АКТУАЛЬНЫЕ НАПРАВЛЕНИЯ СОВРЕМЕННОЙ ПСИХОФИЗИОЛОГИИ

EMOTIONAL AND COGNITIVE SELF-REGULATION

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A brief outline of four studies that investigated interrelations of cognitive and emotional regulation in collaboration between Departments of Psychology of the University of Cincinnati and Kazakh National University is presented in this article. The aim of the first research was to examine the role of EI in regulating the affective response to a potentially threatening video and relation to brain electrical activity. The second study, conducted at the University of Cincinnati, explored the role of emotion in the search for information relevant to decision-making. The third study was devoted to the evaluating the sensitivity of a range of EEG indexes of engagement to time-on-task effects and to workload manipulation (cueing) during vigilance task performance. The fourth research was based on Posner's theory of executive control and Matthews' theory of task engagement. Results of empirical studies has theoretical meaning in understanding selfregulation and practical value in different fields of applied psychology.

Key words: Self-regulation, emotion, cognitive function, EEG, Brain oscillations, attention.

Emotion regulation has become an increasingly important topic in affective science. It is also a research topic that has its roots in both Western and Eastern European psychological traditions. The cognitive approach to emotion developed by Richard Lazarus [23] in his transactional theory, as well as self-regulative theories, detached emotion from the biological substrate and suggested that emotion may relate to "knowledge level meaning", that does not map straightforwardly into neuronal or computational models [32]. Hence, emotions may have both beneficial and harmful effects. On the positive side, emotions may help the decision-maker to judge the personal impact of the consequences of decisions, and motivate evaluation of different choices. On the negative side, emotions may distort appraisal of the problem and of the decision-maker's own personal resources. Lazarus' (e. g., 1964) development of appraisal theory was a key advance in Western cognitive theories of emotion [23]. He showed that subjects could be induced to process threatening images according to different instructions, which moderated the anxiety response to threat. Specifically, instructions that encouraged participants to deny or intellectualize the threat lowered anxiety compared to a neutral control condition. Furthermore, manipulating appraisal via instructions also influenced psychophysiological response. Thus, the subject's cognitive strategy for processing threat has powerful effects on emotion.

In Eastern Europe the idea that behavior is regulated by a hierarchy of control systems is central to major psychological theories, including those of A.R. Luria, P.K. Anokhin, O.K. Tikhomirov, Yu.I. Aleksandrov and others [20]. The concept of emotional and cognitive integrity was suggested by O.K. Tikhomirov, who is author of the book "Psychology of thinking". Emotional functioning is the holistic coordination of different levels of human activity [2; 3]. Tikhomirov and his colleagues described the effect of the emotional predetermination in decision making and its influence on activity. These authors underlined the importance of intellectual emotion in activity. Other authors have advanced similar views. Yu. I. Aleksandrov argued that emotion and consciousness could be considered as characteristics of different levels of systemic organization of the given behavioral act that correspond to different levels of the differentiation [1]. The ratio of involvement of low differentiated and high differentiated structures in the current behaviour determines whether behaviour is more emotional or more cognitively regulated. Therefore, inducing emotion engages "dedifferentiation or regression" towards earlier forms of organized behaviour, whereas emotion regulation has the opposite effect of transforming behaviour toward higher levels of differentiated behaviour.

However, the biasing effects of emotion on behavioural regulation cannot be attributed to any single process or even to cognition exclusively. Empirical studies show that emotions have an array of effects on immediate stimulus processing, such as selective attention and retrieval from memory that may bias decision making. For example, anxiety may lead to excessive awareness of threat and negative self-evaluations that lead to risk aversion [45]. Emotions also influence the projection of cognition into the future, e.g, mood-congruent effects on predictions of future benefits and losses [24]. Damasio [8] suggested that the emotions facilitate social-problem solving through providing somatic markers ('gut feelings') for possible outcomes. Loewenstein et al. [25] suggested that "anticipatory emotions are immediate visceral reactions (fear, anxiety, dread) to risk and uncertainties" and "anticipated emotions are typically not experienced in the immediate present but are expected to be experienced in the future". These emotions are additional information resources. From a behavioural position, Ketelaar and Clore [18] proposed that emotions function to influence the weighing up and estimation of alternative choices.

