INDIVIDUAL, RELATIONAL, AND CONTEXTUAL DYNAMICS OF EMOTIONS

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RESEARCH ON EMOTION IN ORGANIZATIONS VOLUME 14

INDIVIDUAL, RELATIONAL, AND CONTEXTUAL DYNAMICS OF EMOTIONS

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INVESTOR IN PEOPLE

To my soulmate, my forever love, eternally grateful we found each other.
C.E.J.H.

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INTRODUCTION: INDIVIDUAL, RELATIONAL, AND CONTEXTUAL DYNAMICS OF EMOTIONS

The concept of "dynamics" refers to processes that are constantly changing and in motion as opposed to static and stable. Globalization processes and worldwide economic instability have increased scholars' and practitioners' attention to cross-cultural and contextual factors affecting organizational behavior, and also to the transient nature of current work arrangements and related uncertainty (Probst, Sinclair, & Cheung, 2017). In this volume, we address the complexity of emotional forces interacting with physiological, cognitive, and contextual factors in shaping organizational behavior at different levels of organizational functioning consistent with the Ashkanasy (2003) multilevel model of emotions in organizations (see also Ashkanasy & Dorris, 2017). Specifically, Level 1 is related to neuropsychological and a within-person level of analysis of emotional processes; Level 2 refers to between-persons phenomena; Level 3 analyses emotions in dyadic relationships; Level 4 involves emotion at the group level of analysis; and Level 5 deals with macro-level organizational manifestation of emotions (e.g. emotional climate). While the boundaries among the different levels may sometimes be blurred and complicated by emotional phenomena of mixed nature (e.g. crossing intra- and interindividual levels), in this volume we build upon this multilayered perspective and address the emotion-related forces that underlie the functioning of the individual (i.e. self), interpersonal workplace relationships, and the organizational system as a whole.

Evidence regarding people's interest in the current volume's emotion-related topics at individual (e.g. managing emotions), relational (e.g. relationships at work, group emotions), and organizational/context (e.g. emotional climate) level of analysis can be tracked through Google Trends (2018). Two observations stand out from this timeline. First, there is a significant degree of attention to the three domains of individual, relational, and contextual dynamics. Second, there are some intriguing differences in the focus of interest; specifically, the trend for relational topics (e.g. relationships at work/group emotions) is greater than that for organizational level topics (e.g. emotional climate), which in turn is greater than that for individual-level emotion-related topics (e.g. managing emotions).

Given that the dynamics of emotions emerge at all levels of organizational life, the authors of the chapters in this volume provide insights into how emotional processes and their interplay with cognition and context underpin the organizational behavior of individuals, groups, and whole organizations. We have organized the volume into three parts: Part I: "Individual Dynamics of Emotions"; Part II: "Relational Dynamics of Emotions"; and Part III: "Contextual Dynamics of Emotions".

The authors in Part I investigate more self-related topics and contribute to our understanding of decision-making under uncertainty as well as the effects of emotional intelligence and the wellbeing qualities required to lead in the new world of work. Authors also investigate the impact of outward emotional states/display on relationships, and how the brain interacts with body and the social context in order to accomplish work-related tasks.

The relational-centered chapters in Part II deal with topics such as interpersonal (in addition to intrapersonal) strategies for emotional regulation, emotions in virtual teams, and workgroup emotional climate. Authors also cover the interplay between emotional contagion processes and cognitive prototypes in shaping perceptions of abusive supervision, the role of neural networks in determining effective work-related encounters, and how emotions impact employees' effective copying with the loss of workplace relational ties (friendship) and the resulting engagement in work tasks.

Finally, the chapters in Part III examine contextual factors such as emotional contagion and the workplace factors that affect two contrasting dynamics: how emotions facilitate creativity and the experience of fear in the workplace.

THE 2016 EMONET CONFERENCE

The chapters in this volume are drawn principally from the *Tenth International Conference on Emotions and Organizational Life* (EMONET X), which took place in Rome, Italy, in July, 2016, supplemented by additional invited contributions to complement and complete the theme of the volume. We gratefully acknowledge the assistance of conference paper reviewers in this process (see Appendix).

CHAPTERS

Part I: Individual Dynamics of Emotions

In the opening chapter, Yan Li and Neal M. Ashkanasy focus on the dynamic changes that occur within the emotional system when coping with uncertainty. Drawing upon the self-organization theory and using a computer-based experimental study, the authors explore the intensity of pleasant and unpleasant emotional experiences, following immediate outcomes of risky choices over time under three levels of uncertainty. A total of 175 undergraduate students attending a large university in the Asia-Pacific region were randomly divided into three groups corresponding to three risky choice probability distributions (80%, 50%, 20%) and completed a total of 20 binary investment trials. Next, participants received feedback immediately following their choice. Finally, they were asked to report on their immediate emotional feeling state and to complete a manipulation check instrument. Overall, the results suggested a different temporal pattern (i.e., linear vs wave-like) of pleasant emotions from correct decisions and unpleasant emotions resulting from wrong decisions in the face of uncertainty. The study in this chapter contributes to our understanding of the intraindividual dynamics of emotions by suggesting nonlinear changes in the emotional system when performing risk taking tasks under different types of uncertain conditions and dealing with the consequences of the decision made.

In the next chapter, Mark P. Healey, Gerard P. Hodgkinson, and Sebastiano Massaro contribute to the ongoing neuroscience explanation of organizational behavior by assessing whether brains can manage without bodies and without extracranial resources (i.e., in social isolation), and whether brains are the ultimate controllers of emotional and cognitive aspects of organizational behavior. Drawing upon a socially situated perspective, the authors propose a framework that connects brain, body, and mind to social, cultural, and environmental forces, as significant components of complex emotional and cognitive organizational systems. Their arguments suggest that in order to accomplish work-related tasks in organizations, the brain relies on and closely interfaces with the body, interpersonal and social dynamics and cognitive and emotional processes that are distributed across persons and artifacts. The chapter adds to our knowledge of the conceptualization of the interaction among the brain, cognition, and emotion in organizations. As such, it also contributes to the emerging field of organizational cognitive neuroscience.

In the third chapter, Marianne Roux and Charmine E. J. Härtel introduce readers to the fast-paced and dynamic new world of work and the challenges it presents to leadership. They do so by assessing what does and does not work for leaders in the new world of work as evidenced by the literature. Specifically, they suggest abandoning competence only and personality based models as well as values only approaches. Instead, they argue for the adoption of adult developmental theories and placing a greater emphasis on the specific emotional intelligence and wellbeing qualities required for leaders to effectively and sustainably lead in the new world of work.

The contribution by Phatcharasiri Ratcharak, Dimitrios Spyridonidis, and Bernd Vogel in Chapter 4 is also situated in a healthcare setting. Ratcharak and her coauthors consider how the relational identity of professional managers in health care may affect manager–employee relationships in settings where managers hold hybrid roles. They propose that emotional dynamics play a role in two important ways: First, emotions emerge as the result of identity discrepancies and subject to inward regulation. Second manager's emotional displays have a direct effect on relationships through processes such as emotional contagion and outward regulation. In particular, Ratcharak and her associates examine the challenges that emerge when employees face role transitions, such as when health care professionals become managers. The authors further elaborate on their proposed framework by developing a series of propositions that predict the form that emotion regulation strategies will take, which depend on the degree of personal latitude and role identity salience experienced by the manager as well as the kinds of effects that emotional displays by managers have in different work environments.

