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Neuroscience and a Nomological Network for the Understanding and Assessment of Emotions in Information Systems Research

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Abstract: Human emotions' role in phenomena related to information systems (IS) is increasingly of interest to research and practice, and is now informed by a burgeoning literature in neuroscience. This study develops a nomological network with an overarching view of relationships among emotions and other constructs of interest in IS research. The resulting 3-emotion systems' nomological network includes three interacting emotion systems: language, physiology, and behavior. Two laboratory experiments were conducted to test the nomological network, with six online travel service Web pages used as stimuli. The first study used paper-based self-report measures and qualitative comments, whereas the second included both self-reports and electroencephalography (EEG) measures. An outcome measure of e-loyalty was included in each study. The results of both studies showed positive and negative emotion-inducing stimuli were related to positive and negative emotions when viewing the Web sites as indicated by both self-reports and EEG data. In turn, positive and negative emotions as measured by both self-reports and EEG measures were linked to e-loyalty to some degree. This research is novel and significant because it is possibly the first in-depth study to link the study of emotions in IS with a sound theory base and multiple measurement approaches, including neuroscience measures. It shows that an EEG measure has some predictive power for an outcome such as e-loyalty. Implications of the research are that IS studies should distinguish between the different emotion systems of language and physiology, choose emotion measures carefully, and also recognize the intertwining of the emotion systems and cognitive processing.

Key words and phrases: emotions in information systems, measurement, NeuroIS, neuroscience, nomological net.

Human emotions' role in phenomena related to information systems (IS), which include e-commerce, information acquisition, decision making, and social networking, is increasingly of interest to research and practice. Damasio [16] has demonstrated the critical role of emotions in high-level cognition using neuroscience techniques. Norman [57] has been influential in arguing that emotion is a key component of people's experiences of the people and objects with which they interact. His work on design recognizes that people respond not only in practical or logical terms to design features, but also in aesthetic and emotional terms. In marketing, increased attention to emotions has followed Zajonc [89], who argued that emotions have primacy over and can operate independently of cognition. Indeed, IS interest in emotions is growing, with reports of both positive emotions [51, 62, 65, 76, 81, 83] and negative emotions [3] linked to cognitive states, such as attention and memory, and a range of outcomes. A recent overview by Zhang [90] considers affect in general in the IS context. The advent of neuroscience techniques in IS (NeuroIS) promises new and exciting means for understanding and assessing constructs such as human emotions [24].

With the burgeoning interest in NeuroIS measures, it is timely to consider the theoretical basis for assessing emotion constructs. For research rigor, the understanding and measurement of emotion concepts and understanding of all the theoretical concepts should be soundly based on relevant theory [33]. Theoretical perspectives on emotions are diverse, as are the views on how emotions can be measured; yet the IS field lacks a full treatment of the theoretical base for investigating emotion-related phenomena.

Primarily, this study develops a nomological network that provides a theoretical grounding for understanding and assessing emotions in IS research. The nomological network (hereafter, "the network") overviews how emotion concepts are linked to other concepts of interest in IS research. The network is based on *3-emotion systems theory* [8, 47] and a considerable body of empirical work that incorporates both neuroscience and more conventional investigations. The three emotion systems are physiology, language, and behavior. The network has implications for how emotions are assessed, suggesting that a multimethod approach is desirable for emotion assessment [47]. Neuroscience measures that are linked to one of the three systems in emotional experiences should be seen as complementing measures that are linked to one of the other systems, rather than replacing them. This view diverges from one in which NeuroIS methods are seen primarily as a way of increasing research rigor by providing more objective measures than subjective self-report measures (e.g., see [21]). The viewpoint that we advance here suggests that NeuroIS and self-report measures tap into different aspects of an emotional experience and hence give different insights; thus, there are advantages in using them in combination.

Our study investigated the following research questions:

RQ1: Is there empirical support for the 3-emotion systems' nomological network for IS?

RQ2: Do measures from different emotion systems converge?

RQ3: Do measures from different emotion systems offer different insights and advantages?

To address these questions, we compare two of the three emotion systems: physiology and language.

Two experiments were performed. The first incorporated two self-report (language) measures and qualitative commentary, and allowed a larger sample than was possible with the second experiment, which used both self-report and electroencephalography (EEG) measures. Both experiments used online travel services' home pages as stimuli. The home-page stimuli included different images taken from the International Affective Picture System (IAPS) [44], and were designed to elicit different emotions in viewers. The experiments also included an outcome construct of e-loyalty, representative of the attitudes and behaviors influenced by emotional experiences.

This study contributes to theory by proposing the high-level 3-emotion systems' nomological network, soundly based in prior theory and empirical work. The results support the network and show that emotion theory developed in fields outside of IS can be applied to the IS context. There are several important implications for IS research. IS studies should distinguish between the different emotion systems of language and physiology and not regard NeuroIS measures as a replacement for language-based measures. Language-based measures of emotion should be chosen carefully, and the relative merits of the dimensional versus the discrete emotion approaches appreciated. Furthermore, the intertwining of emotional and cognitive reactions should be recognized.

We proceed by first outlining the conceptual background and the 3-emotion systems' nomological network. We present the hypotheses for testing the model's validity in the third section. We then present the research method in the fourth section and the results in the fifth section. A discussion and conclusions completes the paper.

Conceptual Background

This study rests on the premise that the understanding, definition, and measurement of theoretical concepts cannot be separated from the body of theory to which they belong (see [33]). Thus, any discussion of emotional experiences and any method for the measurement of emotions should be cognizant of current theories of emotion.

In this section, we first discuss the overarching theory of emotion and use this theory to develop the 3-emotion systems' nomological network for understanding emotional experiences in the usage of IS. A nomological network shows how concepts of interest are linked in a web of relationships in a specific domain. Subsequent discussion in this section deals with different perspectives on the categorization of emotions and the means by which they can be measured. Hypotheses are then developed from the 3-emotion systems' network for testing in the empirical studies described later in the paper.

To begin, we offer a working definition of emotion as "[a]n evaluative response (a positive or negative feeling) that typically includes some combination of psychological arousal, subjective experience and behavioral or emotional expression" [10, p. 392]. An emotion is distinguished from affect, which is seen as a pattern of observable behaviors that indicate an individual's emotions, and from mood, which is mostly a longer-lasting and more general emotional state [10].

A Nomological Network for Emotions in IS Research

There are many theories of emotions and many conflicting views. The theoretical perspectives we follow provide a functional view of emotions. In functional views, emotions "serve clearly specified functions, prioritizing and organizing ongoing behaviors in ways that optimize the individual's adjustment to the demands of the physical and social environment" [38, p. 468]. Functions are a consequence of goal-directed activity and have regular systematic consequences that benefit an organism. A functional viewpoint is appropriate in the context of our investigation because we are concerned with specific causes and consequences of emotion in an environment (IS design and use).

A functional viewpoint is congruent with evolutionary theory and the Darwinian view that emotions serve an adaptive purpose in human communication; for example, through facial expressions [17]. Emotions also motivate individuals to perform actions. A perceived threat leads to fear, which leads to fight (aggression) or flight (avoidance). A pleasantly perceived stimulus that heralds future reward leads to positive emotions and approach behavior toward the stimulus (see [63]). The perception of the stimulus involves an appraisal of its personal significance [72]. This appraisal can occur at several levels, which includes very low automatic levels of the central nervous system. A cognitive appraisal process can precede the emotional experience: a stimulus that is appraised as affecting a person's well-being leads to happiness or fear. However, some spontaneous and automatic emotional reactions can precede a conscious evaluation of a stimulus (see [68]). Zajonc [89] showed that preferences for some stimuli resulted from previous exposure to the stimuli, although participants were not consciously aware that they had seen the stimulus. Zajonc [89] concluded that "preferences needs no inferences" [89, p. 151]. These ideas are congruent with dual-process-type theories of human thinking, where one process is intuitive, fast, unconscious, and emotion linked and the other process is conscious, slower, and more controlled. Kahneman [37] depicts the two styles of processing as intuition (system 1) and reasoning (system 2). Following this stream of thought, the nomological network in Figure 1 shows cognitive processing and emotional experiences as intertwined. Seeing a snake close by can automatically cause fear, while fear in another situation may result from a conscious appraisal (the fear of pain anticipated at the dentist).

