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Abstract

Since the introduction of empirical methods for studying facial expression, the interpretation of infant facial expressions has generated much debate. The premise of this paper is that action tendencies of approach and withdrawal constitute a core organizational feature of emotion in humans, promoting coherence of behavior, facial signaling and physiological responses. The approach/withdrawal framework can provide a taxonomy of contexts and the neurobehavioral framework for the systematic, empirical study of individual differences in expression, physiology, and behavior within individuals as well as across contexts over time. By adopting this framework in developmental work on basic emotion processes, it may be possible to better understand the behavioral principles governing facial displays, and how individual differences in them are related to physiology and behavior, function in context.

Key Words: infant emotion, facial expression, approach, withdrawal, motivation

Infant Expressions in an Approach/Withdrawal Framework

Since the introduction of empirical methods for studying facial expression, there has been ongoing discussion about the relation of infants' expressions to state and to emotional development more broadly; see for example (Camras et al., 2007; Camras, Sullivan, & Michel, 1993; Izard, 2007a). In the emotion literature, there is some consensus that emotions may be best conceptualized as processes or dimensions rather than states (Barrett, Mesquita, Ochsner, & Gross, 2007).This paper proposes that approach and withdrawal (A/W) neurobehavioral systems constitute core organizational processes of emotional behavior, promoting the coherence of behavior, facial expression and physiological responses. Facial expressions are viewed as components of action tendencies within these two bio-behavioral systems. Expressions are displayed in conjunction with action impulses motivating behavior. For example, approach activates the tendency to seek/explore and obtain stimulation and may be accompanied by the emotion of interest.

The capacity to approach and withdraw from stimulation has long been regarded as a key aspect of motivated behavior (Gray, 1991; Schneirla, 1939, 1959). Approach and withdrawal are recognized as fundamental behavioral systems for organizing behavior in both mammals and humans, but they have not typically been viewed as features of infant behavior until late in the first year (Putnam & Stfter, 2005). An A/W model provides a coherent framework for understanding infant emotional behavior and development in contrast to extant models including facial expression. Differential Emotions Theory--DET (Izard, 2007a) and Dynamical Systems Theory--DST (Camras & Fatani, 2008; Camras et al., 2007) offer opposing theories of infant expression but have little to say about emotion processes relative to expression and behavior. A/W offers a third model. Moreover, conceptual and theoretical advantages of an A/W framework are that it integrates a number of perspectives on emotion from the animal and adult literature with developmental findings and provides a way to classify contexts and toaddresses individual differences within and across those contexts. Adopting this framework may help the field move past the long-running debate about expression-state equivalence toward discussions of how emotion and behavior evolve in context during the infancy and beyond.

Before discussing an A/W model in detail, the two major competing theoretical views of infant expression, DET (Izard, 1977; 1987, 2009) and DST (Camras, 1992; Camras et al., 2007) will be briefly described. It is also necessary to reference facial coding systems which unfortunately are not independent of these perspectives. Though not a comprehensive review, noted for each theory will be its view of expressions, their ontogeny, relations to core feeling states and contextual specificity as these are key features of a long-running repartee in the literature (Camras, Malatesta & Izard, 1991; Camras,et al., 2007; Camras & Shutter, 2010; Izard, 2004; Izard & Abe, 2004; Izard, Woodburn, & Finlon, 2010; Oster, 2005).

Differential Emotions Theory (DET)

DET (Izard, 1977; Izard, et al,, 2010) derives from the theoretical and ethological work on human emotion by Tomkins (1962,1963). Of the postulated 10 fundamental human emotions, eight were observed in subsequent observations of infants and young children (Izard, 1977) and have been specified in an anatomically-based coding system that focused on the most discriminative features of each expression in the brow, eye/cheek, and mouth/jaw regions of the face (Izard, 1995). Interest-Excitement, Enjoyment-Joy, Surprise-Startle, Sadness-Distress, Anger-Rage, Disgust-Revulsion, Contempt-Scorn, and Fear-Terror have documented full face displays. One additional emotion display, Shame/Shyness, can be identified with the addition of head and body position. These correspond roughly to adult counterparts with allowance for differences between the morphology of infant versus adult facial structure. For brief descriptions and images of these expressions refer to Sullivan & Lewis (2003) or the MAX manual (Izard, 1995). Figure 1 illustrates the MAX-coded expressions observed in work with infants under six months of age and pre-schoolers.