Part II: Relational Dynamics of Emotions

The research outlined in Chapter 5, authored by Shalini Vohra, deals with the way financial traders use interpersonal emotional regulation to improve their financial decision-making. Based on prior research showing that financial decision-making depends upon traders' ability to regulate their emotions, Vohra argues that, by engaging in interpersonal emotion regulation (i.e., sharing emotions with others and seeking to regulate their emotional states), financial traders can improve the climate of the trading floor, regulate their own emotions, and therefore improve their financial decision-making. The author provides several concrete example of regulation processes and outlines two particular strategies for effective interpersonal regulation: (1) private written expression and reflection and (2) managerial intervention and support. She concludes that managers of financial institutions should try to encourage emotion sharing among traders as a means to improve their decision quality and thereby to boost trading floor effectiveness and productivity.

In Chapter 6, Hieu Nguyen, Neal M. Ashkanasy, Stacey L. Parker, and Yiqiong Li review the theory on abusive supervision and explore how emotion contagion dynamics between leader and followers, and employees' cognitive prototypes of an ideal leader (i.e. implicit leadership theories or ILTs) influence followers' perception of abusive supervision. The authors propose a conceptual model wherein leaders' expressions of negative affect, via emotional contagion, influence followers' negative affect, perceptions of abusive supervision and two behavioral responses: affect-driven and judgment-driven responses. The authors also maintain that a negative emotional contagion process between leader and followers depends upon followers' susceptibility to emotional contagion and their differential interpretation of leaders' emotional expressions (i.e. ILTs). While employees holding a positive implicit leadership theory view their leader as having prototypic features such as compassion, sensitivity, and dedication, those holding a negative implicit leadership theory associate their leader with anti-prototypic characteristics exemplified by abusive supervision and tyranny. On the whole, the dynamic interplay between emotion-related interpersonal processes and cognitive prototypes addressed by the chapter contributes to advance our knowledge on employees' perceptions of abusive supervision and how to prevent unwanted negative leadership.

In Chapter 7, Loren R. Dyck examines the effect of positive and negative emotional ideation in relation to job performance-related outcomes for medical students. Using patient and supervisor evaluations, Dyck hypothesizes that positive self-thoughts, or positive emotional attractors, should be associated with greater student diagnostic accuracy, and patient and supervisor ratings of student effectiveness. He hypothesizes the converse for negative emotional attractors. Moreover, Dyck predicts that student scores on the Medical College Admission test should moderate these relationships. In an empirical field study of student−patient encounters, and using moderated multiple regression analysis, Dyck did not find effects on diagnostic accuracy. Instead, he found positive ideation to be associated with ratings of student effectiveness. Interestingly, he also found a similar effect for negative ideation, suggesting that emotional engagement − irrespective of valance − has a beneficial effect on student effectiveness.

In Chapter 8, authors Melanie E. Hassett, Riikka Harikkala-Laihinen, Niina Nummela, and Johanna Raitis describe a case study of an organization following a Finnish acquisition of a British firm, focusing in particular on the role of virtual teams. Drawing upon in-depth interviews with 32 employees of both firms, Hassett and her colleagues focused on understanding the role emotion played in virtual team interactions following the acquisition. They found that postmerger virtual teams took three forms: (1) virtual teams *per se*, (2) virtual management, and (3) virtual collaboration. While the intensity of virtual communication was highest in virtual teams and virtual management, emotional exchanges played a central role across all three forms. The authors also report finding that face-to-face communication is most helpful in the initial stages in order to establish trust, especially to deal with negative emotions and to overcome cultural differences. They conclude that formation and maintenance of virtual teams is an essential characteristic of contemporary cross-border mergers and acquisitions, but the effectiveness of these teams depends largely on team members' ability to communicate and to interpret emotions accurately in this context.

In Chapter 9, Anna Krzeminska, Joel Lim, and Charmine E. J. Härtel discuss how occupational stress can compromise work performance and team climate. These negative effects can be buffered by internal individual differences and contextual factors. This chapter reports on a study that uses the affective events theory (AET; Weiss & Cropanzano, 1996) as a framework to investigate the perceived stress derived from negative events in emergency service workplaces. The authors employed the experience sampling methodology (ESM;

Csikszentmihalyi & Larson, 2014) to record daily cases of self-reported negative events experienced by participants over a three-week period. They also used a structured survey questionnaire independent of the ESM to collect data from the 44 emergency services operation participants. Their findings indicate that servant leadership behavior, affective team climate, and psychological capital are significantly related to reduced perceived occupational stress. The study advances knowledge on both leadership styles and emotions at workplaces, by considering the impact of servant leadership behavior on affective team climate.

Friendships are an essential part of all workplaces and in some are touted as part of a desired and espoused culture. Yet, as Shimul Melwani and Payal Nangia Sharma discuss in Chapter 10, the transient and dynamic nature of modern work means that as employees move between organizations, friendships become peripheral – with personal, interpersonal, and organizational effects. Melwani and Sharma propose that employees who are left behind (stayers) first experience loss-related emotions, then oscillate between positive gain-related and negative loss-related emotions, and finally integrate these opposing feelings into a discrete but differentiated "granular" emotion. For each of these episodes, the authors posit effects on task and interpersonal engagement. Further, they argue that this process is moderated by the remaining relationships of the stayers and the coping strategies they use. Overall, this chapter advances our conceptual understanding of the effects of changing workplace relationships, the role of emotions in the process of recovery from friendship deterioration, and the factors that enable stayers to recover and maintain their workplace engagement.

Part III: Contextual Dynamics of Emotions

In Chapter 11, Elaine Hatfield, Victoria Narine, and Richard L. Rapson review the literature on emotional contagion and address the role of social context in sparking emotional contagion in occupational settings. Specifically, the authors discuss new evidence intended to provide a better understanding of the role of culture in fostering the ability to read others' thoughts, feelings and emotions. They also provide a global perspective of cultural dynamics shaping the manifestation of emotional contagion in different national contexts. The chapter concludes by proposing future research venues that call for empirical investigation and suggest, among many others, the need to explore cross-cultural differences in terms of individualism vs collectiveness, and people's reactions to in- and out-group social dynamics.

Next, in Chapter 12, author Sue Langley discusses the critical role that positive emotions play in promotion creativity and emotion. Langley presents the results of an online experiment showing the differential effects of positive versus negative emotion on creative output. In the study, she asked 43 adult participants to complete a creative task after watching a video intended to induce a positive or a negative mood. The dependent measure in the study was the number and quality of the ideas that participants could come up within 5 min. Twelve independent experts judged the quality of the ideas generated. The author hypothesized that the positive condition would lead to more and better creative ideas. Results supported these hypotheses. Langley also measured intuition using the Myers-Briggs Type Indicator and found that intuition was associated with higher creative quality but not quantity. These findings provide clear support for the "broaden and build" hypothesis among a working population.

In the final chapter, Marilena Antoniadou, Peter John Sandiford, Gill Wright, and Linda P. Alker explore what fear means to human service workers in the airline industry (flight attendants) and higher education industry (lecturers) of Cyprus, specifically how these employees express fear and how they perceive the consequences of fear. Fear can arise from threats to physical safety, social standing, and self-integrity. The research addresses three questions. (1) Why do human service workers experience fear? (2) How is feared expressed in work settings? (3) What are the consequences of workers' different reactions to fear? Using a phenomenological approach, Antoniadou and her team's interviews showed that fear is not a purely "negative" emotion. In some contexts, controlled or authentic expression of fear (as opposed to suppression) can bring about beneficial consequences such as safer work practices, helpful management responses, and greater ownership of work tasks. The authors' findings suggest that such desirable outcomes at both the organizational and the personal level may be blocked by binary evaluations of emotions as positive or negative and norms dictating emotional expression. The implications for organizational practice point to the need for greater management awareness of the sources, nature, and expressions of fear. It appears that those in authority should consider seeking routine input from employees at all levels, and become more knowledgeable of the antecedents of fear as well as more tolerant of its display. This could help workers to overcome the discomfort of experiencing fear and to address the fear constructively.