Functional theories of emotion tend to treat emotions, behaviors, and biological components as systems of coordinated responses that work together to meet some end. A well-accepted functional view of emotions is the 3-systems emotion theory, which holds that there are three primary interacting emotional response systems: those of subjective experience/language, physiology, and behavior [8, 18, 47]. This view is based on Lang's [41] bioinformational theory. Further distinctions can be made among these systems. The language system, for instance, contains subjective self-reports of emotion as well as vocalizations. Each of the three emotion systems contains channels that convey information about the emotional experience of an individual (see [8, 47]). However, "[t]he multiple channels are not tightly connected to each other, thereby not offering well-calibrated or *interchangeable indicators*" [47, p. 337, emphasis added].

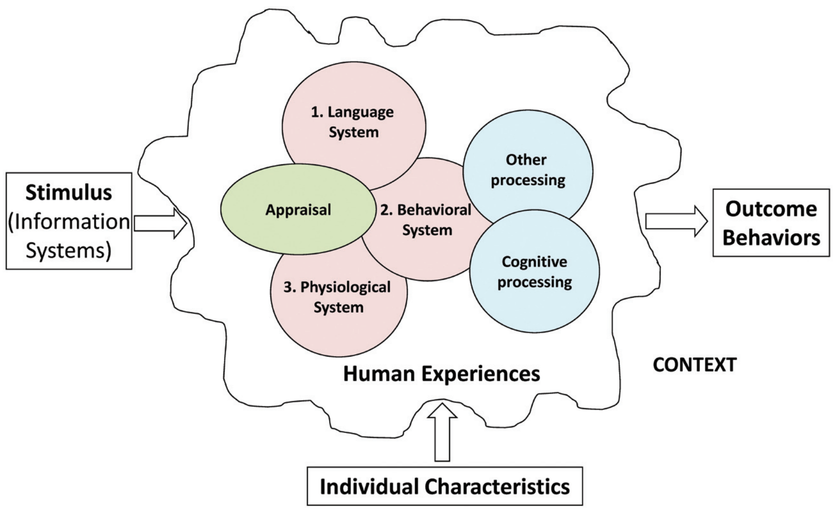

Figure 1. The 3-Emotion Systems' Nomological Network for IS Research

Moreover, the three emotion systems are interlinked with other human systems, such as those for cognitive processing and vision [8, 47].

Thus, we develop a nomological network for the understanding and assessment of emotions based on the 3-emotion systems' theory (see Figure 1). The concept of the three emotion systems is the focal point of this study because it underlies the different means used for assessing emotions. Nevertheless, it is also important to be able to place emotional response in a wider view of IS usage, which is what the nomological net offers.

Other components of the 3-emotion model are explained as follows. At the highest level, the *context* in which the emotion experience occurs should be taken into account. The experiencing of emotions will vary with the context; for example, the fear of a dangerous animal seen nearby in real life would be more intense or of longer duration than the fear of an animal on the Internet [46]. It is important that IS research investigates benchmarks for emotion experiences and relationships in the IS context because these may differ from other contexts. Emotions have been extensively studied in other fields, including marketing, but IS includes novel systems such as social media where emotional experiences may be quite different from other contexts.

On the left-hand side of the model (Figure 1) is the external stimulus that gives rise to the emotion experience, which, in this model, is an *IS stimulus.* The idea that IS can elicit emotional responses is well supported in the literature (see [57]). The emotion experiences follow an initial *appraisal process* [72]. The three emotion systems of language, physiology, and behavior are linked in the emotion experience with *other human systems* that include cognitive systems and visual systems [8]. In investigating emotions, it is also necessary to consider *personal characteristics* of the individual experiencing the emotions, which includes personality differences. Furthermore, individuals differ from each other in their average level of emotional state [45]. Also of interest in IS research are *outcomes* that are influenced by emotions, which include attitudes, intentions, and actions (as in [51, 81]).

Specificity Versus Generality in Conceptualization of Emotions

Another facet of conceptualizating emotions is their classification and measurement, for which there are two dominant perspectives. The dimensional perspective, also referred to as the "Mehrabian–Russell model," proposes three broad dimensions to categorize emotional responses: hedonic valence, arousal, and dominance [43, 53, 60, 69]. The hedonic valence dimension indicates variation in states of pleasure (hedonic experience) that range from unpleasant (e.g., unhappy, displeased) to pleasant (e.g., happy, pleased). The arousal dimension indicates variation in states of arousal that range from unaroused (e.g., quiet, sleepy) to highly aroused (e.g., excited, wide awake). The arousal dimension is also referred to as "activation" [52]. In 1980, Russell and Pratt [70] proposed a modification to the Mehrabian–Russell model that omits the dominance dimension. They argue that dominance requires a cognitive interpretation and that valence (pleasure) and arousal are sufficient to represent people's emotional or affective responses in many environments. This line of argument led to the influential "circumplex model" of emotional reactions to environments [70]. Our study retains the original tridimensional model to allow benchmarking against other studies (including the IAPS studies) that employed all three dimensions (e.g., [44]). However, we employ the two-dimensional model when the dimensions are used as explanatory constructs.

An alternative to the dimensional view is the discrete emotions view, which proposes that more specific emotions are identifiable. Common basic emotions are anger, fear, happiness, sadness, and disgust. These basic emotions are thought to be typical of the human species and culturally independent. More complex emotions such as contentment, loneliness, and guilt may depend more on culture. Emotions tend to be experienced in clusters; that is, when one negative emotion such as guilt is experienced, others such as anxiety and sadness will also be experienced [10, p. 397].

The two views on categorizing emotions are to some extent reconcilable because discrete emotions can be regarded as particular combinations of underlying dimensions. For example, disgust could be represented as a state of negative valence, moderate arousal, and avoidance motivation [52]. The two perspectives on emotions, however, lead to different assessment approaches, as shown in a later section.

Measurement Approaches

Measures of emotion have been developed to match the three emotion systems of subjective experience/language, physiology, and behavior [47]. Table 1 presents different measures of emotion for each of the three systems and the sensitivity of the measures to the dimensions of emotion (valence, arousal, and approach) as well as to discrete emotions. Table 1 is based on Mauss and Robinson [52], who comprehensively reviewed the state of emotion measurement.

Table 1. Measures for the 3-Emotion Response Systems and Measure Sensitivity (Adapted from Mauss and Robinson [52])

Response system	Measure	Sensitivity
Subjective experience/language response system		
Subjective experience	Self-report	Valence, arousal, approach-avoidance, and discrete emotions
Physiology response system		
Peripheral physiology	Autonomic nervous system (ANS) response measures: e.g., electrodermal or cardiovascular	Valence and arousal
Central physiology (CNS)	Electroencephalography (EEG)	Approach and avoidance/ valence
	Functional magnetic resonance imaging (fMRI)	Approach and avoidance/ valence
	Positron Emission Topography (PET)	Approach and avoidance/ valence
Behavior response system		
Vocal characteristics	Acoustic variables: e.g., voice amplitude and pitch	Arousal
Facial behavior	Observer ratings	Valence; some emotion specificity
	Electromyography (EMG)	Valence
Whole body behavior	Observation of body behavior: e.g., posture	Possibly some discrete emotions: e.g., pride, embarrassment
Intersecting response systems		
Affect-modulated startle	Startle response magnitude	Valence, particularly at high levels of arousal

Tools for assessing emotions match the three emotion systems. Our study is limited to just two of the emotion systems: subjective experience/language and physiological (using EEG), and we limit further discussion to the relevant tools.

Subjective Experience Approaches

Measurement approaches for the subjective experience system vary depending on whether a dimensional perspective or a discrete emotions perspective is followed.

Dimensional Perspective. A number of approaches to emotion assessment match the dimensional perspective. In verbal self-report measures, respondents indicate their emotions against a list of emotion items by using semantic differential or Likert scales. Mehrabian and Russell [53] developed the widely used PAD (pleasure, arousal, and dominance) scale to measure the three dimensions. There is also a popular visual scale called the “self-assessment manikin” (SAM) (see [9]) that relies on the PAD dimensions and uses graphic figures of a manikin (mannequin) to represent the end points of the three dimensions.

Discrete Emotions Perspective. Further approaches to emotion assessment follow the this alternative perspective, which includes Plutchik’s [63] emotional profile index and Izard’s [35] differential emotion scale. Our study makes use of the consumer emotion set (CES) developed by Richins [67]. The CES was designed specifically in the context of consumption, which includes anticipatory consumption and product acquisition. The CES has 17 different emotion labels for different descriptor-item sets. For example, “joy” is assessed by the items “happy, pleased, joyful” and “fear” is assessed by the items “scared, afraid, panicky.”

Comparing the two approaches to the assessment of emotions in the subjective experience system, Mauss and Robinson conclude from their review that prior work, taken as a whole, indicates that the dimensional perspective “captures the lion’s share of variance in emotional responses” [52, p. 226].