DET proposes that infant facial movements signaling these emotions are innate, fully differentiated, coordinated facial expressions from birth (Izard et al., 1995) and are morphologically stable from 3 to 18 months (Izard, 1997; Izard & Malatesta, 1987). It is acknowledged that expressions are graded signals, so that maximal, full face expressions need not always be displayed. Full face expressions (upper and lower expressive movements consistent with the same emotion signal) are thought to be a more intense form of the display. Partial (upper face only) expressions index less intense versions of the emotion, appearing at lower levels of arousal. Components from more than one emotion and certain regulatory movements may be combined in a single expression in a given context, but all displays are regarded as unlearned. Ontogentic variation in the occurrence of expressions and sequential patterning of expressions are presumed to be a function of neurobiological maturation and developing *emotion schemas*, or an evolving cognition-emotion interface (Izard et al., 1995; Izard, 2007a, 2007b). Neruophysiological (Sroufe, 1996), and learning and socialization (Holodynski & Friedlmeirr, 2006) have also been proposed to account for ontogenetic as well as individual differences in expression, but none of these mechanisms have been extensively explored.

Expressions and core feeling states are assumed to be equally differentiated and to correspond closely. This has remained a central tenet of DET since its inception (Abe & Izard, 1999; Izard, 2004; 2007a). Combination of different emotion signals in the upper and lower face are also thought to signal unique feeling states (Izard, 1997). When different expressive movements occur in a facial display or rapidly alternating displays are observed, what is seen is what is being felt: mixed feelings. Feeling states are defined as sets of neurobiological processes that integrate affect and cognition into a unified perception or representation (Izard et al., 2010). The nature of cognition required for specific facial displays is not specified, but presumably in young infants such cognitions would be fairly basic and contextually determined. Regarding expression-context relations, expressions are thought to correspond to certain eliciting contexts, but in recent formulations of DET, these linkages are not viewed as “hard-wired” and allowance is made for individual differences. Instead, there are a “families” of contexts and elicitors that might be differentially associated with anger vs. sad, or anger vs. fear, but the developmental status of the child, cognition in context, temperament, and other factors are thought to influence the degree of specificity observed for any expression (Izard, 2004). It is also acknowledged that facial expression alone is insufficient to establish any given emotion and that multiple measures must characterize any determination of emotion (Izard et al., 2010).

Dynamical Systems Theory (DST)

DST was proposed by Camras and others as an alternative to DET given observations of her own infant daughter’s expressions and for philosophical reasons (Camras & Fatini, 2008; Fogel et al., 1993). Camras and Oster (Camras & Fatani, 2008; Oster, 2005) in particular argued that the ontogeny of facial expression should be constructed from direct observation of component movements without reference to emotion expression derived from adult observations. In this way, they propose variation in infant expression, communicative function, as well as affective meaning can be studied independent of any preconceptions derived from the adults work. DST, as described by these investigators, is committed strongly to a micro-analytic as opposed to "whole face" view of expression. DST combines a downward extension of Ekman's (1972) extensive work on adult facial expression with an innovative theory accounting for change in complex systems.