Overall, the empirical and theoretical chapters in this volume make use of a wide range of different and sophisticated approaches and provide a worldwide perspective from different nations on workplace emotional dynamics within the individual, during social interactions, and at the level of the larger organizational context. These contributions show the complex interplay among emotion, cognitive processes, brain functioning, and contextual factors that contribute to a better understanding of organizational behavior at multiple levels of workplace life and in the contest of a fast paced, uncertain and dynamically changing work environment. Taken together, the chapters in this volume provide a compendium of recent advances on the dynamics of emotions and points to future research venues consistent with the increasing interest in cross-country investigation and the role of neuroscience in organizational psychology.

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PART I
INDIVIDUAL DYNAMICS OF EMOTIONS

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CHAPTER 1

TEMPORAL PATTERNS OF PLEASANT AND UNPLEASANT AFFECT FOLLOWING UNCERTAIN DECISION-MAKING

Yan Li and Neal M. Ashkanasy

ABSTRACT

In a computer-based experimental study, we explored intensity of pleasant and unpleasant emotional experiences (affect), following immediate outcomes of risky choices over time under three levels of uncertainty (80%, 50%, 20%). We found that the intensity of pleasant affect initially increased linearly before suddenly reducing after the seventh task, and then resumed the linear upward trend. In contrast, the intensity of unpleasant affect cyclically changed after every five decision tasks, displaying a wave-like pattern. Interestingly, the 50% probability (maximum information entropy) group demonstrated patterns quite different to the other two groups (20%, 80%). For pleasant affect, this group reduced in positive affect significantly more than the other two groups after the seventh decision task. For unpleasant affect, the 50% group displayed an increasing negative affect trend, while the other two groups displayed a reducing negative affect trend. In sum, our findings reveal different temporal patterns of pleasant emotions from correct decisions and unpleasant emotions resulting from wrong decisions. We conclude that, consistent with the self-organization theory, these differences reflect nonlinear changes in the emotional system to cope with the challenge of uncertainty (or entropy).

Keywords: Emotion; uncertainty; entropy; decision-making; temporal patterns; self-organization theory

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Emotion is not an isolated system. In this regard, Frijda, Kuipers, and terSchure (1989) point out that the occurrence of an emotional event is cognitively appraised (see also Lazarus, 1991) and leads to behavioral tendencies of approach or avoidance (Carver, & White, 1994; Elliot & Thrash, 2002; Gray, 1990), accompanied by a concomitant transition between information and energy. We also know that emotions have significant impacts on economic decision-making (e.g. see Bechara & Damasio, 2005), that such impact might take the form of a nonlinear self-organizational process (Dishion, 2012) that appear as emergent patterns that vary over time (Guastello et al., 2012; Guastello, Reiter, Shircel, & Timm, 2014), and that these effects are related to entropy levels (Guastello et al., 2013). At the same time, however, we still know little about how time affects emotion in the process of decision-making under varied uncertainty levels (i.e. in terms of Shannon's, 1948, concept of *entropy*). At issue here is the inherently time-dependent nature of emotions in decision-making. In this instance, without understanding of the effects of time, we do not have a full appreciation of the role of emotions in decision-making. To deal with this problem, we sought in this research to explore the temporal dynamics of emotion in repetitive uncertain decision tasks and to examine in particular how such changes are influenced by uncertainty (or entropy).

Our reasoning is predicated in the idea that uncertainty/entropy lies at the heart of understanding the temporal dynamics of decision-making. As Stephen, Boncoddo, Magnuson, and Dixon (2009) point out, uncertainty that exists in the external environment is initially processed as information before being converted into subjective perception and feelings (see also Stephen, Dixon, & Isenhower, 2009). This uncertainty eventually activates variations in biological energy that are needed to maintain the equilibrium of particular states of certainty versus uncertainty (i.e. from the states disordered by uncertainty such as chaotic or near-equilibrium states, see Grossberg, 1971; Keltner & Haidt, 1999; Pakhomov & Sudin, 2013).

To address this question from an affective perspective, we refer to Ashkanasy's (2003) idea that emotions in organizational settings are embedded in a multilevel structure. We combine this notion with Šesták's (2012) hierarchical model, which divides complex systems into structural, functional, and describable levels. In this instance, we reason that the temporal dynamics of emotion for uncertain choices most likely represent manifestations of its structure together with the functionality of the affective system (accompanying with the exchange between information and energy flow). This idea is also consistent with Morgeson and Hofmann's (1999) concept of functionality embedded in the structural hierarchy of a given system. Based in these ideas, we theorize that the structural distinction of human subsystems (pleasant versus unpleasant affect) and the associated nested functionalities (i.e. self-recovery, adaption, entropy–energy transitions) can be explained in terms of an emotional self-organization theory (Izard, Ackerman, Schoff, & Fine, 2000; Li, Ashkanasy, & Ahlstrom, 2010). If this is so, then may be it possible to visualize that entropy–energy dependency can be interpreted in terms of physical theories such as the second law of thermodynamics (Grossberg, 1971) and the dissipative structure theory (Nicolis & Prigogine, 1977).

In the following sections, we develop these ideas with specific application to decision-making under dynamic conditions of varying uncertainty.

THEORY AND HYPOTHESES

More Than Feelings: Emotion and Energy

Consistent with the circumplex model of affect and emotion (Russell, 1980; Watson, Wiese, Vaidya, & Tellegen, 1999), we argue that it is possible to assign particular activation levels to discrete emotional states. For example, fear is more highly activated than sadness; and high spirit is more activated than happiness. On the other hand, however, this structure also implies a theoretical and empirical paradox. For example, if one emotion is more highly activated than another, why do people still experience varying intensity in response to one particular emotion (see Feldman, 1995; Li, Ahlstrom, & Ashkanasy, 2010)? Moreover, Larsen and Diener (1992) and Barrett (1998) demonstrated empirically that activation provides an incomplete representation of emotional states. To deal with this issue, Watson et al. (1999) proposed that affect is defined in terms of two factors – one representing the positive discrete emotions (e.g. happy, exciting, interesting) and the other negative emotions (e.g. sad, angry, afraid) – needed to drive different functionalities toward affective events and subsequent behavior (Li, Ahlstrom, & Ashkanasy; Weiss & Cropanzano, 1996).

More importantly, and as Barrett (1998) points out, if we are to conceptualize the activation levels of emotion theoretically, then we must also grapple with the psychological meaning of affect. We argue that this level of understanding can be best realized via a self-organization theory of affect (Izard et al. 2000; Li, Ashkanasy et al., 2010), where activation levels of affect represent the perceived intensity of internal conditions and external events. In this model, highly activated emotions mark perceived intensities of affective events. They also leverage the attuned force needed to drive, to motivate or to inhibit subsequent behavior (Shepherd, 2003). This view also places the emphasis on the level of emotion that exists between information and energy, and how these forms exchange.

In this regard, Damasio's (1994) demonstrated the function of affect as a form of transition between information and energy. Specifically, in studies of mentally impaired patients, Damasio found that such patients can perceive risk but feel no fear; they consequently lack the energy to drive or to motivate avoidance of risk, and therefore engage in increased risk-taking behavior. In effect, activation of affect appears to be a pivotal factor in exchanges between information and energy, which in turn drives state transitions of an emotional system.

