and posterior cortical region which encode and represent the information. Sleep plays a crucial role in maintaining this interaction which guides an individual into selectively using executive functions for retaining goal-relevant information in mind and thereby resisting interference from irrelevant material. While this beneficial impact of sleep for emotion regulation is well established, its role in affect regulated risky decision making is less well understood. In order to investigate this procedure in further detail, we use an additional measure of neural responses. Electroencephalographic (EEG) research using event-related brain potentials (ERPs) is more sensitive to subtle processing differences and is a more direct measure of mental processes than the behavioural measures used in previous studies. Event-related brain potentials of positive (i.e., gains) and negative feedback stimuli (i.e., losses) provide additional data on both the timing and the neural substrates of feedback processing. In this experiment, we measure two event-related brain potentials components that are selectively sensitive to feedback: the feedback-related negativity (FRN) and the feedback-related P300. The purpose of this experiment is to determine the effect of emotion regulation strategies on risky decision making across sleep and sleep deprivation condition also decode the event-related brain potentials marker of risk taking behaviour. Here in this experiment, we will use only two emotion regulation strategies (distraction and cognitive reappraisal) because in our previous behavioural experiments another type of strategies turned out non-significant in compared to control condition.

2.5.1 Objectives:

The present experiment has two fold objectives:

a) To evaluate whether sleep and sleep deprivation differentially effect risky decision making in affect and affect regulating individuals.

b) To study the electrophysiological marker of affect regulated decision making across sleep and sleep deprivation.

2.5.2 Hypothesis:

a) Sleep deprivation will significantly affect risky decision-making across affect and affect regulation conditions.

b) Sleep deprivation will have differential electrophysiological signatures as compared with sleep-induced individuals across affect and affect regulation conditions.

2.5.3 Variables:

Independent variables- Sleep (sleep / sleep deprivation), Emotion (view / regulation)

Dependent variables-

a) Risk Taking Behavior: measured in terms of mean adjusted pumps: the average number of pumps on balloons where money was collected before an explosion.

b) event-related brain potentials marker of Risk Taking Behaviour: Feedback related negativity (FRN) and P300.

2.5.4 Design:

The study follows a total repeated measure design with two sleep conditions: full night sleep and sleep deprivation. The interval between the sessions was kept at least seven days and the order of the two was at random. After a full night's sleep or sleep deprived hours' subjects completed the emotion behavioural and Balloon Analogue Risk task. EEG was recorded while performing both the tasks. [See Figure 5 & 6]

2.5.5 Methodology

2.5.5.1 EEG/ERP

EEG signals were acquired with 32 Ag-AgCl referential active electrodes (ActiCap, 10-20 montage), and then amplified by BrainVision ActiChamp [Brain Products GmbH. Gilching, Germany]. The real time signal recording was done using PyCorder software [Brain Vision LLC, Morrisville, USA]. Electrode impedance between subject's scalp and electrodes was adjusted via common procedure and kept below 15 kΩ for each sensor node. The sensors placed on the right and left mastoid were chosen as reference. To record ocular movement for ocular artefact correction, electrodes were placed 1 cm above and below and slightly lateral to the outer canthus of each eye and referenced to the linked mastoid sensor. Data were collected with a sampling rate of 500 Hz and a notch filter at 50 Hz was also applied in order to remove noise from the standard AC electrical line current.

2.5.5.2 Polysomnography

For standard polysomnography, the electroencephalographic (EEG) activity was continuously recorded with (Ag/AgCl) electrodes from C3 and C4 referenced to linked electrodes attached to the mastoids. In addition, horizontal and vertical electrooculography (EOG) and electromyography (EMG) data were recorded. Data were amplified by Nihon Khoden Amplifiers (Nihon-Khoden, Japan) and continuously digitized at a rate of 250 Hz.

2.5.5.3 Procedure

The recruitment and inclusion testing of the participants were similar to the once followed in the behavioural experiments. Subjects were randomly assigned to either sleep or deprivation groups. Each subject served as his own control and thus had to participate randomly on both the sleep and deprivation nights. All subject underwent a compulsory adaptation and baseline night, during which were acquainted to the sleep laboratory settings and calibration of their sleep architecture was done. Before all nights the subjects were called in the morning to the laboratory at 09:00 hrs and given the ActiWatch (for monitoring their daytime activity and to make sure that they were not napping during the day) which the subjects were required to wear all throughout the day and return back to the experimenter while the arrive for the commencement of the night sessions. On adaptation night the subjects slept for eight hours without sleep recordings in the laboratory, while during the baseline night standard polysomnography was recorded for the entire night. The subject left the laboratory in the morning after a light breakfast. On the experimental nights' subjects were first made to practise the regulation strategy execution using standard instructions. Once they mastered the skill, sleep group underwent sensor placement followed by eight hours of uninterrupted sleep with polysomnographic recordings. The sleep deprivation groups remained awake with the experimenter for the eight hours. The following morning both groups were allowed to leave the sleep laboratory with the ActiWatch and were asked to return to the laboratory for retrieval after three hours. On return, subjects were made to wear the EasyCap (which recorded their ERP's using ActiChamp) and perform on the emotion regulation task followed by Balloon Analogue Risk Task. One completed the subjects were thanked and allowed to leave the laboratory. [See Figure 5 & 6]

2.5.5.4 Measures

a) Behavioural Measure- Risk Taking Behaviour: Risk Taking Behavior measured in terms of mean adjusted pumps: the average number of pumps on balloons where money was collected before an explosion.

b) Electrophysiological Measure–

Data were off-line referenced to mathematically linked mastoids. Since in this study we were specifically interested in FRN as well as in P300, EEG data was filtered offline with different parameters, which is in line with previous literature (Luu et al., 2003; Donkers et al., 2005; Wu and Zhou, 2009). For the FRN, data were filtered using a 2 to 12 Hz band pass filter (Donkers et al., 2005). A conventional wideband filter of 0.10 to 30 Hz (phase shift-free Butterworth filters; 24 dB/octave slope) was used to investigate the feedback related P300 amplitude. After ocular correction (Gratton et al., 1983), feedback-locked epochs were created from positive feedback (money collected: gain) and negative feedback (balloon popped: money lost) and were baseline corrected using the 200-ms pre-stimulus interval. The length of the epochs was 1,000 ms (200 ms pre-stimulus until 800 ms post-stimulus). Epochs including out of range voltages (±75 μV) were rejected as artefacts and were excluded from further processing. If 50% or more of the epochs of a participant contained artefacts, this participant was excluded from further analyses. As a result, three participants were rejected from further analyses. Epochs locked to positive and negative feedback were averaged separately for artefact-free trials at each scalp site, producing one average waveform per feedback condition per subject. All epochs, across balloons in the entire test block from the start of the procedure, were included in the average. Derived from inspecting the grand average and individual subject data, the FRN component was identified as the most negative amplitude within an 180 to 250 ms window following feedback onset. The P300 component was defined as the maximum amplitude within 300 to 400 ms following the FRN peak. Statistical analyses for both components were done on fronto-central-parital electrodes Fz, Cz, and Pz.

Further statistical analysis was performed on peak FRN and P300 amplitudes and latency. Amplitude and latency data across experimental groups were analysed using repeated measures ANOVA with 2 Sleep condition (sleep, deprivation) x 2 Affect (view, regulation) x 2 Feedback (positive, negative) x 3 Electrode Site (three midline sites—Fz, Cz, and Pz) as within-subject factors. Pair-wise comparison was performed using the Bonferroni correction with a significance level of $p < 0.05$.

c) Polysomnography data scoring–

Sleep recordings were scored off-line according to standardized criteria (Rechtschaffen and Kales, 1968). Total sleep time (Total sleep time (TST), in min) and time spent in the different sleep stages (wake, sleep stage 1, 2, 3, 4; SWS; REM in minutes and in percentage of TST) was calculated. (See Figure 19)

2.5.6 Results

2.5.6.1 Behavioural:

2.5.6.1.1 Emotion regulation effectiveness across sleep and total sleep deprivation:

Four separate repeated measure ANOVA were performed for arousal and valance rating to check if the participant followed the instructions for both emotion regulation strategies.

a) Arousal rating:

I) Distraction: ANOVA with 2 Sleep condition (sleep, deprivation) x 2 Affect (view/ distraction) as within subject factor and Self- Assessment Manikin rating for arousal as dependent variable was performed. There was no significant differences [(F (1, 16) = 0.03, p > 0.05)] for Self-Assessment Manikin rating as a function of sleep condition. F value [F (1, 16) = 72.29, p < 0.05] which shows a significant main effect across emotion vs emotion regulation. The mean difference for sleep in emotion view is 5.1 ± 0.7 and in emotion regulation is 3.06 ± 1.19 similarly mean difference for sleep deprivation in emotion view is 5.2 ± 0.91 and in emotion regulation is 3.1 ± 0.9 (Figure 16 A). Thus, emotion regulation of negative affect arousal by distraction strategy was not significantly affected by manipulation of sleep. No significant interaction effects were found.

II) Cognitive reappraisal Strategy: ANOVA with 2 Sleep condition (sleep, deprivation) x 2 Affect (view/ reappraisal) as within subject factor and Self- Assessment Manikin rating for arousal as dependent variable was performed. There was no significant differences [(F (1, 16) = 0.60, p > 0.05)] for Self-Assessment Manikin rating as a function of sleep condition. F value [F (1, 16) = 62.62, p < 0.05] which shows a significant main effect across emotion vs emotion regulation. The mean difference for sleep in emotion view is 5.1 ± 0.7 and in emotion regulation is 2.97 ± 1.18 similarly mean difference for sleep deprivation in emotion view is 5.2 ± 0.9 and in emotion regulation is 3.23 ± 1.12 (Figure 16 B). Thus, emotion regulation of negative affect arousal by cognitive reappraisal strategy was not significantly affected by manipulation of sleep. No significant interaction effects were found.

b) Valance rating:

I) Distraction: ANOVA with 2 Sleep condition (sleep, deprivation) x 2 Affect (view/ distraction) as within subject factor and Self- Assessment Manikin rating for valance as dependent variable was performed. There was a significant difference [(F (1, 16) = 4.56, p <

0.05)] for Self-Assessment Manikin rating as a function of sleep condition. F value [F (1, 16) = 24.97, $p < 0.05$] which shows a significant main effect across emotion vs emotion regulation. The mean difference for sleep in emotion view is 2.17 ± 0.68 and in emotion regulation is 2.87 ± 0.88 similarly mean difference for sleep deprivation in emotion view is 2.3 ± .74 and in emotion regulation is 3.37 ± 0.62 (Figure 17A). Thus, emotion regulation of negative affect valance by distraction strategy was significantly affected by manipulation of sleep. No significant interaction effects were found.

II) Cognitive reappraisal Strategy: ANOVA with 2 Sleep condition (sleep, sleep deprivation) x 2 Affect (view/ reappraisal) as within subject factor and Self- Assessment Manikin rating for valance as dependent variable was performed. There were no significant differences [(F (1, 16) = 1.02, $p > 0.05$)] for Self-Assessment Manikin rating as a function of sleep condition. F value [F (1, 16) = 66.49, $p < 0.05$] which shows a significant main effect across emotion vs emotion regulation. The mean difference for sleep in emotion view is 2.17 ± 0.68 and in emotion regulation is 3.5± 0.74 similarly mean difference for sleep deprivation in emotion view is 2.3 ± .74 and in emotion regulation is 3.8 ± 0.63 (Figure 17 B). Thus, emotion regulation of negative affect valance by cognitive reappraisal strategy was not significantly affected by manipulation of sleep but mean value showed better regulation after full night of sleep in comparison of full night sleep deprivation. No significant interaction effects were found.

2.5.6.1.2 BART - Adjusted average number of pumps

Consistent with previous uses of the Balloon Analogue Risk Task (Lejuez et al., 2002) the average number of pumps on balloons that did not explode was used as the index of riskiness. This adjusted value is optimal compared to other variables such as the average number of pumps or number of explosions because the adjusted value includes only balloons in which the participant's behavior was not constrained by the explosion point of the balloon. For example, on a balloon set that explodes at a very low number of pumps, most participants, regardless of riskiness on the task, will pump that particular balloon until it explodes. Although this balloon is useful for establishing the low range of explosion points, it does not provide useful data for those who explode it because their behavior is necessarily constrained by the low number of pumps until explosion for that balloon.

Two separate repeated measure ANOVAs were performed to find out risk taking behaviour of participants. One for the cognitive reappraisal strategy of emotion regulation and other for distraction strategy of emotion regulation across sleep and sleep deprived conditions.

I) Distraction strategy: A 2 Sleep condition (sleep, sleep deprivation) x 2 Affect (emotion view and emotion regulation (distraction)) repeated measure ANOVA reveal the main significant effect of sleep condition (sleep = 46.79 ± 2.3 vs. sleep deprivation = 58.55 ± 2.25, F (1, 16) = 22.94; $p < 0.05$; $\eta^2 = 0.58$) and non-significant effect for affect (view = 50.13 ± 1.4 vs. distraction = 55.21 ± 3.2, F (1, 16) = 2.70; $p < 0.05$; $\eta^2 = 0.14$). But there was a significant interaction between sleep condition and affect (F (1, 16) =36.09, $p < 0.05$). A pair-wise comparison using the Bonferroni correction revealed a significant effect of emotion view in both sleep and sleep deprived condition but not in distraction strategy ($p < 0.05$) (see Figure 18).

Further analysis showed that , during the trials immediately following a negative feedback, subjects pumped the balloon more times in the sleep deprivation condition than in the full night sleep condition (sleep = 42.67 ± 2.4vs. sleep deprivation = 43.98 ± 1.8, f (1,16) = 0.007, $p > 0.05$). During affect analysis subjects pumped the balloon more times in the distraction strategy in comparison of no emotion regulation strategy (view = 42.04 ± 1.6 vs. distraction = 43.61 ± 1.19, f (1, 16) = 1.23, $p > 0.05$) following a negative feedback.

However, during the trials immediately following a positive feedback, the number of balloon pumps did not differ significantly between the sleep conditions (sleep = 43.81 ± 1.7 vs. sleep deprivation = 43.71 ± 2.0, f (1, 16) = 0.001, $p > 0.05$) and affect (view = 43.26 ± 1.6 vs distraction = 44.26 ± 1.27, f (1, 16) = 0.22, $p > 0.05$) (see Figure 20A).

These results showed that subjects tended to inflate the balloon fewer times in the full night sleep condition compared to the sleep deprivation, especially after negative feedback of balloon burst (loss). While comparing emotion regulation strategy, subjects tended to inflate the balloon more times in the distraction strategy compared to the emotion view.

II) Cognitive Reappraisal Strategy: To calculate risky choice behavior in cognitive reappraisal strategy, mean number of adjusted pumps on the Balloon Analogue Risk Task across the 2 Sleep condition (sleep and sleep deprivation) X 2 Affect (emotion view and emotion regulation (reappraisal)) were subjected to repeated measure ANOVA. Results indicated a significant value for sleep condition (sleep = 58.74 ± 1.7 vs. sleep deprivation = 64.38 ± 1.2, F (1, 16) = 6.00; $p < 0.05$; $\eta^2 = 0.27$) and affect (view = 50.13 ± 1.4 vs. reappraisal = 72.99 ± 1.8, F (1, 16) = 74.87; $p < 0.05$; $\eta^2 = 0.82$). Also there was a significant interaction between sleep condition and emotion (F (1, 16) =107.22, $p < 0.05$) (see Figure 18).

Further analysis showed that , during the trials immediately following a negative feedback, subjects pumped the balloon more times in the sleep deprivation condition than in the full night sleep condition (sleep = 43.45 ± 2.3 vs. sleep deprivation = 44.49 ± 1.7, f (1,16) = 0.15, $p > 0.05$). During affect analysis subjects pumped the balloon significantly more times in the reappraisal strategy in comparison of no emotion regulation strategy (view = 42.04 ± 1.6 vs. reappraisal = 45.90 ± 1.7, f (1, 16) = 7.01, $p < 0.05$) following a negative feedback.

However, during the trials immediately following a positive feedback, the number of balloon pumps did not differ significantly between the sleep conditions (sleep = 42.81 ± 1.7 vs. sleep deprivation = 44.71 ± 2.0, $f(1, 16) = 0.83$, $p > 0.05$) and affect (view = 43.26 ± 1.6 vs reappraisal = 44.82 ± 1.3, $f(1, 16) = 0.55$, $p > 0.05$) (see Figure 20B).

These results showed that subjects tended to inflate the balloon fewer times in the full night sleep condition compared to the sleep deprivation, especially after negative feedback of balloon burst (loss). While comparing emotion regulation strategy, subjects tended to inflate the balloon significantly more in the reappraisal strategy compared to the emotion view.

2.5.6.2 Electrophysiological- Feedback-related negativity and Feedback-related P300

Two major ERP components have been described that are particularly sensitive to feedback: the feedback related negativity [FRN, also known as the medial–frontal negativity (MFN)], and the feedback-related P300. The FRN is a negative deflection at fronto-central recording sites that reaches its maximum between 200 and 300 ms post-onset of feedback stimulus. The feedback-related P300 amplitude, reflect a later, attention-sensitive, more elaborated appraisal of outcome evaluation, in which factors that affect the allocation of attentional resources come into play in a top down controlled manner (Sato et al., 2005; Goyer et al., 2008; Christie and Tata, 2009; Wu and Zhou, 2009; Leng and Zhou, 2010; Zhou et al., 2010). P300 is the most positive peak in the 300–600 ms post-onset of feedback and has been shown to be sensitive to various aspects of outcome, including the magnitude and the valence of reward (Wu and Zhou, 2009). Here in this thesis, positive feedback indicating the gain and negative feedback indicating a loss in Balloon Analogue Risk task.

2.5.6.2.1 Feedback- related negativity (FRN)

Mean FRN amplitude for positive feedback (balloon that did not explode was encoded as a "positive feedback" trial) and negative feedback (balloon that exploded was encoded as a "negative feedback" trial) for the three electrode sites (Fz, Cz, and Pz) across the condition (sleep / sleep deprivation) are presented in Table 5. The grand average for the two type of feedback at central electrode site across condition and emotion regulation strategies are depicted in Figure 21 and the topographical distribution of the current source density (CSD) of the FRN for each sleep condition (sleep/sleep deprivation) and affect (emotion/regulation) is displayed in Figure 23.

Statistical Analysis

I) Cognitive Reappraisal Strategy: A 2 Sleep condition (sleep, deprivation) x 2 Affect (emotion, regulation (reappraisal)) x 2 Feedback (Positive, negative) x 3 Electrode site (Fz, Cz, Pz) repeated measures ANOVA conducted on peak FRN amplitude and latency. Results ($F(1, 16) = 11.8$, $p < 0.05$) revealed a significant main effect of sleep condition (sleep, sleep deprivation). Post par-wise comparison revealed that the FRN was larger for sleep condition indicating subjects are more loss sensitive (sleep = -5.39 ± 0.50, sleep deprivation= -3.78 ± 0.57) as compared to sleep deprivation condition. A significant main effect of feedback valance [($F(1, 16) = 118.8$, $p < 0.05$)] was also reported. Mean wise comparison revealed that the FRN was larger for negative feedback (-10.32 ± 0.87) as compared to positive feedback indicating gain (1.14 ± 0.51). There was no significant main effect of electrode site [($F(1, 16) = 0.88$, $p > 0.05$)] and affect (view, regulation) [($F(1, 16) = .09$, $p > 0.05$)]. There is a significant effect found of interaction of feedback and electrodes position [($F(1, 16) = 9.8$, $p < 0.05$)]. Post hoc test revealed that the FRN was larger at frontal site for loss (-11.72 ± 1.2) compared to parietal site for loss (-9.0 ± 0.67).

For the latency we found the significant main effect of feedback valance [(F (1, 16) = 20.85, p < 0.05)]. There was no significant main effect of sleep condition [(F (1, 16) = 0.011, p > 0.05)]; electrode site [(F (1, 16) = 1.83, p > 0.05)]; and affect [(F (1, 16) = 0.38, p > 0.05)] nor the interaction effects was found significant.

II) Distraction strategy: A 2 Sleep condition (sleep, deprivation) x 2 Affect (emotion, regulation (distraction)) x 2 Feedback (Positive, negative) x 3 Electrode site (Fz, Cz, Pz) repeated measures ANOVA was run on peak FRN amplitude and latency. A significant main effect of feedback valance [(F (1, 16) = 171.63, p < 0.05)] was reported which was backed by individual t-test that revealed the FRN was larger for negative feedback (Mean amplitude = -10.39 ± 0.72) as compared to positive feedback indicating gain (Mean amplitude = 1.6 ± 0.52).There was no significant main effect of sleep condition [(F (1, 16) = 2.36, p > 0.05)]; electrode site [(F (1, 16) = 2.18, p > 0.05)] and affect (view, regulation) [(F (1, 16) = 0.14, p > 0.05)]. There is a significant effect found of interaction of feedback and electrodes position [(F (1, 16) = 15.25, p < 0.05)]. Post hoc test revealed that the FRN was larger at central site for loss (-11.94 ± 1.08) compared to parietal site for loss (-9.2 ± 0.69).

For the latency we found the significant main effect of feedback valance [(F (1, 16) = 19.79, p < 0.05)].There was no significant main effect of sleep condition [(F (1, 16) = 0.41, p > 0.05)]; electrode site [(F (1, 16) = 1.38, p > 0.05)]; and affect [(F (1, 16) = 1.81, p > 0.05)] nor the interaction effects was found significant.

2.5.6.2.2 Feedback-related P300

Mean P300 amplitude for positive and negative feedback for the three electrode sites (Fz, Cz, and Pz) across the group (sleep/sleep deprivation) and condition (view/regulation) are presented in Table 6. The grand average for the two type of feedback at each electrode site are depicted in Figure 22 and the topographical distribution of the current source density

(CSD) of the P300 amplitude for each sleep condition (sleep/sleep deprivation) and affect (emotion/regulation) is displayed in Figure 24.

Statistical Analysis

I) Cognitive Reappraisal Strategy: A 2 Sleep condition (sleep/deprivation) x 2 Affect (emotion/emotion regulation (reappraisal)) x 2 Feedback (positive, negative) x3 Electrode site (Fz, Cz, Pz) repeated measures ANOVA conducted on peak P300 amplitude and latency. A significant main effect of feedback valance [(F (1, 16) = 119.28, $p < 0.05$)]. Pair wise comparison showed that P300 amplitude was larger in response to negative feedback (39.62 ± 1.5) than to positive feedback (21.27 ± 1.6).Furthermore, P300 amplitude was largest at Fz (35.30 ± 1.8) followed by the amplitude at Cz and Pz (31.85 ± 1.4; 24.19 ± 1.4 respectively). The main effect of sleep condition (sleep/deprivation) [(F (1, 16) = 1.51, p= 0.23)]; and electrode site [(F (1, 16) = 43.16, $p < 0.05$)] and affect (view/regulation) [(F (1, 16) = 0.29, $p > 0.05$)] was not statistically significant. There is a significant effect found of interaction of feedback and electrodes position [(F (2, 32) = 17.25, $p < 0.05$)]. Post hoc test revealed that the P300 was larger at frontal site for loss (44.19 ± 2.1) compared to parietal site for loss (31.16 ± 1.6). Another interaction found significant for sleep condition x electrode [(F (2, 32) = 3.74, $p < 0.05$)].post hoc test revealed that P300 was larger at frontal site for sleep deprivation (35.5 ± 2.2) compared to frontal site for sleep (35.08 ± 2.1).

For the latency we found the significant main effect of feedback valance [[(F (1, 16) = 63.92, $p < 0.05$].There was no significant main effect of sleep condition [[(F (1, 16) = 0.39, $p > 0.05$]; electrode site [[(F (1, 16) = 0.20, $p > 0.05$]; and affect [[(F (1, 16) = 0.37, $p > 0.05$] nor the interaction effects was found significant.

II) Distraction strategy: A 2 Sleep condition (sleep/deprivation) x 2 Affect (emotion/emotion regulation (distraction)) x 2 Feedback (positive, negative) x 3 Electrode site (Fz, Cz, Pz) repeated measures ANOVA conducted on peak P300 amplitude and latency. A significant main effect of feedback valance [($F (1, 16) = 77.29$, $p < 0.05$)]. Pair wise comparison showed that P300 amplitude was larger in response to negative feedback than to positive feedback ($p < 0.05$). Furthermore, the main effect of electrode site [($F (1, 16) = 39.69$, $p < 0.05$)] was also significant. P300 amplitude was largest at Fz (36.11 ± 2.4) followed by the amplitude at Cz and Pz (32.73 ± 2.0; 25.36 ± 1.5 respectively). The main effect of sleep condition (sleep/deprivation) [($F (1, 16) = 0.08$, $p= 0.77$)]; and affect (view/regulation) [($F (1, 16) = 1.94$, $p > 0.05$)] was not statistically significant. Importantly, we found a significant interaction effect of sleep condition and electrode [($F (2, 32) = 5.9$, $p < 0.05$)]. Further pair wise comparison revealed that P300 amp at Fz (37.22 ± 2.3) was largest for sleep deprived condition as compared to sleep condition. There is a significant interaction effect of feedback and electrodes position [($F (2, 32) = 18.62$, $p < 0.05$)]. Post hoc test revealed that the P300 was larger at frontal site for loss (43.57 ± 2.9) compared to parietal site for loss (31.58 ± 1.9).

For the latency we found the significant main effect of feedback valance [($F (1, 16) = 49.84$, $p < 0.05$)]. There was no significant main effect of sleep condition [($F (1, 16) = 0.33$, $p > 0.05$)]; electrode site [($F (1, 16) = 0.4$, $p > 0.05$)]; and affect [($F (1, 16) = 3.5$, $p > 0.05$)] nor the interaction effects was found significant.

2.5.7 Conclusion

On the basis of behavioral results, we can conclude that subjects tended to inflate the balloon fewer times in the full night sleep condition, especially after negative feedback in comparison to full night sleep deprivation. Which indicates that sleep and sleep deprivation have a differential effect on risk taking behaviour. While talking about emotion regulation strategies, subjects led to less risk aversive behavior where they followed emotion regulation strategy in comparison to no emotion regulation strategy condition. Within emotion regulation strategies, cognitive reappraisal strategy has been significantly altering subjective experience and also have a carryover effect on risky decision making. ERP findings are also in support of behavioral data. FRN and P300 amplitude found to increase in loss trials compare to gain trials in both sleep and sleep deprived condition but larger amplitude in sleep condition in comparison to sleep deprivation condition. Larger FRN amplitude in sleep condition showed that subjects after a full night of sleep were more sensitive to loss, which lead to less risk aversion after using emotion regulation strategy.

2.6 Experiment 3 – Assess the Role of First or Second Half Sleep Deprivation in Affect Regulated Risky Decision Making.

The present experiment is a part of our previous experiment two, here we will study the role of specific stage of sleep (REM and NREM) in affect regulated risky decision making. To study this participants of experiment 2 further divided into two groups: second half sleep deprivation (where participants sleep till 0200h and awake from 0200h to 0700h) and first half sleep deprivation (where participants awake from 2200 to 0200 h and sleep from 0200h to 0700h). According to previous literature on sleep, it has been suggested that first half of the night sleep mainly comprises NREM (non-rapid eye movement sleep) and the second half of sleep REM (rapid eye movements).

A growing line of research in sleep and cognition showed that sleep plays a crucial role in the processing of emotions. Moreover, REM sleep in particular has been implicated in the consolidation of negative emotional episodic experiences (Wagner et al. 2001, 2006; Nishida et al. 2009), whereas manipulations of REM have been shown to alter the evaluation of affective stimuli, particularly those of negative valence (Wagner et al., 2007; Lara-Carrasco et al., 2009). Theory suggests that REM may offer an ideal neurobiological medium by reduction in aminergic neurochemistry and reactivated limbic anatomy (Hobson and Pace-Schott, 2002) which depotentiate prior negative experiences, restoring optimal post sleep affective reactivity (Levin and Nielsen, 2009; Walker, 2009a, 2009b; Walker and van der Helm, 2009).Thus two events take place in REM that are crucial to daytime emotional regulation: 1) reactivity of the amygdala is down-regulated due to suppression of central noradrengic tone and 2) emotional memories are re-activated in amygdalar-hippocampal networks during REM. On the basis of above discussion on the role played by REM in emotion regulation , this thesis targets to find out specific role of sleep stages (REM and NREM) play in affect regulated decision making.

2.6.1 Objectives:

The present experiment has two fold objectives:

a) To examine the role of first or second half of sleep deprivation in affect regulated risky decision making.

b) To study the electrophysiological marker of affect regulated decision making across first or second half of sleep deprivation.

2.6.2 Hypothesis:

a) Deprivation of the first or second half of sleep will significantly affect risky decision-making across affect and affect regulation conditions.

b) REM deprivation will have differential electrophysiological signatures as compared with REM sleep induced individuals across affect and affect regulation conditions.

2.6.3 Variables:

Independent variables- Sleep (second half sleep deprivation/ first half sleep deprivation), Emotion (view/regulation)

Dependent variables-

a) Risk Taking Behaviour measured in terms of mean adjusted pumps: the average number of pumps on balloons where money was collected before an explosion.

b) ERP marker of Risk Taking Behaviour: Feedback related negativity (FRN) and P300.

2.6.4 Design:

The study follows a crossover between subject designs with two sleep group: Second half sleep deprivation (where participants sleep till 0200h and awake from 0200h to 0700h) and first half sleep deprivation (where participants awake from 2200 to 0200 h and sleep from

0200h to 0700h). The interval between the sessions was kept at least seven days and the order of the two was at random. After first or second half of sleep deprivation hours subjects completed the emotion behavioural and BART task. EEG was recorded while performing both the tasks.

2.6.5 Methodology

There are total 14 participants in Experiment 3 and each of the two groups has seven participants. EEG signals and polysomnography were acquired and analysed with the same protocol as described in experiment 2 section in detail.

2.6.5.1 Procedure

The recruitment and inclusion testing of the participants were similar to the once followed in the previous experiments. Subjects were randomly assigned to first or second half of sleep deprivation groups. All subject underwent a compulsory adaptation and baseline night, during which were acquainted to the sleep laboratory settings and calibration of their sleep architecture was done. Before all nights the subjects were called in the morning to the laboratory at 09:00 hrs and given the actiwatch (for monitoring their daytime activity) which the subjects were required to wear all throughout the day and return back to the experimenter while the arrive for the commencement of the night sessions. On adaptation night the subjects slept for eight hours without sleep recordings in the laboratory, while during the baseline night standard polysomnography was recorded for the entire night. The subject left the laboratory in the morning after a light breakfast. On the experimental nights' subjects were first made to practise the regulation strategy execution using standard instructions. Once they mastered the skill, second half sleep deprivation group underwent sensor placement at 10:00h followed by uninterrupted sleep with polysomnographic recordings till 02:00h and then awake till morning 07:00h. The first half deprivation sleep groups remained awake with the experimenter till 1:00h and then underwent sensor placement at 01:00h followed by uninterrupted sleep with polysomnographic recordings till morning 07:00h. The following morning both groups were allowed to leave the sleep laboratory with the ActiWatch and were asked to return to the laboratory for retrieval after three hours. On return, subjects were made to wear the EasyCap (which recorded their ERP's using ActiChamp) and perform on the emotion regulation task followed by Balloon Analogue Risk taking Task. One completed the subjects were thanked and allowed to leave the laboratory. [See Figure 7 & 8]

2.6.6 Results

2.6.6.1 Behavioural:

2.6.6.1.1 Emotion regulation effectiveness across first or second half of sleep deprivation:

Four separate repeated measure ANOVA were performed to check if the participant followed the instructions for emotion regulation we measured the subjective rating for valance and arousal both emotion regulation strategy.

a) Arousal rating:

I) Distraction: ANOVA with 2 Sleep condition (second half of sleep deprivation/ first half of sleep deprivation) as between subject factor x 2 Affect (view/ distraction) as within subject factor and Self-Assessment Manikin rating for arousal as dependent variable was performed. There was no significant differences [(F (1, 12) = 0.11, $p > 0.05$)] for Self-Assessment Manikin rating as a function of sleep condition. F value [F (1, 12) = 11.90, $p < 0.05$] which shows a significant main effect across emotion vs emotion regulation. The mean difference for first-half in emotion view is 4.82 ± 0.92 and in emotion regulation is 3.4 ± 0.69 similarly mean difference for second-half in emotion view is 4.8 ± .70 and in emotion regulation is 3.2

± 1.4 (See Figure 25B). Thus, emotion regulation of negative affect arousal by distraction strategy was not significantly affected by manipulation of sleep. No significant interaction effects were found.

II) Cognitive reappraisal Strategy: ANOVA with 2 Sleep condition (second half of sleep deprivation, first half of sleep deprivation) as between subject factor x 2 Affect (view/ reappraisal) as within subject factor and Self-Assessment Manikin rating for arousal as dependent variable was performed. There was no significant differences [(F (1, 12) = 0.01, $p > 0.05$)] for Self-Assessment Manikin rating as a function of sleep condition. F value [F (1, 12) = 25.27, $p < 0.05$] which shows a significant main effect across emotion vs emotion regulation. The mean difference for first-half in emotion view is 4.82 ± 0.92 and in emotion regulation is 3.02 ± 1.15 similarly mean difference for second-half in emotion view is 4.8 ± .70 and in emotion regulation is 3.1 ± 1.06 (See Figure 25A). Thus, emotion regulation of negative affect arousal by cognitive reappraisal strategy was not significantly affected by manipulation of sleep. No significant interaction effects were found.

b) Valance rating:

I) Distraction: ANOVA with 2 Sleep condition (second half of sleep deprivation/ first half of sleep deprivation) as between subject factor x 2 Affect (view/ distraction) as within subject factor and Self-Assessment Manikin rating for valance as dependent variable was performed. There was a significant difference [(F (1, 12) = 12.39, $p < 0.05$)] for Self-Assessment Manikin rating as a function of sleep condition. F value [F (1, 12) = 4.51, $p < 0.05$] which shows a significant main effect across emotion vs emotion regulation. The mean difference for second half sleep deprivation in emotion view is 2.35 ± 0.48 and in emotion regulation is 3.37 ± 0.58 similarly mean difference for first-half sleep deprivation in emotion view is 4.8 ±

.70 and in emotion regulation is 2.95 ± 0.85 (See Figure 26B). Thus, emotion regulation of negative affect valance by distraction strategy was significantly affected by manipulation of sleep. No significant interaction effects were found.

II) Cognitive reappraisal Strategy: ANOVA with 2 Sleep condition (second half of sleep deprivation/ first half of sleep deprivation) as between subject factor x 2 Affect (view/ reappraisal) as within subject factor and Self-Assessment Manikin rating for valance as dependent variable was performed. There was a significant difference [(F (1, 12) = 13.74, p < 0.05)] for Self-Assessment Manikin rating as a function of sleep condition. F value [F (1, 12) = 5.27, p < 0.05] which shows a significant main effect across emotion vs emotion regulation. The mean difference for second-half sleep deprivation in emotion view is 2.35 ± 0.48 and in emotion regulation is 4.01± 0.83 similarly mean difference for first-half sleep deprivation in emotion view is 4.8 ± .70 and in emotion regulation is 2.9 ± 0.57 (See Figure 26A). Thus, emotion regulation of negative affect valance by cognitive reappraisal strategy was significantly affected by manipulation of sleep. No significant interaction effects were found.

2.6.6.1.2 BART- Adjusted average number of pumps

Two separate repeated measure ANOVAs were performed to find out risk taking behaviour of participants. One for the cognitive reappraisal strategy of emotion regulation and other for distraction strategy of emotion regulation across sleep and sleep deprived conditions.

I) Distraction strategy: To calculate risky choice behavior in distraction strategy, mean number of adjusted pumps on the Balloon Analogue Risk task across the 2 Sleep condition (second half of sleep deprivation/ first half of sleep deprivation) X 2 Affect (emotion view and emotion regulation (distraction))] were subjected to ANOVA. Results indicated a non-significant value for sleep condition (second half sleep deprivation = 50.35 ± 5.24 vs. first half sleep deprivation = 46.80 ± 5.24, F (1, 12) = 0.23; p > 0.05, $\eta^2 = 0.36$) and affect (view = 48.61 ± 3.6 vs. distraction = 48.54 ± 4.0, F (1, 12) = 0.001; p > 0.05, $\eta^2 = 0.27$) (See Figure 27). There was a no significant interaction between sleep condition and affect.

Further analysis showed that , during the trials immediately following a negative feedback, subjects pumped the balloon more times in the second half sleep deprivation condition than in the first half sleep deprivation condition (second half sleep deprivation = 46.67 ± 3.4vs. first half sleep deprivation = 43.44 ± 3.4, f (1, 16) = 0.05, p> 0.05,). During affect analysis subjects pumped the balloon fewer times in the distraction strategy in comparison of no emotion regulation strategy (view = 47.03 ± 3.1 vs. distraction = 44.93 ± 2.4, f (1, 16) = 0.51, p> 0.05) following a negative feedback.

However, during the trials immediately following a positive feedback, the number of balloon pumps did not differ significantly between the sleep conditions (second half sleep deprivation = 45.28 ± 3.47 vs. first half sleep deprivation = 44.72 ± 3.4, f (1, 16) = 0.52, p> 0.05) and affect (view = 41.77 ± 1.6 vs distract = 43.23 ± 3.9, f (1, 16) = 1.03, p > 0.05) (See Figure 29A).

II) Cognitive Reappraisal Strategy: A 2 Sleep condition (second half of sleep deprivation/ first half of sleep deprivation) x 2 Affect (emotion view and emotion regulation (cognitive reappraisal))] ANOVA reveal the non-significant effect of condition (second half sleep deprivation = 50.35 ± 5.3 vs. first half sleep deprivation = 46.29 ± 5.3, F (1, 12) = 0.28; p > 0.05, $\eta^2 = 0.23$) and non-significant effect for affect (view = 48.61 ± 3.6 vs. reappraisal = 48.03 ± 4.3, F (1, 12) = 0.04; p > 0.05, $\eta^2 = 0.14$) (See Figure 27). No interaction effect was found significant.

Further analysis showed that , during the trials immediately following a negative feedback, subjects pumped the balloon more times in the second half sleep deprivation condition than in the first half sleep deprivation condition (second half sleep deprivation = 47.49 ± 3.6 vs. first half sleep deprivation = 45.52 ± 3.6, f (1,16) = 0.14, p> 0.05). During affect analysis subjects pumped the balloon fewer times in the reappraisal strategy in comparison of no emotion regulation strategy (view = 47.03 ± 3.1 vs. reappraisal = 45.99 ± 2.61, f (1, 16) = 0.14, p> 0.05) following a negative feedback.

However, during the trials immediately following a positive feedback, the number of balloon pumps did not differ significantly between the sleep conditions (second half sleep deprivation = 41.96 ± 2.60 vs. first half sleep deprivation = 41.94 ± 2.6, f (1, 16) = 0.001, p> 0.05) and affect (view = 41.77 ± 1.6 vs reappraisal = 42.13 ± 2.6, f (1, 16) = 0.02, p> 0.05) (See Figure 29B).

2.6.6.2 Electrophysiological - Feedback-related negativity and Feedback-related P300

Two major ERP components have been described that are particularly sensitive to feedback: the feedback related negativity [FRN, also known as the medial–frontal negativity (MFN)], and the feedback-related P300. The FRN is a negative deflection at fronto-central recording sites that reaches its maximum between 200 and 300ms post-onset of feedback stimulus. The feedback-related P300 amplitude, seems to reflect a later, attention-sensitive, more elaborated appraisal of outcome evaluation, in which factors that affect the allocation of attentional resources come into play in a top down controlled manner (Sato et al., 2005; Goyer et al., 2008; Christie and Tata, 2009; Wu and Zhou, 2009; Leng and Zhou, 2010; Zhou et al., 2010). P300 is the most positive peak in the 300–600 ms post-onset of feedback and has been shown to be sensitive to various aspects of outcome, including the magnitude and the valence of reward (Wu and Zhou, 2009). Here in this thesis, positive feedback indicating the gain and negative feedback indicating a loss in BART task.

2.6.6.2.1 Feedback- related negativity (FRN)

Mean FRN amplitude for positive feedback (balloon that did not explode was encoded as a "positive feedback" trial) and negative feedback (balloon that exploded was encoded as a "negative feedback" trial) for the three electrode sites (Fz, Cz, and Pz) across the condition (second half sleep deprivation/ first half sleep deprivation) are presented in Table 12. The grand average for the two type of feedback at each electrode site is depicted in Figure 30 and the topographical distribution of the current source density (CSD) of the FRN for each group (second half sleep deprivation/first half sleep deprivation) and affect (emotion/regulation) is displayed in Figure 32.

