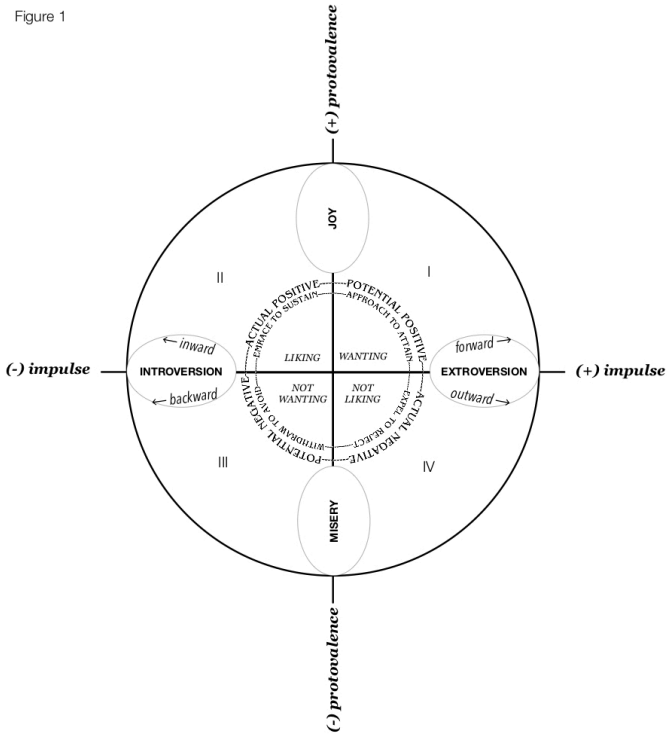
ABSTRACT

The Circumplex Model of Affect has two deficiencies. The valence dimension does not reflect that all positive/negative states can be equally pleasant/unpleasant. This can be improved using a *protovalence* dimension measuring prototypical valence, i.e. a joy-misery axis, while allowing general pleasantness/unpleasantness (valence) to be defined by the intensity of a state in any direction. The arousal dimension is problematic because it is unipolar, meaning that the valence and arousal dimensions do not cross at the origin. This can be improved using a bipolar *impulse* dimension, an axis measuring the degree to which the subject is primed for action. In this way, the axes cross at the origin, yielding four Cartesian quadrants that automatically segregate states into potential and actual modes and spontaneously generate four directionally meaningful action tendencies (approach, withdraw, embrace, expel). These alternative dimensions should be compatible with the same statistical methods and affective probes that produce the circumplex, needing only modifications to instructions given to report impulse instead of arousal. This structure has multiple benefits, including the amenability of the model to convenient mathematical representation, as well as new insight into how emotions might be constructed and differentiated. Pathoscape, a model proposed here for the cognitive structure of emotions, combines these features.

Pathoscape is a proposed model for the cognitive structure of emotions. It is a two-dimensional affect space (Figure 1) defined by Cartesian axes: ***x*** (impulse) and ***y*** (protovalence). States are represented by vectors in the plane, differentiated by their directions and magnitudes. The positive direction of the protovalence axis represents *joy*, while the negative direction represents *misery*. Positively-valenced emotions have positive protovalence values, and therefore a joy component, while negatively-valenced emotions have negative protovalence values, and therefore a misery component. However, the ***y***-axis is not a valence dimension, per se, but rather the direction of prototypical valence, i.e. a joy-misery axis. The degree of positive or negative valence, i.e. the pleasantness/unpleasantness, is actually measured by the intensity of a state, represented by the magnitude of a state's vector, regardless of its direction. Therefore, all states of equal intensity in quadrants I and II have equal positive valence and all states of equal intensity in quadrants III and IV have equal negative valence. This forms a circular arrangement of states having equal intensity, with positively-valenced states in the upper half of the plane and negatively-valenced states in the lower half of the plane. In this way, valence is still the degree to which a state feels pleasant or unpleasant; however, hedonic quality is not confined to one dimension ranging from joy to misery, but instead allows any positive state to be equally pleasant as any other, even if not equally joyous, and allows any negative state to be equally unpleasant as any other, even if not equally miserable. After all, under some circumstances, *excitement* or *awe* can feel as pleasant as *joy*, and *terror* or *fury* as unpleasant as *misery*. Since the vectors for these states other than *joy* and *misery* vary at different angles from the ***y***-axis, valence cannot be a dimension of the affect space like protovalence can.