Emotion and Self-organizing Process

Li, Ashkanasy et al. (2010) point out further that emotion acts as an open system. As such, it is therefore comparable to a physical system that exchanges mass, energy, and information with other systems – where emotions change states temporally; varying among equilibrium (e.g. calm, relaxed), near-equilibrium (e.g. happy, exciting, angry, sad), and chaos (e.g. fear, anxiety). Li and her associates (p. 193) refer to this as the "bifurcation model of affect." According to this view, emotions should revert back to an equilibrium state after being disordered into near-equilibrium or chaos states. As we noted earlier, this self-organizing system presents certain properties in common with the generic nature of such systems, such as self-recovery and adaption.

According to the Li, Ashkanasy et al. (2010) bifurcation model of affect, temporal changes in the emotional intensity are influenced by both emotional activation (→ increased intensity) and self-recovery (→ decreased intensity). Activation drives emotion far-from-equilibrium (calm, relaxed), but self-recovery spontaneously draws emotion back to the equilibrium state. The interaction between these states is in turn manifested by cycling patterns of repetitive emotion over time. Moreover, self-recovery always works to reduce the intensity of activated emotion. Note here that self-recovery differs from emotional regulation insofar as it does not demand attention, appraisal, or self-control (Gross, 1998). Instead, emotional self-recovery is driven by biological impulses that are automatically executed (i.e. without awareness). It acts in effect as a kind of "program" implanted into the human mind. This notion leads us to our first hypothesis:

> **Hypothesis 1.** Self-organization mechanisms of emotion make temporal changes inactivated pleasant and unpleasant emotions repetitively periodic.

Emotion and Energy–entropy Dependency

The question that arises at this point is: How does an open system dissipate energy input from the environment so as to maintain its state far-from-equilibrium or to evolve new patterns? We answer this question by referring to Nicolis and Prigogine's (1977) dissipative structure theory, which holds that a self-organized system is also a dissipative structure. Thus, the amount of input energy must be larger than the energy the emotion dissipates within the system to maintain its state far from equilibrium or to emerge new patterns. The dissipative structure theory explains why an open system transfers to nonequilibrium states or emergent new properties in forward order, rather than backward as might be expected in a self-recovery process. In other words, if an emotional system transfers to a near-equilibrium or chaotic state far-from-equilibrium, the emotional intensity is likely to increase. If on the other hand the system transfers in the opposite direction (chaos or near-equilibrium back to equilibrium), the energy levels (or emotional intensity) should decrease.

Moreover, as Guastello and his colleagues (Guastello et al., 2012; Guastello et al., 2013) point out, apart from energy, state transition is largely determined by *entropy*. The entropy in this instance is initially defined as the amount of thermodynamic energy that *cannot* be used for the state transformation for a system. As such, entropy can be used to denote the randomness of a system, where the highest entropy has the most randomness (see Uffink, 2006, for a review of the entropy theory in the physical sciences). Based on these ideas, Shannon (1948) created *information entropy*, which is denoted by the distribution of possible outcomes and reflects the unpredictable nature of random variables in the context of human information communication. Information entropy thus places the emphasis on the information needed to generate a clear perception of surroundings. Thus, if all of the possible outcomes have an *equal* possibility of occurrence, then the system has the highest entropy. Information entropy can also be utilized to denote uncertainty. This effect is represented in Eq 1 (Shannon, 1948, p. 11, Theorem 2):

$$H = -K \sum_{i=1}^{n} p(x_i) \log_2 p(x_i) \tag{1}$$

where H = entropy, K is a positive constant, and $p(x_i)$ = probability of event (x_i).

Based in this notion, uncertainty can be seen to be the key element that triggers the system to enter a far-from-equilibrium state. As Ashby (1947) posited in his classic article, intelligent open systems favor clarity and certainty (i.e. low entropy states) and therefore struggle to reduce subjective or perceived uncertainty automatically and back to equilibrium as all self-organizations. In this regard, Hirsh, Mar, and Peterson (2012) point out that seeking subjective certainty needs energy. In this instance, uncertainty (represented by informational entropy) must also indicate the tendency of energy change of the system from far-from-equilibrium to the equilibrium state in terms entropy–energy dependency. Moreover, since high entropy consumes energy to maintain its equilibrium state, a long-lasting high entropy state should lead to a system becoming exhausted and ultimately to its death (Schrödinger, 1944).

Based in this line of reasoning, we argue that emotion is analogous to a dissipative structure that involves information, energy, and uncertainty exchanges. It follows therefore that emotional states should seek a low entropy state (equilibrium emotions such as relaxed, clam) in preference to a highly uncertain entropy state (anxiety or fear). If this is so, then such a transition (among equilibrium, near-equilibrium, and chaos or far-from-equilibrium) must involve a cognitive change, such as perceived reduction in uncertainty or an increase in certainty.

Nicolis and Prigogine's (1977) dissipative structure theory in turn elucidates the nature of general energy–entropy dependency in the dynamic process of status changes for a self-organizing open system. While this theory was developed for application in physics, we argue that it can be applied to the human emotional system, if it is recognized that the energy–entropy dependency may present different trajectories. Taking the simplest example, the thermodynamics of an isolated container is simply determined by the temperature differences (a single element) over different parts of the container.

In the instance of human behavior, this can be seen to be reflected in maintaining order in consequences of interactions between different mechanisms. To develop this idea further, we refer to Gray's (1982, 2000) twin notions of the behavioral inhibitory system (BIS) versus the behavioral approach system (BAS). Gray argues that, to cope with uncertainty, these bi-mechanisms develop differentiated strategies. For example, BIS on one hand is responsible for behavior inhibition in response to unexpected features of the environment. BAS on the other hand acts to trigger approach behavior to a target, or intensifies previous decisions or behavior. Despite the variety of phenomenal emotional experience (Weiss & Cropanzano, 1996), studies (see Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Davidson, Jackson, & Kalin, 2000; Sutton & Davidson, 1997) have shown constantly that pleasant affect and unpleasant affect are two independent systems that we argue can be associated with BIS and BAS.

Given the oppositional force of pleasant emotion and unpleasant emotion on behavior, it appears reasonable further to conclude that the same level entropy of a system may lead to oppositional trends of energy change in approaching and inhibition. The dissipation or transition of energy needs to differentiate the biological functionality of the interactive subsystems (an idea that has not been well developed to date in the extant literature). In particular, if the opposite functionalities are operating simultaneously, the results would be to distract from goal-oriented action, resulting in inefficiency (Kunde & Weigelt, 2005) – much like a driver who hits the brake while pressing the accelerator.

Specifically, the principle of maximum entropy (Jaynes, 1957) suggests that information entropy is at its maximum when the prior probability of outcomes is completely unknown. To illustrate this, consider a person making a decision (which might be correct or wrong): As she engages in repetitive decisions, she learns and consequently her uncertainty (i.e. entropy) should decrease; as a result, the decision makers can be expected to generate clearer inferences in the following decision-making tasks. In this regard, correct decisions serve to confirm previous inferences under low entropy conditions. In consequence of this, the positive energy elicited by pleasant affect following correct decisions should progressively increase; and negative energy elicited by unpleasant affect following wrong decisions should progressively decrease. Based on this line of reasoning, our next hypothesis is:

Hypothesis 2a. Under low entropy conditions (i.e. high certainty), the intensity of *pleasant* affect (resulting from making *correct* decisions) *increases* with time.

Hypothesis 2b. Under low entropy conditions (i.e. high certainty), the intensity of *unpleasant* affect (resulting from making *wrong* decisions) *decreases* with time.