The importance — and interdependence — of cognitive and emotional self-regulative processes provides the starting point for our joint research conducted at the Kazakh National University and University of Cincinnati.We will briefly outline four studies that investigated interrelations of cognitive and emotional regulation. These studies used subjective scales to assess cognitive-emotional response in several demanding task settings. For example, the Dundee Stress State Questionnaire (DSSQ: Matthews et al.,

2002) assesses subjective state dimensions including task engagement, distress and worry [31]. Often, the person must regulate such states in order to perform optimally, e.g., by down-regulating distress and negative affect under conditions of cognitive overload, or up-regulating engagement in fatiguing environments.

The first research study, conducted at Kazakh National University, studied the role of EI in regulating the affective response to a potentially threatening video. EEG recordings were taken to explore the role of emotion regulation. This study has also received impetus from the new psychological construct of 'emotional intelligence' (EI), which may be broadly defined as a set of abilities and competencies that support more effective processing and management of emotional stimuli and events [32; 33]. While EI has various facets, a key competence is effective emotion-regulation, i.e., being able to maintain an emotional state appropriate to current goals and avoid excessive negative emotion [42]. The second study, conducted at University of Cincinnati, explored the role of emotion in the search for information relevant to decision-making. Dysregulation of emotion may lead the decision-maker to fail to sample information appropriately, leading to poor decisions. Negative and positive feedback delivery was used as an emotion induction procedure during decision making based on evaluation of probabilities between choices. The third study was devoted to the evaluating the sensitivity of a range of EEG indexes of engagement to time-on-task effects and to a workload manipulation (cueing) during performance of a stressful vigilance task. Finally, the fourth research study also aimed to investigate changes in cognitive regulation during prolonged task performance. According to Posner's theory [40] attention is controlled by three neural networks: Alerting, Orienting, and Executive control. The networks have been differentiated on the basis of both behavioral evidence from studies of attentional task performance, and cognitive neuroscience methods including functional magnetic resonance imaging (fMRI). Our study tested for temporal change in network functioning, using a long-duration version of Posner's Attention Network Test.

An EEG study of Emotion Regulation

Building on Lazarus' [23] early work on appraisal and emotion, Gross [13] has developed experimental techniques for inducing two different emotion-regulation strategies. *Reappraisal* is a strategy that focused on modifying the processing of an emotive stimuli, typically towards constructing a more positive meaning. By contrast, *suppression* operates later in processing, following extraction of meaning, such that the person attempts to inhibit behavioral expressions of emotion. Gross proposes that reappraisal is normally the more effective strategy for regulating negative emotion. Ochsner and Gross [37] suggest that reappraisal is supported by the dorsal prefrontal and cingulate cortex brain areas that are implicated in executive control, which modulate lower-level emotion systems including amygdala and striatum. This hypothesis is supported by fMRI data obtained during emotion-regulation activities.

We might expect that emotionally intelligent individuals were better able to use reappraisal as a means for regulating negative affect. Salovey et al. [42] discriminated three relevant aspects of emotion-regulation. The first is *attention*; regulating emotion requires that the person is aware of their emotional experience. Next is *clarity*, referring to be able to discriminate and understand one's different emotions clearly. The third aspect is *repair*, being able to change one's emotional state constructively, for example, through reappraisal. Salovey et al. [42] developed the Trait Meta-Mood Scale (TMMS) to measure the individual's levels of these three aspects of emotion-regulation. The questionnaire was validated in several subsequent studies.

Our experiment [44] aimed to test whether the TMMS related to the EEG during reappraisal and suppression, using Gross's [13] experimental paradigm. It was hypothesized that subjects high in TMMS repair would show greater frontal activity during reappraisal, but not during suppression, which is not considered an emotionally intelligent strategy. 150 participants viewed a video sequence from a fear-inducing film. They were randomly allocated to one of three experimental groups: control (i.e., no instruction), reappraisal or suppression instruction. They completed a Russian translation of the TMMS (Salovey et al., 1995) prior to watching the video; we verified that the translated scales were acceptably reliable. Spectral power densities (SPDs) in several EEG bands were recorded from multiple electrode sites. Consistent with the hypothesis, scores on the TMMS correlated positively with frontal SPD in two bands related to cognitive regulation (gamma and theta-2) [21]. It appears that one of the many facets of EI (effective mood repair) is supported by frontal functioning.