Statistical Analysis

I) Cognitive Reappraisal Strategy: ANOVA with 2 Sleep condition (second half of sleep deprivation/ first half of sleep deprivation) x 2 Affect (emotion/emotion regulation (reappraisal)) x 2 Feedback (positive, negative) x 3 Electrode site (Fz, Cz, Pz) as within subject factor and sleep condition as between subject factor, conducted on peak FRN amplitude and latency. F value [(F (1, 12) = 42.64, $p < 0.05$)] revealed a significant main effect of feedback valance (gain/loss). Mean wise comparison revealed that the FRN was larger for negative feedback (-8.9 ± 1.1) as compared to positive feedback indicating gain (1.5 ± 0.90). A significant main effect of affect (view/regulation) [(F (1, 12) = 9.54, $p < 0.05$)]. Post hoc test revealed that the FRN was larger for emotion view indicating more loss (-4.7 ± 0.62) as compared to emotion regulation (-2.5 ± 0.84).There was no significant main effect of electrode site [(F (2, 24) = 22.5, p= 0.25)] and sleep condition (second half sleep deprivation/first half sleep deprivation) [(F (1, 12) = 0.02, $p > 0.05$)]. There is a significant interaction effect of feedback and electrodes position [(F (2, 24) = 4.49, $p < 0.05$)]. Post hoc test revealed that the FRN was larger at central site for loss (-10.85 ± 1.5) compared to parietal site for loss (-8.04 ± 0.95).

For the latency we found the significant main effect of affect (view/regulation) [(F (1, 12) = 5.56, p < 0.05)]. Mean value showed that the FRN latency was greater for emotion regulation condition (214.85 ± 5.0) compared to emotion view condition (200.33 ± 7.4). There was no significant main effect of sleep condition [(F (1, 12) = 0.14, p= 0.7)]; electrode site [(F (2, 24) = 0.50, p > 0.05)]; and feedback valance [(F (1, 12) = 3.69, p > 0.05)] nor the interaction effects was found significant.

II) Distraction strategy: ANOVA with 2 Sleep condition (second half of sleep deprivation/ first half of sleep deprivation) x 2 Affect (emotion/emotion regulation (distraction)) x 2 Feedback (positive, negative) x 3 Electrode site (Fz, Cz, Pz) as within subject factor and sleep condition as between subject factor, conducted on peak FRN amplitude and latency. F value [(F (1, 12) = 51.99, p < 0.05)] revealed a significant main effect of feedback valance (gain/loss). Mean wise comparison revealed that the FRN was larger for negative feedback (-9.2 ± 1.1) as compared to positive feedback indicating gain (2.4 ± 0.87). A significant main effect of emotion (view/regulation) [(F (1, 12) = 14.22, p < 0.05)]. Post hoc test revealed that the FRN was larger for emotion view indicating loss (-4.7 ± 0.6) as compared to emotion regulation (-2.0 ± 0.86).There was no significant main effect of electrode site [(F (2, 24) = 2.9, p > 0.05)] and sleep condition (second half sleep deprivation/first half sleep deprivation) [(F (1, 12) = 0.006, p > 0.05)]. There is a significant effect found of interaction of feedback and electrodes position [(F (2, 24) = 6.52, p < 0.05)]. Post hoc test revealed that the FRN was larger at central site for loss (-11.31 ± 1.6) compared to parietal site for loss (-8.2 ± 0.9). Another interaction found significant for electrode x affect [(F (2, 24) = 6.81, p < 0.05)].post hoc test revealed that FRN was larger at central site for emotion view condition (-5.5 ± 0.7) compared to emotion regulation at central site (-2.9 ± 0.94).

For the latency we found the significant main effect of feedback valance [(F (1, 12) = 6.13, p < 0.05)]. Mean value showed that the FRN latency was greater for negative feedback condition (210.59 ± 4.1) compared to positive feedback condition (201.33 ± 4.9) .There was no significant main effect of sleep condition [(F (1, 12) = 0.006, p > 0.05)]; electrode site [(F (2, 24) = 0.06, p > 0.05)]; and affect [(F (1, 12) = 2.30, p > 0.05)] nor the interaction effects was found significant.

2.6.6.2.2 Feedback-related P300

Mean P300 amplitude for positive and negative feedback for the three electrode sites (Fz, Cz, and Pz) across the group (second half of sleep deprivation/ first half of sleep deprivation) and condition (view/regulation) are presented in Table 13. The grand average for the two type of feedback at each electrode site is depicted in Figure 31 and the topographical distribution of the current source density (CSD) of the P300 amplitude for each sleep condition (second half sleep deprivation/first half sleep deprivation) and affect (emotion/regulation) is displayed in Figure 33.

Statistical Analysis

I) Cognitive Reappraisal Strategy: ANOVA with 2 Sleep condition (second half of sleep deprivation/ first half of sleep deprivation) x 2 Affect (emotion/emotion regulation (reappraisal)) x 2 Feedback (positive, negative) x 3 Electrode site (Fz, Cz, Pz) as within subject factor and sleep condition as between subject factor, conducted on peak P300 amplitude and latency. F value [(F (1, 12) = 36.71, p < 0.05)] revealed a significant main effect of feedback valance (gain/loss). Pair wise comparison showed that P300 amplitude was larger in response to negative feedback (41.92 ± 3.6) than to positive feedback (16.25 ± 3.5). A significant main effect of electrode site [(F (2, 24) = 20.03, p < 0.05)]. Furthermore, P300 amplitude was largest at Fz (33.06 ± 3.6) followed by the amplitude at Cz and Pz (30.57 ± 2.8; 23.63 ± 2.4 respectively). There was no significant main effect of affect (view/regulation) [($F(1, 12) = 0.37$, $p > 0.05$)] and sleep condition (second half of sleep deprivation/ first half of sleep deprivation) [($F(1, 12) = 0.31$, $p > 0.05$)]. There is a significant effect found of interaction of feedback and electrodes position [($F(2, 24) = 6.24$, $p < 0.05$)].

For the latency we found the significant main effect of feedback valance [($F(1, 12) = 35.71$, $p < 0.05$)]. Mean value showed that the P300 latency was larger for negative feedback (363.88 ± 3.37) compare to positive feedback (341.47 ± 4.07). There was no significant main effect of sleep condition [($F(1, 12) = 0.03$, $p > 0.05$)]; electrode site [($F(2, 24) = 0.15$, $p > 0.05$)]; and affect [($F(1, 12) = 0.07$, $p > 0.05$)] nor the interaction effects was found significant.

II) Distraction strategy: ANOVA with 2 Sleep condition (second half of sleep deprivation/ first half of sleep deprivation) x 2 Affect (emotion/emotion regulation (distraction)) x 2 Feedback (positive, negative) x 3 Electrode site (Fz, Cz, Pz) as within subject factor and sleep condition as between subject factor, conducted on peak P300 amplitude and latency. F value [($F(1, 12) = 14.31$, $p < 0.05$)] revealed a significant main effect of feedback valance (gain/loss). Pair wise comparison showed that P300 amplitude was larger in response to negative feedback (42.66 ± 4.06) than to positive feedback (19.56 ± 4.05). A significant main effect of electrode site [($F(2, 24) = 34.98$, $p < 0.05$)]. Furthermore, P300 amplitude was largest at Fz (36.46 ± 3.4) followed by the amplitude at Cz and Pz (32.17 ± 2.5; 24.69 ± 2.27 respectively). There was no significant main effect of affect (view/regulation) [($F(1, 12) = 0.28$, $p > 0.05$)] and condition (second half of sleep deprivation/ first half of sleep deprivation) [($F(1, 12) = 0.29$, $p > 0.05$)]. There is a significant effect found of interaction of feedback and electrodes position [($F(2, 24) = 6.31$, $p < 0.05$)]. Post hoc test revealed that the

FRN was larger at frontal site for loss (48.28 ± 4.9) compared to parietal site for loss (33.36 ± 3.4).

For the latency we found the significant main effect of feedback valance [(F (1, 12) = 37.50, p < 0.05)]. Mean value showed that the P300 latency was larger for negative feedback (366.83 ± 2.7) compare to positive feedback (338.47 ± 4.3) .There was no significant main effect of sleep condition [(F (1, 12) = 0.02, p > 0.05)]; electrode site [(F (2, 24) = 0.04, p > 0.05)]; and affect [(F (1, 12) = 1.22, p > 0.05)] nor the interaction effects was found significant.

2.6.7 Conclusion

Results indicated better emotion regulation of negative valance in both regulation strategies (distraction and cognitive reappraisal) but for negative arousal only in cognitive reappraisal strategy. The results of the study suggest that there is no significant difference between risk taking behavior across second half and first half sleep deprived condition, but first half sleep deprived condition does lead to less risk aversive behavior which also confirmed by effective regulation of emotions in first half sleep deprivation sleep condition compared to second half sleep deprivation group. Further, FRN and P300 amplitude were larger in response to negative feedback than to positive feedback. With respect to the sleep effect on feedback processing components, the result revealed no differences in any emotion regulation strategy across the sleep condition.

Experimental Design Tables and Figures

Experiment 1: Effectiveness of Emotion Regulation in Terms of Stimuli Type and Affect

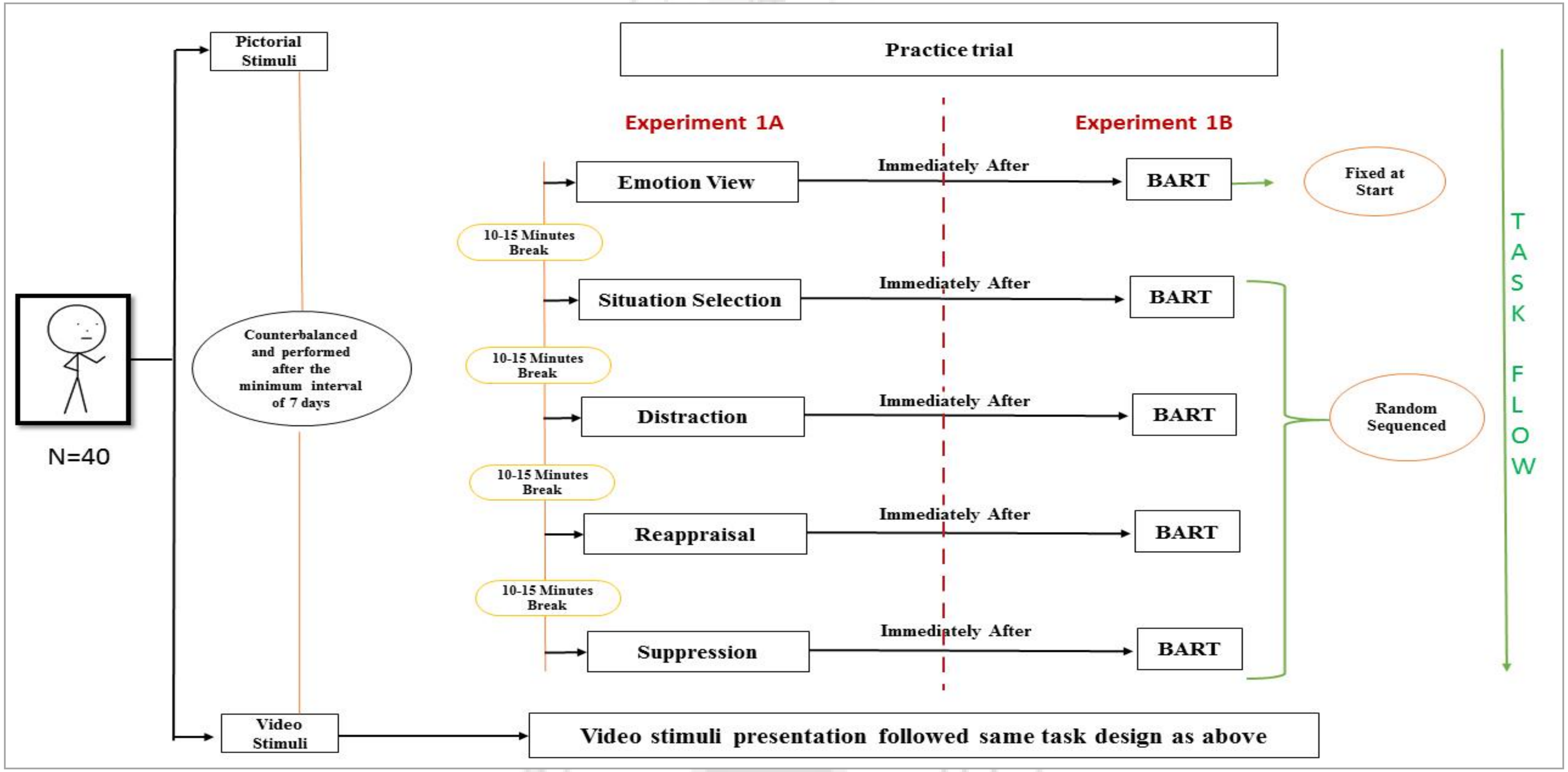


Figure 4 | Represents procedural design where participants' were performed for both stimuli type (pictorial, video). In both, the stimuli type participants asked to follow emotion regulation instructions for each of emotion regulation strategy and immediately after the ER task all the participants' performed BART task to assess risk-taking scores. Total duration for the ER task was around half an hour and for BART is 20 minutes.

Experiment 2: Effect of Emotion regulation on risky decision making across sleep and sleep deprivation.

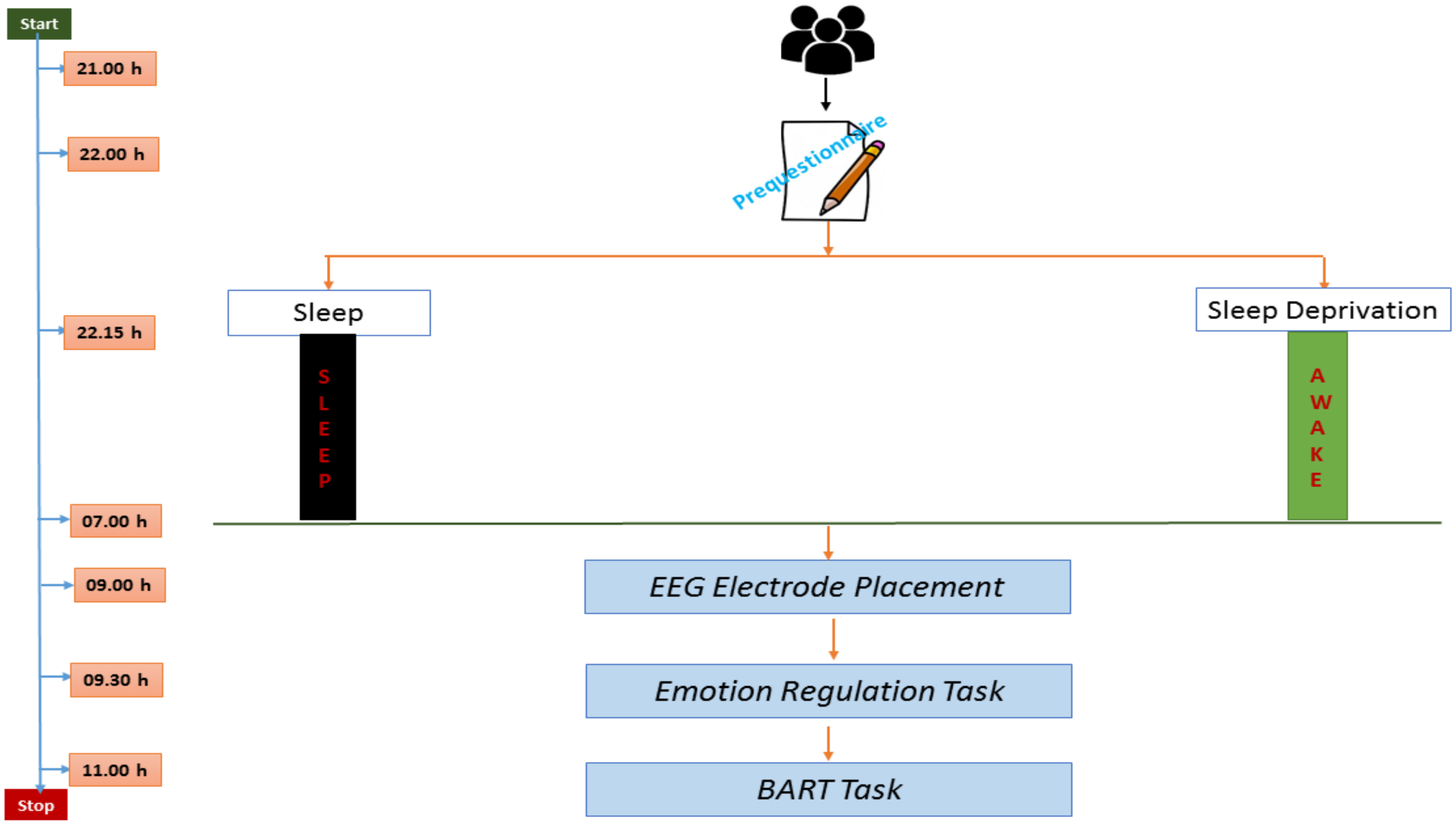


Figure 5 | Procedural design used in experiment 2. Depicts the flow of procedures followed by each participant on an experimental night. Each participant finished preliminary testing and Emotion regulation task practice trial before starting sleep/ sleep deprivation. ER task and BART task followed the next morning.

Experiment 2: Effect of Emotion regulation on risky decision making across sleep and sleep deprivation.

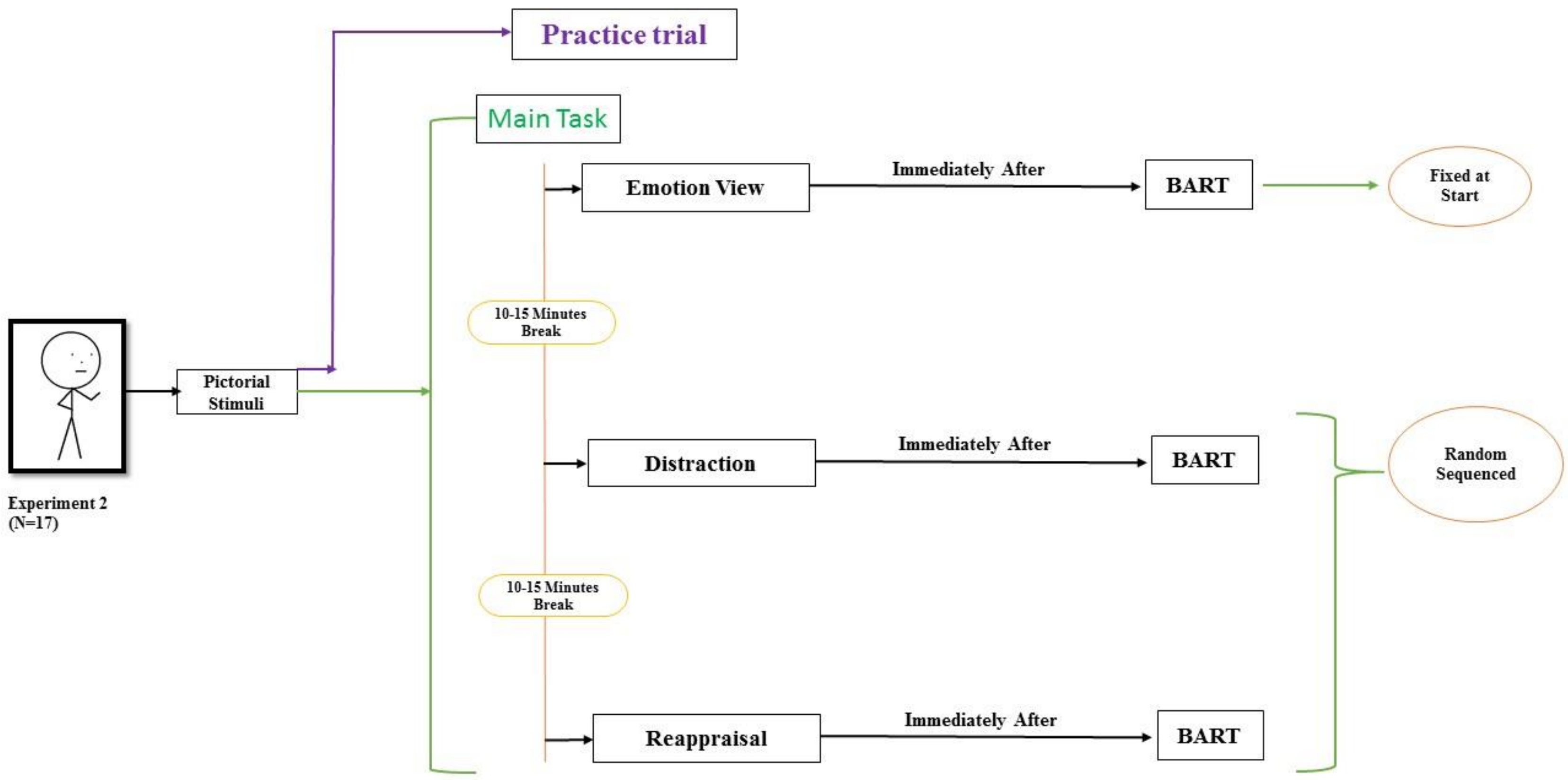


Figure 6 | Represent experimental design used in experiment 2. Emotion view block always appeared first and regulation strategies (Distraction and cognitive reappraisal) appeared in random order for each subject.

Experiment 3: Assess the role of second half or first half of sleep deprivation in affect regulated risky decision making.

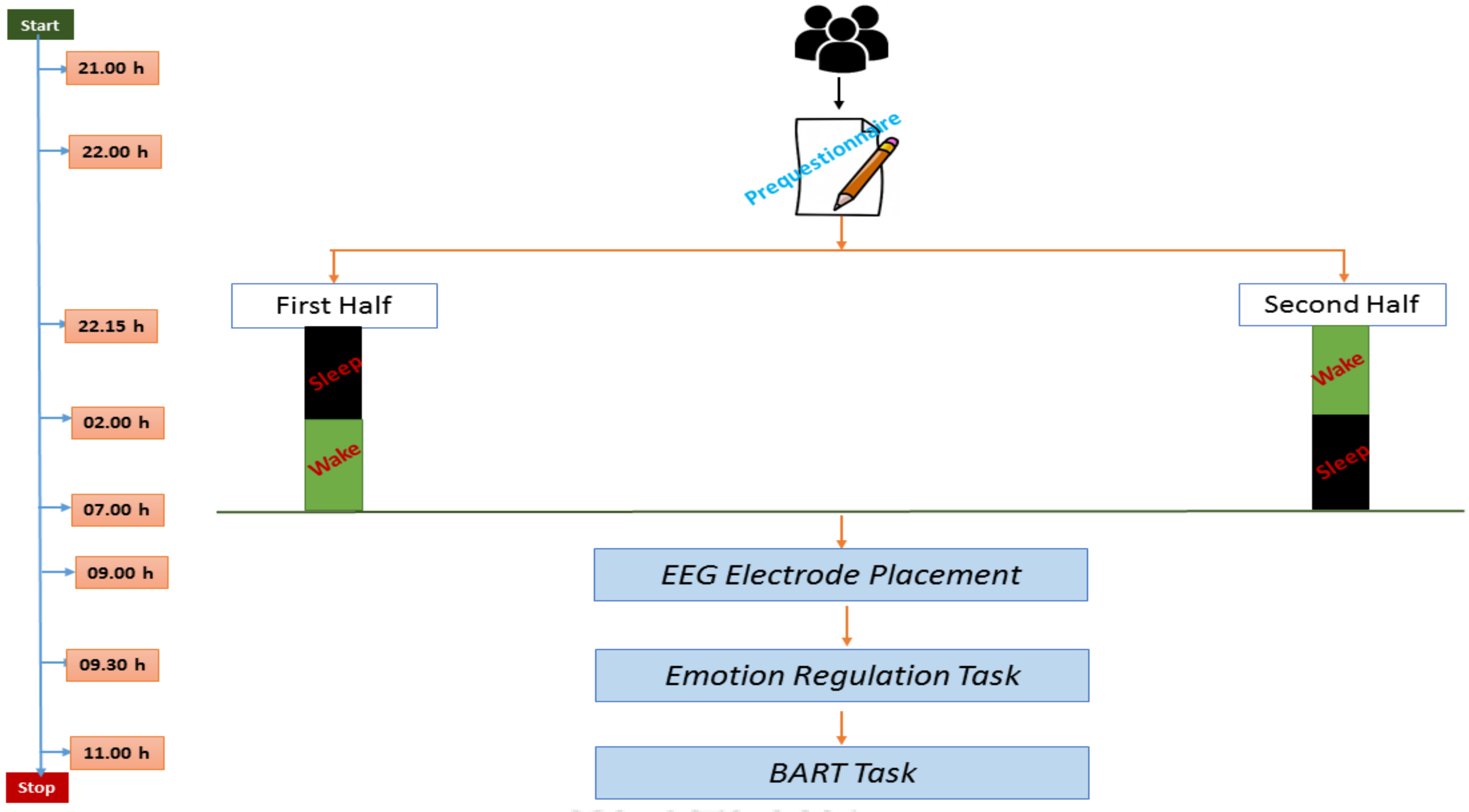


Figure 7 | Procedural design used in experiment 3. Depicts the flow of procedures followed by each participant' on an experimental night. Each participant finished preliminary testing and Emotion regulation task practice trial before starting second half of sleep deprivation/ first half of sleep deprivation. ER task and BART task followed the next morning.

Experiment 3: Assess the role of second half or first half of sleep deprivation in affect regulated risky decision making.

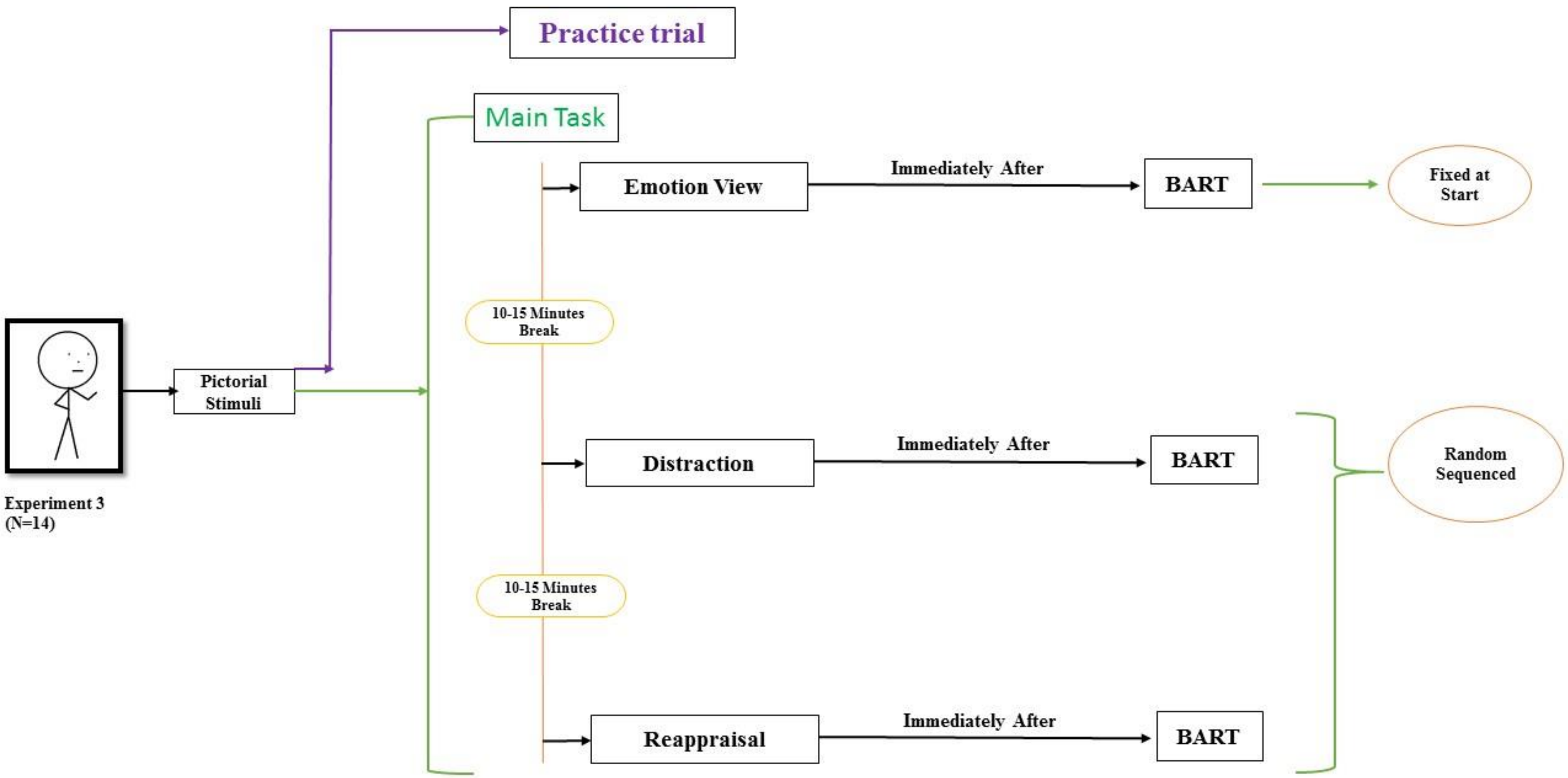


Figure 8 | Represent experimental design used in experiment 3. Emotion view block always appeared first and regulation strategies (Distraction and cognitive reappraisal) appeared in random order for each subject.

Emotion Regulation Task

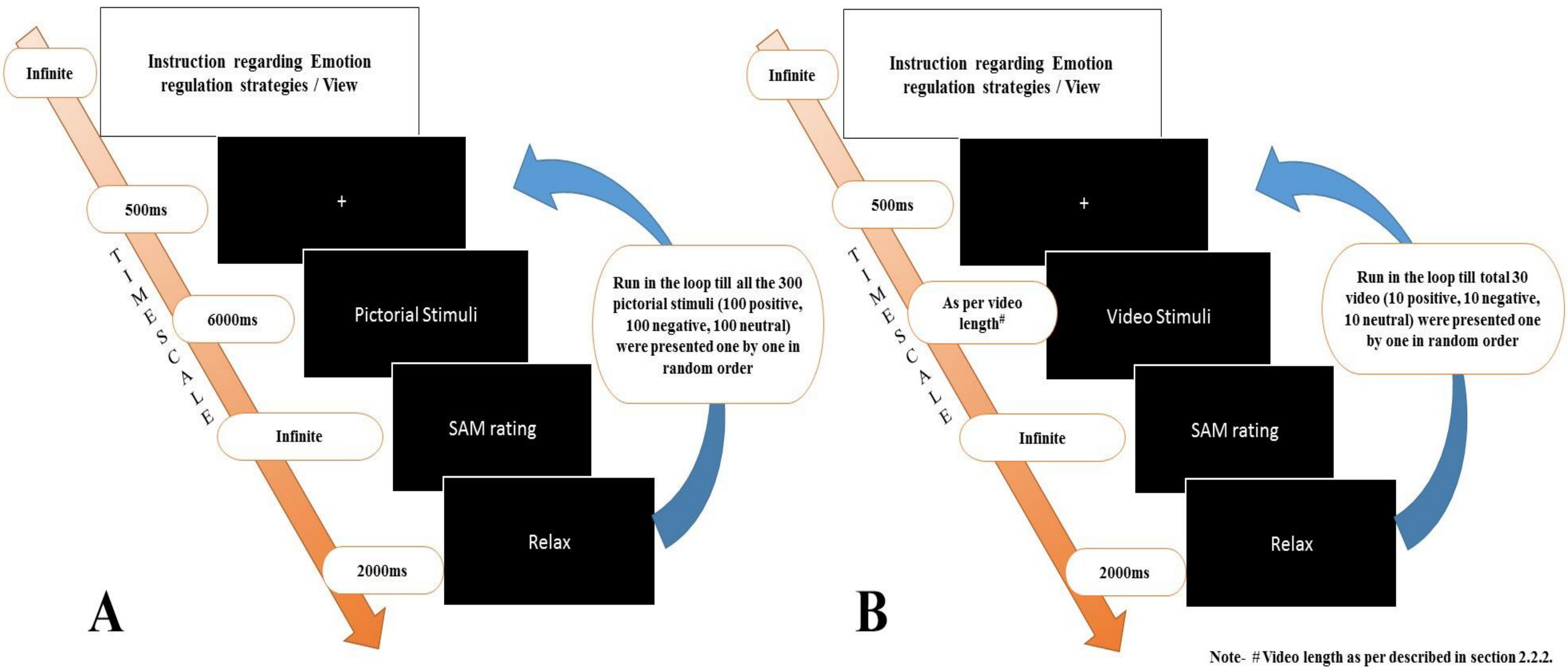


Figure 9 | Schematic of the Emotion Behaviour Task, the experimental task used in all the experiments. The arrow on the left indicates the phases of the task and their durations. A) Represents the pictorial stimuli presentation. B) Represents the video stimuli presentation.

Task Design – Balloon Analogue Risk Task (BART; Lejuez et al., 2002)

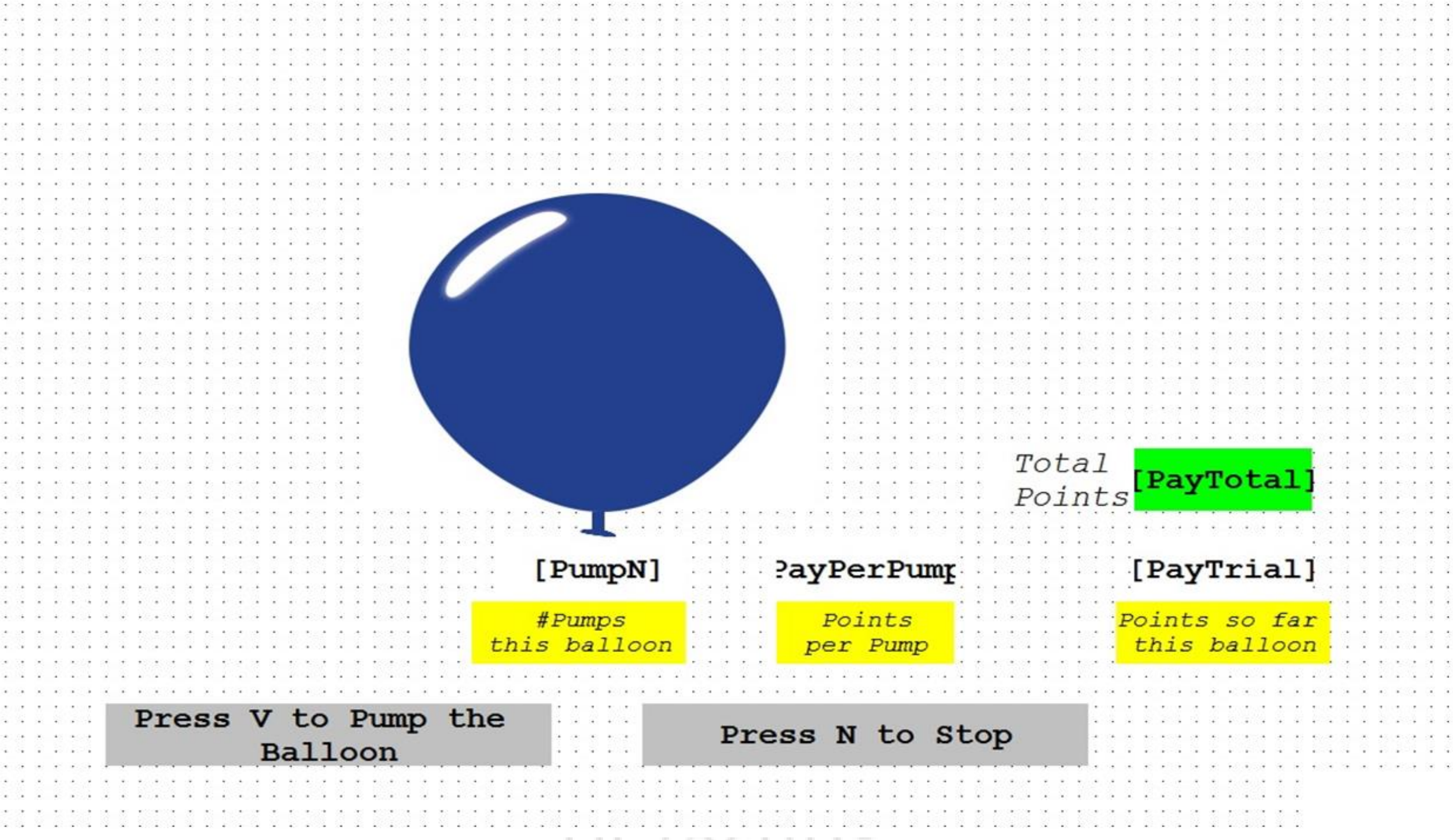
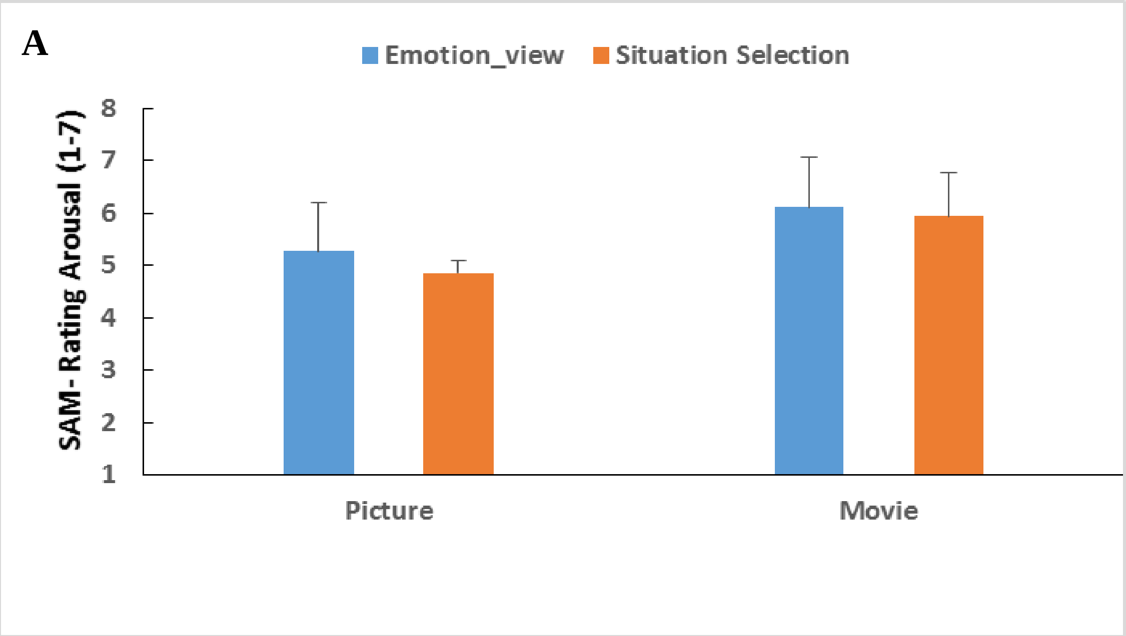
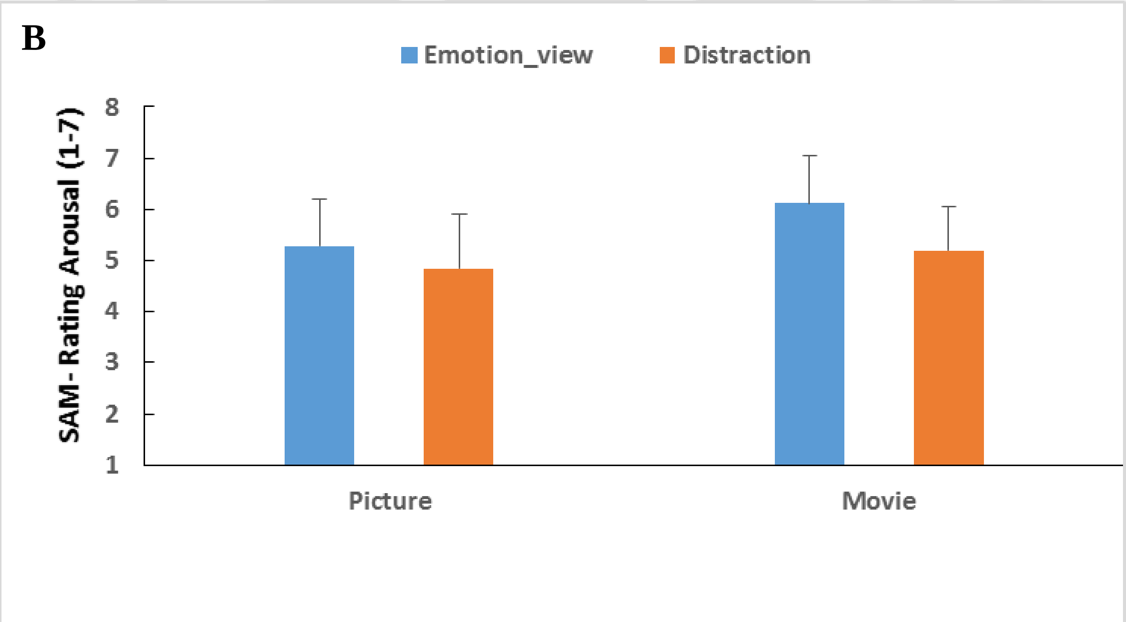
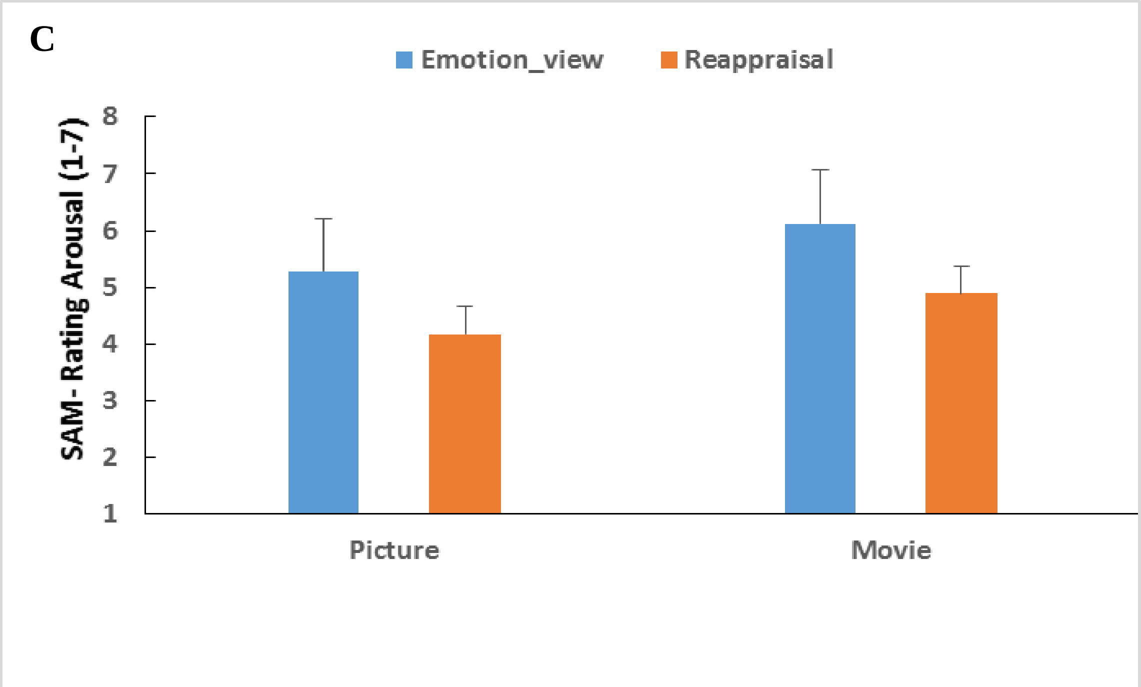