Under a maximum objective entropy condition, however, the decision situation remains ambiguous over time. Decision makers in this situation are unable to follow previous preferences, knowledge, or inferences to make the next decision. Under such highly uncertain conditions, correct decisions appear to the decision maker to be random. As a consequence, their corresponding energy (triggered by correct decisions) should decrease. On the other hand, wrong decisions are seen to belie previous inferences so that the inhibitory energy elicited by wrong decision-making can be expected to escalate under high entropy. Therefore, our final hypotheses are:

Hypothesis 3a. Under high entropy conditions (i.e. high uncertainty), the intensity of *pleasant* affect (resulting from making *correct* decisions) *decreases* over time.

Hypothesis 3b. Under high entropy conditions (i.e. high uncertainty), the intensity of *unpleasant* affect (resulting from making *wrong* decisions) *increases* over time.

METHODS

Participants

Participants comprised 175 undergraduate students attending a large university in the Asia-Pacific region, with an average age 21 years (range: 17–37) and 57.1% female, who were recruited via the course e-learning BlackBoard™ and informed that their participation was voluntary. Participants were told that they could quit without penalty at any stage and that their performance in the study was unrelated to their ability. Participants received a coffee voucher.

Procedure

Participants were required to complete 20 binary investment tasks under three objective probability conditions (20%, 50%, 80%). Each binary task contained one certain project and one risky project. The *risky project* was denoted as "Project A: $2200K \leftrightarrow 0$," which meant that, if the participant selected this project and won, the participant earned $2200K; if the risky project failed, however, the participant received nothing. The *certain project* was denoted as "Project B: 500K." This meant the participant would earn $500K if s/he selects the project, irrespective of the outcome.

Participants were randomly divided into three groups corresponding to three risky choice probability distributions (80%, 50%, 20%) and completed a total of 20 binary investment trials (refer to Appendix). Each trial contained one certain project and one risky project, and participants were required to decide between the risky versus the certain project. They received feedback immediately following their choice – corresponding to one of the four quadrants in Fig. 1 – together with a statement of their earnings. Quadrant 1 (correct risk-taking) meant the participant selected the risky choice and the risky choice won. Q4 (correct risk avoided) meant the participant selected the certain choice and the risky choice failed. Thus, if they chose quadrants 1 or 4, participants were informed that their decision was "correct." Quadrants 2 (wrong risk taking) meant that the participant selected the risky choice but the risky choice failed. Quadrant 3 (missed opportunity) meant the participant selected the certain choice but the risky choice won. Thus, if participants chose quadrants 2 and 3, they were informed that their decision was "wrong." Following the receipt of feedback, participants were asked to report on their immediate emotional feeling state: pleasant emotion following a correct decision and unpleasant emotion following a wrong decision. Following the 20 decision trials, participants completed a manipulation check instrument.

ANOVA across the three groups indicated that the random distributed groups could be considered as equivalent insofar as the participants in the three groups showed no significant differences in age, gender, expected income, race, or ethnic background. At the same time, the total number of correct and wrong decisions was not significantly different across the three groups, though the probability of risky choices winning differed (which indicates that no group

Outcome / Choice	Win	Lose
Risky (High risk)	**Correct risk-taking**[a] (High payoff)	**Wrong risk-taking**[b] (Zero payoff)
Certain (No risk)	**Opportunity missed**[b] (Low payoff)	**Risk avoided**[a] (Low but nonzero payoff)

[a]Participants informed their choice is "correct."
[b]Participants informed their choice is "wrong."

Fig. 1. The Outcomes of Decision-making.

found it easier to make correct decisions). We also checked on their emotional state for two-week period preceding the study, and found no differences among the three groups.

Between-person Factorial Design

The experimental design followed the typical procedure of probability learning (cf. Erev & Barron, 2005; Estes, 1976), with three probability groups of risky choice winning (20%, 50%, 80%).

80% Probability group	Sixteen risky projects (80%) were randomly designed to win, with other four (20%) resulting in a fail outcomes
20% Probability group	Four risky projects (20%) were randomly designed to win, whereas the other 16 (80%) were designed to fail
50% Probability group	Ten risky projects (50%) were randomly designed to win, the other 10 designated to fail

Decision Scenario and Decision Tasks

Participants were informed, "Assuming you are a CEO of a company in charge of project investments, you will make 20 independent project investment decisions. Each investment decision contains one risky project with possible higher return and one certain project with a relatively low – but sure – return." In each trial, participants were required to decide to invest in either a risky project or a certain project (as we outlined earlier). We asked participants to try to meet two objectives: (1) "Make as much money as you can." (2) "Make as many correct decisions as you can."

Measures

Affective reactions: Barrett and Russell (1998) differentiated affective experiences by valence (pleasant versus unpleasant). Following the structure and the emotion items listed, Seo and Barrett (2007) studied the nine pleasant emotions such as "excited," "joyful," "enthusiastic," "proud," "interested," "happy," "satisfied," "clam," and "relaxed," and nine unpleasant emotions, including "irritated," "afraid," "angry," "nervous," "frustrated," "disappointed," "sad," "tired," and "depressed." In our study, we measured the affective reactions to the decision-making outcomes in terms of the corresponding 18 items. When the participant made a correct decision, pleasant emotions were assumed to be present; their unpleasant emotions were coded as zero. Similarly, wrong decisions were taken to elicit unpleasant emotions and pleasant emotions were coded as zero. We aggregated the nine pleasant and unpleasant emotions to reflect the pleasant and unpleasant emotions overall. The Cronbach's Alpha of pleasant emotions was 0.97 and for unpleasant emotions was 0.98.

Manipulation check: Following the 20 trials, one more binary decision task was present to participants (Project A: 3120K, Project B: 200K). They were asked to rate two questions: (1) subjective probability: "Do you think that risky choices have more chances of winning" on a 1–5 scale (1 = not at all, 5 = extremely). The three groups demonstrated significant differences, $F(172, 2) = 23.9$, $p < 0.01$. The 80% group (3.07 ± 1.22) was higher than the 50% group (2.39 ± 0.99), which was higher than the 20% group (1.77 ± 0.84). (2) Subjective entropy: "Do you feel unsure about which choices had the best chance of winning?" This was rated on a 1–5 scale (1 = not at all, 5 = extremely). The three groups also showed significant differences, $F(172, 2) = 2.98$, $p < 0.05$. The 50% group (2.98 ± 1.24) was the highest; higher than both the 20% (2.87 ± 1.21) and the 80% groups (2.47 ± 1.07). These results demonstrated that, consistent with the theory (and our expectations), the participants in the 50% group perceived the highest subjective entropy after the 20 decision tasks.

Number of correct decision-making (NCDM): We scored both quadrants 1 (correct risk-taking) and 4 (risk avoided) as correct decisions. NCDM is therefore the total number of correct decision over the 20 decision tasks (range: 4–16).

Number of wrong decision-making (NWDM): We scored both quadrants 2 (wrong risk-taking) and 3 (opportunity missed) as wrong decisions. NWDM is therefore the total number of wrong decisions over the 20 decision tasks (range: 4–16).

Groups: The three groups were dummy-coded by G_1, G_2. For example, the 80% probability group is coded as 0, 0; 20% group 0, 1; 50% group: 1, 0.

RESULTS

Descriptive Statistics

Table 1 presents the descriptive statistics, including means, standard deviations, and bivariate correlations of the variables in our study. The significant correlations between correct/wrong decision-making and pleasant/unpleasant affect are clearly evident in the table.