The Facial Action Coding System (FACS) and Baby FACS (Ekman, 1972; Oster & Rosenstein, 1991) represent an exhaustive catalogue of possible movements of human facial musculature. Despite an overwhelmingly large number of different possible facial configurations, Ekman (1982) described a limited set that are universally recognized as conveying emotion in adults (We set aside the controversial issue of whether the emotions they signal are themselves universal equivalents). The basic emotion expressions identified parallel those proposed by DET, omitting interest and shyness/shame. Baby FACS includes the same component movements that are scored in DET's MAX as either single movements or combinations, and many others, allowing for much greater precision and detail in coding the face and the intensity of observed displays. The major differences between the coding systems are their theoretical model and this level of comprehensiveness. Unlike MAX, DST and Baby FACS specify no full face emotion displays and studies using this theoretical perspective typically do not compile movements into expressions. Instead, they focus primarily on the description of individual components such as brow lowering or pouts, i.e., an inverted U-frown. (Kohut, Riddell, Flora, & Oster, 2012; Camras, Oster, Campos, & Bakeman, 2003; Camras, Oster, Campos, Miyake, & Bradshaw, 2005). Moreover, Camras &Shutter (2010) state that there is no support for a 1-to 1 correspondence between specific expressions and specific "emotion states" during infancy. By "emotion", Camras means the coordinated biological components and presumably core feelings, identified as positive, such as smiling and general positive tone and negative expressions, such as anger, sadness, and fear, and generalized negative tone (Camras & Fatini, 2008).

Initially, Camras (1992) applied DST to account for the "assembly" of facial displays themselves. However, more recently she applied it to emotion broadly (Camras & Fatini, 2008). DST is a complex theory with many key variables and a unique jargon. It was originally introduced into psychology to model the coordination of multiple, complex, neuropsychological systems such as the interaction between emotion and cognition (Lewis, 2005) and the development of locomotor coordination (Thelen & Ulrich, 1991) (See Table 1). Applied to infant facial expression, DST proposes that recognizable facial displays assemble themselves from component movements (Camras,et al., 1991). Specific facial movements are biological givens due to anatomy, but they are regarded only as lower order motor patterns or coordinated motor structures that assemble facial expressions in much the same way that bipedal walking is assembled from precursor reflexive stepping of neonates (Camras, 1992). Facial movements are hypothesized to vary around an *attractor state* (Camras, 1992; Camras & Shutter, 2010). An attractor is a larger stable pattern or set of subcomponents which emerges under the influence of one or more lower-order variables termed *collector(s).* What might constitute these constructs with reference to facial expression is unclear. Presumably, if a specific full-face display, or some "larger assemblies of emotion components" constituted an attractor, facial muscles would be 'pulled" toward this configuration over time. Facial expression in the DST model consists of these self-assembled, organized patterns in context. Unspecified is whether assembly of the pattern occurs within seconds, minutes, or over a longer developmental period. Variability of movement patterns is expected within and across contexts, but coordinated expressions emerge over some unspecified time. The face is biased toward the attractor, but variability around the attractor may or may not be random. The theory allows for either possibility. The greatest variation around the attractor is hypothesized when a critical threshold of one of the subcomponents, called the *control parameter*, is reached, causing the pattern to change or *phase shift* to another level of organization. Control parameters for facial expression have not been specified, but candidates such as arousal level, or various social and nonsocial variables have been suggested (Camras & Fatini, 2008; Shutter & Camras, 2010). Sequential time studies or longitudincal studies examining this central feature of DST have not been conducted to our knowledge.

DST has no specific developmental theory, although time is clearly important in DST models. Oster (2005) has argued for an ontogentic progression of expressions. Feeling state as generalized positive and negative valence is hypothesized to be related loosely to expression at least initially (Camras & Fatini, 2008), although expression /emotion linkages, presumably including state, emerge with development. It is still unspecified when or how, specific feeling-expression relations emerge.

Assessment: Debate with Little Forward Momentum.