Figure 10 | Graphical Representation of Balloon Analogue Risk Taking Task, the experimental task used in all the Experiments to assess risk taking behaviour of participants'. Total duration for BART task is around 20 minutes

Experiment 1A: Effectiveness of Emotion Regulation in Terms of Stimuli Type and Affect







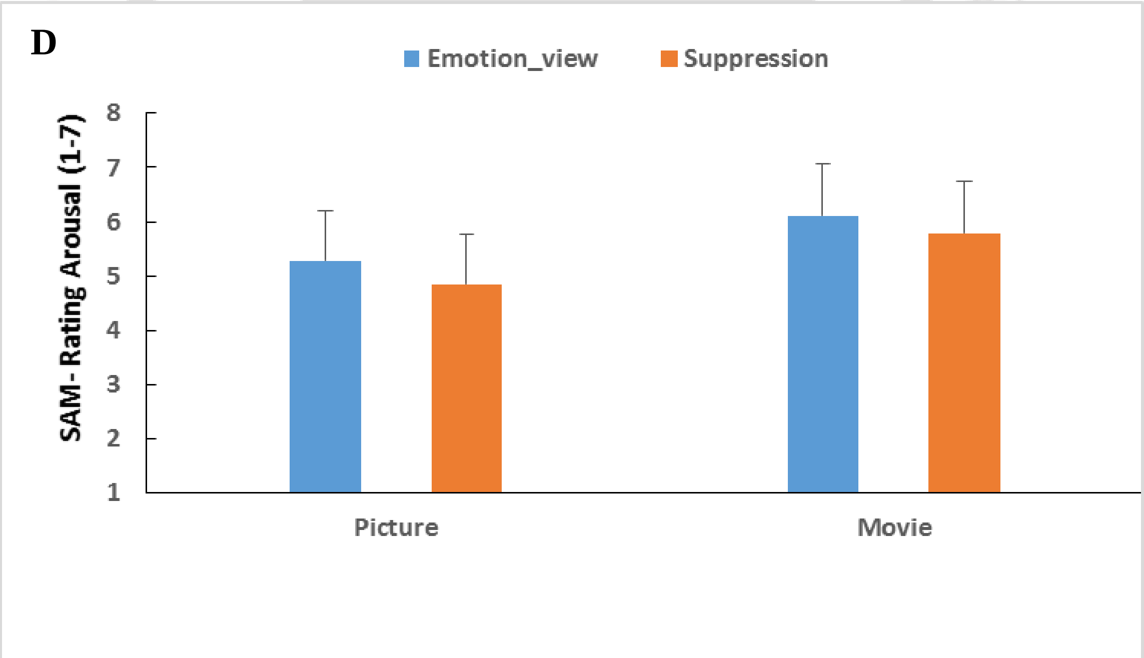
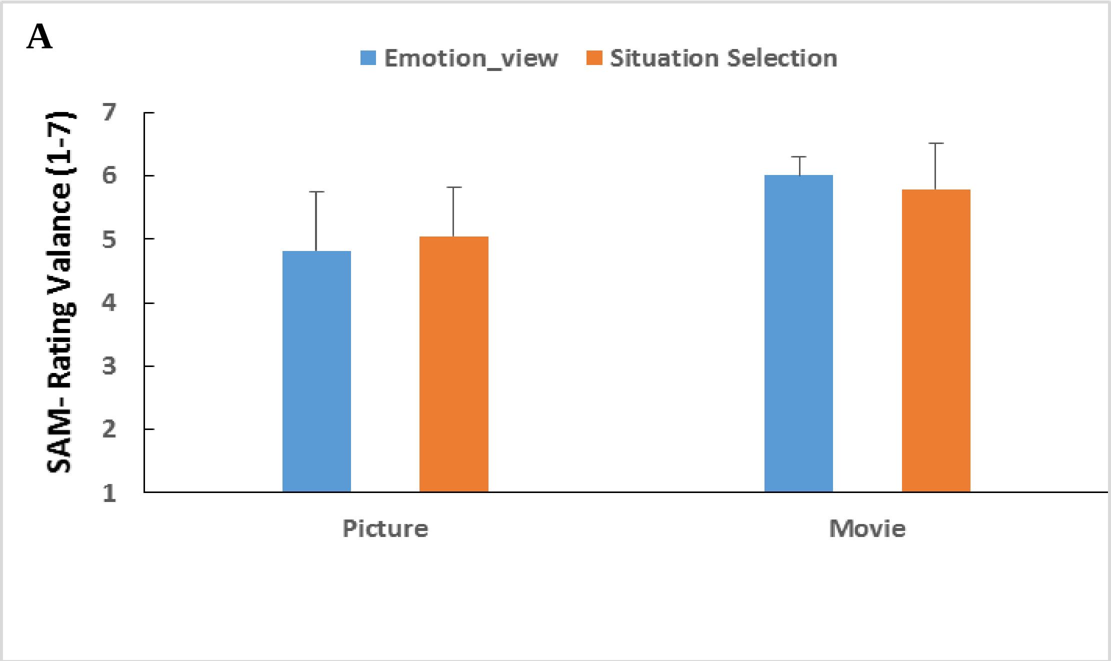
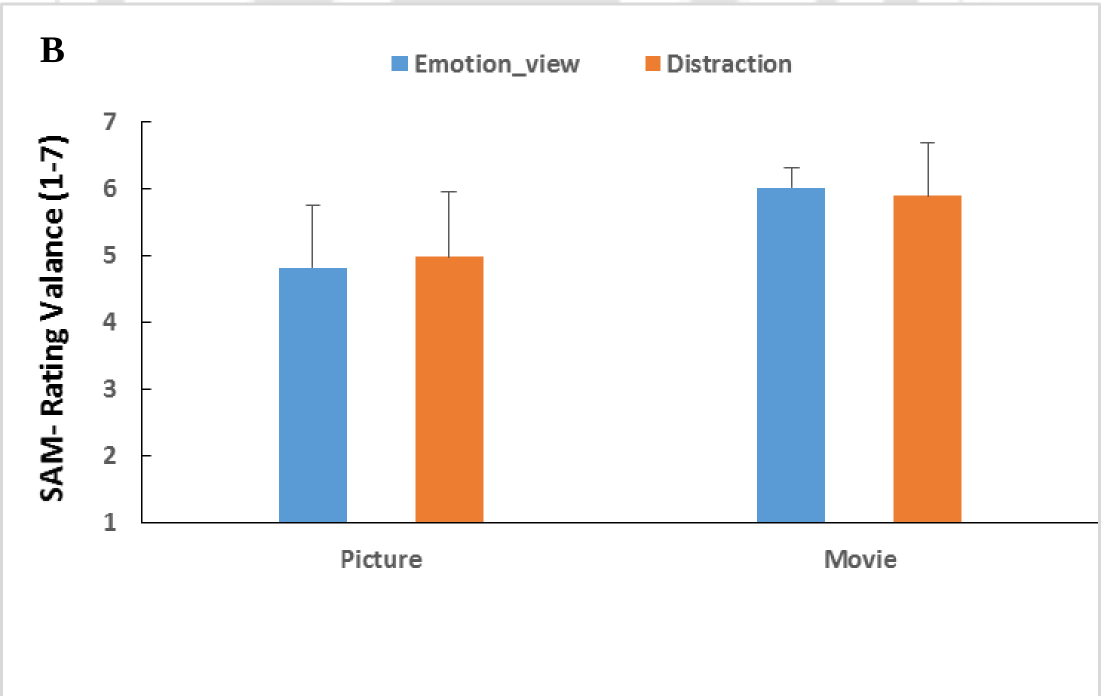


Figure 11 | Arousal Rating of Positive Affect by Stimuli Type.

Data presented as group means ± standard deviation. Higher ratings present more positive arousal state. (A) Emotion view versus situation selection strategy (B) Emotion view versus distraction (C) Emotion view versus cognitive reappraisal (D) Emotion view versus suppression strategy.


A
Emotion_view
Situation Selection
SAM- Rating Valance (1-7)
7
6
5
4
3
2
1
Picture
Movie


B
Emotion_view
Distraction
SAM- Rating Valance (1-7)
7
6
5
4
3
2
1
Picture
Movie

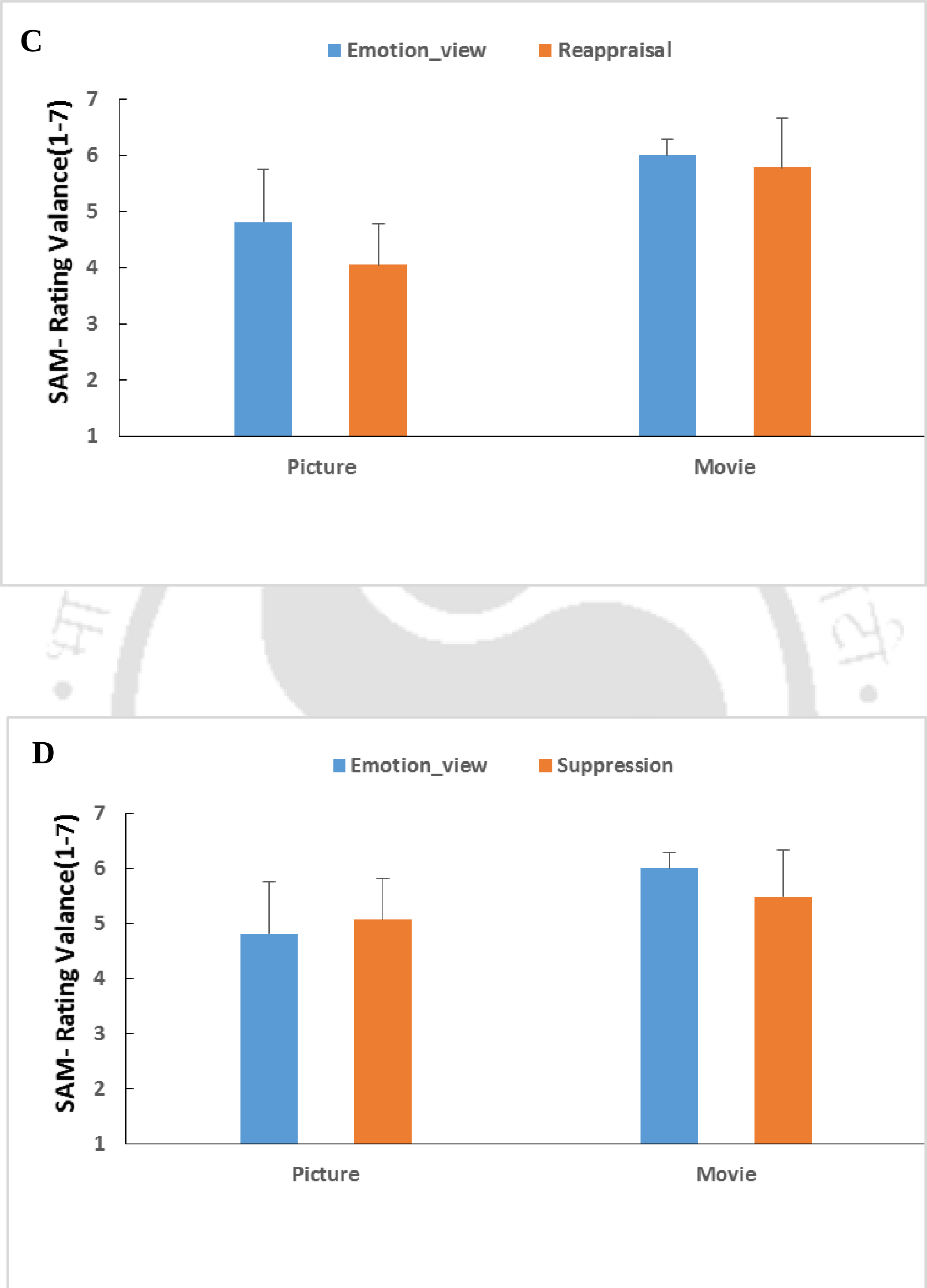
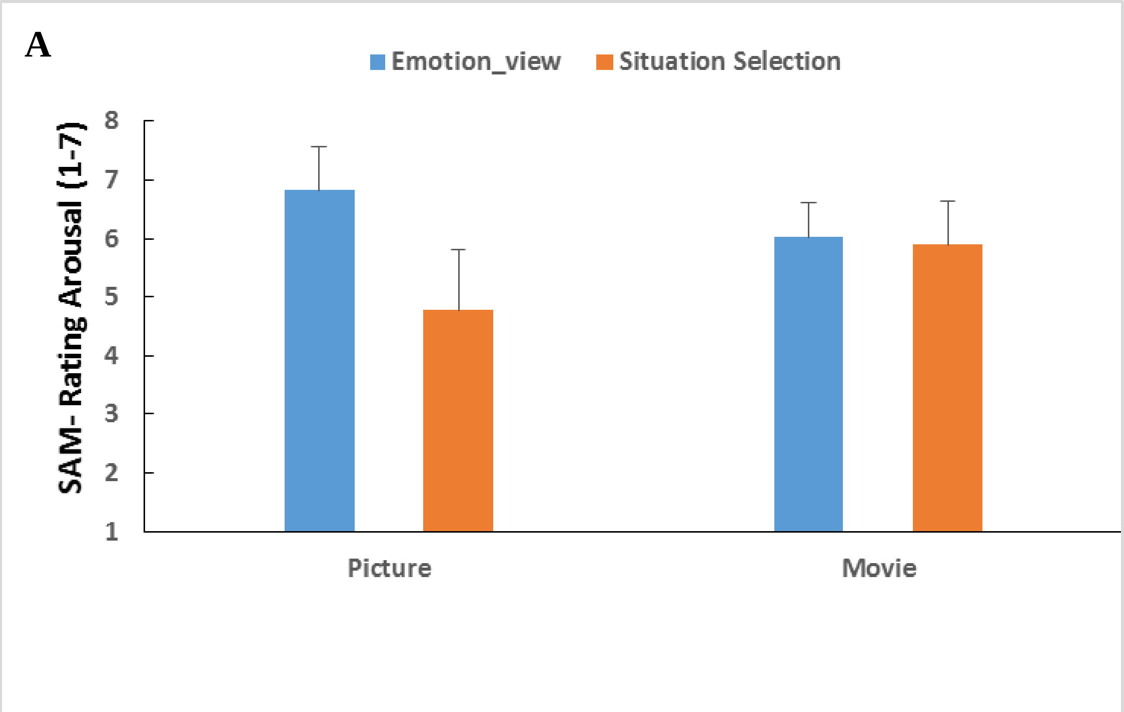
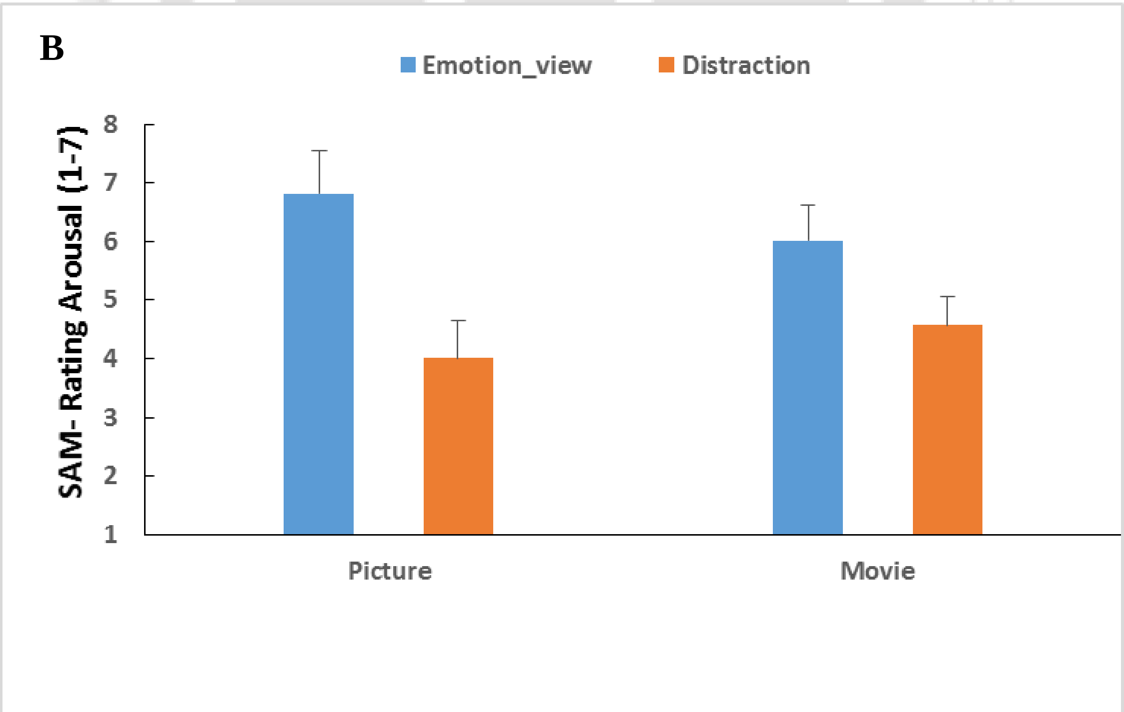
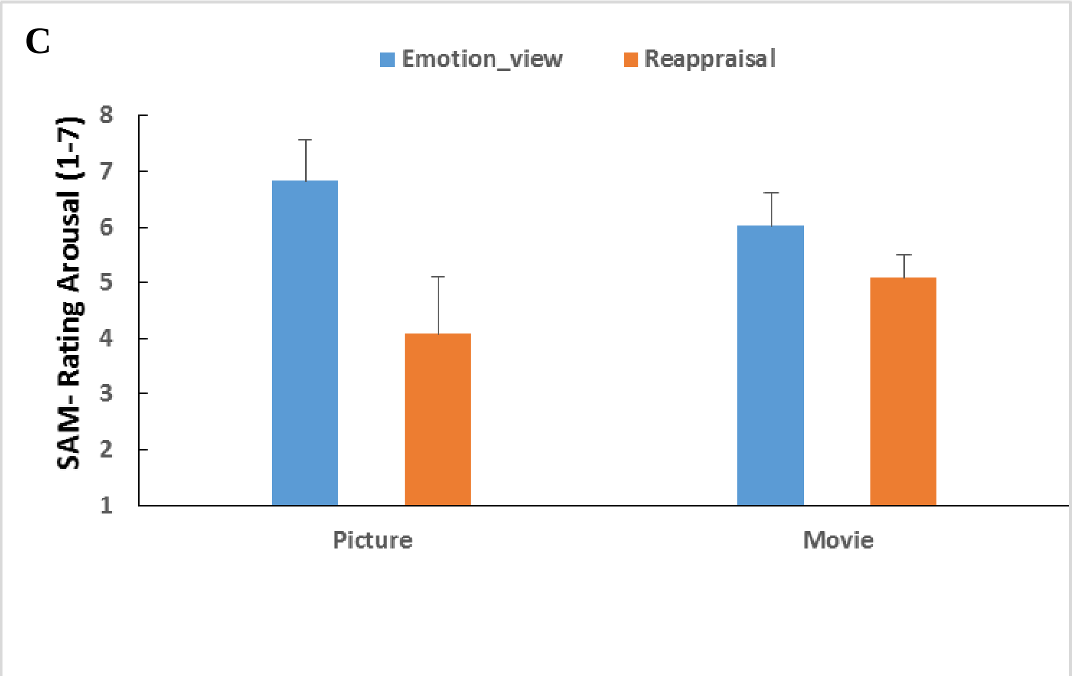


Figure 12 | Valance rating of Positive Affect by stimuli type.

Data presented as group means ± standard deviation. Higher ratings present more positive valance state. (A) Emotion view versus situation selection (B) Emotion view versus distraction (C) Emotion view versus cognitive reappraisal (D) Emotion view versus suppression strategy.


A
Emotion_view
Situation Selection
SAM- Rating Arousal (1-7)
8
7
6
5
4
3
2
1
Picture
Movie


B
Emotion_view
Distraction
SAM- Rating Arousal (1-7)
8
7
6
5
4
3
2
1
Picture
Movie



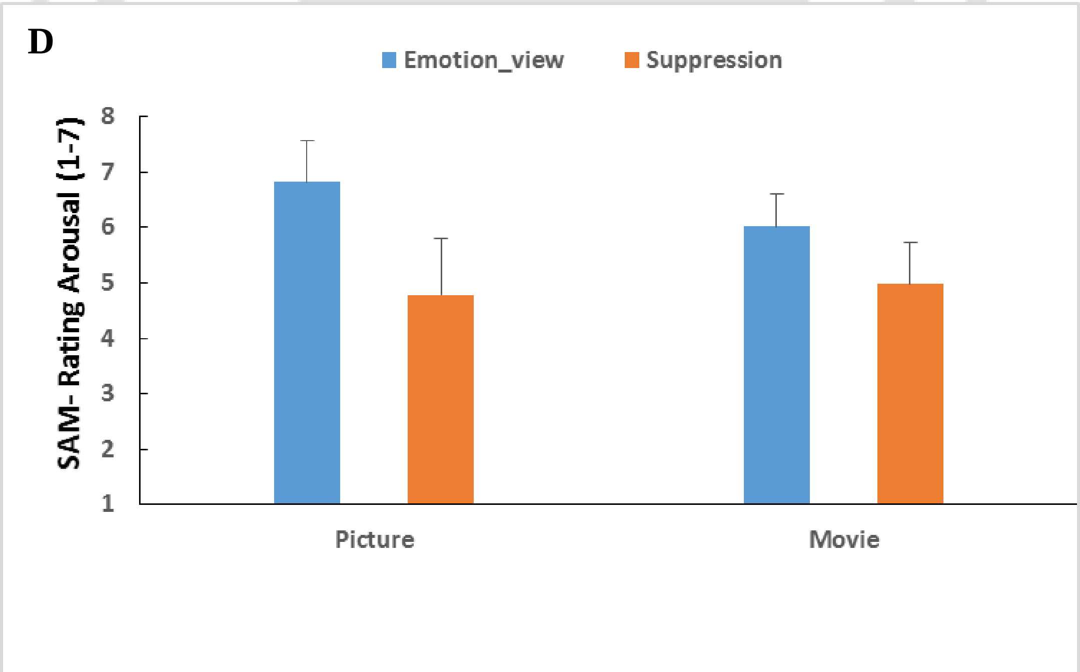
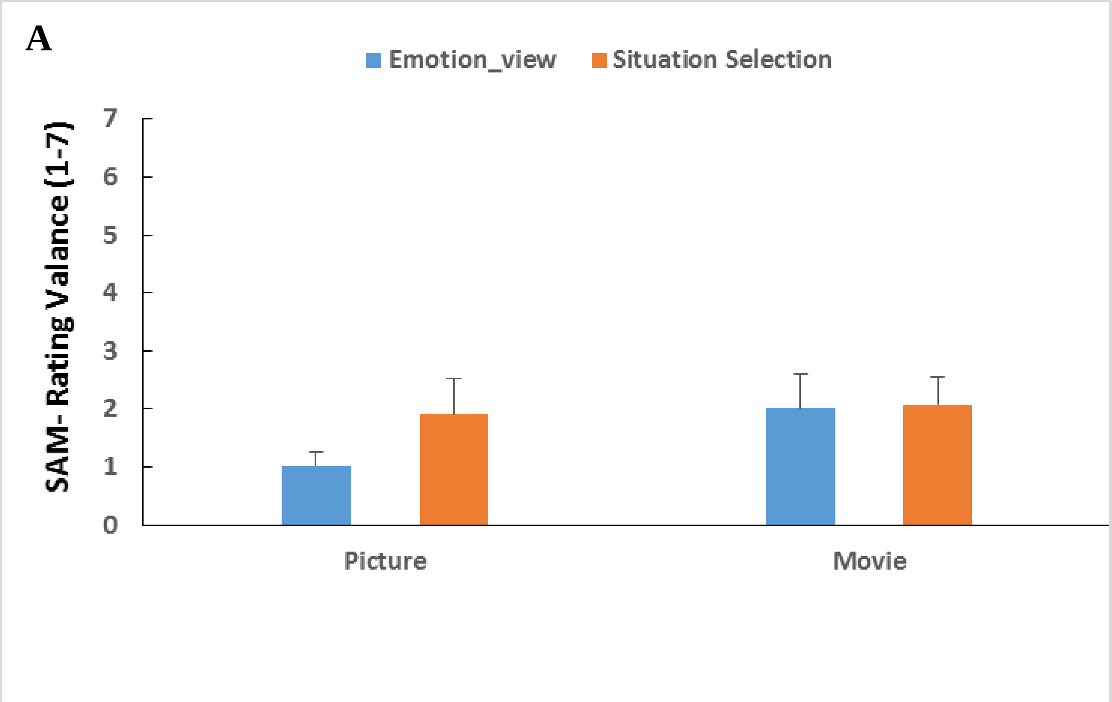


Figure 13 | Arousal rating of Negative Affect by stimuli type.

Data presented as group means ± standard deviation. Higher ratings present more negative arousal state. (A) Emotion view versus situation selection strategy (B) Emotion view versus distraction (C) Emotion view versus cognitive reappraisal (D) Emotion view versus suppression strategy.


A
Emotion_view
Situation Selection
SAM- Rating Valance (1-7)
0
1
2
3
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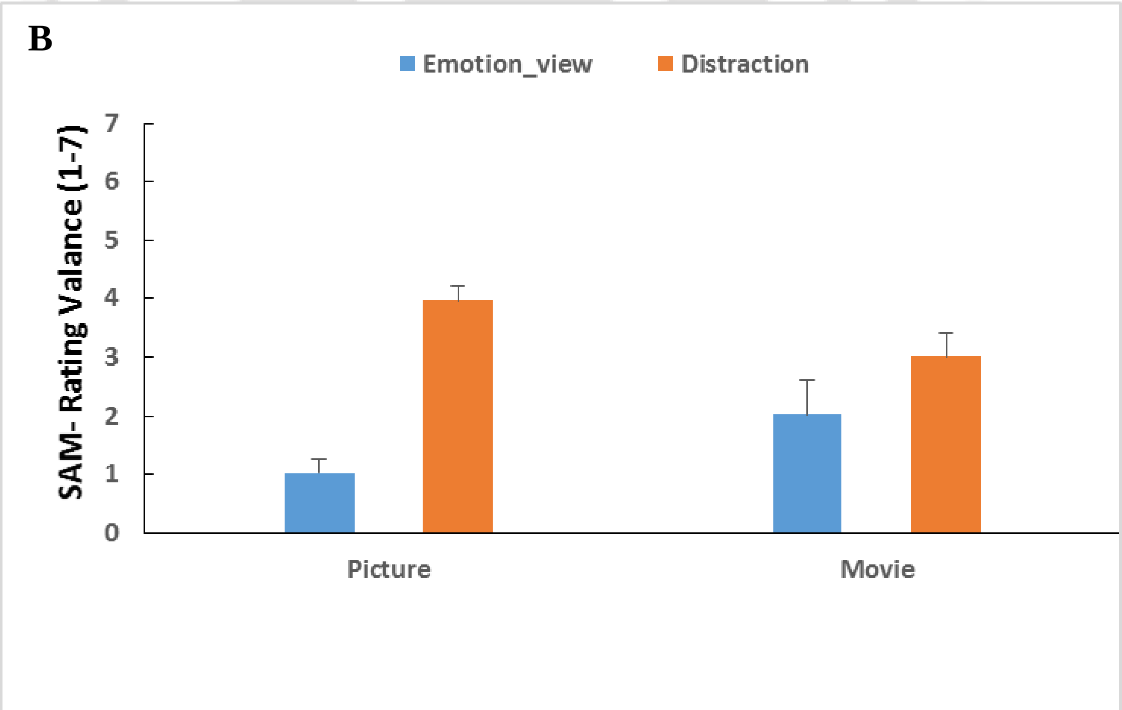
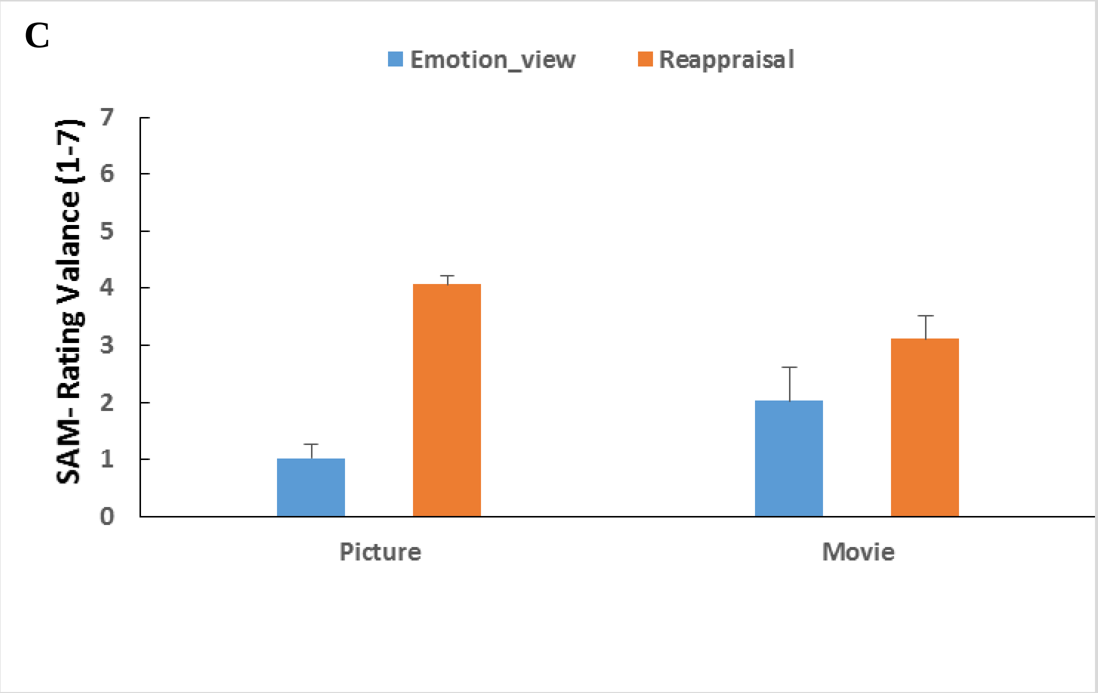
6
7
Picture
Movie


B
Emotion_view
Distraction
SAM- Rating Valance (1-7)
0
1
2
3
4
5
6
7
Picture
Movie



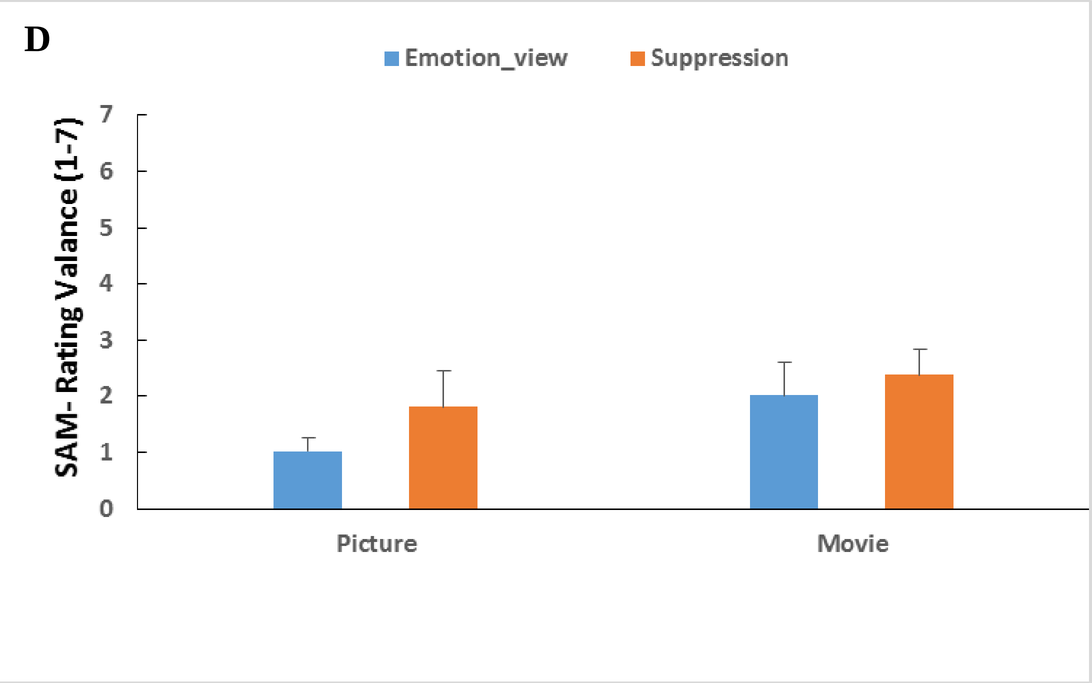


Figure 14 | Valance rating of Negative Affect by stimuli type.

Data presented as group means ± standard deviation. Lower ratings present more negative valance state. (A) Emotion view versus situation selection strategy (B) Emotion view versus distraction (C) Emotion view versus cognitive reappraisal (D) Emotion view versus suppression strategy.