Electroencephalography as a Measure of Emotion

From meta-analyses of studies with functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) techniques of brain activation during emotional processing, Bradley and Lang [8] conclude that activation tends to occur across the whole brain when a variety of different induction contexts are included. Even when the specific context, such as visual or auditory induction, is controlled, no specific brain region was found reliably to be activated. However, “[t]he region most likely to be active across different induction contexts was the prefrontal cortex (medial)” [8, p. 597].

The work of Davidson et al. [20], using EEG, showed that hemispheral asymmetry in the prefrontal cortex regions is central in emotion detection. EEG works by recording electrical activity along the scalp, with voltage fluctuation representing current flows in large groups of neurons of the brain. An advantage of EEG is that it can give high temporal resolution in milliseconds (ms), which is useful because most episodes of emotion are estimated to last less than four seconds [27]. Disadvantages of EEG are that it has low spatial resolution; that is, it is sensitive only to comparatively large regions and not able to well detect activity that is below the upper level of the cortical surface of the brain (see [78]). For instance, it does not detect activity in the amygdala, which is believed to be involved in memory of emotional events.

A review by Mauss and Robinson [52] concludes that EEG, as with neuroimaging techniques such as fMRI is sensitive mainly to approach-avoidance states. They state that “[a]ny complex reaction such as an emotional state is likely to involve circuits rather than any brain region” [52, p. 219]. Asymmetry in frontal EEG measures has also been interpreted to reflect differences in valence rather than approach-avoidance, and there are problems in making a clear distinction as differences in valence often correlate with differences in approach-avoidance (except in cases such as anger). The "valence hypothesis" holds that "the left prefrontal cortex is activated during positive emotions whereas the right prefrontal cortex is activated during negative emotions" [34, p. 256]. The valence hypothesis originated in the literature on brain lesions, which shows that patients who suffer from an abnormality of brain tissues (a lesion) in the left hemisphere are more inclined to experience negative emotions [19, 55, 61], while patients with a lesion in the right hemisphere tend to experience positive emotions more [75]. Many studies have found support for the valence hypothesis (see [59]), and in this study we will work from this position; that is, we assume that higher levels of activity in the left prefrontal cortex (PFC) represent positive valence and that higher levels of activity in the right PFC represent negative valence.

Research Hypotheses

Research hypotheses were developed to address our research questions concerning the 3-emotion systems' nomological network. The hypotheses are derived from the network and supported by prior literature. While they do not cover the complete model, the hypotheses allow critical relationships to be investigated.

Online commerce Web pages were chosen as examples of IS stimuli. Web pages can be designed with the aim of inducing a positive, negative, or neutral level of emotion. Emotions induced were considered in two of the three systems. In the subjective experience system, measures for both the dimensional view (valence, arousal, and dominance) and a number of discrete emotions were included, in addition to qualitative responses. In the physiological system, the measure of emotion was the level of valence (degree of PFC activation) [34]. *E-loyalty* was chosen as a typical outcome construct because it has been found to be influenced by emotional experiences with Web pages. It increases when pages have positive emotional appeal and decreases when there is negative emotional appeal [13]. The following hypotheses follow from the nomological network instantiated with these constructs. H1–H4 address the first research question: Is there empirical support for the 3-emotion systems' nomological network for IS? Each set of hypotheses is followed with support from prior literature that provides justification for its advancement in the broader nomological network in Figure 1.

First, antecedents of the subjective-experience-type emotion in the Web context are proposed:

> *Hypothesis 1a: A positive-emotion stimulus will lead to higher levels of the dimensions of valence and dominance (subjective-experience type) compared with a negative-emotion stimulus.*
>
> *Hypothesis 1b: The levels of the arousal dimension (subjective-experience type) will be higher with both a positive-emotion stimulus and a negative-emotion stimulus compared with a neutral condition.*

Supporting evidence for these hypotheses comes from the theory of emotion. Stimuli in an environment produce an emotional state that can be characterized in terms of the three PAD dimensions (valence, arousal, and dominance) [53]. Lang et al. [44] generated a database of such stimuli called the "International Affective Picture System," which is a collection of pictures of varying degree of valence, arousal, and dominance. Many studies have used images from the IAPS and found that positive-emotion images result in higher levels of valence and dominance, whereas negative-emotion pictures result in lower levels (e.g., [44]). Our argument is that a Web site that includes positive-emotion stimuli, such as a pleasing image, will also lead to higher levels of valence and dominance, whereas a Web site with negative stimuli, such as a displeasing or frightening image, will have the opposite effect. Comparatively few studies in IS have explored the effect of positive and negative stimuli on emotion using the dimensional approach, with many preferring to use the discrete motion approach (e.g., [28]); an exception is Mummalaneni [56], who found that better-designed online shopping Web sites led to higher levels of pleasure (valence) and arousal (dominance was not included).

H1b is proposed because a U-shaped relationship is expected between the dimension of arousal and positive, neutral, and negative stimuli. Arousal is expected to be higher in both strong positive and strong negative conditions compared with a neutral condition. The circumplex model of Russell and Pratt [70] shows clearly that high arousal can occur with both pleasant emotions (excitement) and unpleasant emotions (distress). Bradley and Lang [9] have confirmed this expectation in studies with IAPS. This relationship, however, appears to have been barely investigated in the IS context, where few studies include the arousal dimension (as many follow the discrete emotion approach).

Second, the antecedents of emotion of the physiological type (with EEG) are considered. Due to the characteristics of the EEG measures, only the valence dimension is assessed. It is expected that a positive-emotion stimulus will lead to higher levels of valence (physiological type) compared with a negative-emotion stimulus in the Web site context. More precisely:

Hypothesis 2a: A positive-emotion stimulus will be associated with greater relative left prefrontal cortex activation (higher valence).

Hypothesis 2b: A negative-emotion stimulus will be associated with greater relative right PFC activation (lower valence).

These hypotheses are congruent with findings in prior studies in neurophysiology. Activation in the PFC "may be a good predictor of emotion regulation processes" [36, p. 612]. According to the valence hypothesis discussed earlier, the left PFC reflects positive emotions and the right PFC reflects negative emotions [34, p. 256]. However, the literature investigating these relationships with IS applications is sparse.

In terms of the effects of emotion experiences on outcomes, the following hypotheses are proposed. Subjective-experience emotions are considered first. Prior work has shown that valence and arousal are the two factors that account for the most variance in emotion evaluation research conducted in the physical environment (e.g., [4, 26]), with dominance accounting for much less variance, and with dominance covarying highly with valence in nonsocial situations (see [9]). Thus, our hypotheses include only valence and arousal as explanatory factors:

Hypothesis 3a: Higher levels of valence (subjective-experience type) will be associated with higher levels of e-loyalty.

Hypothesis 3b: Higher levels of arousal (subjective-experience type) will be associated with higher levels of e-loyalty in a positive stimulus condition.

Hypothesis 3c: Higher levels of arousal (subjective-experience type) will be associated with lower levels of e-loyalty in a negative stimulus condition.

There is theoretical support for these hypotheses. From the Mehrabian–Russell model, it is expected that approach behaviors, such as a desire to stay in, return to an environment, and interact with, are encouraged by positive emotional states, which are amplified by arousal when in a pleasant environment. Negative emotional states are also amplified by high arousal but lead to opposite behaviors: avoidance and a desire to leave an environment and not return (see [26]). E-loyalty is user loyalty toward a Web site such that the user intends "to return to the website or purchase from it in the future" [14, p. 2]. Thus, we expect that higher levels of valence will lead to higher e-loyalty (H3a). Increased arousal will add to this effect with positive stimuli (H3b) and add to a negative effect with negative stimuli (H3c).

A review of the IS literature shows that many studies have investigated the antecedents of e-loyalty, including (1) user perceptions such as satisfaction, usefulness, perceived service outcome, or perceived risk with vender [1, 12, 14, 31, 39, 40, 49, 80, 88]; (2) online user attitudes or behaviors, such as trust, switching cost, and purchase decision [12, 14, 23, 31, 39, 40, 49, 80]; (3) Web site design features [54]; and (4) external factors such as retailer's efficiency with customers [91].

Some studies have found support for a relationship between emotions and e-loyalty or related outcomes with the discrete approach (see [13, 84, 92]). For example, Cyr et al. [13] found a significant influence of positive emotions such as enjoyment on the loyalty of customers toward a mobile service. Research outside IS indicates that emotions directly influence commitment to a company [71] and loyalty behavior [2, 5, 6, 50, 64]. However in IS there is still a significant research gap in applying the dimensional emotion approach to study e-loyalty. H3a helps to address this knowledge gap.