Full-face expressions homologous with the proposed universal emotions of anger, sadness, and enjoyment do appear from the first months of life regardless of the coding system used. There is some consensus that some neonatal expressions may be reflexive due to neurological immaturity (Izard, 2009; Camras & Fatini, 2008). Although morphologically stable from 3 months of age (Izard, 1995, 1997), infant facial expressions are often fleeting. Infants also often show mixed expressions and some expressions unique to infancy in addition to full face configurations to specific eliciting contexts (Bennett, Bendersky, & Lewis, 2002; Matais & Cohen, 1993). There is evidence of decrease of mixed expressions and less intense expressions with age in response to at least some contexts (Bennett, Bendersky, & Lewis, 2002, 2005; Izard & Abe, 2004). Negative expressions and/or components associated with putative anger, sadness and fear have shown the least evidence of specificity although the number of contexts studied is still limited (Bennett et al., 2002, 2004). There is only limited evidence for correspondence between specific negative emotion states and specific contexts; for example, anger to contingency blockage reliably elicits anger expressions in most infants (Sullivan and Lewis, 2003). Generally, infant facial expression studies have supported the view that all negative expressions are correlated, essentially the DST position. Distinct forms of negativity, with the possible exception of wariness to novelty /behavioral inhibition, are not thought to be psychologically meaningful in the first year of life. Only early negativity to novelty thus far has shown a relation to later behavioral inhibition (Fox et al., 2001; Rothbart & Derryberry, 1981). Evidence against some aspects of DET is not equivalent to support for DST, however. Moreover, at least some findings by DST research are compatible with DET. Brows and widened eyes (part of the surprise expression) may be coordinated motor structures (Camras, 2000), as already recognized in DET which notes the high correlation of these brow/eye components (Izard, 1995). The fact that they co-occur commonly when gaze is directed upward as opposed to downward, is a potential source of coding error but that can be evaluated on a study by study basis. Similarly, the finding that narrowed eyes is a signal of smiling intensity is also consistent with DET (Messinger, Fogel, & Dickson, 1999). Work on newborn pain responses has come closest to achieving DST's goal of examining assemblies of negative expressions to stimuli independent of preconceived notions of adult emotion templates (Kohut et al., 2012). However, to maintain emotion "neutral" language for the observed displays of correlated brow, eye/cheek and mouth components, the investigators resorted to color labels to communicate their findings for the various facial expressions. The results for the “colors” of newborn pain suggest that a variety of facial displays occur with pain. Their stability and implications for clinical practice remain to be established. They can be “translated” into MAX basic expressions, perhaps with greater practical face validity for practitioners. In the long run, the appropriate coding choice would seem to depend on the aims of the study: If the purpose is to track subtle changes in expression longitudinally, Baby FACS (the DST model) may be more appropriate, but if the purpose is to assess nursing response to readily readable pain expressions, MAX (the DET model) seems preferable.

DST is attractive because it accounts for how rapid shifts between expressions might occur, but it has not yet demonstrated that full-face expressions are assembled from various components as originally proposed. Most work on DST mechanisms in the coordination of facial expression has involved positive expressions of infants within dyadic social interaction with mothers (Fogel et al, 1992). In this work, it is the dynamics of dyadic social interaction that are stressed rather than the motor assembly of expressions themselves. There has been limited information about the sequencing of negative expression components in either social or nonsocial contexts, which would seem to be necessary to adequately test DST assumptions about the coordination of separate facial movements into recognizable expressions. Consequently, we do not know whether more regular occurrence of full-face expressions of anger and sadness, for example, develops over time to the same or more intense elicitors. Perhaps the reason there has been so little work on testing DST’s hypotheses regarding the coordination of facial components is that until recently, Camras did not specify which aspects of facial expressions mapped onto DST variables (Camras & Fatini, 2008; Messmen, Oster, & Camras, 2012). For example, what might constitute an attractor variable for facial expression? “Emotion”, defined as larger assemblies of emotion components has now been suggested (Camaras & Fatini, 2008), but it is as yet unclear how this might be tested using the DST model.