Figure 1

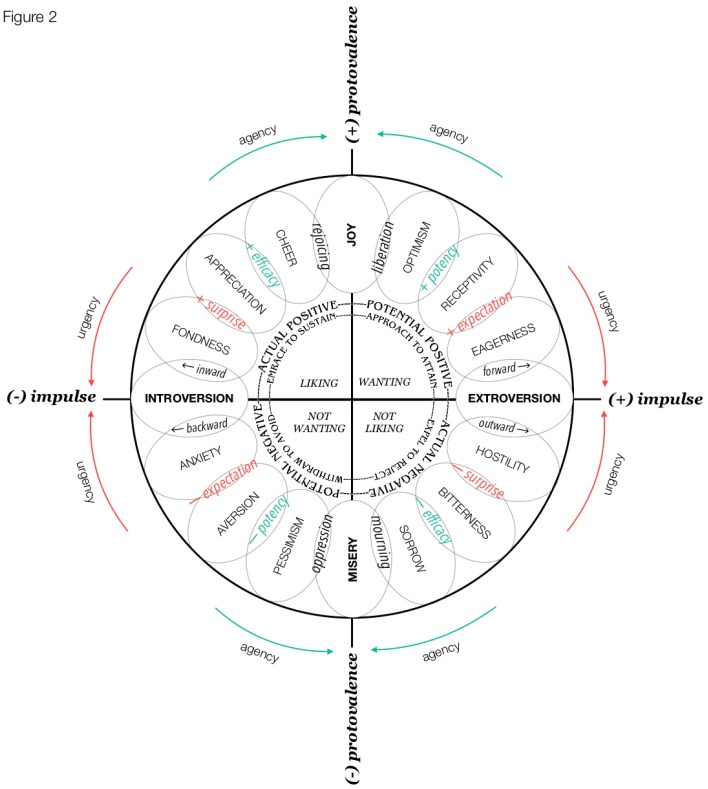


The ***x***-axis, impulse, measures a subjective drive to action, and ranges from extroverted impulses to introverted impulses. Extroverted impulses, in the positive ***x*** direction, are *forward* impulses for positively-valenced states (quadrant I) and *outward* impulses for negatively-valenced states (quadrant IV). Forward impulses urge the subject to approach the intentional object of the state (its *stimulus*) in order to attain something potentially positive in value. Outward impulses urge the subject to expel the stimulus to reject something actually negative in value. Introverted impulses, in the negative ***x*** direction, are *inward* impulses for positively-valenced states (quadrant II) and *backward* impulses for negatively-valenced states (quadrant III). Inward impulses urge the subject to embrace the stimulus to sustain something actually positive in value. Backward impulses urge

the subject to withdraw from the stimulus to avoid something potentially negative in value. This interpretation of the bipolar impulse axis automatically assigns an important characteristic to the stimulus of any state, a characteristic intrinsic to each quadrant: all states in quadrant I (states of *wanting*) are about something with potentially positive value, all states in quadrant III (states of *not wanting*) are about something with potentially negative value, all states in quadrant II (states of *liking*) are about something with actually positive value, and all states in quadrant IV (states of *not liking*) are about something with actually negative value. This arrangement places *opposite* states, having opposite values for both impulse and protovalence, as polar opposites in the plane. States that have the same value for protovalence but opposite value for impulse are termed *complements*. States that have the same value for impulse but opposite value for protovalence are termed *conjugates*.