The support for H3b and H3c—associating level of arousal with e-loyalty—is ambiguous. Bigne and Andreu [4] found in tourism research that higher levels of valence and arousal in a physical environment were related to higher levels of willingness to pay and loyalty toward a service-providing company, but did not consider that arousal might have a different effect if there was a negative stimulus. In retailing research with physical stores, Wirtz et at. [85] found that increased arousal enhanced satisfaction in conditions of high-target arousal, but decreased satisfaction in conditions of low-target arousal, where the target arousal level is the level of arousal the person is looking for (e.g., high in an amusement park, but low in a fine-dining experience). There are gaps in the IS literature here, as no studies can be found that investigate the interplay between levels of arousal and valence and the effect on e-loyalty. H3b and H3c address these gaps.

The effect on outcomes of emotions of the physiological type are also considered:

Hypothesis 4a: In positive stimuli conditions, greater left PFC activation (positive valence) will be associated with greater e-loyalty.

Hypothesis 4b: In negative stimuli conditions, greater right PFC activation (negative valence) will be associated with lower e-loyalty.

There is support for these hypotheses in the literature on neurophysiology. As discussed previously, the valence hypothesis suggests that activation in the left PFC is related to positive emotions, whereas activation in the right PFC is related to negative emotions [34]. In turn, it is expected that higher activation in the left PFC will be associated with greater e-loyalty, whereas higher activation in the right PFC will be associated with lower e-loyalty. No studies can be found that test these hypotheses in an IS context.

The next set of hypotheses addresses the second research question: Do measures from different emotion systems converge?

Hypothesis 5a: In positive stimuli conditions, greater left PFC activation will be associated with higher levels of valence (self-report type).

Hypothesis 5b: In negative stimuli conditions, greater right PFC activation will be associated with lower levels of valence (self-report type).

Emotions (i.e., positive and negative valence) are mostly measured in IS studies with self-reports measures (e.g., [22]). The neuroscience literature (e.g., [32]) suggests that emotions can equally and effectively be measured via the brain activity that they evoke. In accordance with the valence hypothesis, damage to the right hemisphere results in the reduction of negative emotionality while damage to the left hemisphere results in the reduction of positive emotionality [11, 25].

There is some support for convergence between PFC activation and self-report measures. Canli et al. [11] showed positive and negative pictures taken from the IAPS and measured participants' brain activity in the left and right PFC using fMRI. Participants rated how each picture made them feel by using a visual scale (SAM). There was no direct correlation of measures from SAM with the fMRI measure, but ratings of positive and negative pictures were significantly different. Positive pictures led to greater left PFC activation, whereas negative pictures led to greater right PFC. The 3-emotion systems theory, however, suggests that there will not necessarily be significant convergence between the emotion system of language (self-report) and the system of physiology (EEG) [47]. The H5 set hypotheses are proposed for exploration purposes. Such exploration should be helpful to the IS research stream that relates emotions to behavioral outcomes (e.g., [48, 86, 87]).

Our third research question concerns the relative advantage of measures from the two different emotion systems, and is addressed by considering the overall results from the empirical work.

Figure 2. Travel Agency Web Page Example for High Valence/Joy Emotion Inducement

Method

Two studies were conducted to investigate the 3-emotion systems' nomological network and different approaches to the assessment of emotion. The first study was performed with only self-report measures—the SAM and the CES scales—as a preliminary to the main study. The second study included both self-reports and EEG measures. The materials used are described first as they were common to both studies.

Materials

Simulated Web pages were constructed for the three experimental conditions: neutral, positive, and negative emotion inducement. There were two pages for each condition. Figure 2 shows the Web page for one of the positive conditions. Although only one Web page is presented for each travel service, it gives an impression of the travel service sufficient for the experiment. From signaling theory [7], it is expected that when limited information is available and an individual does not have complete data, he or she will typically make a judgment based on cues from the available data. In the interviews following the EEG experiments support was found for the view that participants can form an opinion even with limited data. For example, one participant commented: "I like the look of this company. It has a very impressive looking graphic." A number of studies in the IS domain that employ NeuroIS tools have used simple static Web pages (i.e., Web pages that do not allow any functions to be performed) as experimental material. For example, Cyr et al. [15] used eye tracking and presented static Web pages to participants who provided responses on a trust scale (i.e., made an assessment about the Web site transactional functionality).

The six simulated Web pages differed only in terms of the images they incorporated. To increase nomological validity, the images used were taken from the IAPS [44]. These pictures have been extensively tested, and norms have been established for their usage in terms of emotions elicited. Figure 3 shows images indicative of those presented in each condition. Bradley and Lang [9] provide norms for the standard-

Emotion inducement condition	**Images**	
Positive valence (joy) inducing		
Negative valence (fear) inducing		
Neutral		

Figure 3. Emotion-Inducing Images

Notes: The images used in the study were selected from the International Affective Picture System, numbers 1202, 1440, 1460, 1931, 7090, 7185 in IAPS [44]. Because IAPS pictures are not intended for publication, the pictures in this figure were drawn from public domain photographs available on the Internet to illustrate the type of pictures used (available at www.dreamstime.com).

ized images in IAPS. The neutral conditions used images that promote only moderate levels of any emotion, such as medium values for valence, arousal, and dominance. The positive emotion conditions had higher levels for valence and the negative conditions had lower levels for valence. The images were also chosen to induce specific emotions. The positive emotion conditions used images found to be associated with joy; for example, baby animals. The negative emotion conditions used images found to be associated with fear, such as threatening wildlife (see [9]).

The measure for emotions in the dimensional perspective was the SAM [42]. The measure for discrete emotions was CES [67]. Originally, we included all the emotions in CES so that there would be a basis for assessing discriminant validity. However, the pilot test showed that including all 17 emotions in CES fatigued the participants, so the 6 emotions that were recorded least often (discontent, envy, loneliness, romantic love, shame, and other) were omitted from the final experiment. The emotion items were ordered alphabetically on the third level of the item descriptor. The instrument for e-loyalty was taken from Cyr et al. [14], measured on a seven-point Likert scale from 1 (strongly disagree) to 7 (strongly agree) (alpha = 0.953).

Study 1 Procedures

Forty-one participants took part individually in a laboratory experiment with Web pages viewed on a computer screen. An initial screen told the participants that they were looking at home pages for a number of different online travel services and that they were to assume that they were planning a trip and intended to use a service for advice and bookings. The six experimental screen conditions were then presented in turn. A screen that was blank except for a "Continue" button was presented between the conditions. The order of presentation was varied with two different sequences, and the participants were randomly assigned to one of the sequences. Sequence 1 was cube, seal, shark, tiger, spider, and book. Sequence 2 was book, spider, tiger, shark, seal, and cube. Each sequence began and ended with a neutral condition. After each Web page was viewed, the participants gave their responses on the emotions and e-loyalty scales in a response booklet. This arrangement allowed the participants to look at the screen again while they entered their responses. Comments made by the participants while viewing the screens were recorded. After all of the screens were presented, demographic information was gathered. The participants were asked if they had further comments and were asked manipulation check questions. Each session took 30–45 minutes.

Study 2 Procedures

Study 2 had 21 right-handed participants. The procedure was similar to Study 1, apart from the use of the EEG equipment. Before viewing the Web pages, each subject was asked to perform a two-minute eyes-open and eyes-closed activity to establish a baseline for data recording. Participants were shown the Web pages for a fixed time of 20 seconds but did not look at the Web pages while completing the self-report instruments.

The EEG data analysis was performed with Matlab R2011a 64-bit and EEGLab v11.0.1.1b. The basic finite impulse response filter was used to filter the data from the lower edge (1 Hz) to the higher edge (30 Hz). Independent component analysis (ICA) was run to remove eye movement and blink artifacts such as electrooculogram (EOG) and electrocardiogram (EKG). Some data sets for participants with an excessive amount of artifactual data were removed. The final data set analyzed included 20 positive data sets, 20 negative data sets, and 20 neutral data sets for the EEG data.

Hypotheses testing involved measures of EEG power. The EEG data for each of the two positive Web pages and each of the two negative Web pages was combined to provide composite positive and negative data sets. The data were normalized with a log transform (see [20]) after adding a constant (the number 2) to each measure to shift the data to positive numbers. The numeric EEG data reported is the transformed data.