A problem with both DST and DET is that they have not made direct reference to how the known, complex neurology directly linking facial muscles to the brain might interact with both cortical development and the neural control of sound production. For example, there is a different enervation pattern, as well as differential inhibitory control, of the lower as opposed to the upper face (Rinn, 1984; Peterson, Shackman, & Harmon-Jones, 2007). Lower face movements have a differential distribution of inhibitory processes in the brain than upper face movements, with some related to vocal production and some to inhibition of expression per se (Peterson et al., 2007). Thus, whether an infant is crying or vocalizing influences the variability seen in the lower, but not the upper face. Distinctive EEG patterns have been observed for full-face anger as opposed to full-face sad configurations when they occurred in the absence of crying (Fox & Davidson, 1988). Active crying, then explains facial variability rather than dynamic assembly of the facial display around some attractor state. At the highest levels of arousal, when vocal crying is added to the emotion signal, variation in expression may have more to do with the breathing patterns that support vocalization than with dynamic assembly of an expressive signal (Just try to cry and inhale at the same time!). If upper face movements are less variable over time than lower faces movements, it may be that an upper face movement might signal emotion and lower face movements, moderated by breathing patterns, or attempts to inhibit crying, are less relevant. Since the neural input reflects a different mechanism, there is no need to posit a complex organizing mechanism.

The facial expression gradient is also not handeled easily in DST. An intensity gradient explains the occurrence of full versus partial expressions (upper face only movement patterns) more parsimoniously than DST (Abe & Izard, 1999).

Finally, neither theory offers a working model of context, although Izard's notion of "families of eliciting situations" and emotion-cognition schemas moves in that direction. Most contexts investigated in infancy have been chosen because it was reasonable to hypothesize a given emotion might occur as a modal expression. However, contexts that on the surface may appear quite different actually be related on a deeper level. The head drop segment of the Enface procedure and the Extinction phase of an instrumental learning experiment, for example, both belong to the same "family" of events. Both involve disruption of contingency---one social, one not---and both elicit primarily anger (Lewis & Ramsay, 2005). Having a theory of context is important to both understanding the range of situations in which expressions might occur based on objective criteria as to what the core motivated behavior –approach or withdrawal--that context is likely to elicit.

What is the A/W model?

Approach and withdrawal are basic behavioral action tendencies of individuals in response to salient stimuli in any given context (Gray, 1991; Carver, 2004). These action tendencies include related clusters of physical actions, supporting physiology, **a**nd facial expressions which signal the infant's behavioral disposition or "modes of readiness" to others (Gray,1991; Fridja & Tcherkassof, 1997). Despite debate as to how readily interpretable specific infant facial signals may be, in this framework, they are hypothesized to be consistent with the overall action tendency and to convey to others both the affective valence and the likely direction of the infant's actions toward or away from a given stimulus. Approach is defined as any behavior which decreases the distance between child and stimulus (Seibt, Neumann, Nussinson, & Strack, 2008). As biologically-based organizing principles, it is reasonable to expect that A/W function in some form from the opening months of life in nonthreatening contexts. Even before the infant attains independent locomotion, approach tendencies can be assessed by behaviors that include attempts to reach, maintain, or gain control of stimuli, as well as by the quality of infant attention toward them. Approach behaviors are dominant in the first months of life because infants must orient to social and nonsocial stimuli in order to grow and adapt. The infant's approach repertoire increases with development. Although initially limited, control of the head and directional movement of the eyes allow the infant to engage with its social and nonsocial world. For example, awake and non-crying newborns will turn their heads toward stimuli of moderate intensity (Cohen, 1973). They may bat at, shimmy, or roll toward objects that attract them before reaching is attained (White, Castle & Held, 1964). Curious, as opposed to wary interest (See Figure 2), and smiling are examples of approach expressions, as are anger expressions to blocked goals (Lewis, Alessandri, & Sullivan, 1990). Adult approach emotions are expected to be similar to or variants of these.