More generally, these findings help to substantiate the validity of Salovey et al.'s [42] TMMS by showing that scores on the questionnaire predict an objective EEG response. Findings also support Ochsner and Gross's [37] general thesis that emotion regulation processes are supported by a distinctive neural architecture.

Regulation of Emotional Feedback and Decision-Making

The study just described was concerned with how the person regulates their emotional state. A different perspective on emotion regulation comes from studies of how emotions may facilitate or disrupt decision-making, culminating in a behavioral choice. Emotion may be both beneficial and damaging to decision-making, depending on the context [25]. One of the factors that may lead to different outcomes in such studies is the complex nature of decision-making processes. Emotions may have differing effects on the various cognitive processes supporting decision, including attending to relevant information, evaluating its relevance and selecting a choice of action [36].

Panganiban, Matthews and Hudlicka [38] developed an experimental paradigm for examining emotion effects on a complex decision-making task. The task puts the participant in the role of a controller of a search-and-rescue mission in the Antarctic. The participant must choose between different routes for reaching a lost party of explorers as quickly as possible. Each route has its own risks (e.g., possible avalanche) and benefits (possible improvement in weather). The participant must actively search through icons on a map display to obtain route information, and weigh up the costs and benefits of each one prior to making their choice. Panganiban et al. [38] found that anxiety was related to frequency of sampling information about possible risks, consistent with the hypothesis that anxiety relates to bias in selective attention.

In our experiment [22] run at the University of Cincinnati, we followed up this first study to look in more depth at the role of mood states as a factor in searching for information during decision-making. The mood-congruence hypothesis [4] broadly suggests that decision-makers in a happy mood should focus attention on positive cues, i.e., information on the benefits of each route. Conversely, a negative mood should bias information-search towards potentially negative information. Both types of bias are potentially harmful to optimal decision-making, if they lead the decision-maker to neglect important information.

The study incorporated an experimental manipulation of mood state, based on feedback. In a positive feedback condition, outcomes of the participant's decisions were manipulated so that their choice of route was generally successful; benefits were realized more often than costs. Conversely, in a negative feedback condition, adverse events occurred more frequently than beneficial ones, so that the participant failed to rescue the lost party of explorers in time. Use of an adjective checklist measure of mood confirmed that participants generally experienced higher levels of positive affect in the positive feedback condition, and more negative affect in the negative feedback condition.

Feedback did not affect the participants' search for positive and negative items of information directly. However, there was considerable variation in mood *within* each of the two experimental conditions (Emotional intelligence may be one of several factors that influences whether, for example, a person can maintain a positive mood in adverse circumstances). Given individual variation in mood, we then tested how mood correlated with information search strategy in each condition. Results were surprising in that they failed to confirm mood-congruence. In fact, positive mood was associated with greater sampling of benefit information in the *negative feedback* condition, but with less sampling of benefit information in the positive feedback condition. Happiness does not necessarily lead to greater attention to positive information.

A tentative explanation for these findings comes from Martin's [28] mood-as-input model, which states that mood effects depend on how the person interprets the information provided by the mood within a given context. In a context marked by general failure, a positive mood may signal to the person that there is still hope and it is worthwhile to keep searching for potentially fast routes. In the success context, positive mood may be interpreted as showing that the task is largely accomplished, and there is little need to apply effort towards searching for beneficial routes. That is, mood effects depend on the person's management of task demands within a given motivational context.

Task engagement and the sensitivity of EEG indexes

Our third and fourth studies addressed sustained attention and vigilance. Vigilance decrement is defined as "deterioration in the ability to remain vigilant for critical signals with time, as indicated by a decline in the rate of the correct detection of signals" [16]. The ability to maintain high levels of focused attention or vigilance over long periods of time underlies success on a range of tasks, from reading to airport security monitoring; but concentration often fails in such situations [27]. Moreover, sustained attention is deemed to be effortful and stressful when one is required to maintain high levels of performance [27; 30; 31]. Among the major theories of vigilance, the resource model [39] proposes that the drop-off in performance over time — the vigilance decrement — is a result of the exhaustion of information processing resources that are not replenished over time. Modern cognitive-psychological theories of vigilance, based on constructs such as resources [5] and loss of mindful awareness [12] have only relatively recently been used as the conceptual framework for vigilance studies. Attentional resource theory [35; 47] is based on the idea that a metaphorical pool of energy ('resources') supports attention and processing of information. Resource theory holds that, as more effort is needed to fulfill the demands of a task, more resources are used and workload increases. Information processing and performance become impaired when demands exceed available resources [29].