Results

Study 1 Results

Multivariate statistical tests were used to investigate the relationships among the variables with between-subject analyses. In some analyses, the results were pooled across conditions, with each participant providing six data sets. Tests were performed for independence of error terms and showed no resultant problems in regression analyses. No effects were found for order of presentation or for any of the control variables (age, gender, first-language, Web usage). Responses to questions in posttests indicated

Table 2. Comparison by Condition for SAM Dimensions (Study 1)

	Condition[1]					
	Negative	Neutral	Positive	df	*F*	*p*
Valence[2]	4.11 (2.096)	5.54 (1.509)	7.37 (1.739)	245	67.586	0.000
Arousal[3]	5.02 (2.049)	2.89 (2.037)	4.59 (2.372)	245	22.360	0.000
Dominance[4]	4.93 (2.408)	6.88 (1.990)	6.87 (1.961)	2,445	22.732	0.000

Notes: df: degrees of freedom. One case omitted due to missing values. [1] Shows means with standard deviations in parentheses. [2] Scheffe test shows pair-wise differences, $p < 0.05$, positive condition significantly higher than neutral condition, neutral condition significantly higher than negative condition. [3] Scheffe test shows pair-wise differences, $p < 0.05$, positive and negative conditions significantly higher than neutral condition. [4] Scheffe test shows pair-wise differences, $p < 0.05$, positive condition significantly higher than negative condition.

that manipulations were effective. The patterns in responses compared well with the norms for SAM scores from Lang et al. [44] (see Appendix Table A1).

The majority of the 41 participants were ages 21 to 50 (83.3 percent), 80 percent used the Internet daily, and 56.7 percent used the Internet for travel services frequently or very frequently. There were 22 females and 19 males.

The results provided some support for the nomological network. The H1 set of hypotheses related the type of stimulus (positive or negative) to valence, arousal, and dominance. Analysis of variance (ANOVA) was used to check these hypotheses (Table 2). Valence and dominance were significantly higher in the positive conditions compared with the negative conditions, which supports H1a. H1b was also supported because arousal was higher in both positive and negative conditions compared with the neutral conditions.

The H3 set of hypotheses related valence to e-loyalty (H3a) and arousal to e-loyalty (H3b, H3c). Regression analyses were used to test these hypotheses across the sample and for the negative, neutral, and positive conditions separately (Table 3). These results show that valence is significantly related to e-loyalty across the whole sample, which supports H3a. The relationship between e-loyalty and arousal was not significant in any conditions or across the sample, which means that neither H3b or H3c is supported. This result could be because of a "low-target" expectation of arousal in the experiment: in this situation, arousal may not add to the effects of either a positive or negative emotion on e-loyalty [85]. Note that a further analysis was performed to test the relationship between valence and arousal as an interaction effect across the sample, but the interaction effect was not significant.

Additional work was done in Study 1 to address the third research question: Do measures from different emotion systems offer different insights and advantages? The study included an instrument to measure discrete emotions (CES) and also some qualitative data. The results from analysis of the discrete emotions experienced show

Table 3. Regression Analyses for E-Loyalty with SAM Dimensions (Study 1)

SAM dimension	β (all conditions) (*n* = 246)	β (negative conditions) (*n* = 82)	β (neutral conditions) (*n* = 82)	β (positive conditions) (*n* = 82)
Valence	0.313***	0.261***	0.323***	0.246***
Arousal	–0.033	0.003	–0.033	0.010
R^2	0.462***	0.320***	0.283***	0.317***

Notes: $n = 246$. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

a surprising amount of diversity (Appendix Table A2). "Peacefulness" was highest across all the conditions. As expected, "joy" was high in positive conditions (seal, tiger cub) and "fear" was high in negative conditions (shark, spider). The surprising finding was the degree to which many other emotions were reported, including surprise, contentment, excitement, worry, anger, and sadness. Scores for some of the participants showed they even experienced contrasting emotions at the same time, such as joy and sadness.

To investigate further the range of emotions experienced, the qualitative data from the participants' comments during and after the experiment were examined (see Appendix Table A3). Four themes emerged from this analysis: (1) confirmation of expected emotions, (2) unexpected emotions, (3) surprise/astonishment, and (4) cognitive appraisals of the Web site. A number of the participants verbalized thoughts confirming emotions expected for a Web site; for example, "scary" for the shark. Some also reported emotions that were not expected; for example, for the neutral box image "The box reminded me of the [X] Bank. I thought it was a bit depressing," or the respondent associated the harp seal with seals being clubbed and felt nervous. A few participants expressed surprise; for example, "little surprised this picture is on a travel site." Note that the images used were similar to those used on some real travel Web sites. Some of the participants had mixed responses to one stimulus; for example, for the seal, "Cute but scary." A final theme in the responses was evaluation of the Web site itself; for example, for the box, "Makes you want to spend more time on the web site. The shape and color give you a good feeling."

In sum, the results from the self-report measures in Study 1 largely supported the hypotheses from the nomological network. Furthermore, the range of emotions shown in the CES responses and in the qualitative response data show a rich picture of the emotions felt. These data showed that unexpected emotions occurred, that sometimes people had mixed or opposing emotions to one stimulus, and that the emotion reactions were in part based on associations with stored memories (the seal being clubbed). Furthermore, emotional reactions influenced cognitive appraisals of the Web site.

Study 2 Results

Data sets from 21 participants were obtained. The majority of these participants were ages 21 to 50 (66.7 percent), 99 percent used the Internet daily, and 67 percent used

Table 4. Comparison by Condition for SAM Dimensions (Study 2)

	Condition[1]					
	Negative	Neutral	Positive	df	*F*	*p*
Valence[2]	3.85 (1.927)	5.10 (1.294)	6.50 (1.670)	59	9.607	0.000
Arousal[3]	5.40 (2.088)	3.15 (2.084)	4.35 (2.084)	59	7.316	0.001
Dominance[4]	4.35 (1.872)	6.10 (2.222)	6.55 (2.188)	59	5.912	0.005

Notes: [1] Means with standard deviations in parentheses. [2] Scheffe test shows pair-wise differences, $p < 0.05$, positive condition significantly higher than neutral condition, neutral condition significantly higher than negative condition. [3] Scheffe test shows pair-wise differences, $p < 0.05$, positive and negative conditions significantly higher than neutral condition. [4] Scheffe test shows pair-wise differences, $p < 0.05$, positive condition significantly higher than negative condition.

the Internet for travel services occasionally or frequently. There were 8 females and 13 males. After removing data sets where there was excessive artifactual data in the EEG analysis, there were 20 data sets in each of the positive, neutral, and negative conditions included in the analysis.

The results of analyses of the self-report data were similar to Study 1. Again, the pattern of responses was similar to the norms for SAM scores from Lang et al. [44] (Appendix Table A4). The results for the H1 and H3 sets of hypotheses are presented first because these concern the self-report data.

The H1 set of hypotheses related the type of stimulus (positive, neutral, or negative) to levels of valence and dominance (H1a) and level of arousal (H1b). H1a and H1b were again supported. Valence and dominance were significantly higher in the positive conditions compared with the negative conditions, and arousal was higher in both the positive and negative conditions compared with the neutral conditions (Table 4).

The H3 set of hypotheses related valence and arousal to e-loyalty (H3a, H3b). Table 5 shows that H3a is supported across all the conditions and that H3b and H3c are not supported. The latter result is possibly due to relatively low levels of arousal in the experiment [85].

The hypotheses concerning the EEG measures are now considered. The H2 set of hypotheses related a positive-emotion stimulus to higher relative left PFC activation (higher valence) (H2a) and a negative-emotion stimulus with greater relative right PFC activation (lower valence) (H2b).