States that have a significantly larger x-component than y-component have a sense of *urgency*. The greater the x-component (in the positive or negative direction) relative to the magnitude of the vector, the greater the urgency of the state. "Negative and positive urgency are emotion-related impulsivity traits that refer to the tendency to act rashly while in an intense emotional state" (Cyders & Smith, 2007, 2008, as cited in Billieux et al., 2021). In Pathoscape, urgency is considered as a state characteristic instead of a trait, having the same emotion-related impulsivity, prompting action without reflection. A feeling state that is urgent is the result of appraisal of a stimulus that has characteristics of urgency (such as novelty or unexpectedness/suddenness, for instance). In this model, a sense of potential urgency (quadrants I & III) is associated with expectations about opportunities and threats, while a sense of actual urgency (quadrants II & IV) is associated with surprises about rewards and punishments (Figure 2, red). The expectations and surprises about the value of a stimulus are distinct from any unexpectedness/suddenness of a stimulus that can also cause a state to be urgent. These feelings of expectancy and surprise may lead to urgent states by making the stimulus more salient and preferentially recruiting exogenous attention. It has been demonstrated, for instance, that "reward-driven attention modulates visual processes by enhancing low level visual salience" (Qin et al., 2021). In quadrant I, a sense of positive expectation means early appraisal of the stimulus signals that reward prediction should be greater than is typically the case, indicative of an opportunity. These states are characterized by feelings ranging from eagerness to positive extroversion, as urgency increases. In quadrant III, a sense of negative expectation means early appraisal of the stimulus signals that reward prediction should be

Figure 2



less than is typically the case, indicative of a threat. These states are characterized by feelings ranging from anxiety to negative introversion, as urgency increases. In quadrant II, a sense of positive surprise means early appraisal of the stimulus signals that actuality is more rewarding than the reward prediction, indicative of gaining undue reward. These states are characterized by feelings ranging from fondness to positive introversion, as urgency increases. In quadrant IV, a sense of negative surprise means early appraisal of the stimulus signals that actuality is less rewarding than the reward prediction, indicative of incurring undue punishment. These states are characterized by feelings ranging from hostility to negative extroversion, as urgency increases. All four cases draw attention involuntarily and lead to rapid processing. The greater the involvement of exogenous attention, the more urgent the resulting state feels. The more urgent a state feels, the stronger the directional impulse that accompanies the state. I speculate exogenous (bottom-up) attention modulates perception of emotions after appraisal of urgency, and that cognitive interpretation of this activity helps define emotional states.

States that have a significantly larger y-component than x-component have a sense of *agency*. The greater the y-component (in the positive or negative direction) relative to the magnitude of the vector, the greater the agency of the state. The sense of agency, "i.e., the registration that I am the initiator and controller of my actions and relevant events" (Gentsch et al., 2014), is a factor that can be appraised in the elicitation of emotions (Agrawal et al., 2013). A state with a sense of agency results from appraisal of a stimulus that has characteristics of agency (such as current goal-relevance or controllability). In this model, a sense of potential agency (quadrants I & III) is termed *potency*, while a sense of actual agency (quadrants II & IV) is termed *efficacy* (Figure 2, green). Feelings of potency and efficacy may lead to states with a sense of agency by making the stimulus more relevant to personal goals and preferentially recruiting endogenous attention. As with urgency, expectation and surprise play a role in agency. In quadrant I, a sense of positive potency means that positive agency is expected, due to significant or adequate progress toward achieving a goal. With a strong sense of positive potency, states are accompanied by a sense of liberation, and comprise feeling states ranging from optimism to joy, as agency is expected to increase. In quadrant III, a sense of negative potency means that negative agency is expected, due to low progress or regression in working toward a goal. With a strong sense of negative potency, states are accompanied by a sense of oppression, and comprise feeling states ranging from pessimism to misery, as agency is expected to increase. In quadrant II, a sense of positive efficacy means positive agency has been actualized, due to perceived success in working toward a goal. With a strong sense of positive efficacy, states are accompanied by a sense of rejoicing, and comprise feeling states ranging from cheer to joy, as surprise about agency increases. In quadrant IV, a sense of negative efficacy means negative agency has been actualized, due to perceived failure in working toward a goal. With a strong sense of negative efficacy, states are accompanied by a sense of mourning, and comprise feeling states ranging from sorrow to misery, as surprise about agency increases. Appraisal of agency recruits endogenous attention and leads to relatively slower processing. I speculate endogenous (top-down) attention modulates perception of emotions after appraisal of agency, and that cognitive interpretation of this activity helps define emotional states.