There are probably multiple pathways through which fatigue and stress may impact performance [19]. In addition, temporary mental states such as fatigue and stress may be related to individual differences in attentional processes. Task Engagement is a subjective state linked to vigilance, which includes energetic arousal, intrinsic motivation, motivation for success and concentration. Low task engagement corresponds to a state of fatigue.

Levels of task engagement predict perceptual sensitivity on a range of vigilance tasks [31], as well as other demanding attentional tasks [14]. Task Engagement is seen as an index of attentional resource availability. It may also serve as an indicator of cognitive-adaptive processes such as task-focused coping, and mobilization and direction of resources to task processing. Subjective task engagement tends to decline during vigilance, so that successfully sustaining attention may depend on the person's ability to regulate engagement so as to counter this temporal trend. A number of EEG researchers [26] have revealed that both beta and alpha or theta rhythms negatively correlated with alertness and task engagement. They suggested an EEG engagement index with the following formula: β/θ. Freeman, [11] and Pope [39] suggested the inclusion of the alpha rhythm in any index of engagement. According to these authors an improved EEG engagement index defined by the new formula $\beta/(\alpha+\theta)$ enables not only the systematization of the psychophysiological data, but also allows definition of the EEG parameters signaling cognitive processes such as information processing and attention resources. An EEG study of cognitive task performance confirmed the validity of the "EEG engagement index" [8]. The task load index (TLI) identified by Gevins and Smith [12] may also be promising as an indicator of task engagement. TLI is defined by increased frontal theta and reduced parietal alpha during demanding task performance, i.e., the ratio of theta activity at frontal midline sites to alpha at parietal sites [theta/alpha]. Similar results have been revealed by Fairclough et al. [9], Holm [15], and Nassef et al. [35].

Other indices may also be used to define cognitive responses to mental demands. Increased theta activity from frontal sites indicates increased demand and a state of focused attention [47]. Lower and upper frequency alpha suppression measures have been found to index separate functions relating to attention and task processing respectively [19]. However, few studies have compared the various indices directly, and there is also little evidence on which index is most effective for detection of the loss of alertness associated with the vigilance decrement in performance. Therefore, aims of our study were: 1) to verify that cueing vigilance influences resource availability; 2) to compare a range of EEG indices in relation to their sensitivity to task parameters. Performance data were consistent with the assumption that both the absence of a cue and time-on-task may lead to resource shortfalls, as evidenced by declines in correct detections, findings similar to Hitchcock [14]. In our study, however, RT but not correct detections showed an interactive effect of cuing task period.

The profile of change on the DSSQ suggested decreasing task engagement and increasing distress: a pattern typical of high workload vigilance tasks. There was also higher subjective workload in the uncued condition. The EEG data suggested that TLI and lower frequency alpha were most diagnostic of loss of vigilance. These indices were sensitive to both the cueing manipulation and to task period. Generally, it seemed that lower TLI and higher lower frequency alpha were diagnostic of attentional resource insufficiency. These findings contrast with previous TLI results from multi-tasking studies which link *high* TLI to potential performance breakdown and strain [17]. The significance of TLI may depend on the nature of task demands. The frontal theta and engagement indices showed no general sensitivity to the task manipulations, and may not be diagnostic of resource utilization. The elevation of frontal theta, and depression of the engagement index in period 4 of the uncued task may be linked to the greater stress of the uncued task, evidenced by high tense arousal, and lower self-esteem in the DSSQ data.

Attentional network test and task engagement

A limitation of resource theory is that the underlying cognitive and neural processes that control variation in resource availability are not precisely specified. A more precise account of vigilance and cognitive fatigue may be obtained by investigating temporal change in executive control. Cognitive fatigue may disrupt the person's ability to regulate information-processing, for example, by inhibiting processing of irrelevant stimuli.