Experiment 1B: Effect of Emotion Regulation Strategies on Risky Decision Making

Table 3| A X B ANOVA Summary Table (Repeated on A and B) on BART score

Design: 2 (stimuli type: Picture, Video) X 2 (Affect: Emotion View, Emotion regulation strategy)

i)

A(Stimuli Type)	6.87	1	6.87	0.080	.77
Error(within)	3359.28	39	86.13		
B(Emotion)	293.35	1	293.35	3.98	.35
Error(Within)	2872	39	73.64		
AB	375.67	1	375.67	2.05	.16
Error (Within)	7142	39	183.13		

ii)

A(Stimuli Type)	266.79	1	266.79	85.91	**.00**
Error(within)	121.10	39	3.10		
B(Emotion)	5689.06	1	5689.06	22.53	**.00**
Error(Within)	9846.91	39	252.48		
AB	0.634	1	0.634	0.30	.58
Error (Within)	80.63	39	2.06		

iii)

Source	**SS**	***df***	**MS**	**F**	**Significance**
A(Stimuli Type)	305.97	1	305.97	87.98	**.00**
Error(within)	134.15	39	3.48		
B(Emotion)	7679.06	1	7679.06	27.61	**.00**
Error(Within)	10846.91	39	278.12		
AB	0.734	1	0.734	0.40	.13
Error (Within)	70.63	39	1.81		

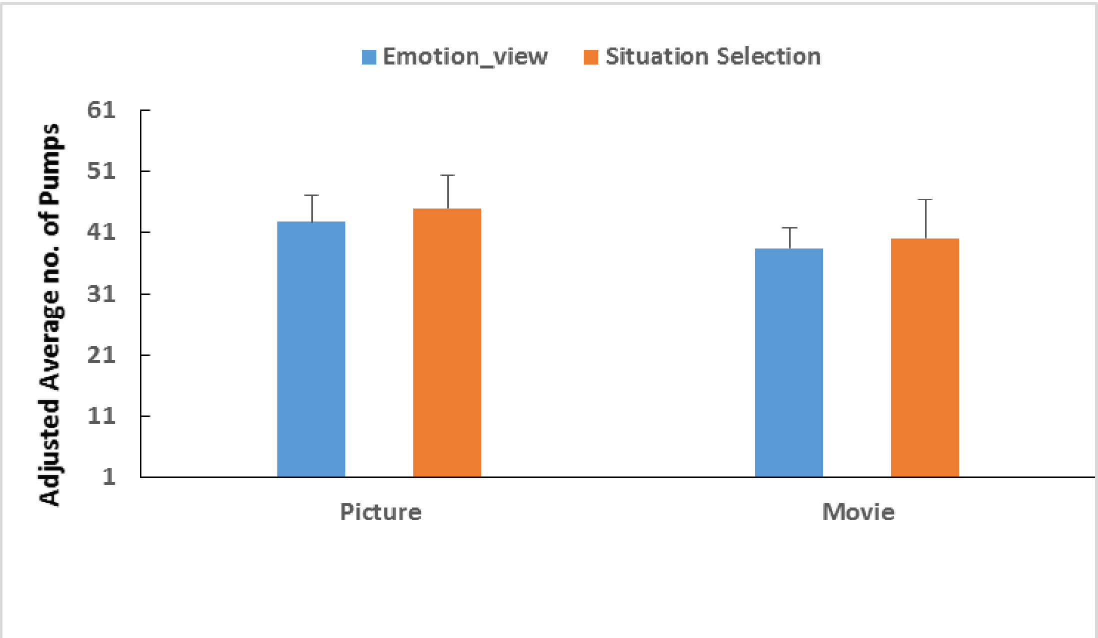
iv)

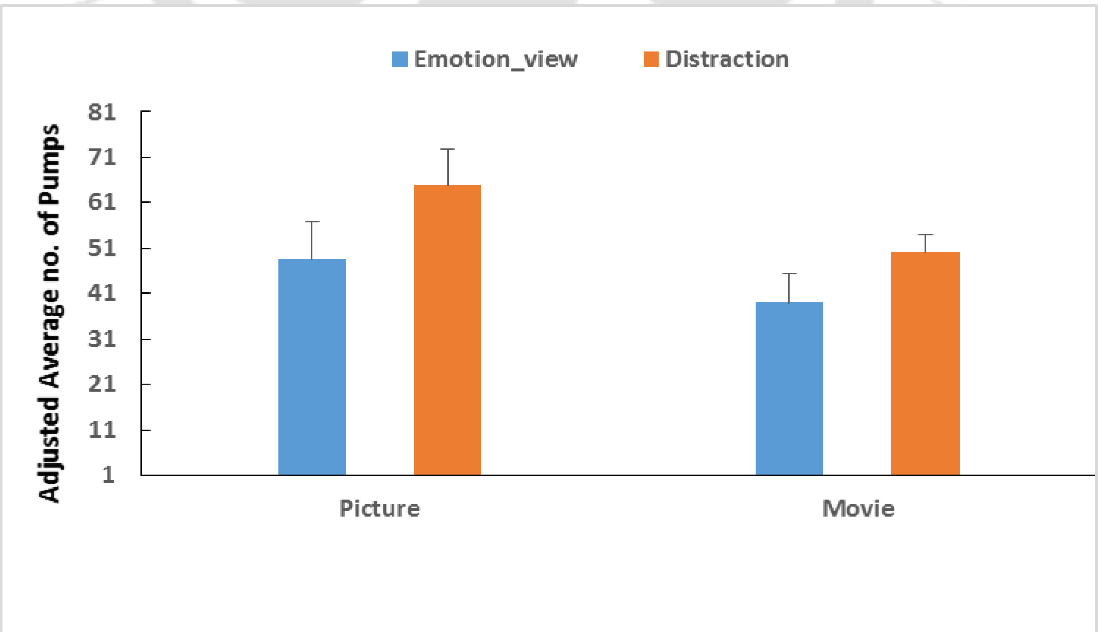
Source	**SS**	***df***	**MS**	**F**	**Significance**
A(Stimuli Type)	10.68	1	10.68	0.130	0.78
Error(within)	3195.28	39	81.92		
B(Emotion)	173.45	1	173.45	2.62	.47
Error(Within)	2582	39	66.20		
AB	393.76	1	393.76	2.00	.19
Error (Within)	7647	39	196.07		

i) View versus Situation selection; ii) View versus Distraction ; iii) View versus Cognitive reappraisal ; iv) View versus Suppression

Experiment 1B: Effect of Emotion Regulation Strategies on Risky Decision Making

BART Score- Mean Adjusted Number of Pump





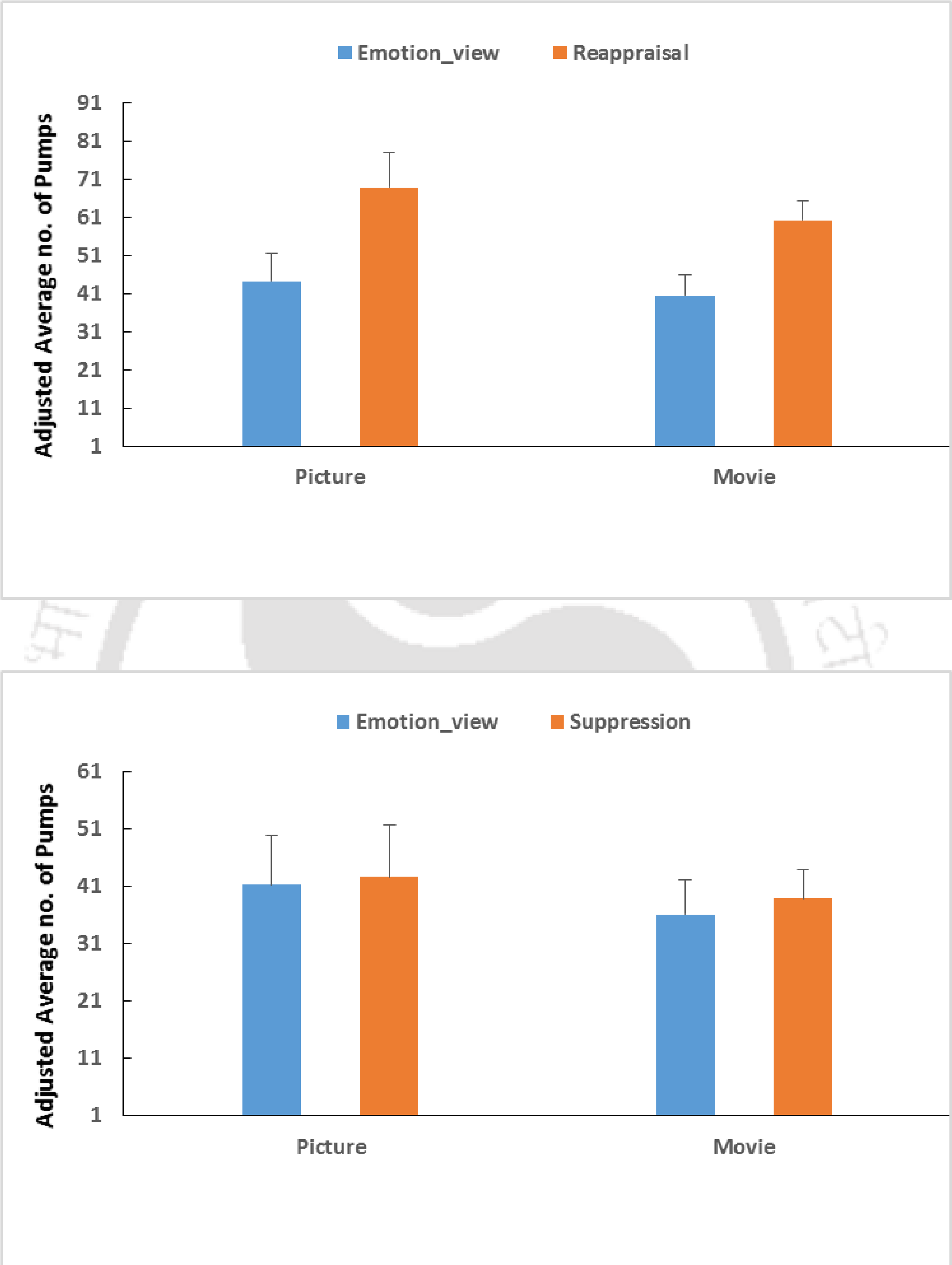


Figure 15 | Mean adjusted number of Pump by stimuli and affect type.

Data presented as group means ± standard deviation. Higher value present more risk taking behaviour. (A) Emotion view versus situation selection strategy (B) Emotion view versus distraction (C) Emotion view versus cognitive reappraisal (D) Emotion view versus suppression strategy.

Experiment 2: Emotion regulation effectiveness after Sleep and sleep deprivation

Table 4: A X B ANOVA Summary Table (Repeated on A and B) on BART score

Design: 2 (Sleep: Full night Sleep, Sleep deprivation) X 2 (Affect: Emotion View, Emotion regulation strategy).

A. Emotion View versus Cognitive Reappraisal

Source	SS	*df*	MS	F	Significance	η^2
A(Sleep)	540.14	1	540.14	6.004	**.02**	.27
Error(Within)	1439.32	16	89.95			
Within-Subjects	1370.84	31.75				
B (Affect)	8881.78	1	8881.78	74.87	**.00**	.82
Error (Within)	1897.86	16	118.61			
AB	6206.15	1	6206.15	107.22	**.00**	.87
Error (Within)	926.11	16	57.88			

B. Emotion View versus Distraction

Source	SS	*df*	MS	F	Significance	η^2
A(Sleep)	2348.81	1	2348.81	22.94	**.00**	.58
Error(Within)	1638.25	16	102.39			
Within-Subjects	1370.84	31.75				
B(Affect)	439.06	1	439.06	2.70	.12	.14
Error (Within)	2599.66	16	162.47			
AB	2868.18	1	2868.18	36.09	**.00**	.69
Error (Within)	1271.58	16	79.47			

Table 5. | Mean and SD of FRN amplitude for the sleep and sleep deprivation

Feedback_FRN	Sleep						Sleep Deprivation					
	View		Distraction		Reappraisal		View		Distraction		Reappraisal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Positive												
Fz	1.11	4.71	3.97	4.34	.53	4.20	1.66	5.26	1.62	3.73	1.68	7.52
Cz	1.40	2.28	3.55	3.50	1.27	2.41	2.25	3.52	2.46	3.64	2.37	3.68
Pz	-.39	2.75	1.75	2.43	.72	2.27	.49	2.99	.44	3.12	.60	2.73
Negative												
Fz	-9.95	4.67	-12.07	6.37	-12.43	6.31	-8.90	4.07	-8.88	5.40	-9.48	6.79
Cz	-12.25	6.08	-13.80	7.10	-14.15	7.18	-10.74	6.07	-10.98	6.05	-9.73	8.07
Pz	-10.62	4.00	-10.29	4.53	-9.95	3.50	-8.00	4.18	-8.22	4.57	-7.58	3.94

Table 6.| Mean and SD of P300 amplitude for the sleep and sleep deprivation

Feedback_P300	Sleep						Sleep Deprivation					
	View		Distraction		Reappraisal		View		Distraction		Reappraisal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Positive												
F_Z	25.92	14.16	26.87	17.08	26.63	16.09	27.01	18.18	34.82	16.90	26.08	21.38
C_Z	20.99	8.26	22.53	13.41	21.46	12.97	20.04	12.28	24.45	12.20	18.28	14.96
P_Z	17.99	6.22	20.36	11.09	18.73	11.71	17.74	11.07	20.43	10.86	14.42	14.58
Negative												
F_Z	40.80	15.85	46.44	22.63	46.98	15.33	40.04	22.22	46.99	18.78	48.93	29.46
C_Z	45.90	10.65	45.39	19.21	46.40	12.04	38.82	20.28	43.67	16.24	42.93	23.39
P_Z	31.85	7.78	34.96	14.30	34.47	11.50	27.71	15.71	31.80	12.23	30.62	17.17

Experiment 2: Emotion regulation effectiveness after Sleep and sleep deprivation

Table 7: A X B X C X D ANOVA Summary Table (Repeated on A, B, C and D) on FRN amplitude

Design: 2 (Sleep: Full night Sleep, Sleep deprivation) X 2 (Affect: Emotion View, Distraction) X 2 (Feedback: Negative, Positive) X 3 (Electrode Site: Fz, Cz, Pz)

Source FRN_D	SS	df	Ms	F	Sig.	η2
A (Sleep)	82.70	1	82.707	2.363	.144	.129
Error(Within)	560.01	16	35.001			
B (Affect)	8.645	1	8.645	.141	.712	.009
Error(Within)	980.784	16	61.299			
C (Feedback)	14917.482	1	14917.482	171.635	**.000**	.915
Error(Within)	1390.625	16	86.914			
D (Electrode)	47.237	2	23.619	2.187	.129	.120
Error(Within)	345.653	32	10.802			
AB	12.165	1	12.165	.613	.445	.037
Error(Within)	317.681	16	19.855			
AC	175.010	1	175.010	6.772	**.019**	.297
Error(Within)	413.461	16	25.841			
BC	86.818	1	86.818	2.538	.131	.137
Error(Within)	547.411	16	34.213			
ABC	69.859	1	69.859	1.709	.210	.096
Error(Within)	654.155	16	40.885			
AD	4.366	2	2.183	.156	.856	.010
Error(Within)	446.957	32	13.967			
BD	3.539	2	1.769	.337	.716	.021
Error(Within)	168.012	32	5.250			
ABD	5.975	2	2.988	.532	.592	.032
Error(Within)	179.643	32	5.614			
CD	344.980	2	172.490	15.250	**.000**	.488
Error(Within)	361.941	32	11.311			
ACD	2.391	2	1.196	.273	.763	.017
Error(Within)	140.308	32	4.385			
BCD	9.736	2	4.868	1.021	.372	.060
Error(Within)	152.566	32	4.768			
ABCD	12.112	2	6.056	1.194	.316	.069
Error(Within)	162.321	32	5.073			

Table 8: A X B X C X D ANOVA Summary Table (Repeated on A, B, C and D) on FRN amplitude

Design: 2 (Sleep: Full night Sleep, Sleep deprivation) X 2 (Affect: Emotion View, cognitive reappraisal) X 2 (Feedback: Negative, Positive) X 3 (Electrode Site: Fz, Cz, Pz)

Source_FRN_reapp	SS	df	MS	F	Sig.	η2
A (Sleep)	265.209	1	265.209	11.871	**.003**	.426
Error (Within)	357.443	16	22.340			
B (Affect)	3.375	1	3.375	.094	.763	.006
Error(Within)	574.721	16	35.920			
C (Feedback)	13408.954	1	13408.954	118.881	**.000**	.881
Error(Within)	1804.692	16	112.793			
D (Electrode Site)	27.426	2	13.713	.880	.425	.052
Error(Within)	498.860	32	15.589			
AB	13.713	1	13.713	.801	.384	.048
Error(Within)	274.077	16	17.130			
AC	78.264	1	78.264	1.940	.183	.108
Error(Within)	645.542	16	40.346			
BC	8.866	1	8.866	.218	.647	.013
Error(Within)	649.322	16	40.583			
ABC	15.807	1	15.807	.245	.628	.015
Error(Within)	1034.204	16	64.638			
AD	6.495	2	3.248	.416	.663	.025
Error(Within)	249.867	32	7.808			
BD	37.670	2	18.835	2.721	.081	.145
Error(Within)	221.548	32	6.923			
ABD	24.206	2	12.103	1.764	.188	.099
Error(Within)	219.541	32	6.861			
CD	292.101	2	146.051	9.838	**.000**	.381
Error(Within)	475.044	32	14.845			
ACD	4.553	2	2.277	.480	.623	.029
Error(Within)	151.817	32	4.744			
BCD	6.047	2	3.023	.579	.566	.035
Error(Within)	167.171	32	5.224			
ABCD	4.076	2	2.038	.322	.727	.020
Error(Within)	202.495	32	6.328			

Table 9: A X B X C X D ANOVA Summary Table (Repeated on A, B, C and D) on P300 amplitude

Design: 2 (Sleep: Full night Sleep, Sleep deprivation) X 2 (Affect: Emotion View, Distraction) X 2 (Feedback: Negative, Positive) X 3 (Electrode Site: Fz, Cz, Pz)

Source_P300_DISTRACT	SS	df	MS	F	Sig.	η2
A (Sleep)	29.503	1	29.503	.086	.773	.005
Error(Within)	5487.299	16	342.956			
B (Affect)	1365.711	1	1365.711	1.941	.183	.108
Error(Within)	11254.997	16	703.437			
C (Feedback)	26998.347	1	26998.347	77.293	**.000**	.828
Error(Within)	5588.787	16	349.299			
D (Electrode Site)	8226.831	2	4113.415	39.698	**.000**	.713
Error(Within)	3315.808	32	103.619			
AB	222.114	1	222.114	.220	.646	.014
Error(Within)	16175.298	16	1010.956			
AC	483.485	1	483.485	2.677	.121	.143
Error(Within)	2889.236	16	180.577			
BC	13.513	1	13.513	.054	.819	.003
Error(Within)	4016.341	16	251.021			
ABC	4.071	1	4.071	.012	.915	.001
Error(Within)	5533.262	16	345.829			
AD	384.998	2	192.499	5.905	**.007**	.270
Error(Within)	1043.212	32	32.600			
BD	147.565	2	73.783	1.048	.362	.061
Error(Within)	2253.509	32	70.422			
ABD	67.053	2	33.526	.810	.454	.048
Error(Within)	1324.782	32	41.399			
CD	1468.551	2	734.276	18.625	**.000**	.538
Error(Within)	1261.602	32	39.425			
ACD	8.272	2	4.136	.147	.864	.009
Error(Within)	899.512	32	28.110			
BCD	32.896	2	16.448	.425	.657	.026
Error(Within)	1238.198	32	38.694			
ABCD	75.666	2	37.833	.824	.448	.049
Error(Within)	1469.603	32	45.925			

Table 10: A X B X C X D ANOVA Summary Table (Repeated on A, B, C and D) on P300 amplitude

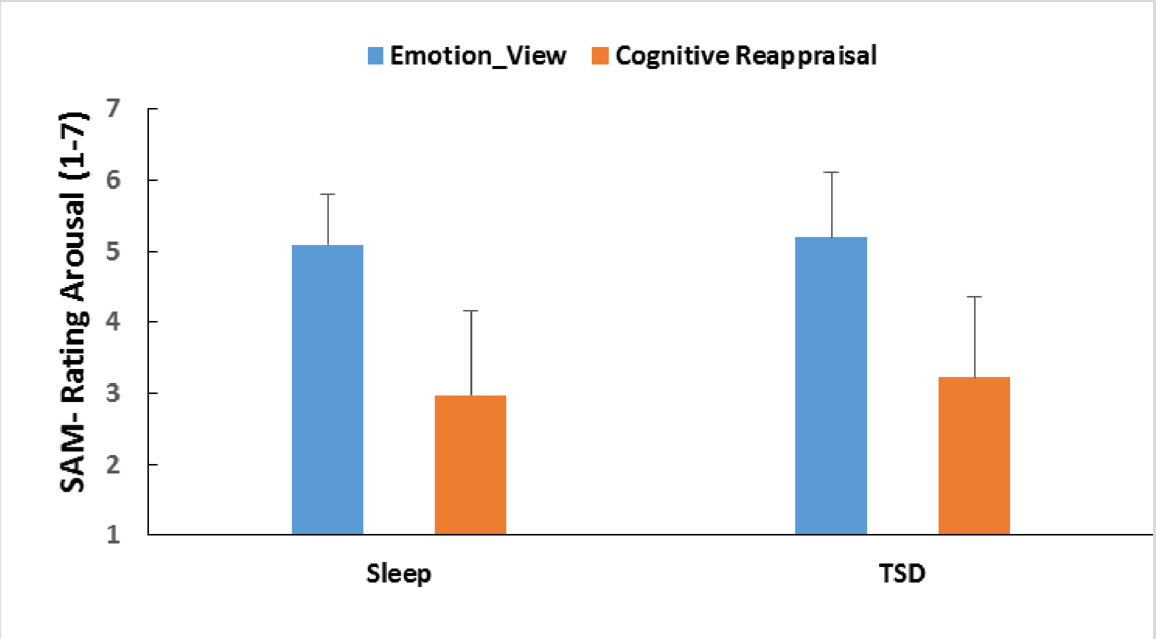
Design: 2 (Sleep: Full night Sleep, Sleep deprivation) X 2 (Affect: Emotion View, Cognitive reappraisal) X 2 (Feedback: Negative, Positive) X 3 (Electrode Site: Fz, Cz, Pz)

Source_P300_REAPP	SS	df	MS	F	Sig.	η2
A (Sleep)	460.293	1	460.293	1.515	.236	.086
Error(Within)	4862.198	16	303.887			
B (Affect)	315.661	1	315.661	.293	.595	.018
Error(Within)	17212.274	16	1075.767			
C (Feedback)	34336.637	1	34336.637	119.281	**.000**	.882
Error(Within)	4605.818	16	287.864			
D (Electrode Site)	8794.265	2	4397.133	43.163	**.000**	.730
Error(Within)	3259.923	32	101.873			
AB	1.253	1	1.253	.001	.975	.000
Error(Within)	20286.324	16	1267.895			
AC	59.962	1	59.962	.148	.705	.009
Error(Within)	6466.116	16	404.132			
BC	608.400	1	608.400	1.513	.236	.086
Error(Within)	6434.520	16	402.158			
ABC	149.504	1	149.504	.224	.642	.014
Error(Within)	10672.820	16	667.051			
AD	338.302	2	169.151	3.746	**.035**	.190
Error(Within)	1444.910	32	45.153			
BD	194.568	2	97.284	1.261	.297	.073
Error(Within)	2468.701	32	77.147			
ABD	35.480	2	17.740	.399	.675	.024
Error(Within)	1424.476	32	44.515			
CD	1511.001	2	755.500	17.776	**.000**	.526
Error(Within)	1360.066	32	42.502			
ACD	53.300	2	26.650	.442	.647	.027
Error(Within)	1929.068	32	60.283			
BCD	102.383	2	51.192	1.275	.293	.074
Error(Within)	1284.358	32	40.136			
ABCD	3.199	2	1.599	.025	.975	.002
Error(Within)	2043.861	32	63.871			

Experiment 2: Effect of Emotion Regulation on Risky Decision Making Across Sleep and Sleep Deprivation.

Behavioural:

1. **Emotion regulation effectiveness across sleep and total sleep deprivation:**



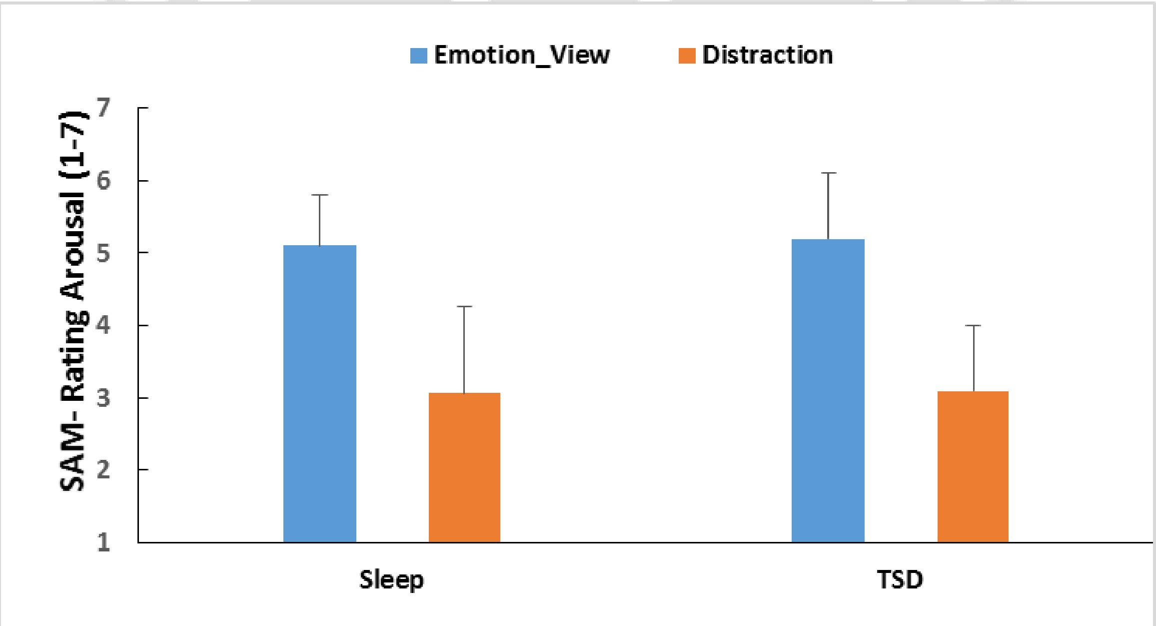


Figure 16 | Arousal rating of Negative Affect by sleep condition and type of affect regulation.

Data presented as group means ± standard deviation. Higher ratings present more negative arousal state. (A) Emotion view versus cognitive reappraisal (B) Emotion view versus distraction

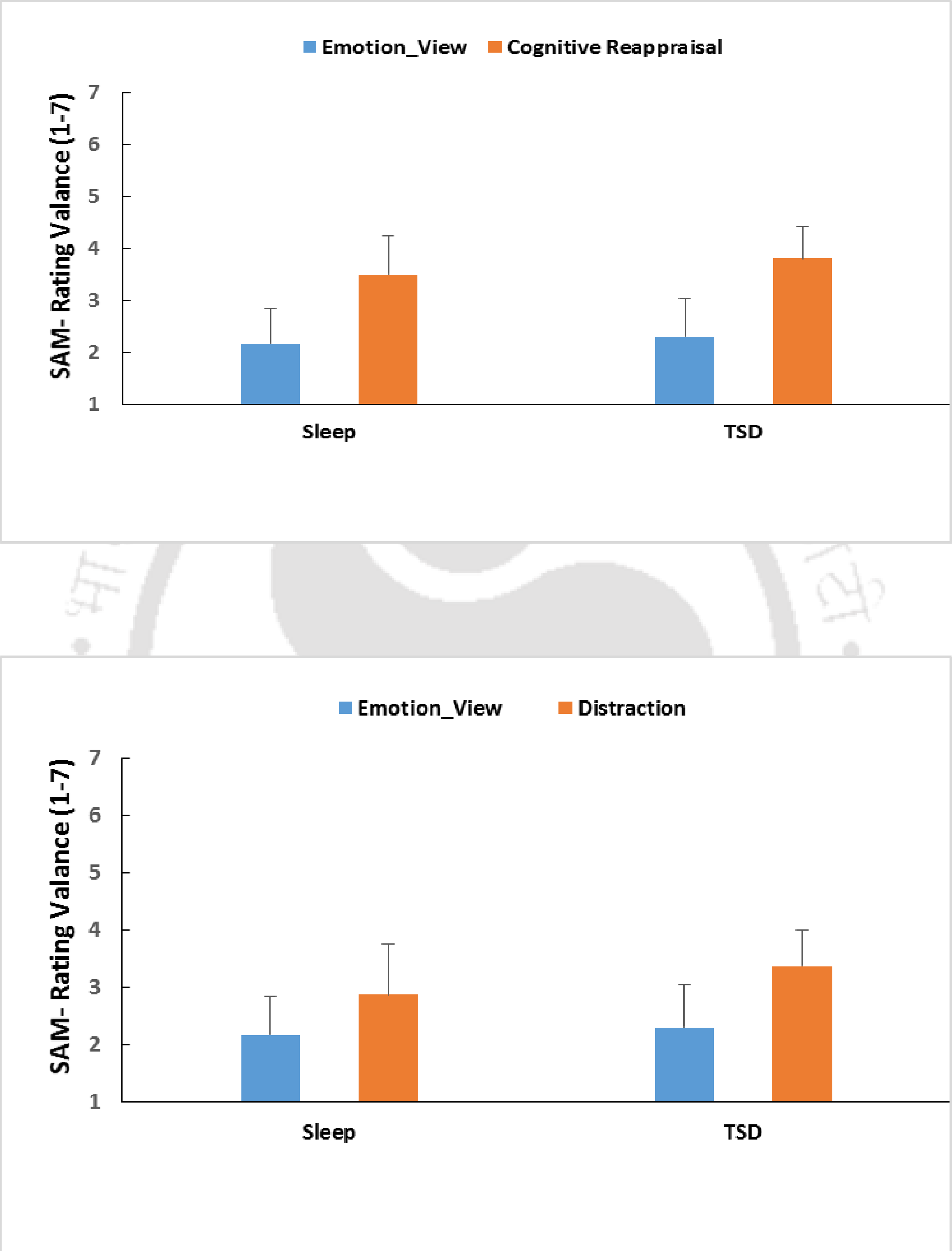


Figure 17 | Valance rating of Negative Affect by sleep condition and affect regulation strategy. Data presented as group means ± standard deviation. Lower ratings present more negative valance state. (A) Emotion view versus cognitive reappraisal (B) Emotion view versus distraction

BART- Mean Adjusted No. of Pumps

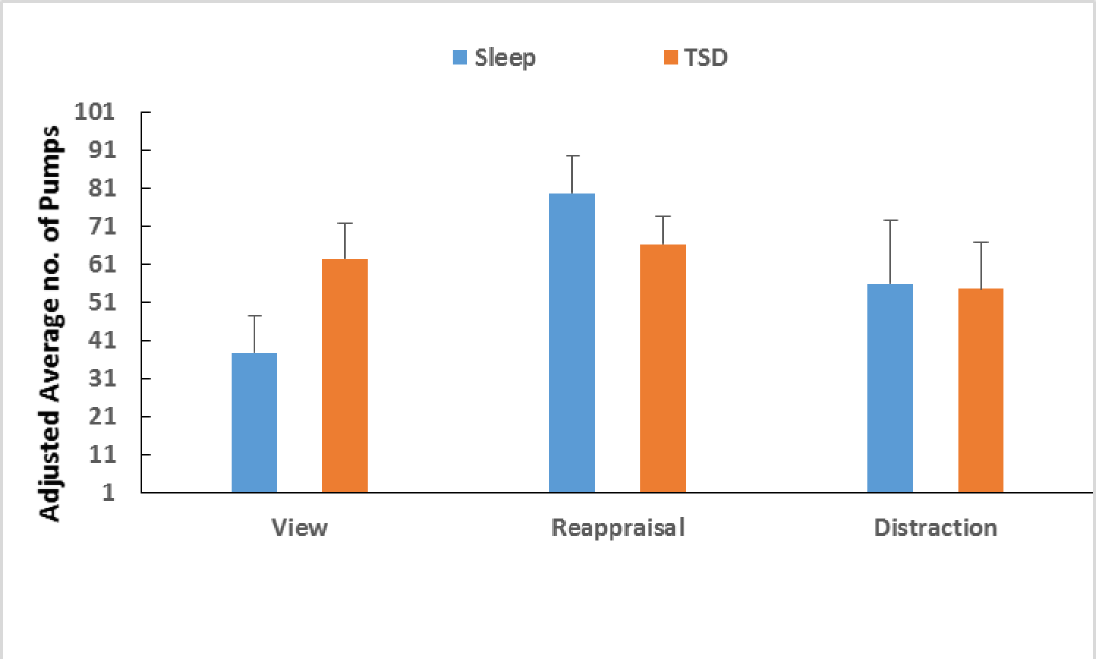


Figure 18 | Mean adjusted number of Pump by sleep condition and emotion regulation

Data presented as group means ± standard deviation. Higher value present more risk taking behaviour for emotion view versus distraction and cognitive reappraisal.

Sleep Scoring –

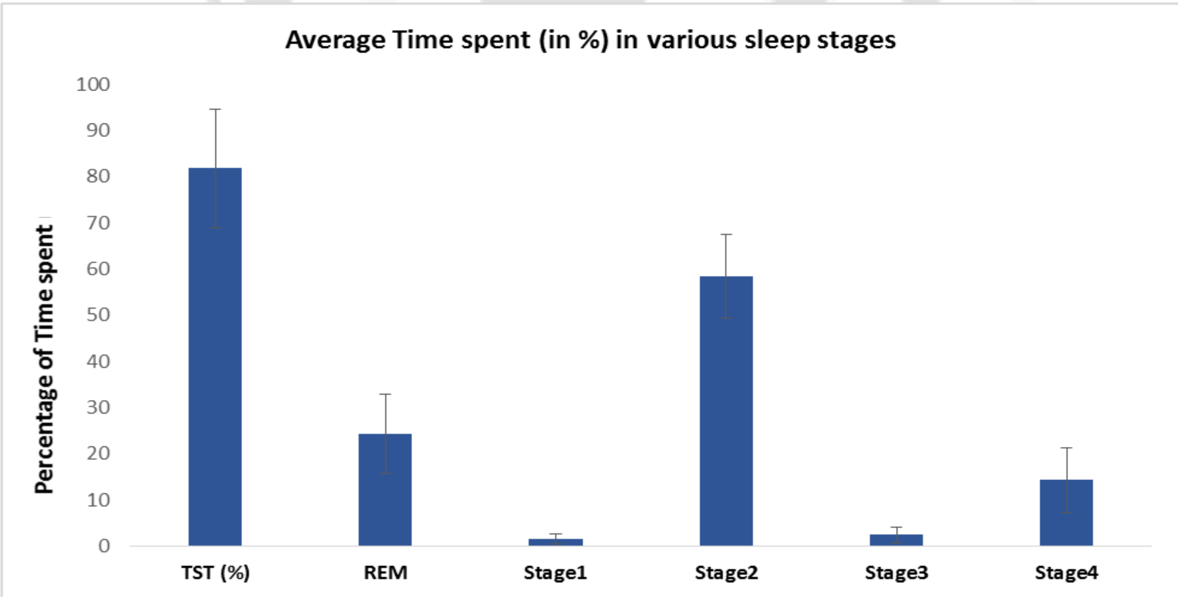


Figure 19 | Represents percentage of sleep stages of participants

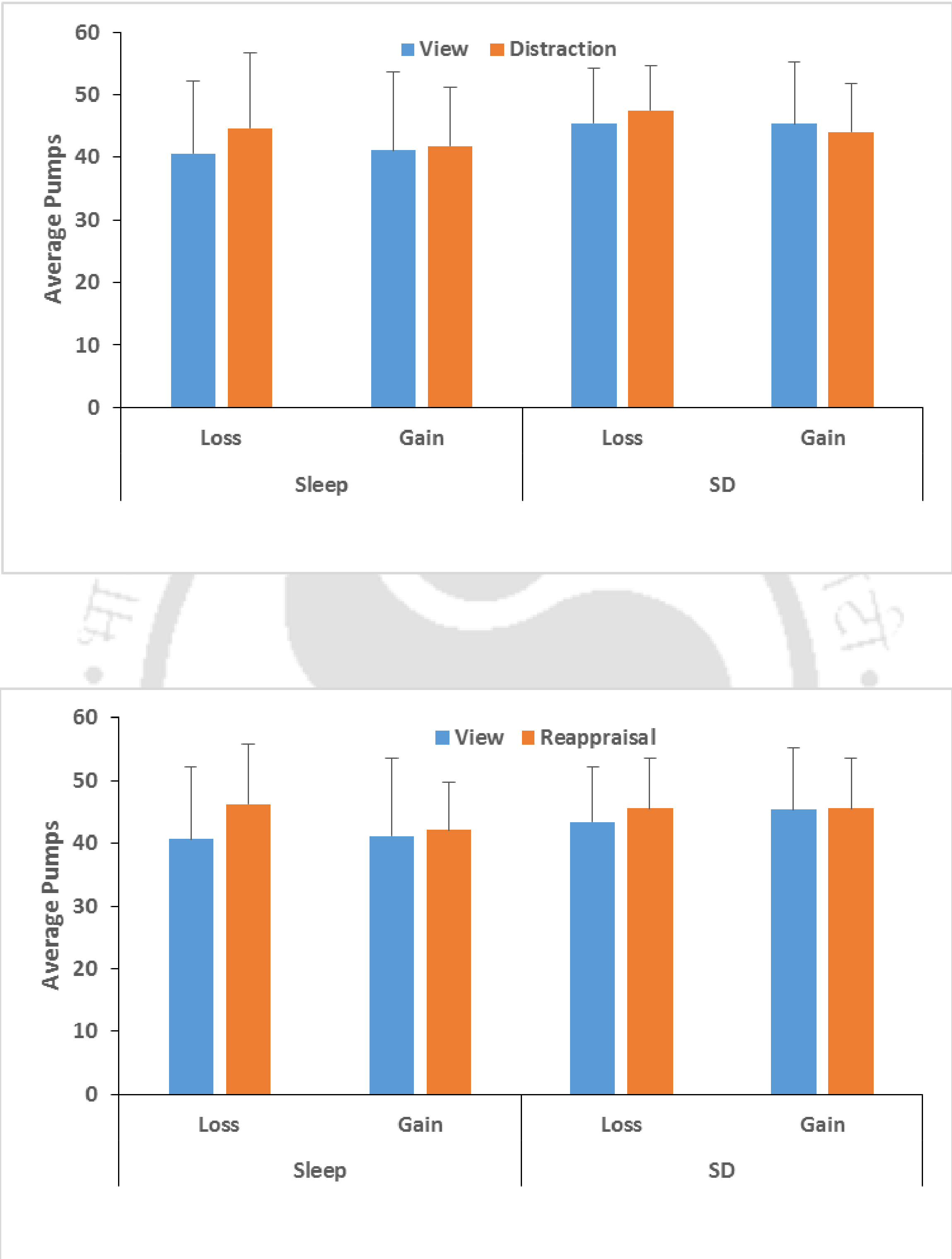
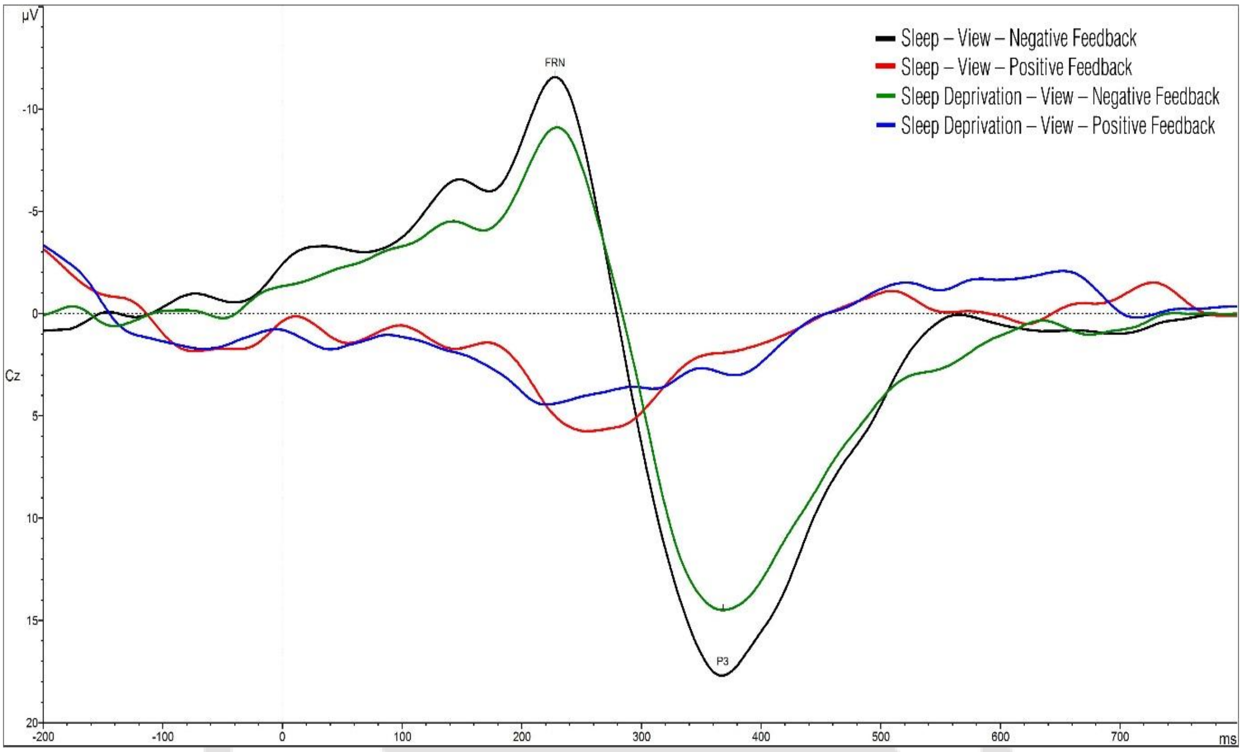
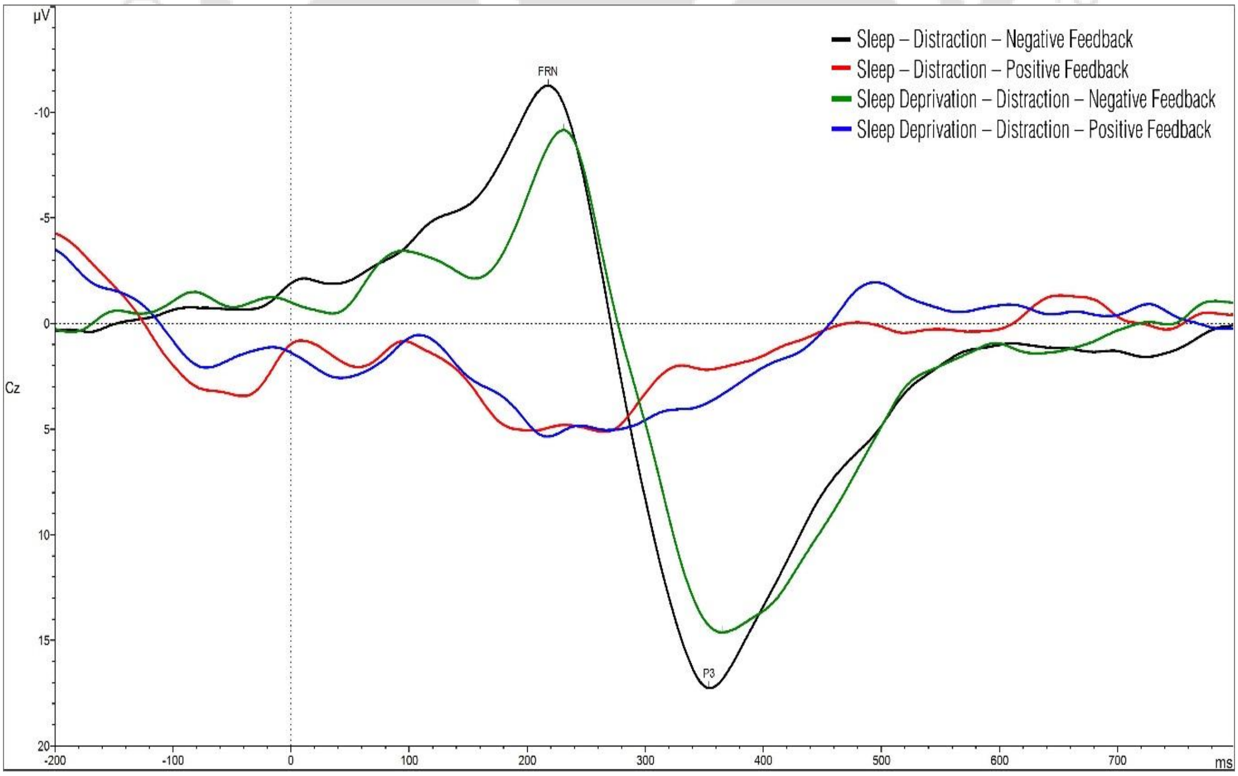


Figure 20 | Average number of Pumps following a loss and gain by sleep condition and emotion regulation strategy.
Data presented as group means ± standard deviation. (A) Emotion view versus distraction (B) Emotion view versus cognitive reappraisal

A **Electrophysiological**



B



C

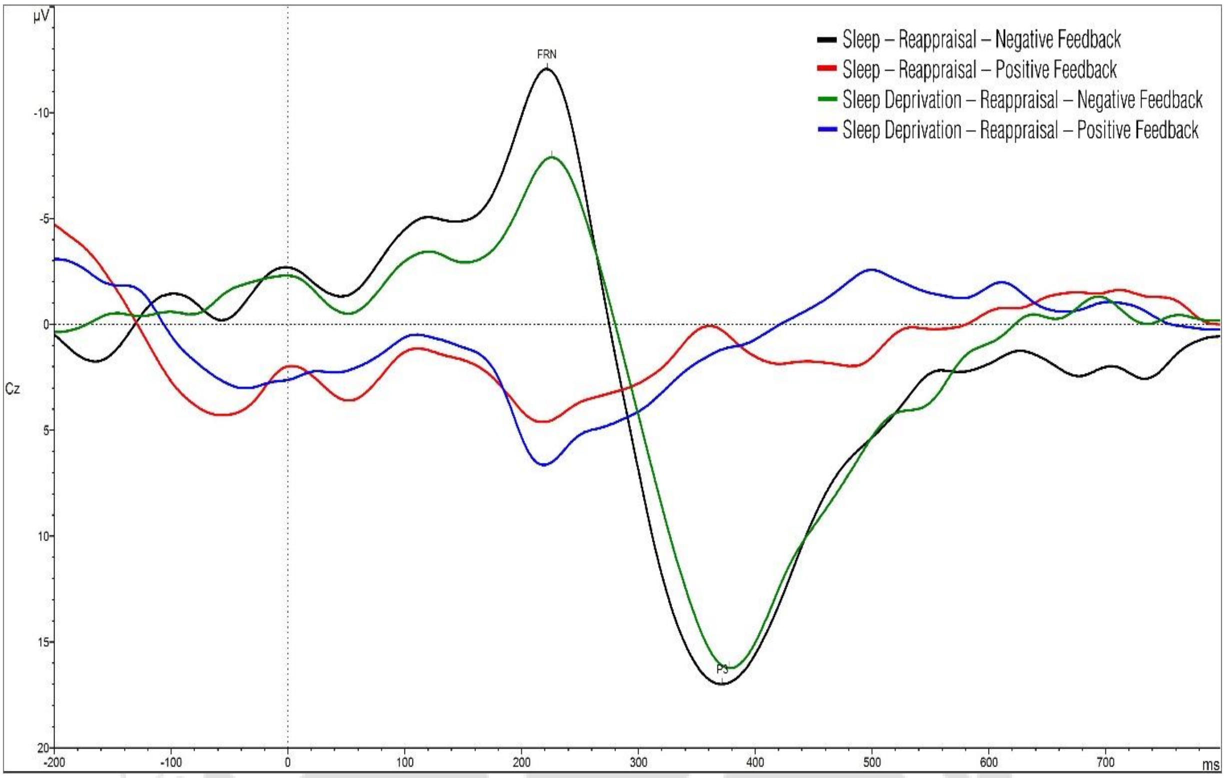


Figure 21 | Represent the stimuli-locked grand average waveforms in Cz electrode evoked by negative feedback (FRN) in the BART. (A) Represent the FRN in emotion view, (B) distraction strategy and (C) cognitive Reappraisal regulated risk taking behaviour across sleep and total sleep deprived condition.