To describe the temporal changes of emotion over the 20 decision tasks (as is normally done when analyzing time series trends), we employed a three-step approach. In step 1, an exploratory step, we graphed the track of pleasant and unpleasant emotions across the 20 decision tasks separately. For step 2, we set

Table 1. Descriptive Statistics.

	1	2	3	4	5	6	7	8
(1) Age								
(2) Gender	0.03							
(3) G_1	−0.06**	0.00						
(4) G_2	0.18**	0.04*	−0.50**					
(5) *N*correct decisions	0.14**	0.01	−0.10**	−0.02				
(6) *N*wrong decisions	−0.14**	−0.00	0.10**	0.02	−1.00**			
(7) Pleasant affect	0.07	0.03	−0.02	−0.03	0.21**	−0.21**		
(8) Unpleasant affect	0.00	0.02	0.02	0.05**	−0.23**	0.23**	−0.76**	
Mean	21.00	0.43	0.31	0.35	10.25	9.75	1.59	1.10
SD	2.79	0.49	0.46	0.48	2.54	2.54	1.71	1.33

Notes: $^{**}p < 0.01$ level (two-tailed); $^{*}p < 0.05$ level (two-tailed). All were estimated based on 3,500 (175 × 20) observations, except the mean and standard deviation of G_1, G_2, and gender which were calculated based on the sample size (175). The three groups are denoted by two dummy variables, G_1 and G_2. Among them, the 80% probability group is coded as 0, 0; 20% group: 0, 1; 50% group: 1, 0.

up models to reflect and the trends of change we could discern in step 1. Finally, we tested in step 3 the models and the possible elements that influence the temporal change using hierarchical linear modeling (HLM), and used these results to test our hypotheses.

Step 1: Graphical Representations

The graphs of unpleasant and pleasant emotions over the 20 decision tasks are shown in Fig. 2(a) and (b). As can be seen in the figures, the patterns for positive affect (Fig. 2(a)) and negative affect (Fig. 2(b)) are markedly different. The intensity of pleasant emotions on one hand demonstrates a discontinuity: After an initial linear increase, there is a sudden slope reversal following the seventh task; then the linear increase resumes from the eighth task. Unpleasant emotions on the other hand showed a cyclical wave-like change every five tasks.

Step 2: Trend Analysis

We set up two statistical models to examine the discontinuous linear change for pleasant emotion (Eq 2 and 3) and the cyclical wave-like changes for unpleasant emotion (Eq 4 and 5). Time is represented in the models by t, with values 1−20. We used dummy variables (G_1 and G_2) to denote the probabilities of three choice groups. Control variables were age, gender, number of correct decisions (N_C), or number of wrong decisions (N_{IC}). For unpleasant emotions, which conformed to a cyclical patters (Fig. 2(b)), we entered four dummy variables (Q_1, Q_2, Q_3, Q_4) to denote the periodic change every five tasks (we represented the wave-like pattern for unpleasant emotions using t^2). For positive emotions, where we found a discontinuity (Fig. 2(a)), we introduced a variable

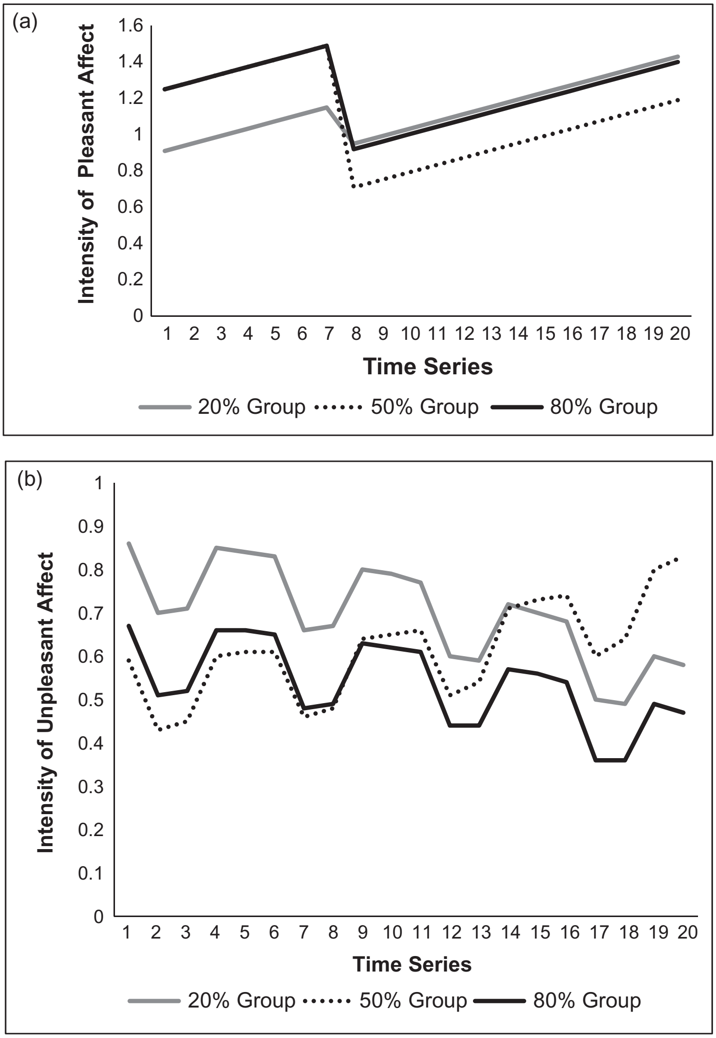

Fig. 2. The Interactive Effects of Probabilities and Time on (a) Pleasant Affect and (b) Unpleasant Affect.

T, where T was zero for $t < 8$, and 1 for $t > 7$. ε represents the error term in both models. The resulting models were therefore:

Pleasant Emotions

$$\begin{aligned}\text{Level-1}: Y = \beta_0 + \beta_1*(G_1) + \beta_2*(G_2) + \beta_3*(\text{Age}) + \beta_4*(\text{Gender}) \\ + \beta_5*(N_C) + \beta_6*(t) + \beta_7*(T) + \varepsilon\end{aligned} \quad (2)$$

$$\text{Level-2}: \beta_7 = \gamma_{70} + \gamma_{71} * (G_1) + \gamma_{72} * (G_2) \tag{3}$$

Unpleasant Emotions

$$\begin{aligned}\text{Level-1}: Y = \beta_0 + \beta_1 * (G_1) + \beta_2 * (G_2) \beta_3 * (\text{Age}) + \beta_4 * (\text{Gender}) + \beta_5 * (N_{\text{IC}}) \\ + \beta_6 * (Q_1) + \beta_7 * (Q_2) + \beta_8 * (Q_3) + \beta_9 * (Q_4) + \beta_{10} * (t^2) + \varepsilon\end{aligned} \tag{4}$$

$$\text{Level-2}: \beta_{10} = \gamma_{100} + \gamma_{101} * (G_1) + \gamma_{102} * (G_2) \tag{5}$$

Step 3: HLM Analysis

We used HLM to test two models and to estimate the relevant parameters underlying our hypotheses; the results can be seen in Tables 2 and 3. The two models represent significant change over time (as shown in Fig. 2). Intra class coefficiencies (ICC) of the second level variables (groups: G_1 and G_2) were significant; they explained 3% of the variance of pleasant emotion temporal change over the 20 tasks (ICC = 0.08/(0.08 + 2.69), df = 174, $\chi^2 = 271$, $p <$ 0.01; and 5% of the variance of unpleasant emotion over the 20 tasks (ICC = 0.09/(0.09 + 1.57), df = 174, $\chi^2 = 374$, $p < 0.01$. The results of general linear hypothesis testing indicated that neither model violated the requirements for the homogeneity.