Recent work on the cognitive neuroscience of attention may provide a methodology for investigating temporal change in attention networks according to Posner's theory [6; 40; 41]. Alerting describes the function of tonically maintaining the alert state and phasically responding to a warning signal. Automatic and voluntary orienting are involved in the selection of information among multiple sensory inputs. The visual orienting function involves aspects of attention that support the selection of specific information from numerous sensory inputs arriving at different spatial locations. Executive control describes a set of operations that includes monitoring and resolving conflicts in order to control thoughts or behaviors. The executive control function of attention involves more complex mental operations in detecting and resolving conflict between computations occurring in different brain areas [7].

Fan et al. (2002) [10] developed the Attentional Network Test (ANT), to provide independent indices of the efficiency of functioning of each network. The ANT is based on a combination of the cued reaction time (RT) [41] and the flanker tasks paradigms. For our aims we used a longer-duration version of the ANT [40]. Two task manipulations were included in the design of the present study in order to increase the likelihood of performance decrement. First, half the subjects performed with masked stimuli to increase the mental demands of the task. Second, to reduce the potential for recovery, we also included modified task conditions, that tested only a single network, and so should give stronger decrements. The study also assessed subjective state and workload.

The data showed that there was no decline in executive function during a period of continuous performance on a version of the ANT exceeding 1 hour in duration. There was also no temporal decline in the alertness and orienting indices. Indeed, task period effects suggested improvements in executive functioning and alertness over time. Thus, the ANT does not appear to show any performance changes similar to vigilance decrement. Improvements in performance may suggest practice effects on the attentional indices concerned.

It was thought that the masking and task condition manipulations might increase performance decrement, but this was not the case. The manipulation of task condition had minimal effects on performance. The masking manipulation was effective in slowing overall response times. However, contrary to expectation, the executive control index indicated greater improvement over time in the masked compared to the unmasked condition. Thus, even a task version more demanding than the standard ANT failed to show a temporal decrement.

There are several possible reasons for the lack of performance decrement. First, the task may not have been sufficiently demanding for resources to become depleted over time. Second, there are multiple executive functions. Miyake et al., 2000 [34] distinguished between inhibition, set-shifting and updating working memory. The ANT assesses inhibition, but other functions may be more susceptible to cognitive fatigue. Previous work on vigilance suggests that working memory load may be important for the development of a performance decrement [30]. Third, the DSSQ data suggest that the task may not have provoked a substantial loss of task engagement. Typically, the performance of vigilance tasks influences all the DSSQ scales associated with task engagement. Energetic arousal, task motivation and concentration all decrease substantially [43; 31]. In the present study, intrinsic motivation and concentration declined, but the drop in energy was non-significant, and success motivation actually increased. Participants' ability to maintain motivation through striving for superior performance (i.e., success motivation) may have helped to preserve resources and executive control.

In conclusion, there may be various factors contributing to participants' sustained effectiveness on the ANT, including limited cognitive demands, insensitivity of inhibition to cognitive fatigue, and participants' ability to maintain motivation. In any case, the ANT does not appear to be well-suited for investigating the cognitive processes that may contribute to vigilance decrement. Future sustained attention research might explore other information-processing tasks requiring executive control. By contrast, the present research does suggest that the ANT is a fairly robust measure for other types of inquiry, given that performance is fairly insensitive to temporal change.

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ЭМОЦИОНАЛЬНАЯ И КОГНИТИВНАЯ САМОРЕГУЛЯЦИЯ

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Данная статья посвящена серии эмпирических исследований, объединенных единой проблематикой взаимоотношения эмоциональной и когнитивной саморегуляции поведения, проведенных в рамках сотрудничества между кафедрами психологии Университета Цинциннати и Казахского национального университета. Целью первого эксперимента явилось изучение изменений электрической активности головного мозга во время саморегуляции методом подавления и переоценки эмоциональных ситуаций. Второй эксперимент, проведенный в Университете Цинциннати, посвящен изучению отрицательной и положительной обратной связи на поиск информации и принятие решения. Третий психофизиологический эксперимент ставил задачи выявления психофизиологических индикаторов вовлеченности в экспериментальную задачу на устойчивость внимания. Четвертый эксперимент основан на представлениях М. Познера об экзекутивном контроле поведения и теории вовлеченности в выполнение задачи Дж. Мэттьюса. Результаты описанных экспериментов вносят теоретический вклад в развитие понимания механизмов саморегуляции и имеют практическое значение в различных сферах прикладной психологии.

Ключевые слова: саморегуляция, эмоции, когнитивные функции, ЭЭГ, осцилляции мозга, внимание.