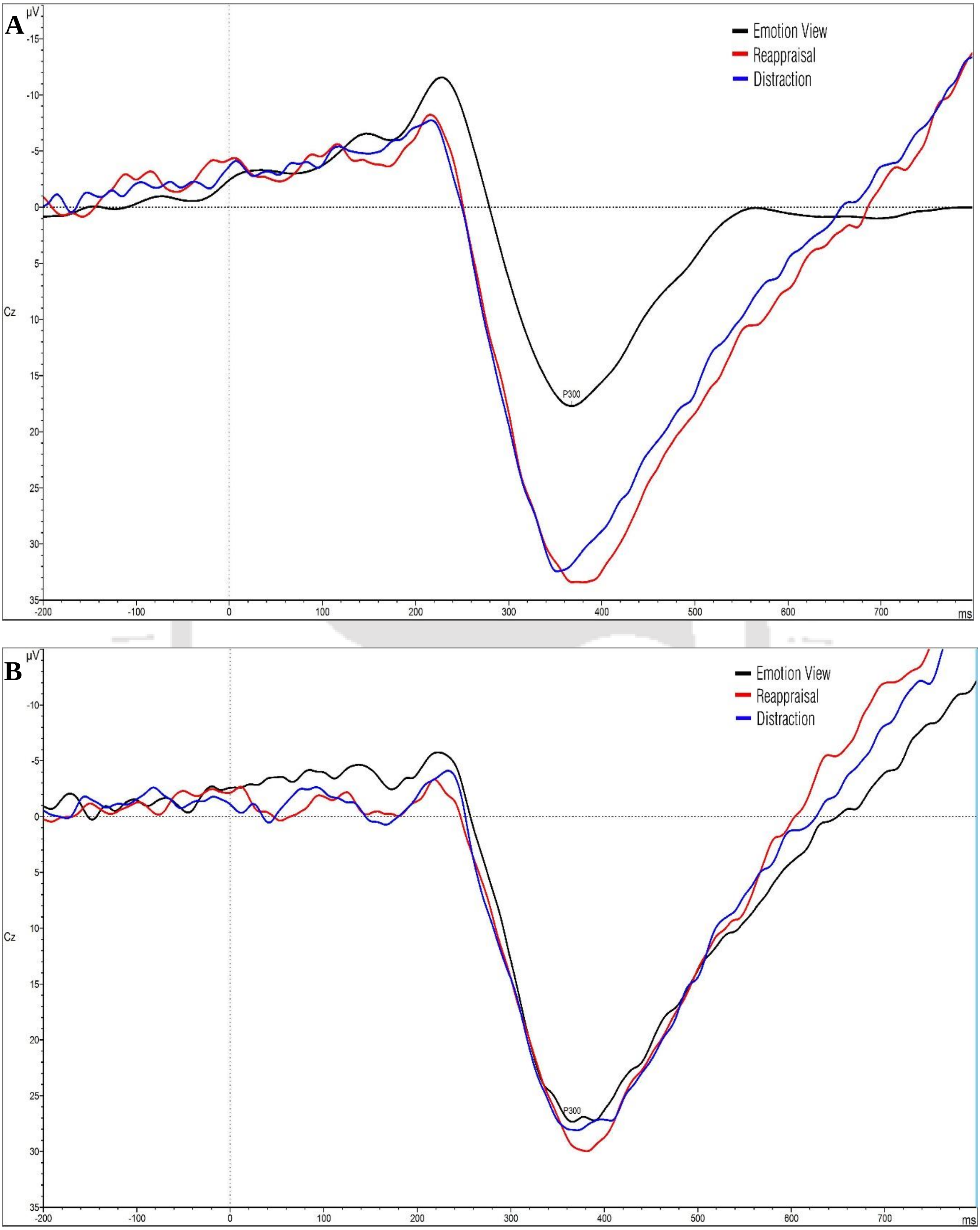


Figure 22| Represent the comparative stimuli-locked grand average waveforms in Cz electrode evoked by P300 in the BART task in all emotion regulation strategies across sleep and sleep deprived condition (A) Represent the P300 in Sleep condition and (B) Sleep deprived condition.

Topographical distribution of the current source density (CSD)

SLEEP-Deprivation_FRN

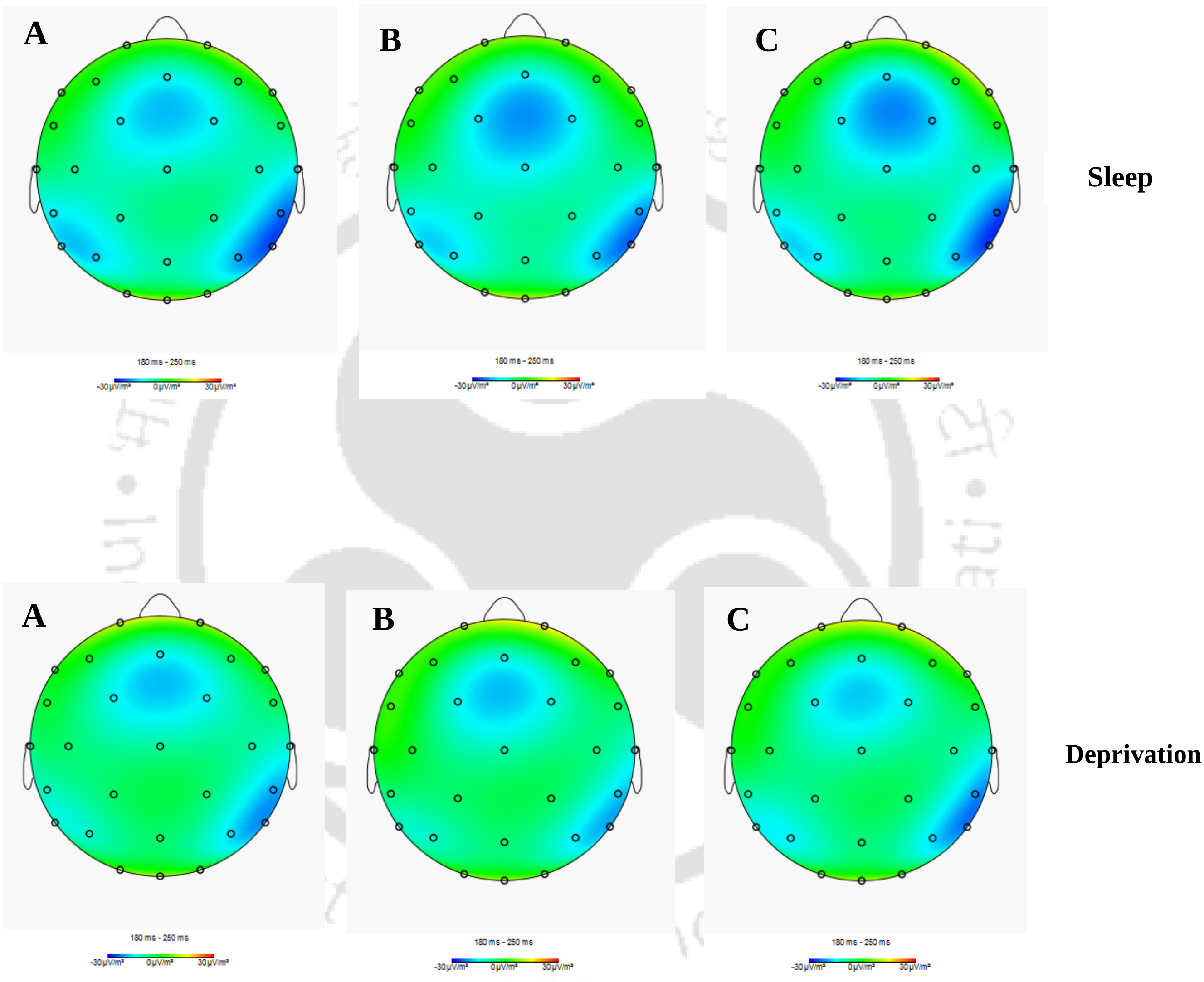


Figure 23 | Represents the topographical distribution of the current source density (CSD) of the FRN (180-250 ms) associated with losses for each affect condition after sleep (upper) and total sleep deprivation (lower) A) Emotion view B) Cognitive Reappraisal C) Distraction

SLEEP-TSD_P300

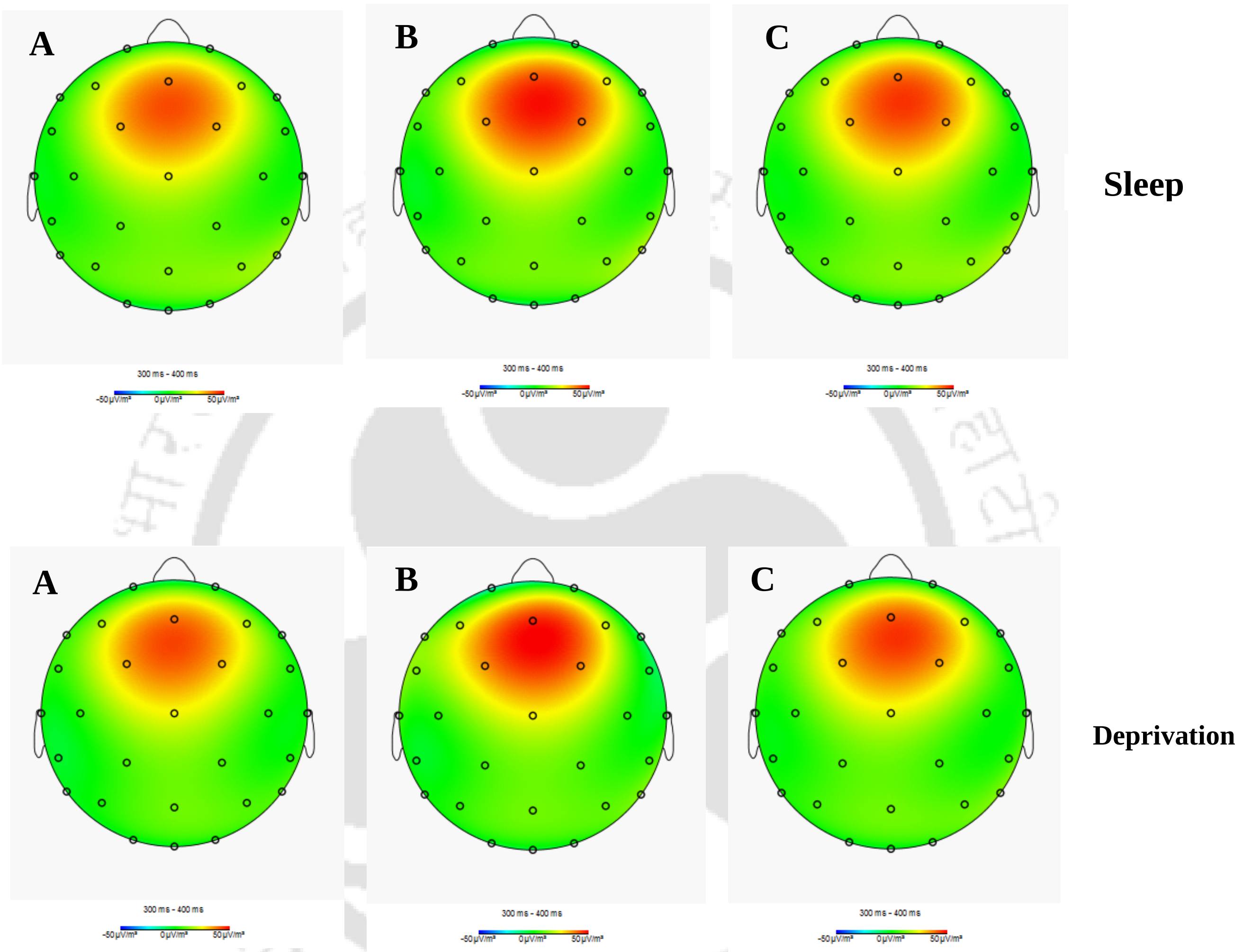


Figure 24 | Represents the topographical distribution of the current source density (CSD) of the P300 (300-400 ms) associated with losses for each affect condition after sleep (upper) and total sleep deprivation (lower) A) Emotion view B) Cognitive Reappraisal C) Distraction

Experiment 3: Assess the role of first half or second half sleep deprivation in affect regulated risky decision making

Table 11: A X B ANOVA Summary Table (Repeated on B) on BART score

Design: 2 Sleep (second half of sleep deprivation/ first half of sleep deprivation) X 2 (Affect: Emotion View, Emotion regulation strategy)

A. Emotion View versus Cognitive Reappraisal

Source	SS	*df*	MS	F	Significance	η^2
A(Sleep)	57.896	1	57.896	.286	.603	.023
Error(between)	2428.798	12	202.400			
B(Affect)	2.355	1	2.355	.044	.838	.004
Error (Within)	643.346	12	53.612			
AB	100.473	1	100.473	1.874	.196	.135

B. Emotion View versus Distraction

Source	SS	*df*	MS	F	Significance	η^2
A(Sleep)	44.269	1	44.269	.230	.640	.019
Error(between)	2307.982	12	192.332			
B(Affect)	.031	1	.031	.001	.978	.000
Error (Within)	464.238	12	38.686			
AB	75.210	1	75.210	1.944	.189	.139

Table. 12 | Mean and SD of FRN amplitude for the first half and second half sleep deprivation

Feedback_FRN	First-half Sleep						Second-half Sleep					
	View		Distraction		Reappraisal		View		Distraction		Reappraisal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Positive												
F_Z	1.68	2.90	5.85	3.88	4.32	6.09	.13	6.26	4.57	7.38	1.20	8.00
C_Z	2.29	1.78	5.19	3.60	3.43	4.62	1.53	4.13	2.57	4.61	1.39	3.79
P_Z	1.38	2.25	3.26	2.56	1.48	3.54	-.11	3.99	.81	5.31	.01	3.20
Negative												
F_Z	-10.60	6.26	-8.67	6.73	-8.10	6.73	-9.81	8.20	-3.43	4.63	-3.43	4.63
C_Z	-12.79	5.84	-11.03	5.42	-9.17	4.26	-13.06	7.60	-8.38	7.88	-8.38	7.88
P_Z	-9.89	3.27	-8.18	3.08	-7.17	2.49	-8.32	5.10	-6.76	4.87	-6.76	4.87

Table. 13 | Mean and SD of P300 amplitude for the first half and second half sleep deprivation

Feedback_P300	First-half Sleep						Second-half Sleep					
	View		Distraction		Reappraisal		View		Distraction		Reappraisal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Positive												
Fz	34.13	26.60	28.73	15.73	16.66	20.85	13.82	24.26	21.86	26.16	15.01	17.02
Cz	25.61	14.11	18.50	12.04	13.46	13.06	11.06	17.08	16.85	17.70	11.10	12.08
Pz	21.32	11.73	17.17	9.06	12.35	10.52	11.44	17.62	14.19	15.48	12.35	10.52
Negative												
Fz	45.69	18.89	45.24	18.60	44.28	16.49	43.96	25.64	58.24	22.01	50.90	18.40
Cz	43.20	18.64	44.05	18.08	44.31	17.61	46.51	16.13	51.57	18.95	49.32	14.82
Pz	33.41	15.80	33.67	14.16	34.29	15.89	31.68	13.87	34.68	16.48	35.47	14.22

Experiment 3: Assess the role of first or second half sleep deprivation in affect regulated risky decision making

Table 14: A X B X C X D Anova Summary Table (Repeated on B, C and D) on FRN amplitude

Design: 2 (Sleep: second half sleep deprivation, first half sleep deprivation) X 2 (Affect: Emotion View, Distraction) X 2 (Feedback: Negative, Positive) X 3 (Electrode Site: Fz, Cz, Pz)

Source_1ST_2ND_FRN _DIST	SS	df	MS	F	Sig.	η2
A (Sleep)	.037	1	.037	.006	.939	.001
Error (Within)	72.093	12	6.008			
B (Affect)	325.234	1	325.234	14.220	**.003**	.542
Error(Within)	274.460	12	22.872			
AC	135.560	1	135.560	1.230	.289	.093
C (Feedback)	5732.396	1	5732.396	51.996	**.000**	.812
Error(Within)	1322.956	12	110.246			
AB	6.385	1	6.385	.279	.607	.023
D (Electrode Site)	78.766	2	39.383	2.907	.074	.195
Error(Within)	325.165	24	13.549			
AD	10.282	2	5.141	.379	.688	.031
BC	2.103	1	2.103	.040	.846	.003
Error(Within)	638.895	12	53.241			
ABC	27.811	1	27.811	.522	.484	.042
CD	152.427	2	76.213	6.528	**.005**	.352
Error(Within)	280.203	24	11.675			
ACD	4.258	2	2.129	.182	.834	.015
BD	52.241	2	26.120	6.818	**.005**	.362
Error(Within)	91.950	24	3.831			
ABD	15.177	2	7.588	1.981	.160	.142
BCD	3.674	2	1.837	.340	.715	.028
Error(Within)	129.764	24	5.407			
ABCD	8.068	2	4.034	.746	.485	.059

Experiment 3: Assess the role of first or second half sleep deprivation in affect regulated risky decision making

Table 15: A X B X C X D ANOVA Summary Table (Repeated on B, C and D) on FRN amplitude

Design: 2 (Sleep: second half sleep deprivation, first half sleep deprivation) X 2 (Affect: Emotion View, Cognitive reappraisal) X 2 (Feedback: Negative, Positive) X 3 (Electrode Site: Fz, Cz, Pz)

Source_FRN_Reapp	SS	df	MS	F	Sig.	η2
A (Sleep)	0.151	1	0.151	.026	.876	.002
Error (Within)	70.710	12	5.893			
B (Affect)	203.594	1	203.594	9.544	**.009**	.443
Error(Within)	255.973	12	21.331			
AB	.263	1	.263	.012	.913	.001
C (Feedback)	4654.688	1	4654.688	42.647	**.000**	.780
Error(Within)	1309.720	12	109.143			
AC	98.701	1	98.701	.904	.360	.070
D (Electrode Site)	45.019	2	22.510	1.440	.257	.107
Error(Within)	375.231	24	15.635			
CD	4.181	2	2.090	.134	.876	.011
BC	79.881	1	79.881	1.535	.239	.113
Error(Within)	624.613	12	52.051			
ABC	12.712	1	12.712	.244	.630	.020
BD	28.913	2	14.457	2.875	.076	.193
Error(Within)	120.701	24	5.029			
ABD	5.536	2	2.768	.550	.584	.044
CD	138.763	2	69.381	4.499	**.022**	.273
Error(Within)	370.078	24	15.420			
ACD	22.147	2	11.073	.718	.498	.056
BCD	4.787	2	2.393	.914	.414	.071
Error(Within)	62.832	24	2.618			
ABCD	19.446	2	9.723	3.714	**.039**	.236

Experiment 3: Assess the role of first or second half sleep deprivation in affect regulated risky decision making

Table 16: A X B X C X D ANOVA Summary Table (Repeated on B, C and D) on P300 amplitude

Design: 2 (Sleep: second half sleep deprivation, first half sleep deprivation) X 2 (Affect: Emotion View, Distraction) X 2 (Feedback: Negative, Positive) X 3 (Electrode Site: Fz, Cz, Pz)

Source_p300_distraction	SS	df	MS	F	Sig.	η2
A(Sleep)	29.484	1	29.484	.293	.598	.024
Error (Within)	1207.325	12	100.610			
B (Affect)	153.376	1	153.376	.280	.606	.023
Error(Within)	6576.839	12	548.070			
AB	880.432	1	880.432	1.606	.229	.118
C (Feedback)	22414.884	1	22414.884	14.312	**.003**	.544
Error(Within)	18794.250	12	1566.187			
AC	1757.772	1	1757.772	1.122	.310	.086
D (Electrode Site)	3970.424	2	1985.212	34.983	**.000**	.745
Error(Within)	1361.938	24	56.747			
AD	53.613	2	26.806	.472	.629	.038
BC	154.957	1	154.957	.559	.469	.044
Error(Within)	3328.729	12	277.394			
ABC	38.919	1	38.919	.140	.715	.012
CD	852.681	2	426.340	6.316	**.006**	.345
Error(Within)	1620.102	24	67.504			
ACD	304.911	2	152.455	2.258	.126	.158
BD	105.473	2	52.736	1.800	.187	.130
Error(Within)	703.258	24	29.302			
ABD	152.024	2	76.012	2.594	.096	.178
BCD	18.929	2	9.465	.198	.822	.016
Error(Within)	1146.772	24	47.782			
ABCD	43.696	2	21.848	.457	.638	.037

Experiment 3: Assess the role of first half or second half sleep deprivation in affect regulated risky decision making

Table 17: A X B X C X D ANOVA Summary Table (Repeated on B, C and D) on P300 amplitude

Design: 2 (Sleep: second half sleep deprivation, first half sleep deprivation) X 2 (Affect: Emotion View, Cognitive reappraisal) X 2 (Feedback: Negative, Positive) X 3 (Electrode Site: Fz, Cz, Pz)

Source_p300_Reapp	SS	df	MS	F	Sig.	η2
A (Sleep)	37.636	1	37.636	.315	.585	.026
Error (Within)	1435.151	12	119.596			
B (Affect)	191.129	1	191.129	.373	.553	.030
Error (Within)	6148.947	12	512.412			
AB	741.469	1	741.469	1.447	.252	.108
C (Feedback)	27666.449	1	27666.449	36.712	**.000**	.754
Error (Within)	9043.284	12	753.607			
AC	1219.994	1	1219.994	1.619	.227	.119
D (Electrode Site)	2673.097	2	1336.548	20.036	**.000**	.625
Error (Within)	1600.961	24	66.707			
AD	31.929	2	15.965	.239	.789	.020
BC	844.747	1	844.747	1.629	.226	.120
Error (Within)	6223.321	12	518.610			
ABC	175.189	1	175.189	.338	.572	.027
CD	759.563	2	379.781	6.242	**.007**	.342
Error (Within)	1460.128	24	60.839			
ACD	106.600	2	53.300	.876	.429	.068
BD	7.504	2	3.752	.102	.904	.008
Error (Within)	886.789	24	36.950			
ABD	145.061	2	72.531	1.963	.162	.141
BCD	19.525	2	9.763	.593	.561	.047
Error (Within)	395.209	24	16.467			
ABCD	26.254	2	13.127	.797	.462	.062

Experiment 3: Assess the role of first half or second half sleep deprivation in affect regulated risky decision making.

Behavioural:

1. **Emotion regulation effectiveness across second half sleep deprivation and first half sleep deprivation:**

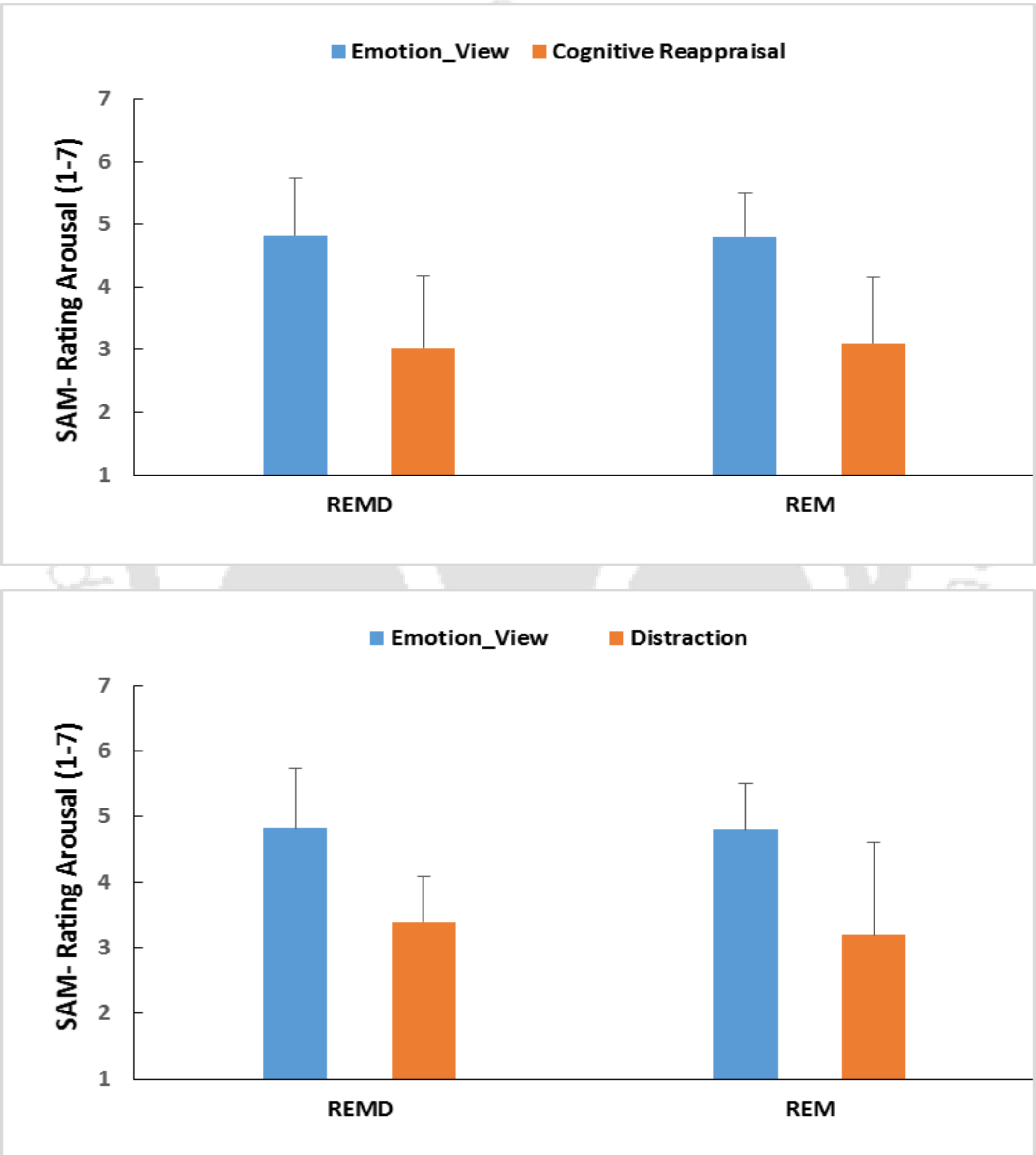
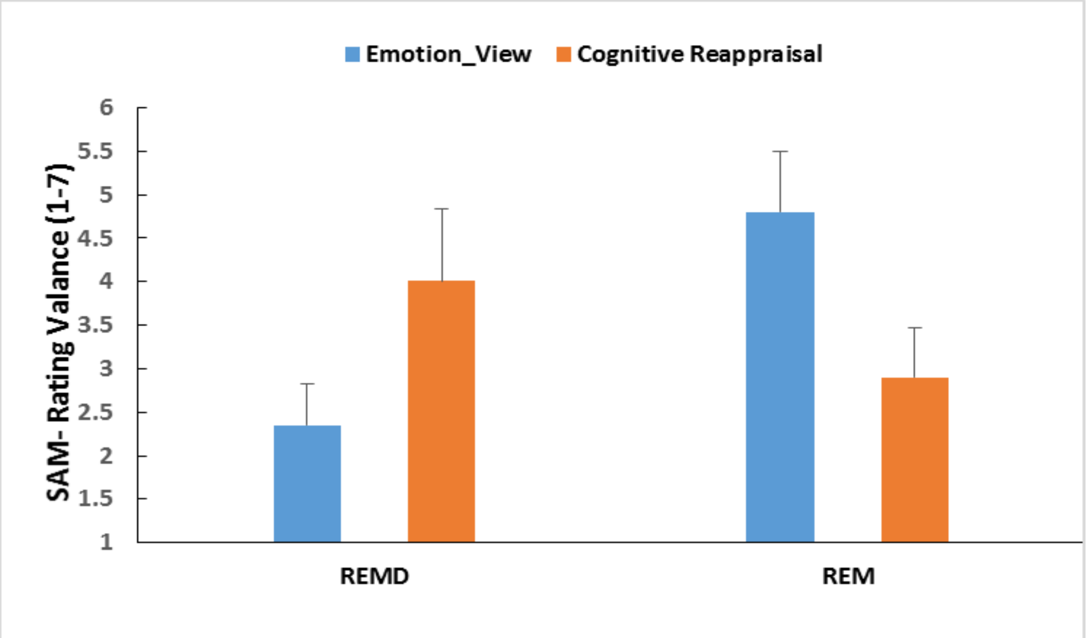


Figure 25 | Arousal rating of Negative Affect by partial sleep condition and type of affect regulation.
Data presented as group means ± standard deviation. Higher ratings present more negative arousal state. (A) Emotion view versus cognitive reappraisal (B) Emotion view versus distraction



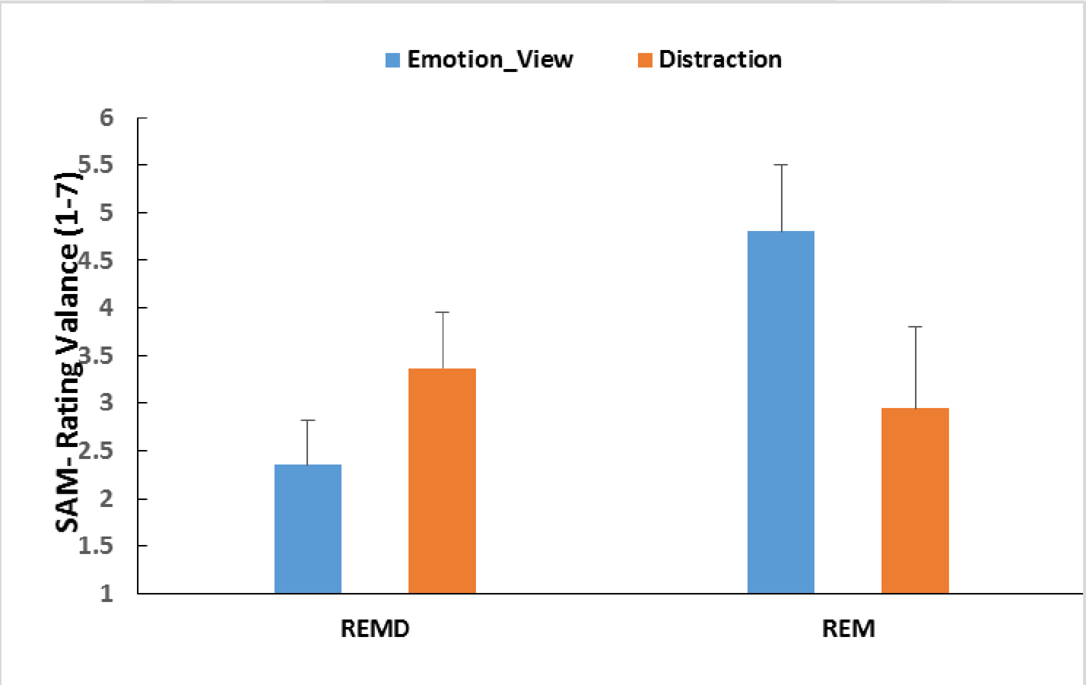


Figure 26 | Valance rating of Negative Affect by partial sleep condition and affect regulation strategy.

Data presented as group means ± standard deviation. Lower ratings present more negative valance state. (A) Emotion view versus cognitive reappraisal (B) Emotion view versus distraction

2. BART- Mean Adjusted No. of Pumps

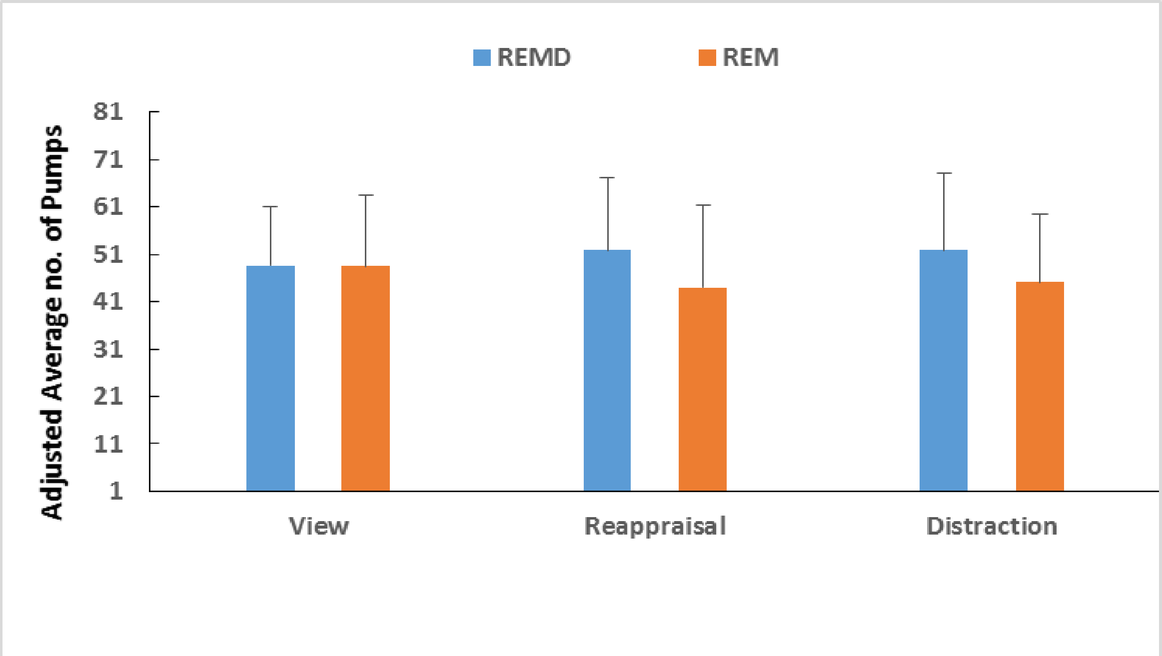


Figure 27 | Mean adjusted number of Pump by partial sleep condition and emotion regulation

Data presented as group means ± standard deviation. Higher value present more risk taking behaviour for emotion view versus distraction and cognitive reappraisal after second half sleep deprivation and first half sleep deprivation.

Sleep Scoring

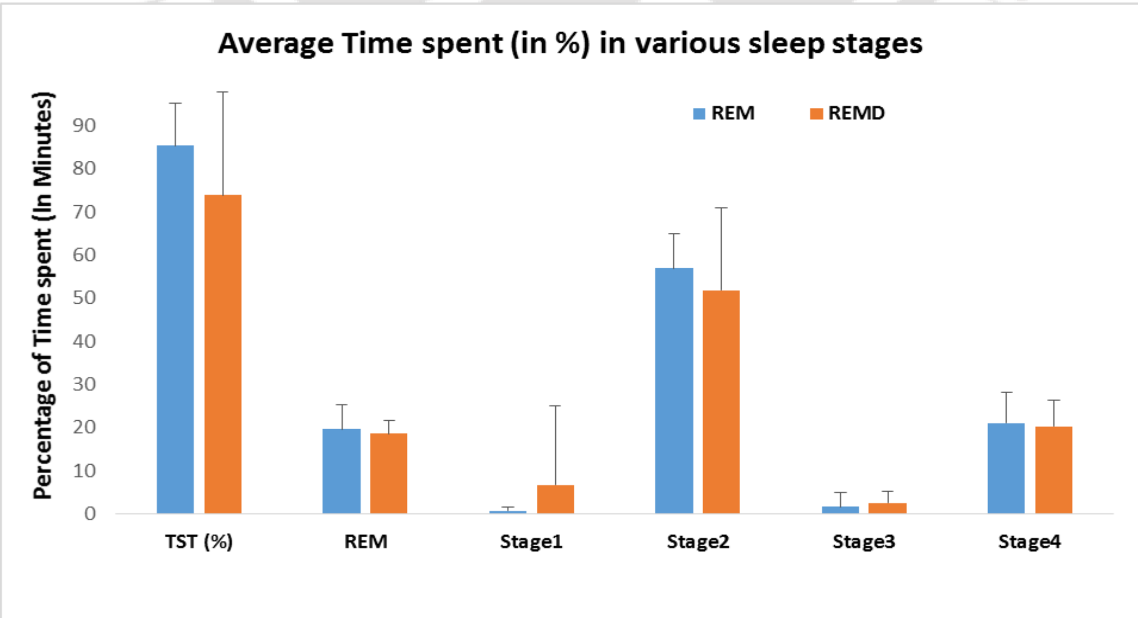


Figure 28 | Represents percentage of sleep stages of participants for first half and second half sleep deprivation.