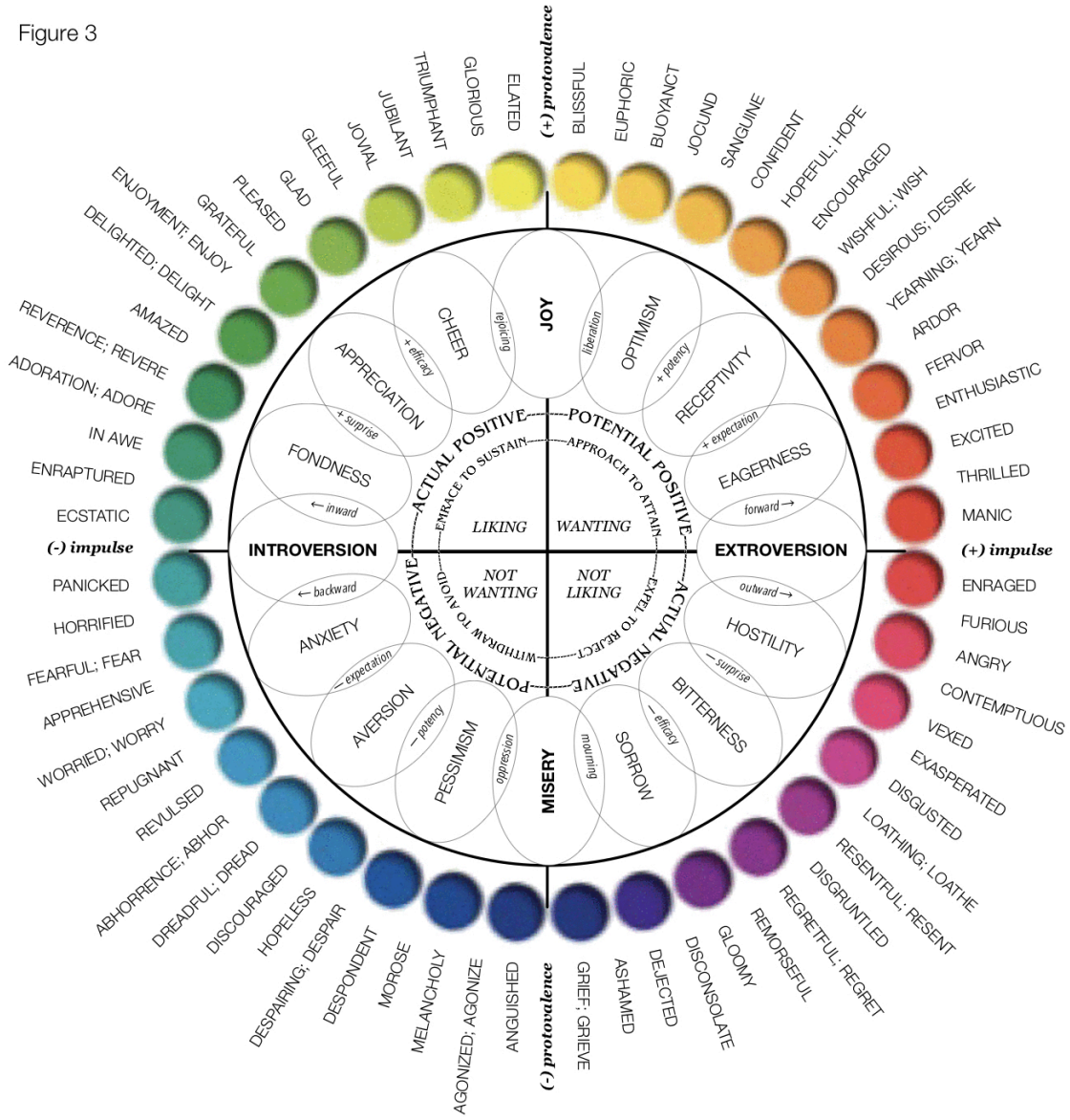
States that have x-components near in value to y-components are less associated with a sense of urgency or a sense of agency. These middling states reflect the action tendencies in each quadrant (Figure 2). In quadrant I, where the action tendency is to approach in order to attain some potentially positive aspect of the stimulus, these states are characterized by receptivity. In

quadrant III, where the action tendency is to withdraw in order to avoid some potentially negative aspect of the stimulus, these states are characterized by aversion. In quadrant II, where the action tendency is to embrace in order to sustain some actually positive aspect of the stimulus, these states are characterized by appreciation. In quadrant IV, where the action tendency is to expel in order to reject some actually negative aspect of the stimulus, these states are characterized by bitterness.