Direction of behavior, not the valence of emotion, is key in an A/W model**.** A/W actionssignaled the direction of motivated behavior well before facial expressions evolved (Schneirla, 1959; von Honk & Schutter, 2006). In contrast to A/W, a valence model of emotion emphasizes only the positive/negative or pleasant versus aversive quality of emotion rather than its behavioral direction. The theoretical insight that direction is key to "unpacking" the negative emotions is important as it allows the parsing of the negative affects into those that are related to perceived threat vs. nonthreat (Carver, 2004). The field has tended to view early negative emotion as monolithic and nonspecific, yet there has been no plausible account of how or when negative emotions become differentiated from nonspecific negative emotion, or if they ever do. Anger, with the same directional impetus as positive expressions, is an approach emotion because it signals determination or persistence when approach of an object or goal has been blocked (C. Harmon-Jones, Schmeichel, Mennitt, & E. Harmon-Jones, 2011; Sullivan & Lewis, 2003). The evidence in support of this view continues to mount in the adult literature as well (E. Harmon-Jones, 2003, 2004; E. Harmon-Jones, Lueck, Fearn, & C. Harmon-Jones, 2006; E. Harmon-Jones & Gable, 2009; E. Harmon-Jones, Gable, & Price, 2013). Anger is distinct from sadness and fear although all are negative emotions.

Withdrawal is defined as any behavior that promotes disengagement from a stimulus perceived to be unpleasant, unpredictable, uncontrollable, or undesirable, but not threatening. Low activity toward goals, increased cortisol response, expressions of sadness or fear, and behavioral signals of helplessness or a need to move away from a stimulus index withdrawal emotion (Buss et al., 2003; Lewis, Ramsay, & Sullivan, 2006). Withdrawal tendencies need not require self-initiated movement away from stimuli in non-locomoting infants, only the ability to vocalize distress and display sadness. Sad expressions facilitate movement away fromnonthreating stimuli that are, or have become unpleasant, unpredictable or uncertain. Distress vocalizing (fussy or intermittent low intensity crying) usually prompt the action of caregivers to remove or support infants' disengagement from the unpleasant or uncomfortable. Sad expressions upon loss of a stimulus or the inability to control it, or giving up quickly are examples of withdrawal expressions observable by 4 months (Lewis et al., 1990; Putnam & Stifter, 2005). These signals promote caregiver-supported withdrawal or other interventions. Head and gaze aversion are also withdrawal infant behaviors in nonthreatening contexts and may serve this purpose in adults as well.

Context and the A/W model

Past work on infant negative emotion has debated the specificity of emotion expression to eliciting context (Bennett, Bendersky, & Lewis, 2004; Camras et al., 2007; Izard, 2004). No taxonomy of contexts has been proposed by either expression theory. However, there is some work on perception of threat in contexts introducing novel objects or adults to infants' responses of fear/avoidance and behavioral inhibition (e. g., Fox, Henderson, Marshall, Nichols, & Ghera, 2005).Withdrawal occurs in nonthreatening contexts as well. It may follow or occur in competition with approach tendencies in some, if not most, such contexts. The degree to which a given context promotes A/W can be examined empirically. However, withdrawal in nonthreatening contexts is hypothesized to be physiologically distinct from defensive withdrawal to threat. Although what constitutes threat likely differs for infants as opposed to adults, defensive withdrawal is related to the fear/flight physiological response and its action tendencies are not the same as non-defensive withdrawal. Fear/flight responses serve as the emergency response system in mammals and humans. Young infants cannot flee, so their defensive withdrawal is accomplished either through reflex actions (Moro, Head Righting Reflex), body movement, and intense distress responses (rolling cries and pain-related distress expressions), which are likely to lead to rapid caregiver intervention (Ridell et al., 2011). Fear expressions are rarely observed in young infants, but the range of contexts studied has been limited due in part, to ethical concerns.