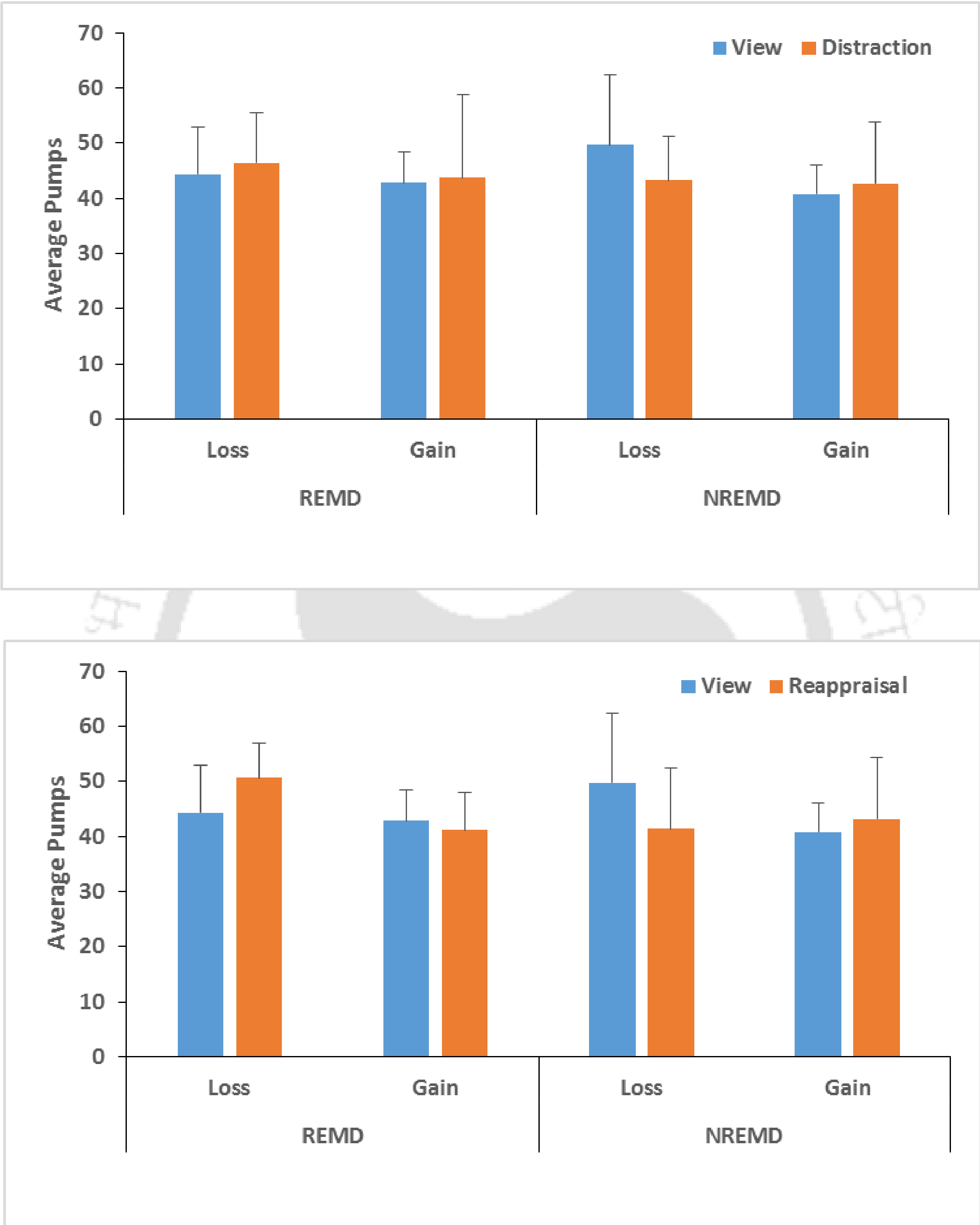
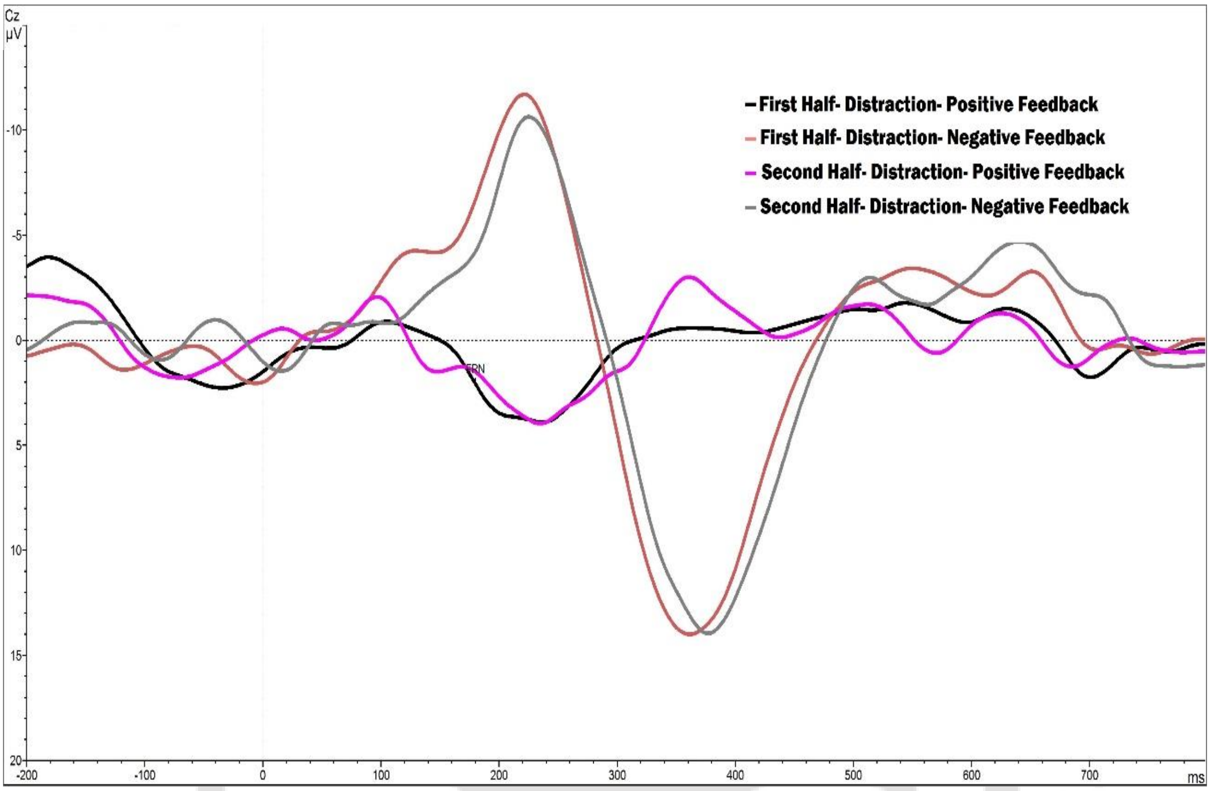


Figure 29 | Average number of Pumps following a loss and gain by sleep condition (second half of sleep deprivation/ first half of sleep deprivation) and emotion regulation strategy.

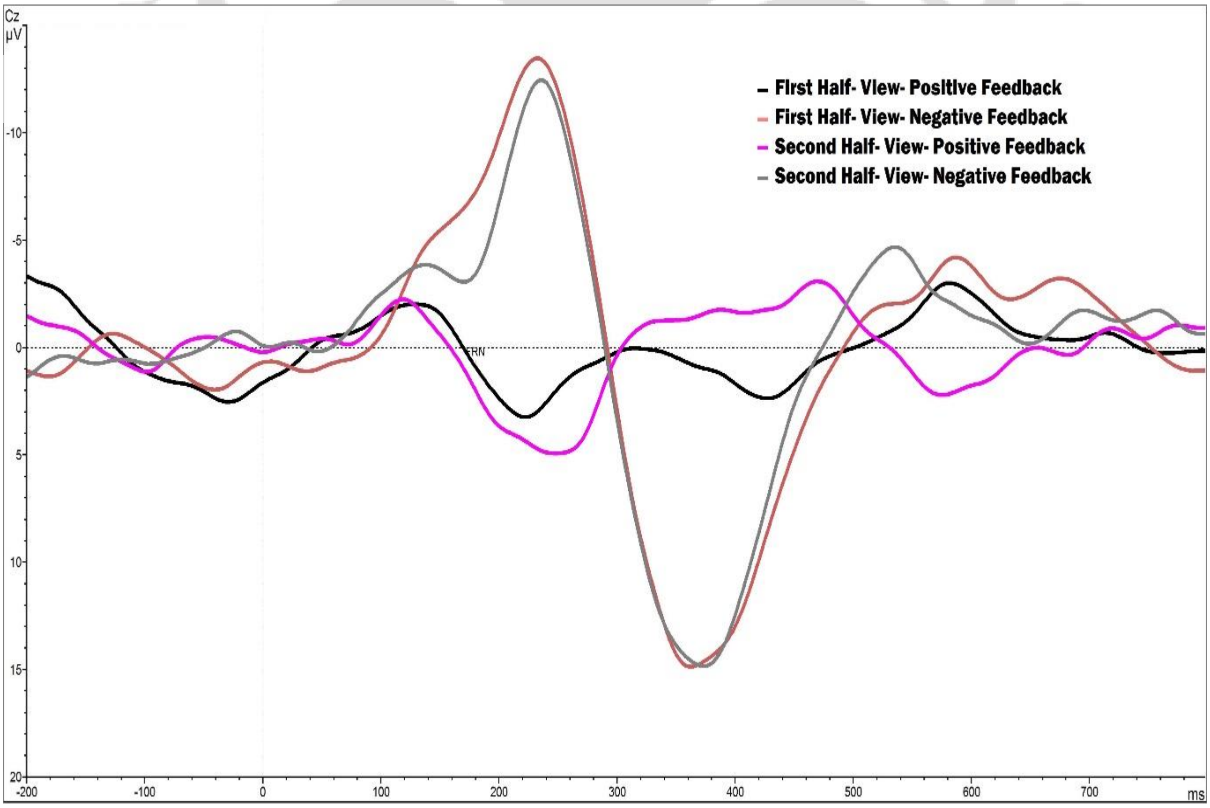
Data presented as group means ± standard deviation. (A) Emotion view versus distraction (B) Emotion view versus cognitive reappraisal

Electrophysiological

A



B



C

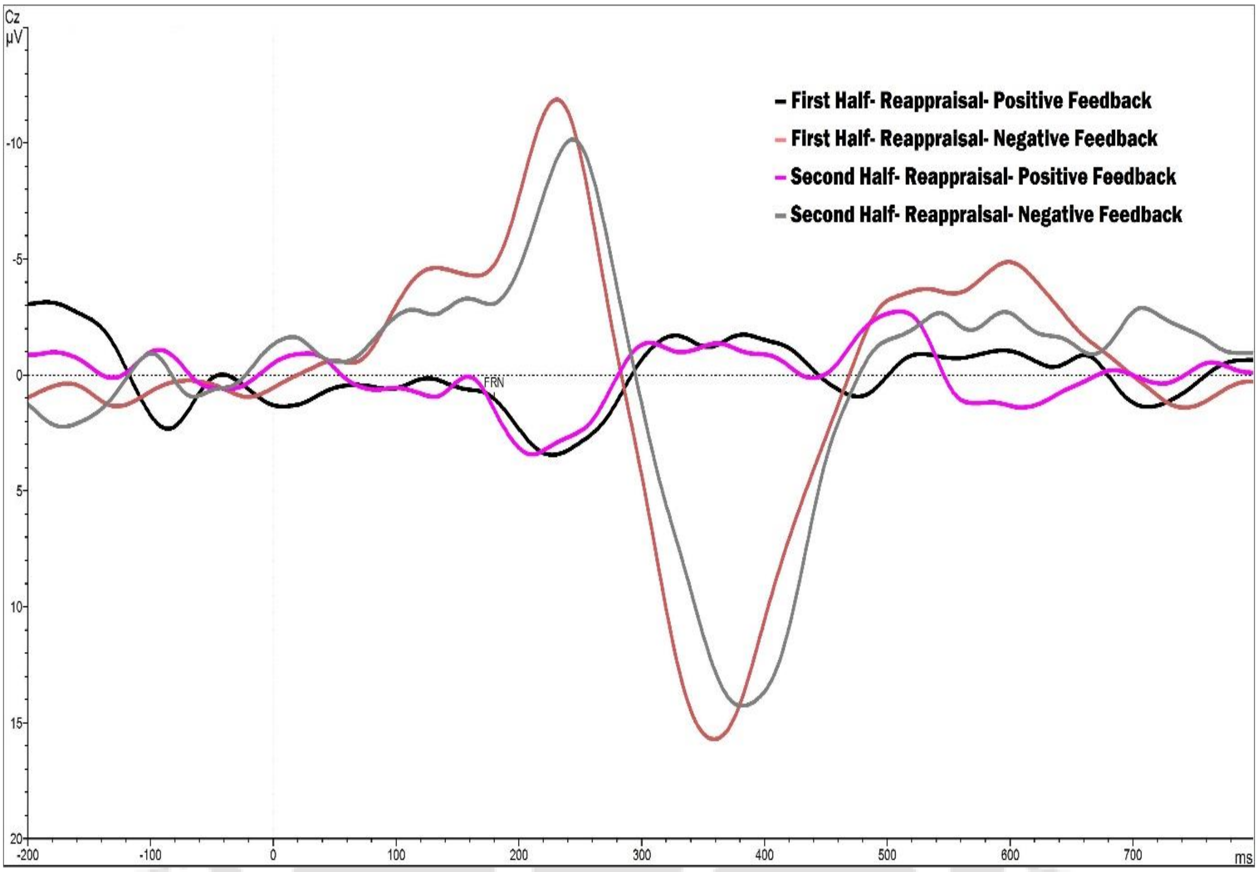
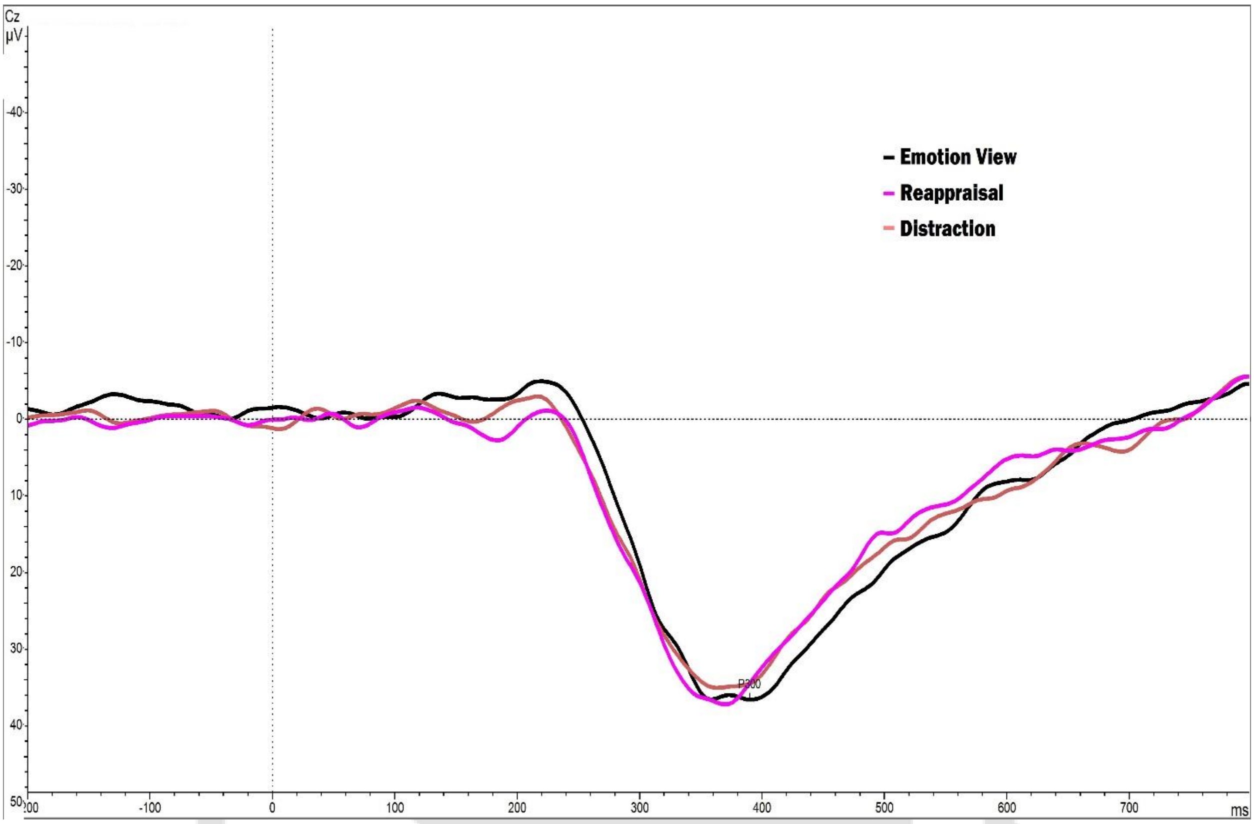


Figure 30 | Represent the stimuli-locked grand average waveforms in Cz electrode evoked by negative feedback (FRN) in the BART. (A) Represent the FRN in emotion view, (B) distraction strategy and (C) cognitive Reappraisal regulated risk taking behaviour across first half and second half sleep deprived condition.

A



B

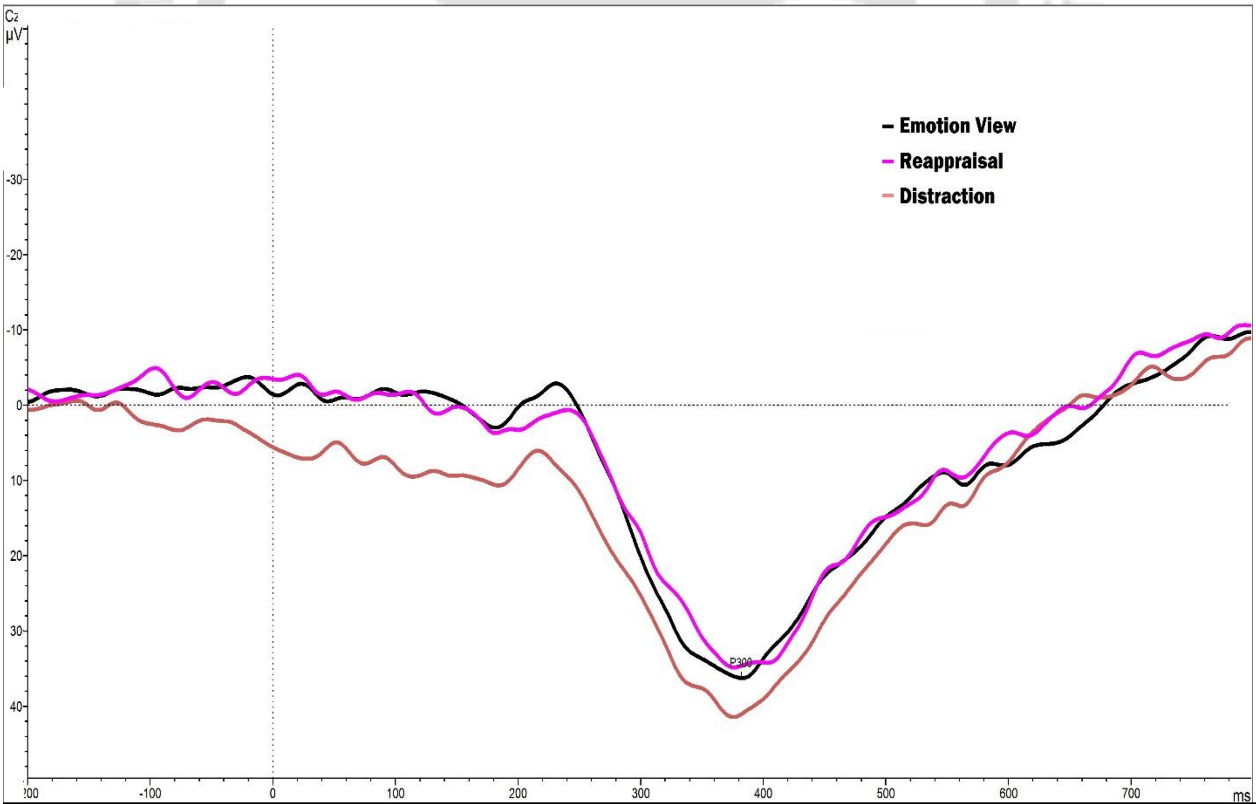
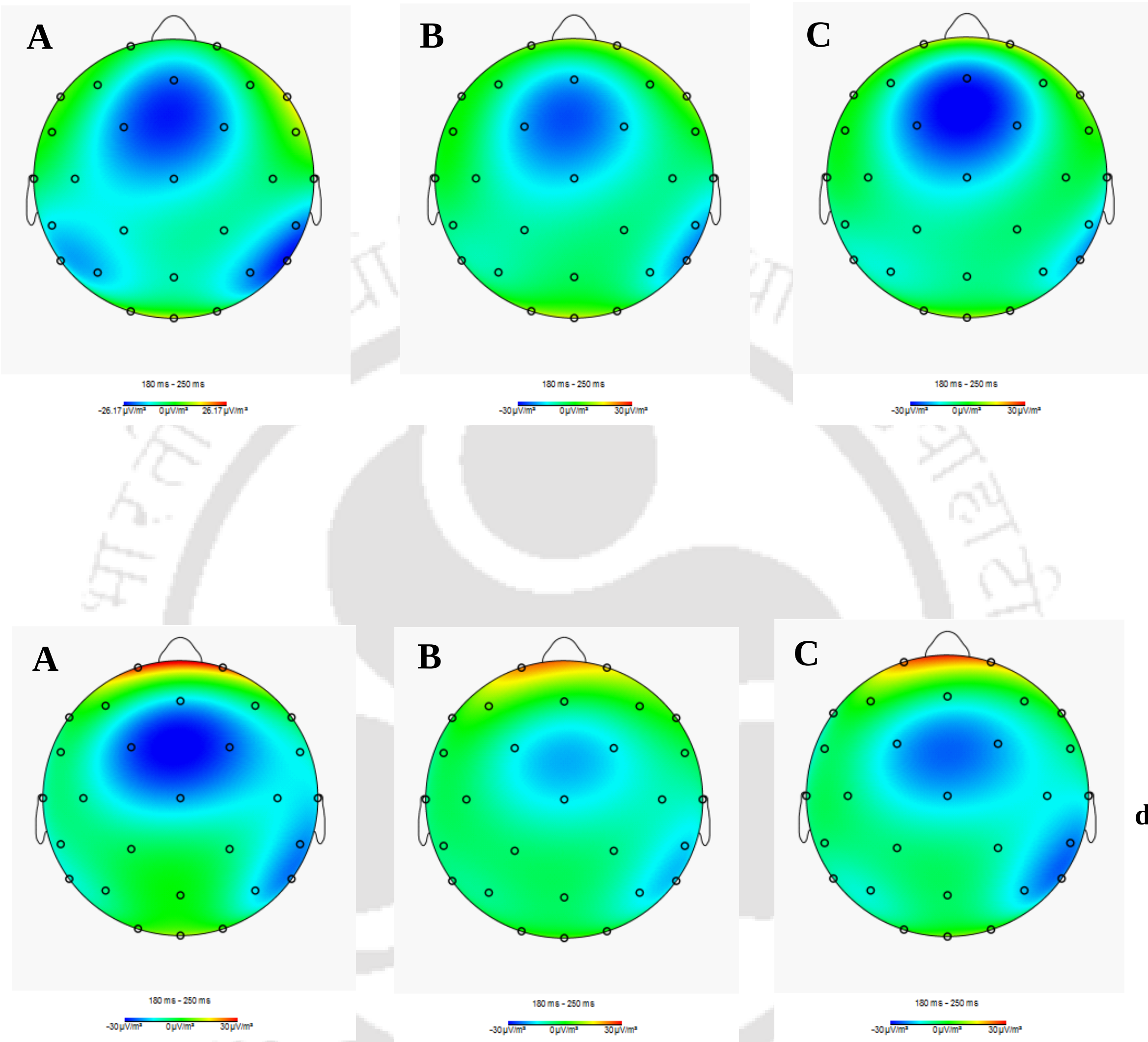


Figure 31 | Represent the comparative stimuli-locked grand average waveforms in Cz electrode evoked by Positive P300 in the BART task in all emotion regulation strategies across second half sleep deprivation and first half sleep deprived condition (A) Represent the P300 in second half sleep deprivation and (B) first half sleep deprived condition.

Topographical distribution of the current source density (CSD)

REMD_NREMD_FRN



Second half sleep deprivation

First half sleep deprivation

Figure 32 | Represents the topographical distribution of the current source density (CSD) of the FRN (180-250 ms) associated with losses for each affect condition after second half sleep deprivation (upper) and first half sleep deprivation (lower) A) Emotion view B) Cognitive Reappraisal C) Distraction

REMD_NREMD_P300

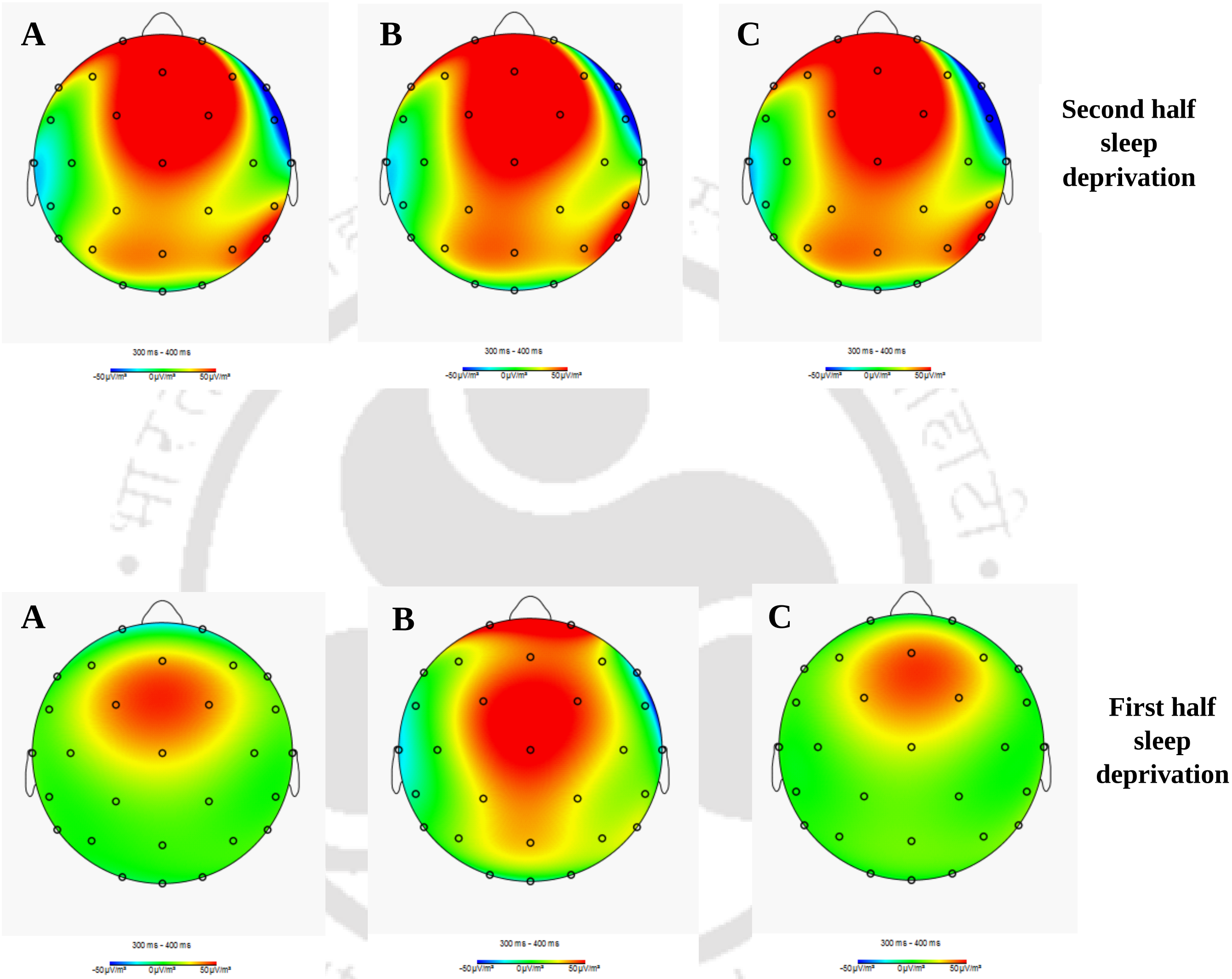


Figure 33 | Represents the topographical distribution of the current source density (CSD) of the P300 (300-400 ms) associated with losses for each affect condition after second half sleep deprivation (upper) and first half sleep deprivation (lower) A) Emotion view B) Cognitive Reappraisal C) Distraction

3.1 Answers to the overall research questions:

The present thesis aims to examine the effect of emotion regulation on risky decision-making. Further, it tries to evaluate how sleep modulates this process. The effectiveness of emotion regulation over emotions was also tested by varying the stimuli inducing emotions (picture/video) and nature of emotions (positive and negative) using the process model of emotion regulation. Effectiveness in this thesis measured how successful a regulatory strategy is at decreasing emotional intensity per unit effort expended. To achieve the objectives outlined the entire thesis was categorized into two parts. The first part of the thesis deals with behavioural experiments where various strategies of emotion regulation are compared based on scores achieved on the self-assessment mannequin and the Balloon Task for risky decision-making. The second part of the thesis examines the role of sleep; total sleep deprivation, second half sleep deprivation and first half sleep deprivation on affect regulated risky decision making as measured by Balloon Analogue Risk Task (BART). Research questions were formulated and tested using laboratory based experimental paradigm to achieve the objectives of the thesis.

The first research question was whether affect regulation strategies differ on processing affect, generated using pictures / videos and to confirm whether the differences extend over processing positive and negative affect. To address this question in experiment one, positive and negative pictures and videos were presented to subjects. Subjects were instructed to either passively view or regulate the emotions induced by the stimuli using specific regulation strategy**.** It was hypothesized that emotion regulation of video stimuli will be better compared to pictorial stimuli. Our hypothesis centred on the fact that compared to static picture and sound, video is the more powerful format for elicitation of emotional states. This is because it can effortlessly stimulate visual and auditory senses simultaneously, thereby multiplying their individual impacts using psychophysiological and neurological underlying mechanisms. The experiment employs, affect (positive, negative) x stimuli (picture, video) x strategies (view/ situation selection/distraction /cognitive reappraisal/ suppression) complete repeated measure design. The dependent variable was Self-Assessment Manikin (SAM) rating of arousal and valance. The result of the study revealed that distraction and cognitive reappraisal were the strategies that significantly regulated positive affect only on the valence dimension. This difference was not evident across both picture and video stimuli. For negative affect too, distraction and cognitive reappraisal effectively regulated negative affect on both arousal and valence dimension. Significant differences favouring picture stimuli in terms of regulation was evident from the experiment. In addition, out of the four-emotion regulation strategies distraction and cognitive reappraisal were found to be the most effective regulation strategies under laboratory condition. One possible reason for differential effectiveness of regulation strategy could be that antecedent-focused strategies divert the emotional trajectory quite early before emotional response tendencies are fully developed, whereas response-focused strategies must overcome a well-developed suite of inter-related emotion processes (Gross, 2001)

The second question of the thesis was whether affect regulation strategies differentially modulate risky decision making on Balloon Analogue Risk Taking (BART) task. To answer this question participant performed on the BART task, after performing emotion regulation task. It was expected that risky choice behaviour (in terms of BART scores) would significantly differ across affect regulation strategies. The result of the experiment revealed significant changes on the BART scores only for the distraction and cognitive reappraisal strategies. Participants in emotion regulation group made less risk aversive behaviour compared to emotion view group. These findings are similar to previous studies using BART that reported that emotion regulation affects decision-making under risk by reducing the experience of emotion (Heilman, R. M., et. al., 2010). We also found that pictorial stimuli were better regulated than video stimuli. A significant carryover effect on emotion regulation resulted in less risk aversive behaviour on decision task for pictorial regulated emotion group.

The third research question was whether sleep/deprivation differentially effect risky decision-making in affect regulating individuals. The third question comprised of two parts. The first part of the question examined whether emotion regulation of negative pictorial stimuli proceeded by one night of sleep/ sleep deprivation has differential ratings on Self-Assessment Manikin (SAM) score dimension. To examine this question self-assessment manikin ratings of arousal and valance were compared across sleep and sleep deprivation for distraction and cognitive reappraisal strategies. In our previous experiment, we compared stimuli type and valance and found negative pictorial stimuli were regulated effectively using extrinsic emotion regulation strategies under laboratory condition also this difference exists only for two emotion regulation strategies: distraction and cognitive reappraisal. The sleep experiments following the above results used negative pictorial stimuli and two emotion regulation strategies: distraction and cognitive reappraisal strategies. Results indicated that distraction emotion regulation strategy led to significant changes in Self-Assessment Manikin ratings across sleep and deprivation but not the cognitive reappraisal strategy. The results indicate that adequate sleep increased executive functioning abilities that are needed for successful emotion regulation. The second part of question was whether sleep and sleep deprivation differentially effect risky decision-making in affect and affect regulating individuals. To address this question in experiment two, participants were invited to sleep laboratory for three nights (adaptation night, experimental nights (sleep/ deprivation). Participants were familiarised with emotion regulation procedure before sleep and were asked to perform the emotion regulation and decision making task the following morning. It was hypothesized that sleep will enhance emotion regulation compared to sleep deprivation and that would lead to less risk aversive behaviour in sleep participants on BART task score. Results of the experiment confirmed our hypothesis showing less risk aversive behaviour in sleep condition compared to total sleep deprivation condition. But only cognitive reappraisal strategy had a carryover effect on risky decision making that successfully reduce the risk aversive behaviour.

The fourth research question was to study the electrophysiological marker of affect-regulated decision making across sleep and sleep deprivation. To examine this question EEG was recorded while performing risky decision-making task (BART) across the sleep and deprivation conditions. Significant FRN and P300 components in the fronto-central region following feedback on BART across sleep/deprivation was found. Both the amplitude and latency of the FRN and feedback related P300 amplitude were modulated by the valance of the outcome. FRN amplitude was larger in response to negative feedback than to positive feedback. These effects were found in previous studies and suggest that overall the task was suitable to elicit robust feedback-related brain potential in the sample. With respect to the sleep effect on feedback processing components, the result revealed larger FRN amplitude in sleep condition in compare to sleep deprivation and these difference present in only cognitive reappraisal strategy across the condition for negative feedback. Larger amplitude of P300 in sleep condition indicates more availability of context updating in working memory which lead to optimized decision making in comparison to sleep deprived condition.

The fifth research question was to assess the role of REM and NREM sleep in affect regulated risky decision-making. The fifth question comprised of two parts. The first part of the question was to examine whether emotion regulation of negative pictorial stimuli had differential ratings of arousal and valance across second half sleep deprivation and first half sleep deprivation condition. To examine this research question the experiment followed a between subject designs with two sleep group: second half sleep deprivation (where participants sleep till 0200h and awake from 0200h to 0700h) and first half sleep deprivation (where participants awake from 2200 to 0200 h and sleep from 0200h to 0700h). After second half of sleep deprivation/ first half of sleep deprivation, subjects completed the emotion behavioural task and Self-Assessment Manikin rating was collected on arousal and valance dimension. The result showed first half sleep deprivation lead to better emotion regulation as compared to second half sleep deprivation for both of the emotion regulation strategies. The second part of question was whether second half of sleep deprivation and first half of sleep deprivation condition differentially effect risky decision-making in affect and affect regulating individuals. To address this question participants were invited to sleep laboratory for three nights (adaptation night, experimental nights (second half of sleep deprivation/ first half of sleep deprivation). It was hypothesized that first half sleep deprivation will enhance emotion regulation compared to second half sleep deprivation and that would lead to more risk aversive behaviour in first half sleep deprivation participants on Balloon Analogue Risk task score. In contrast to our hypothesis, we did not find any significant effect of sleep condition on risky behaviour.

The last research question was to study the electrophysiological marker of affect-regulated decision making across second half of sleep deprivation and first half of sleep deprivation. To examine this research question EEG was recorded while performing a risky decision-making task (BART) across both the condition (second half of sleep deprivation/ first half of sleep deprivation).We found significant FRN and P300 components in the fronto-central region following feedback in a risky decision making task. Both the amplitude and latency of the

FRN and feedback related P300 amplitude were modulated by the valance of the outcome. FRN and P300 amplitude were larger in response to negative feedback than to positive feedback. With respect to the sleep effect on feedback processing components, the result revealed no differences in any emotion regulation strategies across the conditions but there are significant differences in negative feedback processing for control and emotion regulation strategies. Reappraisal strategy of emotion regulation has more prominent negative feedback in comparison of distraction strategy, which indicate increased sensitivity to loss leading to minimum loss and more optimal choices in cognitive reappraisal regulated decision-making. Greater P300 amplitude in first half sleep deprivation condition showed more evaluative process in compare to second half sleep deprivation condition.

3.2 The Findings in relation to previous research

3.2.1 Effectiveness of emotion regulation strategies

3.2.1.1 Emotional valance and emotion regulation

In terms of valence, the results indicated reliably greater emotion regulation for negative over positive valence across both stimuli type, preferentially when stimuli are presented in pictorial mode. Our findings are partially in line with predictions derived from the process model of emotion regulation (Gross, and Thompson, 2007) and with previous studies of emotion regulation, as summarized in a recent meta-analysis (Aldao et al., 2010; Webb et al., 2012). One interpretation of these findings might be that people find it easier to regulate sadness than other forms of emotion, perhaps because this emotion is more frequently encountered and regulated (Wood and Neal, 2007). In contrast, some finding identified that downregulating positive affect is easier than regulating negative affect (Kim and Hamann, 2007; Mak, Hu, Zhang, Xiao and Lee, 2009). Plausible reason could be that these studies targeted very specific emotion i.e. fear, disgust, amusement, in our study we target positive and negative affect in general which suggests that nature of the focal emotion may be an important moderator of the impact of emotion regulation instructions on emotional outcomes (Webb et al., 2012). Further, our result of experiment one showed that downregulation of affect lead to reduce risk aversive behaviour on BART task. Previous studies have shown that happiness reduces risk aversion (Lerner and Keltner, 2001). This view is also supported by the results of the experiment one that showed reduced risk aversion in a condition that involved downregulating of negative emotion. We showed that incidental use of emotion regulation strategies (specifically distraction and reappraisal) to control these negative emotions abolishes their effect on risk aversion. The difference between antecedent and response focused emotion regulation strategies in this condition is the increased effort associated with the latter (Muraven et al., 1998). However, we found no difference in risk taking between the conditions that involved the emotion regulation of positive emotions. The implication is that the differential effectiveness of these emotion regulation strategies in reducing the experience of emotion seems to be the primary mechanism underlying their effects on risk attitudes through emotional (Delgado, Gillis, and Phelps, 2008) or non-emotional route (Leith and Baumeister, 1996; Muraven et al., 1998).