The affect space of Pathoscape allows mapping of every possible feeling state in a two-dimensional plane. The number of emotion labels in even the most expressive natural language corresponds to a small fraction of the affect space. This range of feelings is continuous; however, the feelings mapped to loci in the plane and then described by emotion labels are fuzzy but discrete states that feel a certain way. The range of feelings is like a spectrum, from which patches can be picked out and named different colors. Just like color words, emotion labels and emotional concepts may differ by languages and cultures, but the range of possible feeling states that can be experienced is universal. Pathoscape represents the whole range of possible feeling states. Any emotion labels used to specify and define feeling states within the affect space are a matter of personal opinion. However, there should be a broad consensus about the general arrangement of emotion labels, especially labels for those states that are widely considered basic emotions.

Associating each of the four quadrants with the very broad attitude labels *wanting*, *liking*, *not wanting*, and *not liking* seems obvious and uncontroversial. Likewise, subdividing the quadrants into 16 overlapping broad categories is not problematic. Before attempting to specify narrower ranges of feelings, however, it is important to clarify some difficult ideas about the problems of using emotion words to label the locations of feeling states. Locations in the affect space characterize how states feel (in terms of protovalence and impulse only), but they do not define states as the semantic concepts denoted by any emotion word that might be used to label them. In other words, the meanings of any emotion labels should not be confused with the feelings they label. What a feeling means to someone is something apart from the subjective experience of the feeling itself. An emotion is characterized by the feeling, but the feeling is not defined by the emotion label. In fact, more than one emotion may feel a certain way but mean different things. Because of the ambiguities inherent in language, there are many other ways linguistic labels can cause confusion when referring to feeling states. It is even possible for a single word to refer to more than one feeling. *Disgust*, for example, has both potential and actual forms that are not differentiated in English; however, this same label could be used to describe certain aversive states in quadrant III (not wanting) as well as certain bitter states in quadrant IV (not liking). Yet ill-defined *disgust* is often considered a basic emotion. Likewise, feeling *anxious* can mean feeling anxiety (quadrant III) or feeling eagerness (quadrant I). Furthermore, some words do not describe specific states, but rather describe changes in states. A label like *disappointment* or *frustration*, for example, indicates the stimulus itself is a change from positive to negative protovalence, typically from quadrant I to quadrant IV. There are also labels that are commonly thought of as emotions that refer to combinations, syndromes, or even whole ranges of states. *Love*, for example, is not a unitary emotion that has a single feeling state. Likewise, *happiness* refers to a vague, smeared out region around *joy* (encompassing optimism and cheer), and the same with *sadness* around *misery* (encompassing pessimism and sorrow). In fact, these two emotions may refer to many states that are positive or negative, respectively, not just high-agency states. Some linguistic labels for feelings can also cause problems by conflating the stimulus of the emotion with the feeling itself. The stimulus of an emotion is the actual or prospective state of affairs the emotion is about, not how the emotion feels. Claiming to feel *cheated* versus how one feels about

Figure 3



being cheated, for example, a case about which one might appropriately claim to feel *angry*. The stimuli of emotions do not have to be external; they may also be other internal cognitive or affective states, so it is very often the case that emotions are about emotions, in which case it can be particularly difficult to label such a higher-order feeling state and avoid confusing how it feels with the meaning or significance of the feeling. Additionally, there are labels such as *apathy*, *boredom*, and *calmness*, that can indicate states with exceedingly low intensities, such that any subtle difference in feeling can be easily overshadowed by connotations of the labels. With these caveats in mind, Figure 3 is an attempt to label the affect space more thoroughly, making a particular effort to choose emotion labels that have compelling complements, conjugates, and polar opposites.

The overlapping ovals and the continually changing ring of colored circles are meant to illustrate the fuzziness of the nearly synonymous feeling labels that gradually blend into one another around the circle while expanding on the characteristics of the 16 broad categories. My