A visual analysis of this activity was obtained from “Plot Spectra” in EEGLab, which indicates overall brain activity. Beta absolute power (16.5–20 Hz) was used for the plot spectra (see [66]). Beta 2 power is the state associated with normal waking consciousness when a subject is focusing, analyzing, or thinking about a stimulus [79]. Figure 4 shows the 17 Hz results. In both of the positive conditions (seal and tiger cub), the strongest activity is in the left-hand frontal region (0.46 decibels [dB]). With the neutral conditions there is little activity in either of the frontal regions (nothing

Table 5. Regression Analyses for E-Loyalty with SAM Dimensions (Study 2)

SAM dimension	β (all conditions) (*n* = 60)	β (positive conditions) (*n* = 20)	β (neutral conditions) (*n* = 20)	β (negative conditions) (*n* = 20)
Valence	0.200***	0.165*	0.099	0.404**
Arousal	–0.073	–0.031	–0.206	0.118
R^2	0.270***	0.111	0.306*	0.416**

Notes: *n* = 61. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

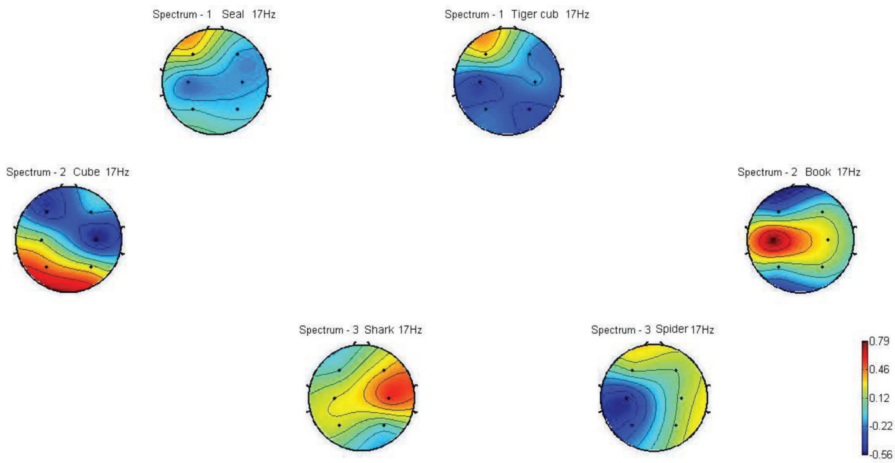

Figure 4. Plot Spectra of the Six Experimental Conditions

Note: These images are best viewed in color.

above zero). In the negative conditions there is strong right-front activity for the shark (0.46 dB and above) and some right-front activity for the spider (around 0.12 dB). The data in this visual form show support for H2a and H2b.

However, the results from a quantitative analyses using ANOVA with data pooled across the two positive and the two negative conditions and measures at F3 and F4 gave mixed outcomes (Table 6). Activity was significantly higher in the left-front region (positive emotion) for the positive conditions, which supports H2a. H2b is not supported because the difference between the two hemispheres in the negative conditions was not significant. This result might have occurred because of the pooling across the two negative conditions (shark and spider), which the visual data suggest led to different reactions. Analysis of the two negative conditions separately showed no significant results, but this analysis had low power (*n* = 10 for each group).

The H4 set of hypotheses states that in a positive stimuli condition, greater left-PFC activation (positive emotion) is associated with greater e-loyalty (H4a), and that in a negative stimuli condition, greater right-PFC activation (negative emotion) is associated with lower e-loyalty (H4b). Testing of the H4 set of hypotheses gave mixed results

Table 6. Comparison by Condition for Frontal Asymmetry (Study 2)

	Prefrontal activity*				
	F3 (left)	F4 (right)	df	*F*	*p*
Positive	0.326 (0.031)	0.297 (0.012)	39	14.970	0.000
Negative	0.317 (0.021)	0.305 (0.025)	39	2.991	0.092

* Means and standard deviations in parentheses.

Table 7. Regression Analyses for E-Loyalty and Prefrontal Activation (Study 2)

	Positive conditions (n = 20)	
Prefrontal activity	β	R^2
Left (F3)	1.916*	0.218*
	Negative conditions (n = 20)	
	β	R^2
Right (F4)	–2.851	0.103

* $p < 0.05$.

(Table 7). H4a is supported because greater activation in the left frontal region (F3) was significantly related to e-loyalty. H4b is not supported because there was no significant relationship between activation in the right frontal region (F4) and e-loyalty.

The H5 set of hypotheses concerns convergence of measures and states that in positive stimuli conditions, greater left-PFC activation is associated with higher levels of valence (self-report type) (H5a), and in negative stimuli conditions, greater right-PFC activation is associated with lower levels of valence (self-report type) (H5b). To test the H5 set of hypotheses, correlations between the EEG and self-report measures were examined. H5a is not supported because, although left frontal activity (F3) was positively associated with valence, the relationship was not significant (r = 0.274, p = 0.242). H5b is supported because right frontal activity (F4) was significantly related to lower valence (r = –0.448, $p < 0.05$).

Summary of Results

Table 8 shows a summary of the results from the hypotheses testing. The majority of the hypotheses were supported. Some explanations for the hypotheses that were not supported can be advanced. H3b and H3c accord with the Mehrabian–Russell

Table 8. Summary of Support for Hypotheses

Hypothesis		Study 1	Study 2
H1a	A positive-emotion stimulus will lead to higher levels of the dimensions of valence and dominance (subjective-experience type) compared with a negative-emotion stimulus.	Yes	Yes
H1b	The levels of the arousal dimension (subjective-experience type) will be higher with both a positive-emotion stimulus and a negative-emotion stimulus compared with a neutral condition.	Yes	Yes
H2a	A positive-emotion stimulus will be associated with greater relative left PFC activation (higher valence).	N/A	Yes
H2b	A negative-emotion stimulus will be associated with greater relative right PFC activation (lower valence).	N/A	Descriptive and visual data only
H3a	Higher levels of valence (subjective-experience type) will be associated with higher levels of e-loyalty.	Yes	Yes
H3b	Higher levels of arousal (subjective-experience type) will be associated with higher levels of e-loyalty in a positive stimulus condition.	No	No
H3c	Higher levels of arousal (subjective-experience type) will be associated with lower levels of e-loyalty in a negative stimulus condition.	No	No
H4a	In positive stimuli conditions, greater left PFC activation (positive valence) will be associated with greater e-loyalty.	N/A	Yes
H4b	In negative stimuli conditions, greater right PFC activation (negative valence) will be associated with lower e-loyalty.	N/A	No
H5a	In positive Web stimuli conditions, greater left PFC activation will be associated with higher levels of valence (self-report type).	No	
H5b	In negative web stimuli conditions, greater right PFC activation will be associated with lower levels of valence (self-report type).	Yes	

Note: N/A = not applicable.

model [53], which indicates a conditional interaction between valence and arousal in determining approach-avoidance behaviors, such as e-loyalty. Arousal is expected to enhance approach in a pleasant environment and enhance avoidance in an unpleasant environment. Our study did not find support for these propositions. However, our findings are congruent with empirical studies in the retail environment, where support for the arousal interaction effect has been limited (e.g., see [26]). Wirtz et al. [85] found that the arousal effect may be dependent on the levels of arousal expected in a specific situation—disappearing when the arousal level is not particularly high (as when viewing Web pages).

The relationship between higher right PFC activity (lower valence) and lower e-loyalty (H4b) in the negative condition was not supported, although a significant result was found for the positive condition, supporting H4a. The relationships between the EEG measures and the self-report measures (H5a, H5b) were advanced for investigation, as the literature suggests that convergence between measures from different emotion systems is not necessarily to be expected [47]. Thus, it is interesting that our study found some degree of convergence, with a significant negative relationship between right PFC activation and valence (self-reported) (H5b). The relationship between left-PFC and valence was positive as hypothesized (H5a), but not significant.

Discussion and Conclusions

Overview

THIS STUDY DEVELOPED A NOMOLOGICAL NETWORK with an overarching theory-based view of relationships among emotion constructs and other constructs of interest in IS research. The resulting 3-emotion systems' nomological network shows three interacting emotion systems: language, physiology, and behavior. The three emotion systems are linked to other human systems, which include the cognitive processing system. Emotional experiences can be directly triggered by emotion-inducing stimuli present in IS; in turn, emotion experiences can influence outcome behaviors such as IS acceptance and usage and human decision making. The network also includes consideration of the context in which these constructs and relationships occur and the human individual differences that influence them.

Two studies were conducted to test portions of the nomological network. Both studies used the same six travel service Web pages as stimuli in controlled laboratory experiments. The Web pages differed only in the images they included, with standard images taken from the IAPS [44]. The first study had 41 participants and the second had 21 participants with usable data. The first study used paper-based self-report measures and the second study included both self-report and EEG measures. An outcome measure of e-loyalty was also included.

Research Questions

Our first research question asked whether there was empirical support for the nomological network. This question was answered in the affirmative, with the results largely supporting the hypotheses based on the network in both Study 1 and Study 2. Positive and negative emotion-inducing stimuli were related to positive and negative emotions when viewing the Web sites. In turn, the degree of positive and negative emotions was related to levels of e-loyalty.

The results were largely consistent with hypotheses with the self-report measures. The only unexpected result with the self-report data was that higher levels of arousal were not related to higher levels of e-loyalty (H3b, H3c). This result might be explained by the relatively low levels of arousal when viewing Web pages, congruent with Wirtz et al. [85].