Table 2. HLM Analysis of Temporal Change of Pleasant Affect.

Fixed Effect	Beta	Coefficient	Robust SE
Intercept	β_0	0.21	0.32
G_1	β_1	0.10	0.12
G_2	β_2	−0.34**	0.11
Age	β_3	−0.01	0.01
Gender	β_4	0.11	0.07
Number of correct decisions (N_C)	β_5	0.14**	0.01
t	β_6	0.04**	0.01
T			
Slope			0.13
Intercept	γ_{70}	−0.61**	0.13
G_1	γ_{71}	−0.21**	0.15
G_2	γ_{72}	0.37**	0.13

Notes: ** $p < 0.01$ level (two-tailed). The three groups are denoted by two dummy variables, G_1 and G_2. Among them, the 80% probability group is coded as 0, 0; 20% group: 0, 1; 50% group: 1, 0. T is 0 for $t < 8$ and 1 for $t > 7$.

Table 3. HLM Analysis of Temporal Change of Unpleasant Affect.

Fixed Effect		Coefficient	Robust SE
Intercept	β_0	−0.33	0.330
G_1	β_1	−0.08	0.090
G_2	β_2	0.19*	0.100
Age	β_3	0.01	0.010
Gender	β_4	0.04	0.060
Number of wrong decisions (N_{IC})	β_5	0.16**	0.010
Q_1	β_6	−0.00	0.060
Q_2	β_7	−0.16*	0.070
Q_3	β_8	−0.15*	0.060
Q_4	β_9	−0.00	0.060
Square of time (t^2)	β_{10}		0.000
Intercept	γ_{100}	−0.0005**	0.013
G_1	γ_{101}	0.0011**	0.000
G_2	γ_{102}	−0.0003**	0.000

Notes: **$p < 0.01$ level (two-tailed); *$p < 0.05$ level (two-tailed). The five tasks were coded by four dummy variables Q_1, Q_2, Q_3, Q_4. The first task is coded as 0, 0, 0, 0; the second task 0, 1, 0, 0; the third 0, 0, 1, 0; the fourth 0, 0, 0, 1; the fifth 1, 0, 0, 0.

Hypothesis Tests

In Hypothesis 1, we predicted that self-recovery of emotion would result in cyclical change. This is supported for both pleasant and unpleasant affect (see Fig. 2), but the nature of two cycles is strikingly different. The cycle occurred only once in the instance of pleasant emotions, but was repetitive in the case of unpleasant emotions. To understand the particular nature of these temporal changes, we need to look at the results of testing Hypotheses 2 and 3.

In Hypothesis 2a, we predicted that, under low entropy conditions, the intensity of *pleasant* affect would *increase* over time. As can be seen in Fig. 2(a), the intensity pleasant emotions did initially increase linearly over time. This is apparent in Table 2, where $\beta_6 = 0.04$, $p < 0.01$, which supports Hypothesis 2a. But the linear increase suddenly reversed following the seventh task, indicating a discontinuity. To examine this further, we introduced a coefficient of T (T is zero when time is less than eight, 1 when larger than 7), which was significantly moderated by the second level variables (G_1 and G_2). This result is reflected the values of β_7: For the 80% group, $\beta_7 = -0.61$; for the 20% group, $\beta_7 = -0.21$; and for the 50% group, $\beta_7 = -0.82$. Among the three groups, the 50% group showed the sharpest reversal. This finding supports Hypothesis 3a to some extent, but the reversal occurred only after the seventh task (which we did not anticipate). In sum, while the discontinuity seems to be a manifestation of self-recovery of pleasant emotion (which we predicted), the cyclical pattern was not repeated.

In the instance of unpleasant emotions, on the other hand, we did find in fact the repetitive cyclical pattern we expected in Hypothesis 1 (see Fig. 2(b)). As can be seen in the figure, *unpleasant* emotions resulting from wrong decision-making (wrong risk-taking or opportunity missed) appear as a wave-like pattern. This is also reflected in Table 2, there the coefficient of t^2 is significant, $\beta_{10} = -0.0005$, $p < 0.05$. Within each wave for five tasks, the coefficients for the second and third quadrants were significant, $\beta_7 = -0.16$, $p < 0.05$; $\beta_8 = -0.15$, $p < 0.05$. Also consistent with our hypothesis, the intensity of unpleasant emotion represented a change cycle and was significantly reduced. In this regard, we see that G_1 ($\gamma_{102} = 0.0011$, $p < 0.05$) and G_2 ($\gamma_{102} = -0.0003$, $p < 0.05$) significantly moderated t^2, which indicates that the three groups manifested different change trends. Further calculation shows support for Hypothesis 2b in that t^2 decreased for the 20% and 80% groups, $\beta_{20\%\text{Group}} = -0.0008$, $p < 0.05$; $\beta_{80\%\text{Group}} = -0.0005$, $p < 0.05$. In support of Hypothesis 3b, we found that a positive relationship for 50% group, $\beta_{50\%\text{Group}} = 0.0006$, $p < 0.01$.

In summary of our results, we found unequivocal support for Hypothesis 1 (cyclical decrease) in the instance of unpleasant emotions, but results for positive emotions indicated a discontinuity, rather than a cyclical effect. In view of this, we developed different models to presentment the dynamic effects of pleasant and unpleasant emotions. Within this proviso, subsequent HLM modeling supported Hypotheses 2 and 3.

DISCUSSION

Through analyzing the temporal changes of emotion in 20 repetitive decisions under three objective probabilities, we found structural differences between decision makers' unpleasant and pleasant emotion across time. As such, our findings suggest some intriguing conclusions regarding the complex but sophisticated functionalities of emotion systems as a form of self-organization to cope with external uncertainty. In particular, our findings reveal some interesting temporal properties of emotional processes, which demonstrate the nonlinear characteristics of self-recovery, adaption to change, and entropy−energy transitions that we theorized. In this regard, we found that self-recovery mechanisms work to draw activated emotional states back to the initial state, but that the mechanisms are different for pleasant and unpleasant emotions. Based on our findings, we argue that these effects appear to occur *between* cycles for pleasant emotions following correct decision-making, but the effects seem to occur *within* cycles in instances of unpleasant emotions following wrong decision-making. In the following paragraphs, we discuss the implications of these findings in more detail.

Time and Period Patterns

Despite differences, both unpleasant and pleasant emotions appear to demonstrate cyclical patterns of variability. But the nature of this variability is strikingly different in each case: For unpleasant emotions, we found a reversible wave-like periodic pattern. This is consistent with the Li, Ashkanasy et al. (2010) notion that emotional states automatically revert back to an equilibrium state after becoming disordered (i.e. near-equilibrium or chaos). In fact, the pattern we found was remarkably regular; the same significant intensity drop in the unpleasant emotion intensity occurred after each set of five decision tasks, whereas changes in pleasant emotions were not repeated. Our participants did not show a sudden decrease in their experience of pleasant emotions after every seven tasks. As can be seen in Fig. 2(a), in the second cycle, the intensity increase of pleasant emotion was sustained.

Another theoretical implication concerns the wave-like function we found for unpleasant emotions. Wave function is well known as a property of quantum behavior – the discrete nonlinear change over time. The wave-like dynamics of unpleasant emotion implies that its temporal change is likely to work following the quantum mechanics (Gell-Mann, 1994). As Kelso (1950) claims: "Time itself cannot change behavior rather the brain's neural activities do." Therefore, the macroscopic wave-like temporal pattern of unpleasant emotion indeed reflects the possible invisible quantum way in which neural activities work. But, as Einstein, Podolsky, and Rosen (1935) speculated, the wave function is incomplete in quantum mechanics. Described as "Einstein's puzzle," Einstein and his colleagues (1935, p. 780) argue that "the wave function does not provide a complete description of the physical reality." They go on to state that "We left open the question of whether or not such a description exists. We believe, however, that such a theory is possible." This leads us to wonder whether the temporal pattern of pleasant affect might constitute further application of quantum theory in human decision-making and management (e.g. see Lord, Dinh, & Hoffman, 2015).