In humans, behavioral inhibition and wariness of novelty have been viewed as the analog of freezing behavior (Fox & Calkins, 1993), so these have been the primary contexts studied. There are clear individual differences in response to these contexts typically studied, but little evidence of fear itself in terms of physiological responses or facial behavior. So, we know more about the behaviorally inhibited temperaments or wariness than fear emotion in the very young (Buss, Davidson, Kalin, & Goldsmith, 2004; J.J. Campos & Stenberg, 1981; Fox, et al., 2005). Early inhibited temperaments, although related to later social inhibition (Fox et al., 2001), are not fear-proneness. Behavioral inhibition, whether state or trait, is neither approach nor defensive withdrawal. It appears to reflect a child's perception that the context is unfamiliar or uncertain, and the need for caution or vigilance. Although inhibited temperament might reflect a lower threshold of threat detection, to demonstrate that a wary, knit brow expression is a signal of threat sensitivity, it would be necessary to show that these children show a wary expression reliably whenever features of threat are present, even at low intensity. We have a good idea of what those features might be. Threatening contexts versus nonthreatening contexts are likely to 1) involve unpredictable, strongly arousing, or uncontrollable stimuli (Gunnar-Vongnechten, 1978; Gunnar, 1980), or 2) have been associated previously with pain. Figure 3 shows a 4-month-old's fear-like expression, observed in response to a nurse's approach during a DPT inoculation sequence. This photo was obtained incidentally during a study of cortisol responses to two consecutively administered inoculations (Ramsay & Lewis, 1994). Cortisol responses peaked with the first inoculation, but for some infants, the second inoculation was associated with responses suggesting defensive withdrawal. It appears that contexts must be defined both in terms of nonthreat/threat features and infants' perceptual/cognitive responses to it (J.J. Campos & Stenberg, 1981).

Coherences of behavior, expression, and physiology most likely arise in the moment from the interaction of various neurobiological processes in context **as infants perceive it,** based on their history and developmental capacity. Incidental perceptual features of context are encoded and remembered by young infants (Rovee-Collier, 1996), so it is important to consider their influence. Infants' basic abilities to discriminate familiar from novel, and to detect contingencies, likely inform or modulate their perceptions in any given context.Context and infants' history with that context, then, is critical to eliciting A/W emotion.

The A/W model allows contexts to be classified based on whether the modal response is approach or withdrawal, but individuals may still differ in either the level or the particular tendency shown. Once a context is classified, individual differences in A/W behavior can be meaningfully studied. Physiological, behavioral and expressive responses vary within and between threat and nonthreat contexts (Braungart-Reiker & Stifter, 1996; Buss et al., 2004; Fox, Henderson, Rubin, Calkins, & Schmidt, 2001). Differences in A/W might reflect differences in the perception of reward vs. threat in a given context, and/or a general bias toward either approach or withdrawal across contexts. A few hypothesized threat contexts have been explored this way, for example, stranger wariness and visual cliff responses (J. J. Campos, R.G. Campos, & Barrett, 1989; Fox et al., 2005). Individual differences in perceived reward have not received as much attention (Crossman, Sullivan, & Lewis, 2009). Having a taxonomy for contexts is important to be able to design and test hypotheses about variation in emotion processes over time, over context, and within individuals.

How transitions between approach and withdrawal occur within a context, a form of emotional regulation that is not well understood, but also may be hypothesized. Figure 4 (Panksepp, 2007; Panksepp, 1998) depicts the proposed neural pathways linking four basic mammalian affect systems in the brain. It shows the excitatory and inhibitory influences among them. Although not designed to illustrate A/W, the figure does so elegantly. It shows four basic behavioral systems, each with its inhibitory and excitatory influences, aligned along approach or withdrawal axes. Fear and distress/help-seeking behavioral systems, the withdrawal emotions, are on the horizontal axis. They promote self-initiated or supported movement away from a stimulus when the context or stimulus is perceived as aversive or threatening. The fear system promotes freezing or flight depending on its level of activation. High fear should promote avoidance or flight. Distress/help-seeking is related to distress calls and agitation, especially in response to social loss, and to unpredictable or uncontrollable events (Seligman, 1975).