The results with the EEG data were more mixed. The visual data showing neural activity over the whole brain supported our hypotheses, with greater activity for positive stimuli in the left hemisphere and greater activity for negative stimuli in the right hemisphere (Figure 4). With measures of activity at the P3 and P4 points, however, we were only partly able to match results such as those of Davidson et al. [20]. Our stimuli were more complex than those of Davidson et al. [20], however, because Davidson et al. used film clips as emotion-inducing stimuli, whereas our studies used travel Web pages, which could elicit more cognitive or other processing compared with film clips. It is important that some significant relationships were found in our study, with hypotheses for the positive emotion conditions supported by EEG data (H2a and H4a). It should be noted that the work here is pioneering and no similar prior work can be found with EEG data in IS.

Further support for the network was given by other patterns in both qualitative and quantitative data. In Study 1, the participants reported a wide range of emotions on the CES discrete emotions scale (see Appendix Table A2). Some of these emotions were unexpected, with, for instance, some level of fear even in neutral conditions and worry in the positive conditions. Qualitative data gave an explanation for these findings, with participants reporting associations between images viewed and stored memories, as in the positive seal image being associated with seals being clubbed to death and the abstract box image compared with a bank logo. This analysis indicates linkages between the subjective emotion system and cognitive processing (associated memory recall).

The second research question asked whether the measures of different emotion systems converged. Our results showed modest convergence. Right prefrontal activation (F4) was significantly correlated with lower valence. Left prefrontal activation (F3) was correlated with higher valence, but not significantly. It is interesting that some relationships were found, because, as Larsen and Priznic-Larsen [47] report, there are many examples of response discordance between systems, with covariation between measures unlikely to be more than 10–15 percent.

The third research question concerned the insights offered by the study of the different emotion systems. The results of the current work, supported by underlying theory and prior empirical work, indicate that the different emotion systems, although interrelated, differ in the understanding offered into emotion phenomena. Physiological EEG measures indicate levels on the basic, evolutionarily old, dimension of approach-avoidance, and reflect the influence of both conscious and unconscious processes. Subjective self-reports are based on conscious acts of introspection and yield more insight into the private life of the individual, although they are subject to bias due to personality or memory limitations [29]. Self-reports allow individuals to explain their reactions in terms of discrete emotions and possibly reasons for these emotions. The introspection into one's own emotions depends on being able to formulate a description in terms of learned emotion labels, a matter of experience and culture. The data obtained from the different emotion systems can be viewed in terms of the different modes of processing in dual processing theory. The physiological (EEG) measures give more insight into the unconscious, fast, and automatic processing mode of human behavior, while the self-report measures tap more into the conscious mode of reflection and reasoning (as in system 1 and system 2 of Kahneman [37]). Our results support a view that a measure from one system should not be seen as a replacement for a measure for another system, but rather a complement. Self-report measures, even with the possibility of bias, offer information not available from physiological measures. The physiological measures offer information about processes possibly not available to conscious introspection.

Potential Limitations

Our study has limitations common to experiments in that tighter control can mean lower external validity. The travel Web pages used were indicative only of a full online travel service and viewers interacted with the pages for a relatively short period of time. Comments from some of the participants did, however, indicate that they made thoughtful judgments on what they could see. We follow other studies that have used a single screen in an experimental setting to represent an e-commerce Web site and investigated outcomes such as e-loyalty and trust [14, 15].

Our study had a relatively small number of participants in the second study, which yielded 20 sets of usable data. Samples of this size are not uncommon in NeuroIS, where use of the specialized equipment is complex and time-consuming. Dimoka et al. suggest that for NeuroIS studies, "given the accuracy of brain data, the required number of subjects is small, and 10 to 15 subjects are typically needed for a study" [24, p. 698]. Other EEG studies have used fewer than 20 participants (e.g., [30, 73, 74, 77]).

A further limitation is that, in this study, we were able to test the nomological network only in part. Further work is suggested, in particular work that uses measures from the third emotion system—that of emotion behavior (e.g., in face recognition).

Implications

The current work has theoretical and practical significance in that it develops and partly tests an overarching nomological network for the understanding and assessment of emotions in IS research. No counterpart for this level of theorizing can be found in the extant literature. The network is based on a substantial base of theory and empirical evidence from different disciplines but, to our knowledge, has not previously been articulated and contextualized for IS. The empirical work investigating the network has strengths, in that it began with an initial study that benchmarked emotion inducement against the well-known IAPS stimuli before undertaking the EEG study, and also gathered qualitative data. This step is important because of the issues in identifying what neural activity means.

Specific implications of the study are as follows:

1. Empirical studies should recognize the 3-emotion system theory that is at the heart of the nomological network. This theory has strong support in the literature outside IS and suggests that a multimethod approach should be taken to

understanding and assessing emotions (see [8]). Our study showed the different insights that could be gained by investigating two systems (physiology and language). The study found modest convergence between measures from the two systems, and theory and prior work suggest that this convergence may be modest in many situations [47]. Thus, exact neural correlates of an emotion should not be expected, and researchers should aim at employing a variety of assessment approaches. Physiological measures can be used as a complement to traditional self-report measures, for example, in investigating technology acceptance (see [82]). However, an important finding was that a physiological measure (EEG) has some ability to predict an outcome such as e-loyalty. This finding complements the findings of prior studies on e-loyalty that have used the discrete emotion approach with self-report measures.

2. Our study shows how both the dimensional approach and the discrete approach to emotion assessment can be used within the emotion language system. The dimensional approach offers the advantage of assessing arousal in addition to degrees of valence and accords with the well-known circumplex model [70]. The dimensional approach is also the approach that allows convergence with EEG measures to be assessed, and has been found to explain most variance in empirical studies [52]. More studies in IS could consider using the dimensional approach, unless the study of one or more discrete emotions is specifically indicated; that is, valence may be a better choice than, say, enjoyment, when all that is wanted is a measure of positive emotion.
3. The nomological network has consequences for how the relationship between emotion and cognitive-evaluative constructs should be modeled. The network suggests that emotions and cognition are linked (see [8]), and from the qualitative comments made in the first study we found that emotions were indeed influenced by cognitive processing and vice versa. The implication is that care needs to be taken in modeling links between emotions and cognitive processing in the formation of evaluative responses such as trust or ease-of-use assessment. For example, the study by van der Heijden [81] shows that both perceived enjoyment and perceived usefulness lead to intention to use a system, but shows no relationship between perceived enjoyment and perceived usefulness. The nomological network suggests that a relationship between these two constructs should be considered.
4. This research has practical implications. Professionals in fields such as Web design and e-marketing have an interest in the emotional reaction to IS because these have been shown to be linked to many outcomes, of which e-loyalty is only one. Our study has shown the importance of using a multimethod approach to assessing emotions, with supporting evidence from theory and empirical work. Different measures, self-report and neurophysiological, can be used to complement each other and yield different insights in the field as well as in research. Managers should be aware of the different approaches and their relative strengths, with the move toward using neurological measures routinely in marketing likely to continue (see [58]).

To conclude, this work is an important step toward a more in-depth and comprehensive understanding of the role of emotions and their assessment in IS research. It provides a high-level theoretical framework that is firmly based on prior work and theorizing in other disciplinary areas and shows how emotions interact with other phenomena of interest in IS. The empirical work reported here—using neuroscience techniques that are relatively novel in IS—provides support for the nomological network.

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Appendix

Table A1. Emotion Dimension Levels from Self-Assessment Mannikin (SAM) Measures (Study 1)

	Norm scores*			Study 1 score		
Condition	Valence	Arousal	Dominance	Valence	Arousal	Dominance
Negative (spider)	3.35 (1.77)	5.94 (2.17)	4.23 (2.36)	3.63 (2.08)	5.12 (1.93)	4.71 (2.48)
Negative (shark)	4.00 (2.28)	6.80 (2.02)	3.51 (2.54)	4.59 (2.02)	4.93 (2.17)	5.15 (2.34)
Neutral (cube)	4.97 (0.87)	2.64 (2.04)	6.13 (2.02)	5.37 (1.59)	2.95 (1.73)	6.80 (2.12)
Neutral (book)	5.19 (1.46)	2.61 (2.03)	6.65 (2.03)	5.71 (1.41)	2.83 (2.32)	6.95 (1.86)
Positive (seal)	8.19 (1.53)	4.61 (2.54)	6.05 (2.38)	7.32 (1.78)	4.63 (2.27)	6.71 (1.94)
Positive (tiger cub)	8.21 (1.21)	4.31 (2.63)	6.00 (2.00)	7.41 (1.71)	4.54 (2.49)	7.02 (1.99)

Notes: Means and standard deviations in parentheses. All items measured on nine-point scale from 1 (low) to 9 (high). * From [44].