Indeed, same as the unpleasant emotion, the temporal change of pleasant emotion – "a well-defined peak" and a sudden drop at the seventh task – also displays a discrete nonlinear change, the property of quantum mechanics but in a different way. The drop at the seventh task would appear to represent an organization of brain activity following positive events. The function of the temporal pattern for the pleasant emotion could be theorized as the principle of a "pressure cooker" – manifest in the form of an accumulation of energy (intensity of emotion), followed by energy release, then a new cycle of linear increase with an increased tolerance to the peak of pleasant emotion.

Entropy–energy Transition

Finally, we argue that our findings present some interesting insights into the role of entropy–energy transitions in human thought processing. According to Prigogine and Stengers (1997), free energy in relationship between a systematic state and its energy level is at minimum at the equilibrium state. When a system is far-from-equilibrium, on the other hand, matter becomes more "active." The findings of our study partially support this idea, but only in the instance of unpleasant emotions. As we found, both the 80% and 20% probability groups (i.e. with the same low information entropy property) decreased their intensity of unpleasant emotion over time. But for the 50% group (i.e. the group with maximum entropy), the intensity of unpleasant emotion appeared to increase over time. For pleasant emotions, however, the intensity of emotion for the gain of correct decision of the two groups (20% and 80% groups) was significantly higher than the 50% group after the slump following the seventh task. It seems that, when the system entered a far-from-equilibrium state, especially for the 50% probability group, the emotion system was unable to return easily to equilibrium. These findings imply that energy levels increase for inhibition of a previous state (i.e. unpleasant emotions) and decrease for approach (i.e. pleasant emotions) to a previous state.

LIMITATIONS, IMPLICATIONS FOR PRACTICE AND POLICY-MAKING, AND FUTURE STUDY

The findings of this study provide important implications for practice and policy-making. First, escalating unhappy inhibitory energy is likely to be turned into neo-revolutionary energy under highly ambiguous situations (maximum entropy), insofar as it keeps on increasing with time. Second, unpleasant affect because of frustration appears to increase progressively under highly uncertain conditions, until it finally becomes a force powerful enough to remove the uncertainty or ambiguity. The resultant surge in anger resulting from accumulated frustration in a highly ambiguous situation, for example, is likely to trigger extremely unpredictable behavior (to avoid the unbearable ambiguity). Finally, time matters in periodical patterns (see Lord et al., 2015). After seven repetitions, the positive feelings will face a new reorganization no matter whether people like or not; each negative effect from negative events will be absorbed after five repetitions. Why seven and five? We do not know. If these effects are replicated in future research, however, researchers will need to try to understand these numbers.

Despite these important implications, we acknowledge that our study is not without limitations. We identify three such limitations.

First, ours was a laboratory study employing undergraduate students who made investment decisions using hypothetical scenarios. In addition, the stimulus scenarios were presented in a skeletal form. This was to enable us to control the objective probabilities of decision-making, but we recognize that more complex factors are likely to come into play in real business organizations. We also recognize that organizations in reality must adapt to more than just the objective probability of outcomes.

Second, is the issue of external validity of laboratory research using undergraduate student participants. In this regard, we approach in the first instance with reference to Mitchell (2012), who found in a meta-comparison of laboratory and field research in applied psychology that results were highly correlated ($r = 0.89$). In addition, consistent with Mook (1983), we are studying the nature of human decision-making, which is not situation-dependent. Nonetheless, we do acknowledge that real-world organizations need to adapt to risky situations based on their knowledge and experiences about markets, technology, products, and finance. In this regard, we call for future research to test our results in field settings.

Finally, we note that this study was based on just 20 decision-making tasks. In this regard, we cannot tell whether or not pleasant emotions would make a second reversal after 20 decisions. We also do not know what behavior participants would react in the case of wrong decision-making after 20 trials under the high entropy state. In future research, more decision trials should be conducted to examine the more extended temporal patterns.

CONCLUSIONS

In this study, we explored the intensity of pleasant and unpleasant emotional experiences (affect), following immediate outcomes of risky choices over time under three levels of uncertainty (80%, 50%, 20%), and employed a quantum analogy to predict and test decision-making outcomes. Based on this analogy, we expected to find a self-organizing effect, reflected in periodic variations in pleasant and unpleasant affect following decision outcomes, and which would be different for low (80% or 20% probability) versus high entropy (50% probability) conditions. While we support for this notion, the results for pleasant versus unpleasant affect were markedly different. In the case of pleasant affect, results indicated a linear increase, followed by a sudden reversal before a resumption of upward trend. In contrast, the intensity of unpleasant affect cyclically changed after every five decision tasks, displaying a wave-like pattern. Moreover, the 50% probability (maximum information entropy) group demonstrated patterns quite different from the other two groups (20%, 80%). For pleasant affect, this group reduced in positive affect significantly more than the other two groups after the seventh decision task. For unpleasant affect, the 50% group displayed an increasing negative affect trend, while the other two groups displayed a reducing negative affect trend. In sum, our findings reveal different temporal patterns of pleasant emotions from correct decisions and unpleasant emotions resulting from wrong decisions. In conclusion, and consistent with self-organization theory, these differences reflect nonlinear changes in the emotional system to cope with the challenge of uncertainty (or entropy).

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APPENDIX

Decision-making Tasks

Trial	Decision Tasks	Designed Results of Whether Risky Choice Win		
		Risky Group	Certain Group	Even group
1	Project A: 2500K ↔ 0 Project B: 500K	✓		
2	Project A: 800 ↔ 0 Project B: 100K	✓		
3	Project A: 2100K ↔ 0 Project B: 300K		✓	✓
4	Project A: 3000K ↔ 0 Project B: 600K	✓		✓
5	Project A: 2800K ↔ 0 Project B: 400K	✓		✓
6	Project A: 2500K ↔ 0 Project B: 250K	✓		✓
7	Project A: 3500K ↔ 0 Project B: 500K	✓		✓
8	Project A: 4800K ↔ 0 Project B: 1200K	✓		✓
9	Project A: 1080K ↔ 0 Project B: 360K		✓	
10	Project A: 1800K ↔ 0 Project B: 600K		✓	
11	Project A: 1920K ↔ 0 Project B: 480K	✓		
12	Project A: 360K ↔ 0 Project B: 120K	✓		✓
13	Project A: 2100K ↔ 0 Project B: 700K	✓		
14	Project A: 1260K ↔ 0 Project B: 420K	✓		
15	Project A: 1000K ↔ 0 Project B: 330K	✓		
16	Project A: 2200K ↔ 0 Project B: 550K		✓	✓
17	Project A: 1400K ↔ 0 Project B: 700K	✓		

(*Continued*)

Trial	Decision Tasks	Designed Results of Whether Risky Choice Win		
		Risky Group	Certain Group	Even group
18	Project A: 600K ↔ 0 Project B: 200K	✓		✓
19	Project A: 6000K ↔ 0 Project B: 2000K	✓		
20	Project A: 2000K ↔ 0 Project B: 900K	✓		✓
Additional Decision task	Project A: 6900K ↔ 0 Project B: 2300K			

✓: means in that task, the risky choice is designed as winning. K: thousand.