specific choices might not be shared by others, but reflect the connotations these words have to me. Nevertheless, I expect broad agreement with the overall structure. The labels for increasingly urgent states might be thought by some instead to represent increasing intensity, but I placed them as I understood their differences in urgency, because it is possible for these different states under some circumstances to have the same intensity, in which case they would need to be distinguished by urgency. All the feelings labeled can have correlates that are higher and lower in intensity, but those labels are not shown. Some labels are such near synonyms, it is difficult to decide if they better fit with a stimulus that has potential or actual value — *blissful* and *elated*, for example. In this case I placed *elated* in quadrant II, because the word has connotations of *delight* and *glee*. Some might object to omitting a label like *love*, but it is not a unitary emotion; it is more like a syndrome that can include such disparate emotions as *desire*, *adoration*, and even *worry*. Similarly, it is also possible to have mixed emotions about the same stimulus, but it seems only one emotion can be attended at a time, even if switching between them can be rapid. I believe, for example, that *mania* is a syndrome of fuzzy mixed emotions, having properties distinct from *euphoria*. Despite the implications of the term bipolar disorder, I believe mania is not the opposite of depression, and that the elevated feelings associated with *mania* are secondary to highly urgent and extroverted feelings, which are themselves extremely positively valenced. This primary, extroverted aspect can be present in a bipolar episode with mixed features, including racing thoughts, rapid speech, or aggression, whereas the high agency, euphoric state is not present. I therefore include *manic* primarily as a highly urgent and impulsive state. Finally, each state in Pathoscape is worded to fit into the statement "I am/feel ___ that stimulus," or "I ___ that stimulus." For example: "I am furious that he wronged me," or "I dread that I will feel pain." This emphasizes the fact that an emotional stimulus is not just a stimulating physical object, but rather a state of affairs. An emotion can be viewed as a propositional attitude about a state of affairs that can be stated as a proposition, even if not always stated as such in practice.

Pathoscape differs from other models in several ways. For example, this model suggests a simple way for constructing and differentiating emotions. First, the emotion is automatically narrowed down to a quadrant just by noticing whether the stimulus has any positive or negative value and if that value is potential or actual. Appropriate action tendencies (approach, withdraw, embrace, expel) are a natural consequence of this primary appraisal alone. Initial impressions of expectation/surprise and potency/efficacy may also result at this point, preferentially recruiting either exogenous or endogenous attention, respectively. Then, I propose the cognitive interpretation of the integrated contributions of exogenous and endogenous attention further narrow the range to a specific region or locus, and refine a state's sense of expectation/surprise and potency/efficacy. The greater the involvement of exogenous attention regarding the salient features of the stimulus, the more the sense of urgency (increasing the x-component of the state), and the greater the stimulation of the reticular system. Likewise, the greater the involvement of endogenous attention regarding the relevant features of the stimulus, the greater the sense of agency (increasing the y-component of the state), and the greater the stimulation of the mesolimbic system. The intensity of the state is automatic, given the Pythagorean relationship between the x-component and y-component from the appraised urgency and agency. Appraisal variables corresponding to an increased sense of urgency or preferential recruitment of exogenous attention may include expectation/surprise about the value of the stimulus, unexpectedness/suddenness of the stimulus, novelty, emotional stimuli, or anything that increases stimulus salience. Appraisal variables corresponding to an increased sense of agency or

preferential recruitment of endogenous attention may include potency/efficacy, control, personal causal attribution or responsibility, and goal-relevance. This straightforward approach may be used for constructing and differentiating conscious and unconscious emotions in the self, as well as for modeling emotions in others. In recursive fashion, this may also explain emotional episodes, by showing how one emotional state can act as the stimulus for the evolution of a higher-order state about it, and so on. Similarly, emotional episodes may result from updating appraisals based on changing subject-stimulus relationships, such as varying urgency and agency, or when a stimulus with potential value is actualized (or vice versa).

Pathoscape not only describes emotions, but also gives insight into intentions and behavior. The appraisals of positive or negative properties of the stimulus depend on three kinds of potential or actual values. (1) The stimulus may be appraised for how it feels, where positive value comes from pleasure, comfort, security, relief, etc. and negative value from opposite qualities. (2) The stimulus may be appraised for its relevance to current goals, where positive value comes from benefit, advantage, ease, efficiency, etc. and negative value from opposite qualities. (3) The stimulus may be appraised for its standing in beliefs (including moral judgments), where positive value comes from being true, correct, right, just, etc. and negative value from opposite qualities. The stimulus can be appraised for any or all of these values. In all cases, positive value comes either from the prospect or success in achieving some positive, or from thwarting or negating some negative. Therefore, both positive and negative emotions can arise from these appraisals. Fear, for example, activates action tendencies serving a goal to avoid or thwart something with potentially negative value. These three values are weighted such that when taken together it is impossible to act voluntarily unless there is a net positive value. There has to be some good that overrides all relevant bad in order to act voluntarily, because an action devoid of all subjective good can never be chosen.