3.2.1.2 Stimuli type and emotion regulation

Looking at the negative stimuli, our results suggest that the film clips were clearly less effective than picture in the effective modulation of negative emotions by extrinsic emotion regulation strategies. This corresponds to the finding, that negative film clips led to lower emotional effectiveness than negative picture in both valance and arousal dimension. Our findings are consistent with previous findings which report that participants were better at regulating their emotional responses to pictures than films or other types of emotion induction method (Webb et. al., 2012). The reason could be that the film clips might have been simply too short. The entire effect of a film evolves during the playing time and peaks at its ending. (Gross and Levenson, 1995; Hewig et al., 2007; Bartolini, 2011). Though a film might cause approximate affect within a single sequence or scene and even within one shot, a strict limitation of a clip length, regardless of its dramaturgic form, might narrow down its emotional power. Recent findings suggest length of film clips effect positively and negatively valence emotion ratings (Bartolini, 2011). A further reason might be that the photographs used show real humans suffering whereas Hollywood films tell fictitious stories, which allows for a greater emotional distance. Another possibility is the potential effect of the novelty of the stimuli on the strength of emotional modulation. Whereas the film clips were largely known to the participants (clips from "Hollywood movies"), IAPS and the additional pictures were typically unknown prior to the presentation. It is known fact that novel or deviant stimuli elicit larger brain responses, like, e.g., the P300 and late sensory components of pain related potentials (Sutton et al., 1965; Legrain et al., 2002). Since these potentials reflect responses to phasic sensory stimuli, other stimuli that contain emotionally relevant content may yield increased responses due to reinforcement mechanisms (Rolls, 1992). According to a meta-analysis review (Webb et.al, 2012), all emotion elicitation method differ on a key dimension which is their personal relevance to the participant. Pictures are more self-relevant than videos/film stimuli. Appraisal theories (Ellsworth and Scherer, 2003) predict that the self-relevance of a stimulus partly determines the intensity of the resulting emotion and thus may influence the effectiveness of the regulation attempt. A recent study (Uhrig, M. K. et. al., 2016) reported that film clips were less effective than pictorial stimuli in producing the corresponding emotional state and were less arousing. Despite all the findings, it is still unclear how the emotion processing is manipulated by nature of stimuli and their neural mechanisms. More work from various aspects and different technological approaches are needed to understand the role of nature of stimuli in the context of affect regulated decision-making.

3.2.2 Emotion regulation strategies and Decision making

Decision-making is essential for everyday functioning. A number of factors moderate decision-making. Research implies that besides cognition, emotion plays a significant role in decision-making. Emotion can effect decision-making either by incidental affect – affect that is unrelated to the decision at hand (Clore, 1992; Lerner and Keltner, 2000; Schwarz, 1990; Lerner, J. S., et al., 2015) or emotion deficits that degrade the quality of decision-making (Damasio, 1994; Wilson et al., 1994). The present thesis supports the notion that incidental emotions (experimentally induced) have an effect on decision-making. This effect can be explained conceptually through the carryover effect of incidental emotions (Bodenhausen, 1993, Loewenstein and Lerner, 2003) which elucidate that *incidental* emotions pervasively carry over from one situation to the next (Han et al., 2007; Keltner and Lerner, 2010; Lerner and Keltner, 2000; Lerner and Tiedens, 2006; Loewenstein and Lerner, 2003; Pham, 2007; Vohs et al., 2007; Yates, 2007). Johnson and Tversky (1983) conducted the first empirical demonstration of incidental affect's influence upon risk perception. In their study, participants read newspaper stories designed to induce positive or negative affect and then estimated fatality frequencies for various potential causes of death (e.g., heart disease). As compared to participants who read positive stories, participants who read negative stories offered pessimistic estimates of fatalities. Surprisingly, the influence of mood on judgment did not depend on the similarity between the content of stories and the content of subsequent judgments. Rather, mood itself affected all judgments.

When humans anticipate or experience an emotion, s/he will often use strategies to control that experience. It follows that emotion regulation, a concept subsuming the processes controlling which emotions we have, when we have them, and how we experience and express them (Gross, 2002), could be crucial to decision making as well as other cognitive processes (e.g., memory; Richards and Gross, 1999, 2000). Recent studies confirm that emotion regulation reduces behavioral loss aversion (Sokol-Hessner et al., 2009, 2012) and the susceptibility to framing (Miu and Crisan, 2011), and promotes optimal decisions (Seo and Barrett, 2007; Heilman et al., 2010). Furthermore, emotion regulation modulates physiological correlates in decision-making (Martin and Delgado, 2011; Sokol-Hessner et al., 2012; Grecucci et al., 2013; Yang et al., 2013), as well as subjective emotional experience to both gains and losses (Yang et al., 2013). Consistent with many previous studies, the result of the experiments indicated emotion regulation as an important variable, which lead to an optimal decision that maximizes gains or minimizes losses in decision making under risk. The thesis attempt to evaluate the differential effect of emotion regulation strategies on risky decision-making. In the context of risk score on BART task, a significant difference was found among all the emotion regulation strategies. These findings suggest that all the emotion regulation strategies differentially modulate the behavioural outcomes that were measured in the present thesis in terms of risk aversion. Antecedent focused emotion regulation strategies act before emotions are activated and response focused emotion regulation strategies act after emotions arise. The process model of emotion regulation (Gross, 2002) that differentiate the emotion regulation strategies in four subtypes: antecedent focussed strategies (situation selection, distraction and cognitive reappraisal) and response focussed strategy (suppression). In this thesis, we use situation selection strategy to see the effectiveness of emotion regulation i.e., how modifying local environment alter its emotional impact on goal directed behaviour. Our results suggest that external stimuli / environment-focused strategy are do not effectively modulate laboratory-induced emotions and carryover effect on goal directed behaviour (risky choice behaviour). It is also possible to regulate emotions without actually changing the environment by using distraction. It refers to how individual direct their attention within a given situation in order to influence their emotions. Distraction strategy in which individual focuses on non-emotional aspect i.e. doing a mathematical calculation to regulate emotions. Thesis result showed that distraction strategy would be able to modulate the emotional aspect of laboratory induced negative emotion and have a carryover effect on a risky decision-making task. Even after a situation has been selected, modified, and selectively attended to, it is still possible to alter its emotional impact by using cognitive reappraisal strategy. Cognitive reappraisal involves evaluating one's present situation and altering its emotional significance, either by changing how s/he thinks about the situation or about their capacity to manage the situation demand. The present thesis evaluates this strategy by asking participants to think using a third person perspective or think in terms of positive outcomes for a negative event. We found that individuals are able to modulate their emotional impact and have a carryover effect on risky decision-making using this strategy. The last strategy is response modulation, which refers to influencing emotion response tendencies after they arise. On the self-report method, we didn't find any significant difference for response modulation strategy, but it had carried over effect on risky decision making and increase risk taking behaviour compared to control condition.

These results of our thesis are in line of previous findings, which showed antecedent focused emotion regulation strategies are superior strategy for dissipating the emotional response (Gross, 2002). Attempting to avoid feeling an emotion will typically reduce one's expressive behaviour but have little or no impact on one's subjective experience of the emotion (Gross and Levenson, 1993). Indeed, physiological reactions to suppression are often mixed and frequently deleterious (Gross, 2002; Gross and Levenson, 1993). Specifically, attempts at suppression are cognitively costly, impairing memory for details of what triggered the emotion (Richards and Gross, 1999). Reframing the meaning of stimuli that led to an emotional response (i.e., reappraisal), includes such behaviours as reminding oneself "it's just a test" after receiving a poor exam grade, adopting the mindset of a medical professional to minimize emotional impact of viewing someone's injury, or viewing a job layoff as an opportunity to pursue long forgotten dreams (Gross, 1998, 2002). In contrast to suppression, reappraisal not only reduces self-reported negative feelings in response to negative events but also mitigates physiological and neural responses to those events (Jamieson et al., 2012, Ochsner et al., 2002). Those who employ strategic reappraisal typically have more positive emotional experiences (Gross and John, 2003) and show fewer incidences of psychopathology (Aldao et al., 2010). Halperin et al., (2013) examined the responses of Israelis to the recent Palestinian bid for United Nations recognition. Participants who were randomly assigned to a reappraisal training condition (compared with a control condition) showed greater support for conciliatory policies and less support for aggressive policies toward Palestinians at planned assessments both one week later and five months later (Halperin et al., 2013).

We used Balloon Analogue Risk Task (BART; Lejuez et al., 2002) to evaluate the risky choice behaviour of individuals. BART is a computer-based measure of risk taking, in which participants can earn financial rewards by pumping balloons presented on a screen; different balloons have variable explosion points, and once a balloon explodes, the money deposited for pumping that balloon is lost (Lejuez et al., 2002). Previous studies showed that negative emotions such as anxiety increase risk aversion in BART (Maner et al., 2007) and impair decision-making optimization in IGT (Miu, Heilman, et al., 2008; Preston et al., 2007). Experimentally induced and naturally, occurring fear is also associated with risk aversion and pessimistic risk appraisals (Lerner and Keltner, 2001; Gasper and Clore, 1998; Miu, Miclea, and Houser, 2008; Sto¨ber, 1997). The magnitude of risk aversion induced by negative emotion in the present thesis (the emotion view condition in experiment 1) was similar to that reported in previous studies using BART (Maner et al., 2007). By effectively downregulating the experience of negative emotions, reappraisal contributes to an increased sense of emotional control that mitigates aversion to risky decisions. This interpretation accords well with previous results suggesting that the appraisal of control mediates the relationship between emotions and risk taking (Lerner and Keltner, 2001). In contrast to reappraisal, suppression is ineffective in reducing the experience of negative emotions. Consequently, risk attitudes among suppressors are not changed in relation to those experiencing negative emotions but not using emotion regulation strategies. Focusing on the ego-depleting capacity of self-regulation, several studies have argued that bad moods increase risk aversion, and the suppression of these moods may augment this effect (Leith and Baumeister, 1996; Muraven et al., 1998). However, these studies have focused on emotions (e.g., embarrassment) that differ in important dimensions of appraisal (e.g., control) and sometimes failed to induce bad moods that significantly differ from neutral moods (Leith and Baumeister, 1996). Our results offer compelling evidence that expressive suppression cannot mitigate risk aversion induced by negative emotions because it cannot decrease the experience of these emotions.

The results of the present thesis can also be expressed in terms of cognitive neuroscience and neuroeconomics. Several studies offer convergent evidence on the key role played by ventromedial prefrontal cortex (VMPFC) in reappraisal (Banks, Eddy, Angstadt, Nathan, and Phan, 2007; Goldin, McRae, Ramel, and Gross, 2008; Wager, Davidson, Hughes, Lindquist, and Ochsner, 2008). The functional connectivity between VMPFC and amygdala (Banks et al., 2007; Goldin et al., 2008), insula (Goldin et al., 2008), as well as nucleus accumbens (Wager et al., 2008) is perhaps connected to the success of reappraisal in reducing experienced emotions. It is intriguing that functional neuroimaging studies have shown that the recruitment of VMPFC is also central in BART performance (Northoff et al., 2006). Indeed, its failure may result in altered risk taking that characterizes the performance of patients with substance dependence or gambling problems (Tanabe et al., 2007). Further evidence suggests that reappraisal may increase the efficacy of emotion– cognition "brain hubs" (Pessoa, 2008), such as prefrontal–amygdala and prefrontal–mesolimbic, circuits that support optimal decision making under risk and uncertainty. In particular, the insula and basal ganglia may be specifically involved in the anticipation of outcomes in IGT (Lin, Chiu, Cheng, and Hsieh, 2008), and voluntary risk taking in BART is believed to involve the activation of a frontal–mesolimbic pathway (Rao, Korczykowski, Pluta, Hoang, and Detre, 2008).

Considering the self-report method, prior work is mixed with respect to the question of which strategy more effectively down-regulates negative affect. Our results showed that cognitive reappraisal strategy is most effective to reduce risk aversive behaviour in comparison to distraction and other strategies. Some study reported that both strategies are effective at down-regulating emotions (Sheppes and Meiran, 2007). A study of everyday strategy use found that distraction was rated as less effective than reappraisal (Totterdell and Parkinson, 1999), a finding that in line with our results showing that distraction is less effective than cognitive reappraisal for downregulating depressive affect (Kross and Ayduk, 2008). The inconsistent effects of distraction on self-reports of emotional responding may be due to the variation in the types of distracting tasks used. Overall, our findings dovetail with prior work, suggesting that reappraisal is one of the most effective ways to down-regulate self-reported negative affect, which lead to reduce risk aversive behaviour. The present findings are in line with the results from Sheppes et al. (2011), which showed that, in low intensity-negative situations, reappraisal is preferred over distraction followed by suppression (Sheppes et al., 2011).

3.2.3 Sleep and Emotion Regulation: Effect on risky Decision-making

Previous findings suggested that the ability to regulate one's emotion serves as a key link in the relationship between poor sleep and mood disturbance. First, disturbed sleep disrupts higher cognitive functions such as cognitive control (Goel, Rao, Durmer, and Dinges, 2009; Tucker, Whitney, Belenky, Hinson, and Van Dongen, 2010) which support effective types of emotion regulation. In addition, in experimental studies participants who have been deprived of sleep (compared to control participants) subsequently exhibit reduced functional connectivity between brain regions responsible for cognitive control (medial prefrontal areas) and emotional responses (amygdala) while viewing negative emotional pictures (Yoo, Gujar, Hu, Jolesz, and Walker, 2007). This decreased connectivity is consistent with decreased emotion-regulatory control by prefrontal brain areas (Ochsner and Gross, 2005). These findings are in line with the idea that poor sleep may disrupt people's ability to regulate emotion-using strategies.

In the present thesis, emotion regulation ability was accessed after one night of undisturbed sleep/deprivation. Results of the experimental manipulation showed better emotion regulation in sleep condition compared to sleep deprivation condition for both emotion regulation strategies (distraction and reappraisal). The results can be supported by two main theoretical viewpoints, which have been proposed to explain the beneficial effect of sleep on emotion regulation. According to physiological perspective, emotion regulation process involves interaction between regions of prefrontal cortex that implement control processes and subcortical regions that encode and represent specific kind of information. By increasing and decreasing activation of particular representations, prefrontal regions enable an individual to selectively use executive functions to attend to and maintain goal-relevant information in mind (Knight et. al., 1999; Miller et.al., 2001; Smith et.al., 1999). The impacts of sleep and sleep loss on these brain circuits have been demonstrated in numerous studies (Harrison Y et. al., 2000, 1998; Horne J A., 1988; Gruber, R., et. al., 2014). Second perspective from the cognitive-energy model; suggest that sleep induced changes in energetic supplies required for self-regulation, which further influence emotional reactions (Zohar et al., 2005). These notions state that sleep influence emotion regulation ability by maintaining the functional integrity of the PFC-amygdala circuit and induced energetic supplies for better emotion regulation. Although the nature of emotion regulation strategy could contribute to the effectiveness of emotion regulation, sleep additionally improves this process by resetting the brain circuits to optimal levels of performance that helps in countering new emotional challenges. In the context of emotion processing, studies suggest that the associations between emotion and sleep are complex and bidirectional. That is, poor sleep may adversely affect emotional well-being, and conversely, certain emotions may lead to compromised sleep (Kahn, Sheppes and Sadeh, 2013). In line with the previous research results, the present thesis also indicates a beneficial effect of sleep over sleep deprivation, which is supported by a number of studies that suggest a beneficial impact of sleep on emotion regulation. For instance, Mauss et al., (2013) conducted a laboratory study to investigate the relationship between sleep quality and performance on a cognitive reappraisal task. The result indicated that participant who reported poor sleep quality performed worse on the cognitive reappraisal task in comparison to who reported adequate sleep quality. Another study by Batool-Anwar, S. et al., (2014) investigated the effect of partial sleep deprivation (4-hour sleep per night) on a psychomotor vigilance task. Following a night of partial sleep deprivation, participants responded slower and facial expression to emotional stimuli were decelerated. There are substantial evidences to indicate that adequate sleep play role in driving the executive functioning abilities necessary for successful emotional regulation.

In terms of specific emotion regulation strategy, we did not find a significant difference among strategies on a self-reported measure of arousal but there is a significant difference on valance dimension of emotion for distraction strategy. These results can be explained through the underlying mechanism and use of cognitive resources in individual strategy. Distraction involves replacing existing emotional information with independent neutral information. Incoming emotional information competes with emotion-regulatory processes at an early processing stage (before stimuli are represented in working memory) for further semantic evaluation. In reappraisal, existing and incoming emotional information are modified via a dependent neutral reinterpretation and a semantic conflict exists between the emotion generative and emotion regulatory representations. That is, reappraisal requires increased cognitive resources to operate (Gal Sheppes and Gross J. J., 2012). Although Distraction strategy lead to better emotion regulation after a full night sleep in compare to cognitive reappraisal but it failed to show its impact on risk aversive behaviour in BART task which was performed immediately after the emotion regulation task. The result of the experiment showed that participants after following cognitive reappraisal strategy showed less risk aversive behaviour in BART Task, in contrast to the condition when participant followed distraction strategy. According to Sheppes and Gross J. J., (2012), early selection strategy like distraction is likely to offer short term relief at a long term cost, because in distraction the affective meaning is blocked from processing and it does not allow elaborated processing and consequential understanding of the emotional event. At the same time, late selection regulation strategy like reappraisal have short-term cost but facilitate long term adaptation, because it involves attending an emotional event and understanding it (Campbell-Sills and Barlow, 2007).

One major objective of the current thesis was to examine shifts in risk taking as a function of monetary decision making while actively regulating emotions (distraction and appraisal) generated from active pictures. Results on BART task showed successful use of cognitive strategies can foster more goal-directed behaviour and promote safer, compared with riskier, decision-making. Findings are in line with previous findings which showed that instructing participants to reappraise significantly reduces the unpleasant experience of the emotions and consequently promotes risky decision making (or decreases risk aversion) in relation to both a control group as well as a group using distraction. Additionally, this finding is in agreement with a study that found that habitual use of reappraisal was associated with increased risk-taking and reduced sensitivity to changes in probability resulting in losses on cognitive risk-taking task (Panno et al., 2013). This is in slight contrast with recent studies that suggest the successful use of emotion regulation can lead to reduce loss aversion (Sokol-Hessner et al., 2009) and maximization of rewards (Seo and Barrett, 2007). Martin, L (2014) suggest reappraisals that heightened the perceived importance of the next decision (Emphasize) decreased risk-taking, whereas reappraisals that reduced the perceived significance of the next decision (Deemphasize) increased risk-taking (Martin L, 2014). One potential difference between these studies are in terms of the methodologies used for conducting research. For instance, the strategy used by Sokol-Hessner et al., (2009) was focused on the particular task at hand, asking participants to place less weight on the outcome of a single decision rather than thinking of it as a series of decisions (e.g., an investor's portfolio). In the current experiment, we tested distraction and reappraisal strategies (previously shown to be successful in attenuating the physiological and neural correlates of induced negative affect (Delgado, Nearing, et al., 2008; McRae et al., 2010) and their carry over effect on risky decision making (Renata M. Heilman, 2010). Although both strategies can be considered a form of cognitive control, they might exert different influences in the underlying neural circuitry, as observed in studies comparing reappraisal and distraction strategies during negative emotions (McRae et al., 2010; Kalisch, Wiech, Herrmann, and Dolan, 2006), that could cause different effects in behavior.

3.2.4 Emotion regulation and Partial Sleep: Effect on risky decision-making

In the previous experiment, the role of sleep was tested on affect regulated decision-making. Research on sleep and emotion reveal that sleep-emotion complex is differentially effected by the stages of sleep (NREM and REM). Considering results from previous sleep-emotion research we decided to test the effect of sleep stages on affect regulated decision-making. Following previous results from sleep research, we deprived subjects of sleep for either for first half or second half of the night sleep. We did because research results suggest that the first half of the night mainly comprises non-rapid eye movement sleep (NREM) and second half of sleep comprises rapid eye movement (REM) sleep. REM sleep, in particular, may promote the regulation of affective processes and optimize waking emotional functioning (Martin D., 2011). Our thesis result showed non-rapid eye moment sleep deprivation (first half sleep deprivation) lead to better emotion regulation in compare to rapid eye moment sleep deprivation (second half sleep deprivation) condition for both the emotion regulation strategies, however, reappraisal strategy was more effective as compared to distraction. The results could be supported by two main theories, which have been proposed to explain the beneficial effect of REM sleep to provide optimal homeostasis for emotion regulation. These theories suggested that reduction in aminergic activity and reactivation of limbic anatomy during REM (Hobson and Pace-Schott 2002) may offer an ideal neurobiological medium which depotentiate prior negative experiences and restores optimal post-sleep affective reactivity (Levin and Nielsen, 2009; Walker, 2009a, 2009b; Walker and van der Helm, 2009). Results are also in support of study by Rosales-Lagarde A., (2012) which emphasized the role of REM sleep in optimizing brain processes needed for successful emotion regulation. Gujar et al., (2011) showed that participants demonstrate enhanced reactions to negative stimuli as homeostatic pressure accumulated throughout the day. They also reported that participant who took an intervening nap were able to reverse such emotional reactivity to negative stimuli. Interestingly, participants who reached REM stage during nap reported the enhancing emotional reactivity effect. In terms of specific emotion regulation strategy, we found that reappraisal strategy lead to better emotion regulation. The plausible reason could be the mechanism underlying emotion processing for both strategies. According to information process theories, people have limited cognitive capacity to execute mental operations (Pashler, 1998). This constraint dictates continuous competition between different sources of information for dominance, and REM plays significant role in source availability for further information processing. In reappraisal, existing and incoming emotional information is modified via a dependent neutral reinterpretation and a semantic conflict exists between the emotion-generative and emotion regulatory representation. As the previous finding suggested that REM provides an ideal neurobiological medium for restoring optimal post-sleep affective reactivity and provides elaborated semantic meaning before it is modified via a weak late selection filter, we believe that this would be a plausible reason for reappraisal strategy effectiveness over distraction. Our findings are not supported by the "cathartic" function of REM sleep because of methodology differences. In the present thesis, we did not use a pre-post measure across sleep periods since our focus was to study how alteration in sleep affects the regulation of our emotions.

Further, in contrast to our hypothesis, we find that difference in emotion regulation does not carry over further and modulate risky choice behaviour on BART task. One reason of not finding difference across specific sleep stages in terms of risk score can be explained in terms of experimental paradigm. In previous findings, all the studies, use an emotional processing property of REM sleep that lower down the emotional tone of affective stimuli. This leads REM sleep to facilitate learning of both complex cognitive task and emotional task and correlate with task improvement (Corrine J. Seeley, 2016). In the present thesis, we study the emotion regulation effectiveness on decision making by downregulating affect and their carry over effect of incidental emotion. Future studies could be designed to study direct effect of emotion regulation on decision-making by designing a task with emotional cues about the decision itself (Martin Braunstein, L, 2014) to see the effect of particular sleep stages or sleep quality in general (Corrine J. Seeley, 2016). Although we used BART task for risk evaluation, which is more or less similar to real life risky scenario. It could be possible that emotion regulation strategies would not be as effective when used with the simple choice task (Martin, L. N., 2011); however, before testing that relationship it would be important to understand the influence of specific sleep stages on affect regulation decision-making.

3.2.5 Electrophysiological correlates of risk and regulation

The current experiments enhance and affirm current knowledge about the ERP effects involved in affect-regulated decision making. Typically, emotion regulation studies have focused on changes in temporal dynamics during regulation of emotional stimuli. Experiment 2 and 3 added to this literature by demonstrating that applying emotion regulation strategies to stimuli affects, subsequent neural processing during decision-making. Experiment 2 and 3 examined regulation-induced shift in neural signal in subcortical brain regions involved in processing risk and reward across sleep. The result showed significant FRN and P300 components in the fronto-central region following feedback in a risky decision making task. FRN amplitude was larger in response to negative feedback than to positive feedback. These results are in the framework of the reinforcement learning theory of the FRN (Holroyd and

Coles, 2002). It shows that reward-prediction error signal increases after a risky decision, where larger potential positive or negative are expected as a consequence of the decision-making process. (Beate Schuermann, 2012). With respect to the sleep effect on feedback processing components, the result revealed larger FRN amplitude in second half sleep deprivation and these differences present only for cognitive reappraisal strategy across the condition for negative feedback. Thus, greater FRN amplitude reflects the motivational or emotional significance of risky decisions in sleep condition compared with sleep deprived condition. Due to the potential negative consequences of risky choices, discriminating between losses and gains seems highly important for optimizing future decision-making (Gehring and Willoughby, 2002). We also find increased FRN amplitude for feedback valance where participants followed reappraisal strategy in compare to distraction strategy of emotion regulation before risky decision-making. Possibly, FRN amplitude reflects enhanced cognitive control that is essential for the optimizing benefits or for maximum gain. The association between FRN and risk aversive behaviour is in line with previous findings, revealing an inverse relation between FRN amplitude and risk aversive behaviour in a healthy individual (Hewig et. al., 2007; Santesso and Segalowitz, 2009). FRN findings complement brain imaging results, suggesting that greater ACC activity predicts less risk taking behaviour (Paulus and Frank, 2006; Martin, L. N., 2014). In contrast, Yang et.al, 2013-showed reduced FRN and P300 amplitude after using reappraisal strategy while performing a gambling task. The difference might be because of the motive of that study to understand the underlying mechanism of the influence of cognitive reappraisal on reward processing. Yang et al., (2013) asked participants to either respond spontaneously or employ the strategy of cognitive reappraisal to calm down when facing the outcome feedback that indicated a gain or loss. During the task, they asked all participants to evaluate the level of their emotional experience to different types of outcomes (Yang et al., 2013). Here in our study, we examined the neural correlates of carry over effect of emotion regulation on risky decisions.

In the context of P300, we find larger amplitude in participants who use cognitive reappraisal strategy after a full night of sleep compared to who did not use any emotion regulation strategy. Larger P300 amplitudes indicate more resources are allocated to the ongoing task (Polich, 1987, 2007; Molna´ r, 1999). In addition, these results suggest that during decision-making, explicit emotion regulation is cognitively demanding and requires the allocation of cognitive resources. These findings are in line with recent ERP studies that proposes a two-step sequential model of outcome processing, including an early coarse detection of outcome information (indexed by the FRN) and a late deliberate evaluation stage (indexed by the P3) (Wu and Zhou, 2009; Philiastides et al., 2010; Zhang et al., 2014; Yang et al., 2013). This finding reveals that explicit emotion regulation influences both the FRN and the P3.

4. CONCLUSIONS AND IMPLICATIONS

4.1 Conclusions

Broadly, present thesis attempt to answer several important questions in the literature, related to the role that emotion regulation strategies play in risky decision-making. The experiments of the thesis evaluate the effectiveness of emotion regulation strategies on risky decision making by manipulating sleep in younger adults. The results of the experiment suggested that sleep lead to better regulation of affect through strategies, which lead to calculated risk taking for maximizing gains or minimizing losses. Sleep benefit those affect regulation strategies that employ cognitive manipulation of emotional situations at hand as sleep downregulates emotional reactivity to baseline values. Affect regulation strategies after sleep are required to regulate the emotional content of the stimuli and not its emotional tone. Affect regulation makes the subject analyse the risky decision-making scenario with detail and thus choose options with the optimal risk that support maximum gain or minimum loss. The electrophysiological data is a direct indicator that sleep induced participants, opt for maximally gain or minimizing loss options on risky decision-making games. The FRN and P300 clearly indicated that the application of cognitive reappraisal strategy significantly modulated the motivational significance and allocation of cognitive resources during the process of outcome evaluation, thus reducing the subjective emotional experience elicited by negative affect. The present thesis thus successfully states that sleep benefits affect regulated risky decision making over sleep deprivation. The current research demonstrates the potential of emotion regulation strategies to influence behaviour. Future research is needed to determine the limits of and extents of these influences. Additionally, future research should test these strategies in clinical populations, for instance, drug addicted individuals or sleep disorder individuals, to determine if emotion regulation will alter behaviour in those individuals.

4.2 Significance

The present thesis incorporates experiments designed using novel paradigms, which can contribute new knowledge to the emotion regulation literature. Most research on emotion regulation has assessed changes in subjective emotional experience, typically via Likert rating self-reports. The current research extends our knowledge about the effects of emotion regulation by applying emotion regulation in decision-making contexts. The first two studies demonstrate that effectiveness of emotion regulation strategies on decision-making could be modified by nature of emotion and method of emotion induction. The last two study demonstrated that sleep provides a baseline state which resets emotional reactivity of brain. This alters the subjective ratings of emotion regulation as well as behaviour measures that had not yet been examined previously. Current research is significant as incidental emotion or state of mind can influence behaviour through carry over effect on next task, which is evident as increased risk aversive and risk seeking tendencies. People often report being ‘out of control’ or acting ‘in the heat of moment’, in a way they know was not in their best interests and which is often followed by regretted behaviour. Curbing affective reaction to these situations using emotion regulation techniques may help prevent the development of addictions in risk populations. Studies like present thesis which examined the effectiveness of emotion regulation strategies on risky decision-making by manipulating sleep hours have a wide applicability in the field like federal governing bodies, diplomatic negotiations, operating rooms, intelligence agencies, major financial institutions and medical policies.

Before making broad generalizations about the application of present work, a few potential limitations need to be considered. These limitations are discussed below:

4.3 Limitations

The present study utilized a convenience sample of undergraduate students, which make the generalization of results onto the general population a bit risky. Undergraduate students are typically younger than most adults are and therefore at a different developmental stage than many adults in the general population. This may have an impact on risk taking behaviour, as prefrontal cortex development, which plays a role in decision-making, is not fully developed until about age 25 (the mean age of the current sample was 22.10). Additionally, certain behaviours may be more socially acceptable among college students (e.g., binge drinking, marijuana use) than among older adults, and reported levels of risk taking behaviour might differ.

The nature of the decisions used in the present thesis potentially limits the generalizability of the results. It is possible that emotion regulation strategies would not be as effective when used with complex or temporally extended decisions as we found in our results; however, before testing that relationship it would be important to understand the influence of emotions on very simple choice task or temporally short decisions.

The distraction and the reappraisal conditions also differed in an important psychological respect. The reappraisal instruction necessarily called the participants attention to the fact that successful reduction of negative affect could be taking place. This might have created a situation of greater experimental demand during the reappraisal condition compared with distraction. Although we took several precautions against these demand effects, we cannot rule out the possibility that experimenter demand may be the cause for some of the results reported in the thesis.

The goal of present research was to understand how emotion regulation alters decision-making. The modern day environment is filled with cues that signal opportunities for rewards and potential punishments. In the present thesis, we use the extrinsic emotion regulation strategies to modulate carry over effect of affect in general rather than targeting specific cues. In future research, it is important to understand how changing thoughts and emotional reactions to theses cues can change decision-making.

In the present study, a self-report method of emotion measurement and electrophysiological measurement for the effect of emotion regulation on experienced emotions during decision-making are used. It would be profitable for future studies to replicate the present result using continuous measurements of the effects. Systems such as the Affect Dial (Ruef and Levenson, 2007) can help achieve capturing continuous measurements of effects.

The present thesis tries to study the differential effects of emotion regulation strategies on decision making using the self-reporting scale for measuring the effectiveness of emotion regulation strategies on emotion and behaviour. Objective measurement of decision-making was focused on changes in behavioural risk-taking instead of changes in emotion. It would be helpful if we could distinguish regulation of emotions from regulation of behaviour in present thesis by evaluating temporal dynamics of emotion regulation.

The broad theory supporting the current thesis is that emotions influence behavior by promoting approach or avoidance tendencies. In all our experiments, we did not demonstrate that shift in arousal that occurs as a function of emotion regulation. The possible reason could be in findings, which showed the different emotional route by which emotion regulation may influence decision-making. We would be in better position to answer these questions if we use specific type of emotion that is different on these dimension of theory.

Sleep has been shown to be essential for adaptive emotion regulation, whereas insufficient sleep may hinder emotional functioning. In the present thesis, we have focused on sleep parameters like duration and quality that affect successful emotion regulation. Future studies should be done to study the post-learning effect of sleep on emotion processing by using pre-post learning (before-after) sleep paradigm.

The objective of the present thesis was to explore the role of sleep duration on emotion regulation effectiveness as applied to decision-making behaviour. The true effect of sleep on decision making may not have been reflected from our thesis experiments since we did not use a control group. Further, it is important to distinguish the effect of sleep on affect regulated decision-making and decision-making without priming.

4.4 External Validity of the outcomes

Present thesis also suffers from the external validity of results from other laboratory studies in the field of emotion regulation and decision-making. The external validity of the outcomes of all the experiments was somewhat limited. All three studies involved actual financial outcomes that were experienced by the participants, but these outcomes never involved the loss of money from the participants own financial reserves.

Although we use BART task, which is a useful and potentially promising task for examining risk taking, it uses contingencies that simulate risk situations in the natural environment to identify an overall propensity for risk taking rather than a particular type of risk behavior. Experimental decisions, however, present a different kind of risk than that encountered in the real world. When a bet is made gambling at a casino, for example, a sum of money is put on the line and there is a chance (typically an unknown probability) that that sum will be lost. Given that the consequences of losing a gamble in the decision-making experiments were less severe, one might have expected that people would often or even almost always take a risk. If the contingencies of the decisions had involved actual losses, it is likely that participants would have exhibited even greater levels of risk aversion in their choices.

Research that examines emotion regulation effectiveness in a context that is lacking personal goals and social interactions may obscure important characteristics of the phenomenon as it occurs in daily life.

4.5 Original contributions of the thesis

Present thesis has several original contributions that we want to acknowledge. We will group these contributions into three broad categories: (1) theoretical, (2) methodological and (3) practical/clinical.

4.5.1 Theoretical contributions

The present study added to evidence that supports the view that emotion regulation decreases the emotional experience and lead to less risk aversive behaviour. The significance of negative emotion in all our studies clearly indicates that negative valence were regulated more effectively compared to positive.

There are very few studies conducted on nature of emotion induction and its effectiveness on emotion regulation. As per our knowledge this is one of the first behavioural study that compares the effect of two emotion inducing stimuli on emotion regulation effectiveness. The results of the study suggest that there is a significant difference between effectiveness for pictorial and video stimuli, however, pictorial stimuli leads to more efficient emotion regulation when compared to video results. The present study thus helps in clarifying the role of nature of induction in the area of emotion regulation effectiveness. As far as researcher knowledge this is one of the first studies to compare the effectiveness of emotion regulation across the nature of emotion induction method and study the self-assessment (emotion ratings) as well as behavioural (risk taking behaviour) measurement. The present study thus provides evidence favouring an increase in the explanatory power for the model of decision-making.

Most of the studies on emotion regulation focused on the effectiveness of various emotion regulation strategies and strategies subtype. The present thesis adds evidence for the role played by a type of emotion inducing stimuli (pictures and videos) and nature of affect (positive and negative), to the existing literature on emotion regulation effectiveness.

The process model of emotion regulation categorizes different emotion regulation strategies according to the time of their introduction on the emotion generative process. The process model suggests the five different families of emotion regulatory processes (situation selection, distraction, attentional deployment, cognitive change, response modulation) can be distinguished according to when in the emotion-generative process they have their primary impact. Most of the previous research compared the cognitive reappraisal and suppression strategies of emotion regulation; this is one of the first study, which compares all the four strategies of the process model in laboratory condition. Thesis results are consistent of many previous findings. The thesis added to evidence that besides these two strategies evaluated in detail in present thesis, distraction strategy offers enough reason to merit its consideration in emotion regulation research. This is important because it would result in a richer delineation of the functional role of each strategy.

Cognitive neuroscience continues to build meaningful connections between affective behavior and human brain function. It is well-established fact that sleep reduces daytime emotion reactivity but the interaction of sleep and emotion regulation research has a recent inception. Drawing from previous research on the role of sleep in emotion regulation, the present thesis compared sleep and deprivation across affect and affect regulated decision-making. The present thesis established that significant effect of distraction and cognitive reappraisal strategies could be found across sleep and sleep deprivation groups. A positive sleep effect on risk aversive behavior in affect-regulated decision-making is reported which has been further validated through electrophysiological measurements.

Recent findings claim that REM sleep functions in part to facilitate emotional regulation but this theoretical explanation has never been tested in the laboratory. To our best knowledge, this is one of the first laboratory study, which tests the effect of specific sleep stages on a process model of emotion regulation. The study further extends the test to affect regulated decision-making. The results of the study suggest that there is no difference between risk taking behavior across REM and NREM deprived sleep condition, but NREM deprived condition does lead to less risk aversive behaviour, which is also confirmed by effective regulation of emotion regulation in first half sleep deprivation as compared to second half sleep deprivation. The study helps to clarify the role of specific stages of sleep in the emotion regulation effectiveness in risky decision-making.

4.5.2 Methodological contributions

Contribution at the methodological level by current thesis is that the researcher developed sets of experiments using E-prime (version 2.0) which can be used to measure the effectiveness of emotion regulation strategies across difference stimuli type and emotional valence. The thesis also states the method for explicit manipulation of emotion regulation by instructions under laboratory condition. The experiments can be used in future research in the area of emotion regulation.

The present thesis paradigm lets us compare the specific emotion regulation strategies to the affect view condition and facilitate the measure carryover effect of incidental emotion on risky decision-making. Another methodological contribution could be designing E-Prime version of BART task, which is more suitable for event related potential (ERP) study of risk taking behaviour.

In our experiments, we used within-subjects designs, which provide additional important information that allows us to measure participants' ability for flexible implementation of various emotion regulation strategies. This ability to flexibly switch from one strategy to another has been associated with low level of psychopathology (Bonanno, Papa, O'Neill, Westphal, and Coifman, 2004; Gupta and Bonanno, 2011; Westphal, Seivert, and Bonanno, 2010) and has a wide variety of application in a clinical population. However, it is also possible that while using within subjects design in the elicitation of affect might lead to spillover effects but we counterbalance the order of emotion regulation strategies.

Most study designs used till date use two emotion regulation strategies (cognitive reappraisal and suppression) or (distraction and reappraisal). With our design, we have been able to show a clear comparative effect of all emotion regulation strategies of the process model of emotion regulation in compare to emotion view group. This allows us to delimit the effects of strategy A not only with respect to strategy B but also in relation to a wider set of strategies.

4.5.3 Practical and clinical implications

The entire thesis examined healthy participants, therefore limiting the clinical implications of our findings. However, our interpretation of the behavioural and imaging results has several implications for understanding the consequences of using distraction and reappraisal both in everyday life and in the course of clinical interventions.

Our data interpretations and results follow from the finding that reappraisal involves greater processing of the affective meaning of the stimulus, whereas distraction involves lesser attention to and poorer encoding of affective meaning than unregulated responding. This suggests superior memory for items viewed while reappraising, which has been demonstrated in several studies (Dillon et al., 2007; Sheppes and Meiran, 2007; Richards and Gross, 2000) and impaired memory for items viewed during distraction, which also has been observed

(Sheppes and Meiran, 2007). This idea has been borne out by laboratory studies showing that cognitive reinterpretation has long-lasting effects, whereas distraction only has immediate effects (Kross and Ayduk, 2008). This suggests that distraction may be best used in situations when ignoring the affective meaning of the eliciting stimulus is permissible—such as situations that do not require memory for the stimulus or when re-exposure is unlikely. Reappraisal, while requiring more extensive processing of affective meaning, might be more appropriate when this meaning must be addressed, manipulated, and remembered and when re-exposure is likely.

A huge number of people are sleep deprived, getting less than 8 hours sleep per night, and this number has increased over the past 20 years (Schoenborn and Adams, 2008; Luckhaupt et al., 2010; Panda, S., 2012). Sleep loss is related to a variety of adverse outcomes, including increased risk taking behaviours (Harrison and Horne, 2000; Luckhaupt et al., 2010). Many individuals have no control over their levels of sleep loss due to their occupation (i.e., nurses and doctors, airline pilots, commercial truck drivers, individuals involved in shift work), or due to conditions that can contribute to the lack of sleep (i.e., sleep apnea). It is important for counsellors to understand the problems faced by their clients and the potential challenges associated with sleep loss. The more counsellors understand the unique needs of their clients, the better they will be able to plan interventions that will be relevant and helpful.

Several studies, including the present study, have demonstrated a link between sleep loss and risk taking behaviour. It is, therefore, possible that individuals who struggle with sleep will have an increased affinity for high risk taking behaviour. It may be helpful for clinicians to work with such clients and address problems with sleep loss in an effort to decrease chances for higher risk taking behaviour. Education about the importance of sleep hygiene, bedtime relaxation exercises (e.g., breathing exercises, progressive muscle relaxation), and other interventions designed to reduce sleep loss might be helpful. Similarly, it might be beneficial for clinicians working with clients who demonstrate higher levels of risk taking behaviour to assess their sleep quality and sleep duration (i.e., factors that influence sleep loss). Interventions designed to improve sleep quality and quantity might be a beneficial component of treatment for risk taking behaviour.