Table A2. Discrete Emotion Levels from Consumer Emotion Set (CES) Measures (Study 1)

Emotion	All	Negative (spider)	Negative (shark)	Neutral (cube)	Neutral (book)	Positive (seal)	Positive (tiger cub)	α
Peacefulness	2.76	1.50	1.90	3.15	3.35	3.26	3.41	0.873
	(1.23)	(0.73)	(0.94)	(0.98)	(1.14)	(1.06)	(0.96)	
Joy	**2.17**	**1.28**	**1.65**	**2.03**	**1.99**	**3.03**	**3.05**	**0.899**
	(1.14)	**(0.45)**	**(0.80)**	**(0.91)**	**(0.89)**	**(1.28)**	**(1.11)**	
Optimism	2.09	1.26	1.61	2.15	2.21	2.52	2.80	0.890
	(1.08)	(0.45)	(0.82)	(0.96)	(1.05)	(1.19)	(1.09)	
Surprise	1.98	2.31	2.46	1.65	1.52	1.96	1.98	0.766
	(0.97)	(1.04)	(0.99)	(0.85)	(0.67)	(0.96)	(0.95)	
Love	1.94	1.20	1.39	1.60	1.78	2.75	2.89	0.802
	(1.01)	(0.41)	(0.60)	(0.74)	(0.77)	(1.03)	(0.94)	
Contentment	1.90	1.25	1.56	2.12	2.09	2.20	2.18	0.702
	(0.88)	(0.48)	(0.71)	(0.86)	(0.93)	(0.92)	(0.89)	
Excitement	1.69	1.51	1.77	1.52	1.43	1.95	1.98	0.662
	(0.76)	(0.51)	(0.81)	(0.67)	(0.56)	(0.92)	(0.83)	
Worry	1.53	2.33	2.07	1.30	1.18	1.24	1.13	0.893
	(0.85)	(1.06)	(1.11)	(0.65)	(0.36)	(0.44)	(0.28)	
Fear	**1.52**	**2.61**	**2.00**	**1.17**	**1.09**	**1.16**	**1.07**	**0.905**
	(0.86)	**(1.04)**	**(1.02)**	**(0.42)**	**(0.20)**	**(0.34)**	**(0.26)**	
Anger	1.46	2.13	1.67	1.33	1.36	1.17	1.14	0.809
	(0.79)	(1.03)	(0.98)	(0.66)	(0.62)	(0.35)	(0.38)	
Sadness	1.36	1.71	1.57	1.26	1.24	1.21	1.17	0.790
	(0.70)	(0.99)	(0.93)	(0.65)	(0.48)	(0.34)	(0.39)	

Notes: Means with standard deviations in parentheses. All items measured on five-point scale from 1 (not at all) to 5 (strongly). The boldface items show the levels of the emotions that were intentionally manipulated: joy in the positive conditions and fear in the negative conditions.

Table A3. Participant Comments in Study 1

Image	Comment
Expected emotions	
Seal	It's a cute baby seal. [Pa6] Very sweet. [Pa7] The picture was warm and fuzzy. Changed my feelings toward the Web site. [Pa8] It was calming. [Pa8] [Laughed] "Aww." [Pa10] Now there's a very cute factor in it. [Pa31]
Tiger cub	It does make you feel happy, doesn't it? [Pa6] It's a cute picture. [Pa11] Better picture than the others. Seal was a bit too cutesy. Tiger did it for me. [Pa13]
Box	Not sure what this makes me feel. [Pa7] Boring. Far too bland to have any appeal. [Pa10] It's a bit too abstract. I don't know what to think about it. [Pa14] I don't really know what that is. [Pa32]
Book	Felt a bit bored. It looked like an old book. [Pa7] Not sure what to interpret from the book. [Pa8] How boring. [Pa13] I don't know how to feel about this one. [Pa31] It's pretty boring. [Pa32]
Shark	Laughed. Not my idea for a holiday—maybe for a diver. Probably makes me feel unhappy. [Pa6] Scary thing. [Pa18] Not happy. No. Not happy. [Pa31]
Spider	Don't like spiders. [Pa5] Doesn't make me happy. [Reacted strongly to the image initially.] Maybe entomologists or something would find it interesting. [Pa6] Don't like spiders. [Pa8] "Ew" sound [that it was disgusting]. [Pa10] Yuck. I don't like spiders. [Pa11] The questions were surprisingly easy to answer with a spider on a travel service. It made me feel strong emotions. [Pa16] Not happy. No. It's creeping me out. [Pa31]
Unexpected emotions	
Seal	Associated with clubbing seals—killing them with a club. Together with the fact that it's a travel service, makes me nervous. [Pa7] Irritating because it has nothing to do with travel. [Pa16] Cute but scary. Its eyes. . . . Mixed feelings. [Pa18]
Box	Made me feel a bit depressed. It's a bit daunting. [Pa8] I didn't like the box. It's a bit boring. The box reminded me of the [X] Bank. It thought it was a bit depressing. [Pa13] It's too spread out. [Pa16]
Book	The book made me think of work. The book too [was depressing]. The book was the worst. [Pa13] That's weird. [Pa16]
Shark	Found the water in the picture calming. Made the distinction between *looking* at the picture and being with the shark. Found looking at it not so scary. [Pa7] A more adventurous feeling with this. The picture is much more what I would expect of a travel company. [Pa8] I love sharks. I want to go diving with sharks. My answers are a bit inconsistent. [Pa11] Might want to go on an adventure travel. [Pa13] Sometimes my emotions change as I think about it. It's interesting what one picture will do. [Pa16]
Spider	The spider is interesting. Wonder what type of spider it is? [Pa7] I don't quite object to spiders. It's not warm and fuzzy though. [Pa13] Very well presented. It isn't real, so I'm not unhappy. [Pa31]
Surprise/astonishment*	
Tiger cub	A little surprised this picture is on a travel site. [Pa7] Amazing how much an image affects you. [Pa18]
Book	A travel service for bibliophiles? [Pa6] Shocked and amazed at how simple the site was. It was straightforward. [Pa18] I was expecting a coffin or something. [Pa25]
Shark	I'm amazed the person used these images on the Web site. [Pa13]

Image	Comment
Spider	The spider's web is pretty amazing. [Pa7] Strange way of attracting attention. [Pa18]
Evaluative reasoning concerning web sites	
Seal	Didn't particularly like the seal. Perhaps I'm being cynical. Seems like a cynical thing to put an unrelated image on a travel Web site. [Pa25]
Tiger cub	It's hard to judge [the Web site] with a cute picture. [Pa11]
Box	Based some feeling decisions on the belief that she was going for a trip. Would depend on usability when deciding for "considering service in the future" [e-loyalty question]. [Pa13] Makes you want to spend more time on the Web site. The shape and color give you a good feeling. [Pa18]
Book	This is more professional—depending on what you're looking for. [Pa10] Book makes you feel that this is a serious thing. [Pa18]
Shark	People with brains would know not to use sharks. [Pa6]
Spider	Because I don't like looking at spiders I probably would not visit the Web site again. [Pa6]

Notes: 18 of 41 participants offered no comments. The participant number is indicated in brackets. * Images similar to those used in the experiment are used on real-life Web sites.

Table A4. Emotion Dimension Levels from Self-Assessment Mannikin (SAM) Measures (Study 2)

	Norm scores*			Study 2 score		
Condition	Valence	Arousal	Dominance	Valence	Arousal	Dominance
Negative (spider)	3.35 (1.77)	5.94 (2.17)	4.23 (2.36)	3.40 (1.51)	5.70 (2.21)	3.60 (1.90)
Negative (shark)	4.00 (2.28)	6.80 (2.02)	3.51 (2.54)	4.30 (2.26)	5.10 (2.02)	5.10 (1.60)
Neutral (cube)	4.97 (0.87)	2.64 (2.04)	6.13 (2.02)	4.50 (1.27)	3.70 (2.45)	5.30 (2.36)
Neutral (book)	5.19 (1.46)	2.61 (2.03)	6.65 (2.03)	5.64 (1.03)	2.45 (1.57)	7.00 (1.79)
Positive (seal)	8.19 (1.53)	4.61 (2.54)	6.05 (2.38)	6.36 (1.75)	4.00 (2.10)	6.73 (2.00)
Positive (tiger cub)	8.21 (1.21)	4.31 (2.63)	6.00 (2.00)	6.67 (1.66)	4.78 (2.11)	6.33 (2.50)

Notes: Shows means and standard deviations in parentheses. All items measured on nine-point scale from 1 (low) to 9 (high). * From [44].