Pathoscape allows quantitative representation of states and their relations. Because this model makes use of true Cartesian axes with two bipolar dimensions, it lends itself well to mathematical representations of states and changes of states. By placing the affect space in the complex plane, with an imaginary protovalence axis, any state z can be specified with just the angle (θ) and the magnitude ($|z|$), where $|z| = \sqrt{x^2 + y^2}$, using $z = |z|(\cos(\theta) + i\sin(\theta))$ and $z = |z|e^{i\theta}$. Rotations and changing magnitudes are made easy in this exponential form. For example, in addition to being able to represent changes in angle (emotional tone), changes in magnitude (intensity) can be represented simultaneously by including a coefficient when multiplying by a change vector $e^{i\phi}$:

$$z_2 = |z_1|e^{i\theta} \cdot |n|e^{i\phi} = |z_1| \cdot |n|e^{i(\theta + \phi)},$$

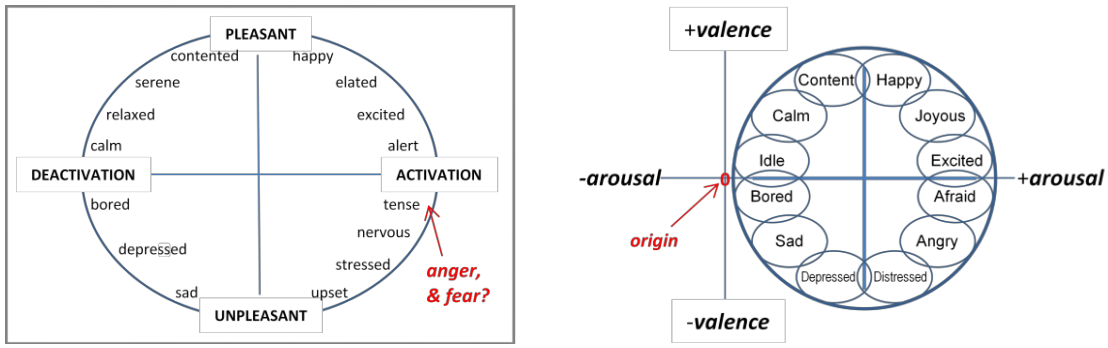
whereby the magnitudes are multiplied (stretching or contracting the state's vector) and the angles are just added together (rotating the state's vector). In this notation, urgency is $|\cos(\theta)| = |x / |z||$, and agency is $|\sin(\theta)| = |y / |z||$. Angles (in radians) for positively-valenced states in quadrants I & II range from 0 to π. Angles for negatively-valenced states in quadrants III & IV range from 0 to $-\pi$.

Because other dimensional models do not use Cartesian axes, various problems arise. Besides the inability to resolve the positions of different states that have similar valence and

arousal (like anger and fear, Figure 4a), the very meaning of relative positions in the affect spaces of these models presents a specific conceptual challenge. Anger and fear can each be more negatively valenced than the other in some circumstances, and likewise, neither is more inherently arousing than the other, so placing the two states relative to one another in the circumplex is somewhat arbitrary. Furthermore, since negative arousal is meaningless in these models, the point of intersection of the two axes at the center of the circumplex is not the common origin of the two dimensions (Figure 4b), and the four regions of the affect space are not the same as the four Cartesian quadrants. In such models, only the Cartesian quadrants I and IV are defined. The states that are nearest the true origin in such a circumplex are *deactivated* or *low arousal* states, but nevertheless, with the exceptions of dreamless sleep and coma, all states have some positive value for arousal and must therefore be positioned to the right of the true origin. The natural consequence of the four action tendencies spontaneously emerging in correspondence to the four quadrants in Pathoscape, due to the directional interpretation of the bipolar impulse axis, is not possible in these dimensional models, because the arousal axis is not bipolar. Additionally, since the origin is meaningless in these models, there is no apparent means for representing various states mathematically in a convenient way.