The current study also found that emotion regulation is mediated by the relationship between sleep loss and risk taking behaviour. It might be beneficial for clinicians working with individuals who demonstrate symptoms of sleep loss and/or elevated levels of risk taking behaviour (e.g., recreational substance use, thrill seeking) to implement interventions aimed at better emotion regulation. It is important to note that a causal relationship between sleep loss and risk taking behaviour has yet to be established, and the partial mediation effect of negative mood is small and has yet to be replicated. These interventions and implications for counselling are tentative but could be useful to some clinicians and clients.

The finding that emotion regulation affects risk attitudes is also relevant to health psychology and psychiatry. On the one hand, a reduced risk aversion due to habitual use of reappraisal may contribute to an enhanced well-being among the general population (Gross and John, 2003; Magar et al., 2008). On the other hand, biased risk aversion has been involved in the pathogenesis of affective disorders (Chandler, Wakeley, Goodwin, and Rogers, 2009), as well as addiction (George, Rogers, and Duka, 2005) and pathological gambling (Brand et al., 2006). Poor emotion regulation skills and reduced ER-related neural activation have also been described in anxiety (Goldin, Manber, Hakimi, Canli, and Gross, 2009). Therefore, training these patients in effective emotion regulation strategies such as reappraisal may provide a means of both enhancing their emotional control as well as reducing decision-making biases.

4.6 Implications for future research

One important direction for future research concerns stimulus generalizability. One strength of the present study is that use of pictorial stimuli permits contact with a large number of previous studies using an emotional picture paradigm to study cognitive reappraisal (Urry et al., 2006; Ochsner et al., 2002). In this context, the present results replicate and extend prior work. By contrast, much of the work in distraction has used painful stimulation rather than image-based paradigms (Kalisch et al., 2006; Bantick et al., 2002). Therefore, a direct comparison of distraction and reappraisal in the context of pain anticipation or delivery—or in the context of other types of emotionally charged stimuli—might further illuminate the similarities and differences between the two strategies.

In experiment one, we used pictorial and video stimuli, which have been found to reliably elicit emotion, but their use has led to limitations in the external and ecological validity of the experimental manipulations. The use of naturally occurring stimuli may be more informative in the context of psychopathology because they can allow researchers to identify the extent to which regulation follows the same pattern of rigidity as in emotional experiences.

Another important direction for future research concerns subtypes of distraction and reappraisal. Based on previous comparisons of different types of reappraisal strategies (Ochsner, et al., 2004), we might expect different types of reappraisal to compare with distraction in different ways. Similarly, the specific way in which one is distracted may also be important. In the present thesis similar to previous studies of distraction we have used other types of demanding cognitive tasks that involve various kinds and combinations of control processes whose relative level of effort is not clear. Therefore, comparisons of several methods of distraction and several types of reappraisals may be important in future research.

A final direction for future research concerns the role that individual and group differences may play in determining whether reappraisal or distraction is more effective. In the present study, we chose to include only male participants so as to avoid gender-related differences that might influence emotional responding (Wrase et al., 2003; Bradley, Codispoti, Sabatinelli, and Lang, 2001) or emotion regulation (McRae et al., 2008; Rusting, 1998). It is possible that the relationship between distraction and reappraisal is different in females, and these gender differences could be investigated in the future studies.

The presence and nature of a clinical disorder may be another important factor determining whether distraction or reappraisal is more effective. For instance, distraction has been shown to be a successful emotion regulation strategy for those who suffer from past or current major depression (Joorman, Siemer, and Gotlib, 2007; Fennell and Teasdale, 1984). However, paradoxical effects of distraction have been reported when it is used during exposure therapy for specific phobias (Telch et al., 2004; Craske, Street, Jayaraman, and Barlow, 1991; Foa and Kozak, 1986). Future work could examine whether and how clinical contexts dictate when distraction can facilitate the down-regulation of negative emotion.

The current research demonstrates the potential of emotion regulation strategies to influence behavior; future research is needed to determine the limits of and extents of these influences. Additionally, future research should test these strategies in clinical populations, for instance, drug addicted individuals, to determine if emotion regulation will alter behavior in those individuals.

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Annexure I.

Behavioral Data Tables

Experiment 1A: Effectiveness of Emotion Regulation in Terms of Stimuli Type and Affect

Table 1| A X B ANOVA Summary Table (Repeated on A and B) of arousal SAM rating of positive affect

Design: 2 (stimuli type: Picture, Video) X 2 (Affect: Emotion View, Emotion regulation strategy)

i)

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	0.560	1	0.560	0.062	0.805
Error(within)	352.000	39	9.026		
B(Emotion)	0.840	1	0.840	0.007	0.930
Error(within)	4460.720	39	114.377		
AB	0.200	1	0.200	0.010	0.920
Error(within)	758.000	39	19.436		

ii)

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	0.750	1	0.750	0.126	0.720
Error(within)	231.900	39	5.946		
B(Emotion)	12.300	1	12.300	0.074	0.780
Error(within)	6463.500	39	165.731		
AB	21.900	1	21.900	1.579	0.220
Error(within)	540.900	39	13.869		

iii

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	0.867	1	0.867	0.086	0.770
Error(within)	392.700	39	10.069		
B(Emotion)	5.270	1	5.270	0.730	0.400
Error(within)	281.690	39	7.223		
AB	1.360	1	1.360	0.692	0.430
Error(within)	76.670	39	1.966		

iv)

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	5.390	1	5.390	0.970	0.330
Error(within)	216.810	39	5.559		
B(Emotion)	1.320	1	1.320	0.099	0.755
Error(within)	518.430	39	13.293		
AB	7.810	1	7.810	2.423	0.136
Error(within)	125.730	39	3.224		

i) View versus Situation selection; ii) View versus Distraction ; iii) View versus Cognitive reappraisal ; iv) View versus Suppression

Experiment 1A: Effectiveness of Emotion Regulation in Terms of Stimuli Type and Affect

Table 2| A X B ANOVA Summary Table (Repeated on A and B) of valance SAM rating of positive affect

Design: 2 (stimuli type: Picture, Video) X 2 (Affect: Emotion View, Emotion regulation strategy)

i)

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	18.600	1	18.600	0.415	0.520
Error(within)	1748.400	39	44.831		
B(Emotion)	6.000	1	6.000	0.058	0.810
Error(within)	4025.400	39	103.215		
AB	48.000	1	48.000	2.225	0.140
Error(within)	841.200	39	21.569		

ii)

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	0.741	1	0.741	0.189	0.660
Error(within)	152.760	39	3.917		
B(Emotion)	3.420	1	3.420	0.033	0.856
Error(within)	3991.330	39	102.342		
AB	12.730	1	12.730	0.695	0.411
Error(within)	714.590	39	18.323		

iii

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	5.369	1	5.369	0.131	0.710
Error(within)	1600.670	39	41.043		
B(Emotion)	2.950	1	2.950	0.025	0.875
Error(within)	4577.810	39	117.380		
AB	52.510	1	52.510	0.584	0.451
Error(within)	3504.010	39	89.846		

iv)

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	6.120	1	6.120	0.018	0.890
Error(within)	13504.868	39	346.279		
B(Emotion)	25.160	1	25.160	0.128	0.720
Error(within)	7665.708	39	196.557		
AB	24.480	1	24.480	1.181	0.285
Error(within)	808.384	39	20.728		

i) View versus Situation selection; ii) View versus Distraction ; iii) View versus Cognitive reappraisal ; iv) View versus Suppression

Experiment 1A: Effectiveness of Emotion Regulation in Terms of Stimuli Type and Affect

Table 3| A X B ANOVA Summary Table (Repeated on A and B) of arousal SAM rating of negative affect

Design: 2 (stimuli type: Picture, Video) X 2 (Affect: Emotion View, Emotion regulation strategy)

i)

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	2.958	1	2.958	0.186	0.660
Error(within)	619.440	39	15.883		
B(Emotion)	87.348	1	87.348	0.549	0.460
Error(within)	6207.160	39	159.158		
AB	11.160	1	11.160	0.060	0.800
Error(within)	7255.260	39	186.032		

ii)

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	10.793	1	10.793	0.184	0.670
Error(within)	2292.760	39	58.789		
B(Emotion)	690.580	1	690.580	5.958	0.010
Error(within)	4520.375	39	115.907		
AB	21.070	1	21.070	0.094	0.760
Error(within)	8779.697	39	225.120		

iii

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	11.232	1	11.232	0.076	0.780
Error(within)	5738.652	39	147.145		
B(Emotion)	1381.680	1	1381.680	7.537	0.000
Error(within)	7149.780	39	183.328		
AB	30.240	1	30.240	2.471	0.120
Error(within)	477.288	39	12.238		

iv)

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	2.924	1	2.924	0.046	0.830
Error(within)	2479.280	39	63.571		
B(Emotion)	59.430	1	59.430	0.556	0.450
Error(within)	4168.311	39	106.880		
AB	0.272	1	0.272	0.008	0.920
Error(within)	1328.992	39	34.077		

i) View versus Situation selection; ii) View versus Distraction ; iii) View versus Cognitive reappraisal ; iv) View versus Suppression

Experiment 1A: Effectiveness of Emotion Regulation in Terms of Stimuli Type and Affect

Table 4| A X B ANOVA Summary Table (Repeated on A and B) of valance SAM rating of negative affect

Design: 2 (stimuli type: Picture, Video) X 2 (Affect: Emotion View, Emotion regulation strategy)

i)

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	17.820	1	17.820	0.180	0.670
Error(within)	3857.544	39	98.911		
B(Emotion)	22.140	1	22.140	0.987	0.320
Error(within)	874.800	39	22.431		
AB	4.320	1	4.320	0.627	0.410
Error(within)	268.542	39	6.886		

ii)

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	489.800	1	489.800	4.863	0.030
Error(within)	3927.880	39	100.715		
B(Emotion)	95.590	1	95.590	5.855	0.020
Error(within)	636.740	39	16.327		
AB	142.200	1	142.200	1.595	0.210
Error(within)	3477.580	39	89.169		

iii

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	918.510	1	918.510	7.383	0.009
Error(within)	4851.630	39	124.401		
B(Emotion)	79.050	1	79.050	5.451	0.020
Error(within)	565.590	39	14.502		
AB	151.980	1	151.980	2.909	0.090
Error(within)	2037.450	39	52.242		

iv)

Source	SS	df	MS	F	Sig.
A(Stimuli Type)	1.053	1	1.053	0.296	0.580
Error(within)	138.780	39	3.558		
B(Emotion)	4.320	1	4.320	0.169	0.680
Error(within)	996.030	39	25.539		
AB	2.187	1	2.187	0.164	0.680
Error(within)	519.750	39	13.327		

i) View versus Situation selection; ii) View versus Distraction ; iii) View versus Cognitive reappraisal ; iv) View versus Suppression

Experiment 2: Emotion regulation effectiveness after sleep and sleep deprivation

Table 5: A X B ANOVA Summary Table (Repeated on A and B) of arousal SAM rating

Design: 2 (Sleep: Full night Sleep, Sleep deprivation) X 2 (Affect: Emotion View, Emotion regulation strategy).

A. Emotion View versus Cognitive Reappraisal

Source	SS	*df*	MS	F	Significance	η^2
A(Sleep)	.311	1	.311	.609	.447	.037
Error(within)	8.175	16	.511			
Within-Subjects	73.924	1	73.924	62.622	.000	.796
B (Affect)	18.888	16	1.180			
Error (within)	.247	1	.247	.285	.601	.017
AB	13.889	16	.868			

B. Emotion View versus Distraction

Source	SS	*df*	MS	F	Significance	η^2
A(Sleep)	.015	1	.015	.035	.854	.002
Error(within)	6.693	16	.418			
Within-Subjects	75.601	1	75.601	72.297	.000	.819
B (Affect)	16.731	16	1.046			
Error (within)	.004	1	.004	.003	.957	.000
AB	19.544	16	1.221			

Experiment 2: Emotion regulation effectiveness after sleep and sleep deprivation

Table 6: A X B ANOVA Summary Table (Repeated on A and B) of valance SAM rating

Design: 2 (Sleep: Full night Sleep, Sleep deprivation) X 2 (Affect: Emotion View, Emotion regulation strategy).

A. Emotion View versus Cognitive Reappraisal

Source	SS	*df*	MS	F	Significance	η^2
A(Sleep)	.318	1	.318	1.020	.328	.060
Error(within)	4.989	16	.312			
Within-Subjects	26.625	1	26.625	66.492	.000	.806
B (Affect)	6.407	16	.400			
Error (within)	.119	1	.119	.231	.637	.014
AB	8.257	16	.516			

B. Emotion View versus Distraction

Source	SS	*df*	MS	F	Significance	η^2
A(Sleep)	2.171	1	2.171	4.556	.049	.222
Error(within)	7.623	16	.476			
Within-Subjects	11.987	1	11.987	24.972	.000	.609
B (Affect)	7.680	16	.480			
Error (within)	.318	1	.318	.533	.476	.032
AB	9.551	16	.597			

Experiment 3: Assess the role of first half or second half sleep deprivation in affect regulated risky decision making

Table 7: A X B ANOVA Summary Table (Repeated on B) of arousal SAM rating

Design: 2 Sleep (second half of sleep deprivation/ first half of sleep deprivation) X 2 (Affect: Emotion View, Emotion regulation strategy)

A. Emotion View versus Cognitive Reappraisal

Source	SS	*df*	MS	F	Significance	η^2
A(Sleep)	.006	1	.006	.013	.912	.001
Error(between)	6.093	12	.508			
B(Affect)	22.500	1	22.500	25.271	.000	.678
Error (Within)	10.684	12	.890			
AB	.013	1	.013	.014	.906	.001

B. Emotion View versus Distraction

Source	SS	*df*	MS	F	Significance	η^2
A(Sleep)	0.038	1	0.038	0.113	0.743	0.009
Error(between)	3.997	12	0.333			
B(Affect)	15.082	1	15.082	11.902	0.005	0.498
Error (Within)	15.206	12	1.267			
AB	0.075	1	0.075	0.059	0.812	0.005

Experiment 3: Assess the role of first half or second half sleep deprivation in affect regulated risky decision making

Table 8: A X B ANOVA Summary Table (Repeated on B) of valance SAM rating

Design: 2 Sleep (second half of sleep deprivation/ first half of sleep deprivation) X 2 (Affect: Emotion View, Emotion regulation strategy)

A. Emotion View versus Cognitive Reappraisal

Source	SS	*df*	MS	F	Significance	η^2
A(Sleep)	4.208	1	4.208	13.746	.003	.534
Error(between)	3.673	12	.306			
B(Affect)	.840	1	.840	3.132	.102	.207
Error (Within)	3.219	12	.268			
AB	13.790	1	13.790	51.414	.000	.811

B. Emotion View versus Distraction

Source	SS	*df*	MS	F	Significance	η^2
A(Sleep)	3.754	1	3.754	12.398	.004	.508
Error(between)	3.634	12	.303			
B(Affect)	1.373	1	1.373	4.519	.055	.274
Error (Within)	3.646	12	.304			
AB	15.009	1	15.009	49.402	.000	.805

Appendix A.

Questionnaires used in the Thesis

General Questionnaire

Age:_________years

Gender: M / F

Occupation/Academic: ___________

Handedness: Left / Right

Spectacles: Yes / No

Non Smoker: Yes / No

At what time in the evening do you normally go to bed?

How many hours of sleep in the night do you have normally?

Do you sleep during the day? (If yes when, how many hours)

Do you suffer from Chronic Illness?

Allergies?

Do you suffer from any clinical sleep disorder at present or in the past?

Do you suffer from any endocrinological, neurological or psychiatric illness at present or in the past?

Have you been a subject in a sleep experiment? (If yes when and with whom)

Do you have partial health restriction? (If yes, what)

Do you take any medications/Drugs?

Have you worked during the night 6 weeks prior to this day? (If yes When and how much)

Did you take cola or coffee today afternoon? (If yes when and how much)

Have been you undergoing special stress? (If yes, which and what exact)

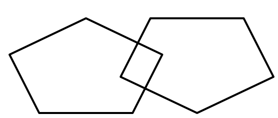
What time did you awake today Morning?

Did you sleep today in the afternoon? (If yes when and what length)

Mini-Mental State Examination (MMSE)

Patient's Name: ________________________________ Date: ____________

Instructions: ***Ask the questions in the order listed. Score one point for each correct response within each question or activity.***

Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day of the week? Month?"
5		"Where are we now: State? County? Town/city? Hospital? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible. Number of trials: ___________
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, …) Stop after five answers. Alternative: "Spell WORLD backwards." (D-L-R-O-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.
1		"Repeat the phrase: 'No ifs, ands, or buts.'"
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes.")
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)
1		"Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.) 
30		TOTAL

(Adapted from Rovner & Folstein, 1987)

PANAS-X

This scale consists of a number of words and phrases that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel this way *right now*. Use the following scale to record your answers:

1	**2**	**3**	**4**	**5**
very slightly or not at all	a little	moderately	quite a bit	extremely

1. ______ cheerful
2. ______ disgusted
3. ______ attentive
4. ______ bashful
5. ______ sluggish
6. ______ daring
7. ______ surprised
8. ______ strong
9. ______ scornful
10. ______ relaxed
11. ______ irritable
12. ______ delighted
13. ______ inspired
14. ______ fearless
15. ______ disgusted with self
16. ______ sad
17. ______ calm
18. ______ afraid
19. ______ tired
20. ______ amazed
21. ______ shaky
22. ______ happy
23. ______ timid
24. ______ alone
25. ______ alert
26. ______ upset
27. ______ angry
28. ______ bold
29. ______ blue
30. ______ shy
31. ______ active
32. ______ guilty
33. ______ joyful
34. ______ nervous

35. ______ lonely

36. ______ sleepy

37. ______ excited

38. ______ hostile

39. ______ proud

40. ______ jittery

41. ______ lively

42. ______ ashamed

43. ______ at ease

44. ______ scared

45. ______ drowsy

46. ______ angry at self

47. ______ enthusiastic

48. ______ downhearted

49. ______ sheepish

50. ______ distressed

51. ______ blameworthy

52. ______ determined

53. ______ frightened

54. ______ astonished

55. ______ interested

56. ______ loathing

57. ______ confident

58. ______ energetic

59. ______ concentrating

60. ______ dissatisfied with self

Scales

General Positive Emotion:= (p31 + p25 + p3 + p52 + p47 + p37 + p13 + p55 + p39 + p8)

General Negative Emotion:= (p18 + p44 + p34 + p40 + p11 + p38 + p32 + p42 + p26 + p50)

fear:= (p18 + p44 + p53 + p34 + p40 + p21)

hostility:= (p37 + p38 + p11 + p9 + p2 + p56)

guilt:= (p32 + p42 + p51 + p46 + p15 + p60)

sadness:= (p16 + p29 + p48 + p24 + p35)

joviality:= (p22 + p33 + p12 + p1 + p37 + p47 + p41 + p58)

self_assurance:= (p39 + p3 + p57 + p28 + p6 + p14)

attentiveness:= (p25 + p3 + p59 + p52)

shyness:= (p30 + p4 + p49 + p23)

fatigue:= (p36 + p19 + p5 + p45)

serenity:= (p17 + p10 + p43)

surprise:= (p20 + p7 + p54)

basic positive affect:= (joviality+self_assurance+attentiveness)/3

basic negative affect:= (sadness+guilt+hostility+fear)/4

Mood Questionnaire

Subject code: _________

Age: ________________

Clock Time: __________

Report as according to your present feeling

I feel the following way now …………

	Not at all				Very much
Sleepy					
Active					
Tense					
Tired					
Bored					
Motivated					
Concentrated					

Memory and Attention test

Memory test: You have to write the name of occupations in 1 minute

Attention Test: You have to write the word starts with "A" but that would not be any Name. Word should not be any compound word. (limit 1 minute)

Subject's Initials________________ID#__________________Date_______________Time_____AM PM

PITTSBURGH SLEEP QUALITY INDEX

INSTRUCTIONS:
The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

1. During the past month, what time have you usually gone to bed at night?

   BED TIME ___________

2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?

   NUMBER OF MINUTES ___________

3. During the past month, what time have you usually gotten up in the morning?

   GETTING UP TIME ___________

4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)

   HOURS OF SLEEP PER NIGHT ___________

For each of the remaining questions, check the one best response. Please answer all questions.

5. During the past month, how often have you had trouble sleeping because you . . .

a) Cannot get to sleep within 30 minutes

Not during the past month_____ Less than once a week_____ Once or twice a week_____ Three or more times a week_____

b) Wake up in the middle of the night or early morning

Not during the past month_____ Less than once a week_____ Once or twice a week_____ Three or more times a week_____

c) Have to get up to use the bathroom

Not during the past month_____ Less than once a week_____ Once or twice a week_____ Three or more times a week_____

d) Cannot breathe comfortably

Not during the past month______	Less than once a week______	Once or twice a week______	Three or more times a week______

e) Cough or snore loudly

Not during the past month______	Less than once a week______	Once or twice a week______	Three or more times a week______

f) Feel too cold

Not during the past month______	Less than once a week______	Once or twice a week______	Three or more times a week______

g) Feel too hot

Not during the past month______	Less than once a week______	Once or twice a week______	Three or more times a week______

h) Had bad dreams

Not during the past month______	Less than once a week______	Once or twice a week______	Three or more times a week______

i) Have pain

Not during the past month______	Less than once a week______	Once or twice a week______	Three or more times a week______

j) Other reason(s), please describe____

____

How often during the past month have you had trouble sleeping because of this?

Not during the past month______	Less than once a week______	Once or twice a week______	Three or more times a week______

6. During the past month, how would you rate your sleep quality overall?

Very good ____________

Fairly good ____________

Fairly bad ____________

Very bad ____________

7. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

No problem at all	__________
Only a very slight problem	__________
Somewhat of a problem	__________
A very big problem	__________

10. Do you have a bed partner or room mate?

No bed partner or room mate	__________
Partner/room mate in other room	__________
Partner in same room, but not same bed	__________
Partner in same bed	__________

If you have a room mate or bed partner, ask him/her how often in the past month you have had . . .

a) Loud snoring

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

b) Long pauses between breaths while asleep

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

c) Legs twitching or jerking while you sleep

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

d) Episodes of disorientation or confusion during sleep

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

e) Other restlessness while you sleep; please describe___________________________________

____

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ: Psychiatry Research, 28:193-213, 1989.

Drug Use Questionnaire (DAST-20)

Name: ______________________________

Case Number: ______________________________

Charges: ______________________________

Test Date: ______________________________

Score: ______________________________

<u>Preliminary Comments</u>

Adapted from language provided by Dr. Harvey Skinner (January 5, 2009)

The following questions concern your potential involvement with drugs other than alcohol. When you answer the questions, remember that the term "drug abuse" does not include alcohol. Instead, it refers to your use of prescribed or over the counter drugs in excess of the recommended dosage. For example, if you were given a prescription for pain killers, but took more than you were supposed to, that would be included. The phrase "drug abuse" also includes *any* non-medical drug use, including illegal drugs. This includes substances like marijuana, valium, cocaine, amphetamines, LSD, and heroin. Remember that the term "drug abuse" does not include alcohol. If you have difficulty with a statement, then choose the response that is mostly right.

Do you understand?

<u>Questions</u>

	These questions refer to the past 12 months.	**Circle the Response**	
1.	Have you used drugs other than those required for medical reasons?	Yes	No
2.	Have you abused prescription drugs?	Yes	No
3.	Do you abuse more than one drug at a time?	Yes	No
4.	Can you get through the week without using drugs?	Yes	No
5.	Are you always able to stop using drugs when you want to?	Yes	No
6.	Have you had "blackouts" or "flashbacks" as a result of drug use?	Yes	No
7.	Do you ever feel bad or guilty about your drug use?	Yes	No
8.	Does your spouse (or parents) ever complain about your involvement with drugs?	Yes	No
9.	Has drug abuse created problems between you and your spouse or your parents?	Yes	No
10.	Have you lost friends because of your use of drugs?	Yes	No
11.	Have you neglected your family because of your use of drugs?	Yes	No
12.	Have you been in trouble at work (or school) because of drug abuse?	Yes	No
13.	Have you lost your job because of drug abuse?	Yes	No
14.	Have you gotten into fights when under the influence of drugs?	Yes	No
15.	Have you engaged in illegal activities in order to obtain drugs?	Yes	No
16.	Have you been arrested for possession of illegal drugs?	Yes	No
17.	Have you ever experienced withdrawal symptoms (felt sick) when you stopped taking drugs?	Yes	No
18.	Have you had medical problems as a result of your drug use? (e.g. memory loss, hepatitis, convulsions, bleeding, etc.)	Yes	No
19.	Have you gone to anyone for help for a drug problem?	Yes	No
20.	Have you been involved in a treatment program specifically related to drug use?	Yes	No

CERQ

How do you cope with events?

Everyone gets confronted with negative or unpleasant events now and then and everyone responds to them in his or her own way. By the following questions you are asked to indicate what you generally think, when you experience negative or unpleasant events.

	(almost) never	some-times	regu-larly	often	(almost) always
1. I think that I have to accept that this has happened	1	2	3	4	5
2. I often think about how I feel about what I have experienced	1	2	3	4	5
3. I think I can learn something from the situation	1	2	3	4	5
4. I feel that I am the one who is responsible for what has happened	1	2	3	4	5
5. I think that I have to accept the situation	1	2	3	4	5
6. I am preoccupied with what I think and feel about what I have experienced	1	2	3	4	5
7. I think of pleasant things that have nothing to do with it	1	2	3	4	5
8. I think that I can become a stronger person as a result of what has happened	1	2	3	4	5
9. I keep thinking about how terrible it is what I have experienced	1	2	3	4	5
10. I feel that others are responsible for what has happened	1	2	3	4	5
11. I think of something nice instead of what has happened	1	2	3	4	5
12. I think about how to change the situation	1	2	3	4	5
13. I think that it hasn’t been too bad compared to other things	1	2	3	4	5
14. I think that basically the cause must lie within myself	1	2	3	4	5
15. I think about a plan of what I can do best	1	2	3	4	5
16. I tell myself that there are worse things in life	1	2	3	4	5
17. I continually think how horrible the situation has been	1	2	3	4	5
18. I feel that basically the cause lies with others	1	2	3	4	5

Thank you for filling out the questionnaire!

Domain-Specific Risk-Taking (Adult) Scale – Risk Taking

For each of the following statements, please indicate the **likelihood** that you would engage in the described activity or behavior if you were to find yourself in that situation. Provide a rating from *Extremely Unlikely* to *Extremely Likely*, using the following scale:

1	2	3	4	5	6	7
Extremely Unlikely	Moderately Unlikely	Somewhat Unlikely	Not Sure	Somewhat Likely	Moderately Likely	Extremely Likely

1. Admitting that your tastes are different from those of a friend. (S)
2. Going camping in the wilderness. (R)
3. Betting a day's income at the horse races. (F)
4. Investing 10% of your annual income in a moderate growth mutual fund. (F)
5. Drinking heavily at a social function. (H/S)
6. Taking some questionable deductions on your income tax return. (E)
7. Disagreeing with an authority figure on a major issue. (S)
8. Betting a day's income at a high-stake poker game. (F)
9. Having an affair with a married man/woman. (E)
10. Passing off somebody else's work as your own. (E)
11. Going down a ski run that is beyond your ability. (R)
12. Investing 5% of your annual income in a very speculative stock. (F)
13. Going whitewater rafting at high water in the spring. (R)
14. Betting a day's income on the outcome of a sporting event (F)
15. Engaging in unprotected sex. (H/S)
16. Revealing a friend's secret to someone else. (E)
17. Driving a car without wearing a seat belt. (H/S)
18. Investing 10% of your annual income in a new business venture. (F)
19. Taking a skydiving class. (R)
20. Riding a motorcycle without a helmet. (H/S)
21. Choosing a career that you truly enjoy over a more prestigious one. (S)
22. Speaking your mind about an unpopular issue in a meeting at work. (S)
23. Sunbathing without sunscreen. (H/S)
24. Bungee jumping off a tall bridge. (R)
25. Piloting a small plane. (R)
26. Walking home alone at night in an unsafe area of town. (H/S)
27. Moving to a city far away from your extended family. (S)
28. Starting a new career in your mid-thirties. (S)
29. Leaving your young children alone at home while running an errand. (E)
30. Not returning a wallet you found that contains $200. (E)

Note. E = Ethical, F = Financial, H/S = Health/Safety, R = Recreational, and S = Social.

Domain-Specific Risk-Taking (Adult) Scale – Risk Perceptions

People often see some risk in situations that contain uncertainty about what the outcome or consequences will be and for which there is the possibility of negative consequences. However, riskiness is a very personal and intuitive notion, and we are interested in **your gut level assessment of how risky** each situation or behavior is.

For each of the following statements, please indicate **how risky you perceive** each situation. Provide a rating from *Not at all Risky* to *Extremely Risky*, using the following scale:

1	2	3	4	5	6	7
Not at all Risky	Slightly Risky	Somewhat Risky	Moderately Risky	Risky	Very Risky	Extremely Risky

The Epworth Sleepiness Scale

The Epworth Sleepiness Scale is widely used in the field of sleep medicine as a subjective measure of a patient's sleepiness. The test is a list of eight situations in which you rate your tendency to become sleepy on a scale of 0, no chance of dozing, to 3, high chance of dozing. When you finish the test, add up the values of your responses. Your total score is based on a scale of 0 to 24. The scale estimates whether you are experiencing excessive sleepiness that possibly requires medical attention.

How Sleepy Are You?

How likely are you to doze off or fall asleep in the following situations? You should rate your chances of dozing off, not just feeling tired. Even if you have not done some of these things recently try to determine how they would have affected you. For each situation, decide whether or not you would have:

- No chance of dozing =0
- Slight chance of dozing =1
- Moderate chance of dozing =2
- High chance of dozing =3

Write down the number corresponding to your choice in the right hand column. Total your score below.

Situation	Chance of Dozing
Sitting and reading	•
Watching TV	•
Sitting inactive in a public place (e.g., a theater or a meeting)	•
As a passenger in a car for an hour without a break	•
Lying down to rest in the afternoon when circumstances permit	•
Sitting and talking to someone	•
Sitting quietly after a lunch without alcohol	•
In a car, while stopped for a few minutes in traffic	•

Total Score = ____________________

Analyze Your Score

Interpretation:

0-7: It is unlikely that you are abnormally sleepy.
8-9: You have an average amount of daytime sleepiness.
10-15: You may be excessively sleepy depending on the situation. You may want to consider seeking medical attention.
16-24: You are excessively sleepy and should consider seeking medical attention.

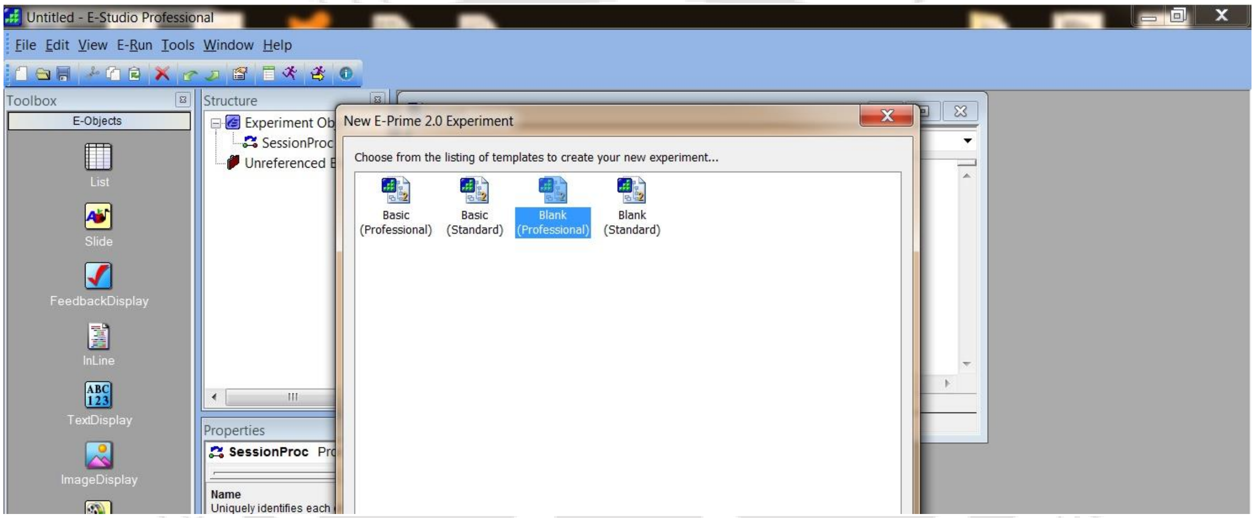
Reference: Johns MW. A new method for measuring daytime sleepiness: The Epworth Sleepiness Scale. *Sleep* 1991; 14(6):540-5.

Appendix B.

Equipments Specification

E-prime 2.0 Professional:

It is a commercially available stimulus presentation software which provides millisecond accuracy while stimuli presentation and response collection. It is written in object oriented programming language and provide both GUI and script writing (Inline) options to make a paradigm for experimentation. It provides the facility to send the event/ stimulus related triggers to EEG system via parallel or serial port at millisecond accuracy. Along with the paradigm design E- prime modules give the options to sort the data in desired output format and graph plotting.



EEG tools and Technique:

EEG is a technique which is used to study and analyze the electrical fields of the brain recorded by amplifying the voltage difference b/w electrodes placed on the scalp or cerebral cortex or brain The resulting traces are known as an electroencephalogram (EEG) and represent an electrical signal from a large number of neurons.

Advantages of EEG over other Techniques:

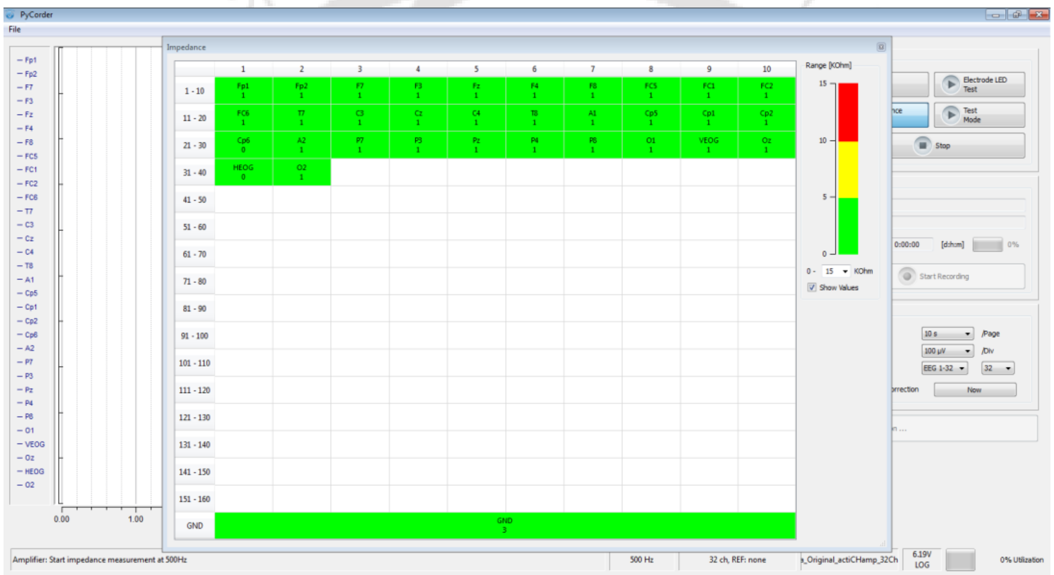
Despite the relatively poor spatial sensitivity of EEG, it possesses multiple advantages over other techniques: EEG is silent, Low Hardware costs, very high temporal resolution on the order of milliseconds, more portable, does not aggravate claustrophobia, not involve exposure to high-intensity magnetic fields or radiation.

EEG data mentioned in this thesis was acquired through the Brain Products EEG system. The components of the EEG system are as follows:

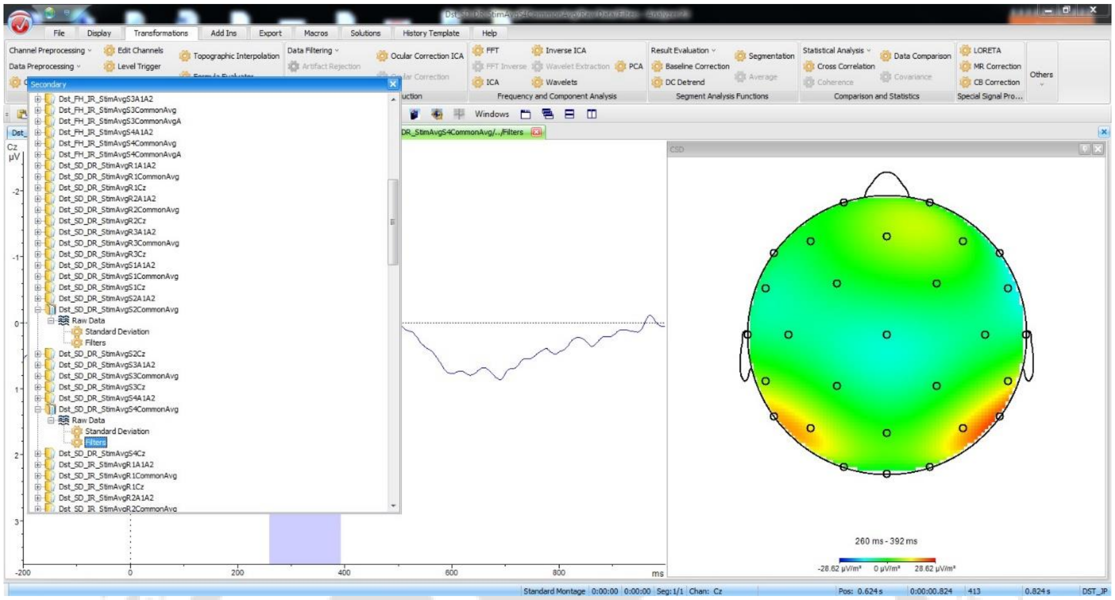
BrainVision actiCHamp: This 24-bit amplifier battery operated EEG amplifier (32 channels + 8 AUX channels) receives the incoming brain signals from scalp surface with the application of actiCAP at sampling rate up to 100 KHz. Its 8 AUX channels inputs the bio signals from bio sensors. This amplifier is intended for research purpose only and follows the EU Directive 93/42/EEC.

actiCAP: This configurable EEG cap containing high-quality Ag/AgCl **active electrodes with the** integrated noise subtraction circuits measure the brain potentials with lower noise level. These caps come with the unique feature of inbuilt LEDs to display the impedance level which reduces the preparation time and extra consumption of recording gel.

BrainVision PyCorder: This Python based source acquisition software allows to setting up the BrainVision actiCHamp amplifier and storing the data. It controls the EEG acquisition as per experimenter requirements and records the EEG signals within user defined module. It records EEG data in .eeg format.



BrainVision Analyser2: This is a commercially available software to analyze the neurophysiological data with highly reliable scientific methods on user friendly interface. This software is comparably fast and compatible to MATLAB and other analysis software. It supports more than 50 file formats for analysis. The software has unique history tree structure of analysis steps and templates which are applicable to multiple datasets and reduces the analysis time efficiently. The software provides multiple options to visualize the output results. Software comprises all analysis methods which include automatic import and export of data, events/triggers, channel coordinates; advanced application of filtering, Raw Data Inspection, interactive ICA, artifact rejection methods, FFT, Wavelets, Coherence, LORETA analysis. The software is compatible to analyze the MR and eye tracker embedded EEEG data.



Polysomnography equipment:

Polysmith™:

This software package from NIHON KOHDEN enables acquisition, real time data display with online automatic sleep scoring, online trending graphs storage, and highly efficient algorithms to measure and analyze the polysomnography data i.e. sleep stages, microarousal apnea/hypopnea, snoring, oxygen desaturation, limb movements, ECG, arousal and SpO_2, EtCO2, pH, BP, Pulse Transit Time, EKG. This 32-bit application runs under Microsoft Windows XP Professional SP2. The package provides flexible and efficient signal processing modules including filtering, FFT analysis, EKG analysis. Our lab uses neurotronix sphinx hardware to acquire the sleep data through which polysmith simultaneously monitor live data with an EEG montage in Nihon Kohden EEG acquisition software neurofax while monitoring a sleep montage with live trending and on-line scoring.

This package is tested for both clinical and research purposes. It manages the patient/participants raw details in structured manner. The package is unique in providing the sleep reports: create a slide show from multiple recordings, extract sleep studies from LTM or epilepsy recordings, combine fragmented recordings, custom create MSLT files for physician review and provide European Data format export capability.