Note: the diagrams in Figures 4a and 4b have been reoriented from their original forms to compare them more clearly with Pathoscape. Additionally, in 4b, the *y*-axis has been shifted to the left and both axes relabeled, while the arousal dimension has been extended into the negative direction to illustrate the position of the origin relative to the circumplex. The relative positions of words have been preserved.

Figure 4



(a) (b)

The dimensional models do not have meaningful quadrants corresponding to the basic attitudes of *wanting*, *not wanting*, *liking*, and *not liking*. Unlike Pathoscape, the structures of other dimensional models do not segregate states into potential and actual modes. The arrangement of states around their circles does not reveal strong patterns or relationships such as the complements, conjugates, and polar opposites present in Pathoscape. The dimensional models do not indicate characteristics of states related to urgency or agency, or show how such characteristics are related to one another in the differentiation of states. The subjective nature of agency is related to psychological (subjective/cognitive) arousal, whereas urgency is related to physical/physiological arousal. The dimensional models lump both kinds of arousal onto one dimension. Additionally, the dimensional models do not take into account the differing roles of

exogenous and endogenous attention. Finally, the structures of the dimensional models do not give any insight into how emotional states can be constructed.

The Circumplex Model of Jonathan Posner, Janes A. Russell, and Bradley S. Peterson (2005) still has much in common with Pathoscape. "Using the statistical tools of factor analysis and multidimensional scaling, a wide variety of psychological assessments have demonstrated the emergence of two underlying, or latent, dimensions of emotion when individuals label and communicate either their own affective states or the affective states of others (Feldman Barrett & Fossum, 2001; Larsen & Diener, 1992; Russell, 1980; Watson, Clark, & Tellegen, 1988)" (Posner et al., 2005). I believe the results of the statistical techniques employed in their analyses of subjective reports are consistent with the structure of Pathoscape, and that the valence and arousal that are being measured are functionally equivalent to the protovalence and impulse dimensions of Pathoscape, but interpreted differently. Protovalence and impulse dimensions, however, would serve as better axes for a dimensional model. I do not know what standardized affective probes are being used or how subjects are instructed to use them in developing the Circumplex Model, but I believe what they are measuring as arousal in self-reports can be understood better in terms of impulse, a directional drive to action. Unlike general CNS arousal, impulse has meaning as a bipolar dimension, and with proper instructions, subjects should reflect this feature in their reports. Similarly, I think there is a problem with the valence dimension in the Circumplex Model. Joy is not the only measure of hedonic quality, even if it is prototypical. All positive emotions can be equally pleasant even if they are not equally joyous. I think this is a confounding issue with the valence dimension in dimensional models. I believe what they are measuring in self-reports is not actually positive/negative valence, but instead the positive/negative prototypes of valence, i.e. joy and misery, the protovalence dimension in Pathoscape. With these differences in mind, I believe using the same techniques used to develop the Circumplex Model, but substituting protovalence and impulse dimensions instead for valence and arousal, would generate the four quadrants of Pathoscape.

Pathoscape has significant potential as a basis for future scientific investigation, and may have value in development of AI that could benefit from such a cognitive architecture in the endeavor to understand or approximate human emotions. The rich structure of Pathoscape, which automatically yields four directional action tendencies upon a simple primary appraisal and spontaneously segregates states into potential and actual modes, is a clear improvement on other dimensional models, and cannot be coincidental. The meaningful relationships and intuitive arrangement of complements, conjugates, and polar opposite states around a circumplex give compelling evidence that the affect space represents real patterns in emotional experience. The introduction of urgency and agency as characteristics of emotional states dependent upon their relative locations in the affect space is a feature absent in other dimensional models. The roles of exogenous and endogenous attention in the construction and differentiation of states is speculative, but their relationships to the subjective senses of urgency and agency, as well as the observation of their associations with the two dimensions, are unequivocally valuable contributions. The introduction of a bipolar impulse dimension in place of a unipolar arousal dimension allows for the structure of the affect space to be centered around an origin, resulting in four Cartesian quadrants, which brings a host of benefits, not the least of which is the amenability of the model to mathematical representation. While other dimensional models, such as the Circumplex Model, are developed using sound scientific techniques, they are not as obviously robust, useful, and insightful as Pathoscape. In total, these qualities of Pathoscape warrant further study.

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