The approach pathways of seeking/interest and anger/rage are shown on the vertical axis. They promote moving toward stimulus goals or objects and energizing action to gain or to regain access to them. The human emotion related to seeking behavior is interest. Interest is not just visual attention, but the receptive, engaged expression of Figure 2. Anger/rage energizes behavior, promoting movement toward blocked goals and against obstacles in approach contexts. In threatening or dominance contexts it energizes, attack and fighting with conspecifics in threatening contexts. In infants and adults, anger, supported by increased heart rate, facilitates action toward regaining goals via persistent approach or determination and a narrowed focus of attention (E. Harmon-Jones & Gable, 2009; Sullivan & Lewis, 2003).

Figure 4 also illustrates that A/W systems should influence one another in specific, predictable ways. The figure's open- and blunt-ended lines show the interactions between and within systems. A major difference between the A and W arms of the model is that the withdrawal emotions mutually facilitate one another (open-ended lines), while approach emotions are organized as opponent processes and mutually inhibit one another (blunt-ended lines); one does not simultaneously attack and explore something. In contrast, fear and distress "feed" one another such that panicked, disorganized agitation may precede freezing or flight. Likewise, depressed individuals may be agitated, suggesting greater activation of defensive flight pathways, or passive, suggesting greater activation of helpless withdrawal.

Approach and withdrawal systems themselves may interact. Seeking stimulation or social contact, interest, and curiosity (Litman, 2005), are all approach tendencies that can inhibit withdrawal (fear and distress) or be inhibited by them, which explains why the distraction of a toy can help calm a child. Cross-facilitation or inhibition of emotions likely underlie lawful transitions between A/W within a context and prevents individuals from being "stuck" in a given mode of behavior. Since we are proposing that infant facial expressions map onto these A/W pathways, transitions between expressions within context and over time should follow these same pathways. Much of the failure to find that infant facial expressions do not mark discrete emotion "states", and lack strong context specificity (Bennett et al., 2002; 2004) might be due to these shared inhibitory and facilitative pathways.

A/W and Issues in Infant Emotion

An A/W model of infant emotion and behavior offers perspectives on several key issues. Some of these views converge, while others diverge, from currently held views of infant emotion and facial expression.

<u>Emotions are functional</u>. Functional theories propose that emotions develop to help infants adapt in context, and that adaptation will vary with individuals (J. J. Campos et al., 1989). Functional accounts of early emotion are largely consistent with an A/W model. However, an A/W model offers a specific qualification: It restricts the range of expected emotions that may arise in any given context on the basis of whether it elicits primarily approach or withdrawal. Approach situations will elicit primarily approach emotions and behaviors whereas threat situations will elicit primarily withdrawal emotions and behaviors, at least initially.

The A/W model, like the functional perspective, also avoids the problem of state. Whether infants experience a unique feeling tone linked to each expression is not critical; only whether their actions and supporting physiology function to get to or away from a stimulus is important. A/W does not eliminate the idea of basic expressions; it reframes them as newer features correlated with more basic biologically-based action tendencies within and across contexts. Feeling state may be either linked directly to expression as has been proposed by Izard (1977) and others (e.g., Zajonc, 1980). It may also be a component of these interacting processes, but the ability to actually measure feelings directly in the nonverbal, young is still limited. So, the relation between feelings and expression remains a theoretical, rather than empirical question. Direct, conscious awareness of emotion seems unlikely before the emergence of self-referential behavior in young children (Lewis & Michalson, 1983). Consequently, feeling quality can only be inferred from the patterning and coherence among other aspects of emotion. While remaining open to the possibility that a unique feeling quality may characterize a specific emotion or may emerge as expressions, behavior and physiology cohere, the A/W model sets this question aside while in search of a better and more psychologically grounded theory of contexts.

Expressions are nonverbal communication**.** As biologically old organization, the neural systems for basic emotions, including the action tendencies, were likely overlaid and integrated with older A/W networks. Expressive behavior became externalized signals in social mammals (Darwin, 1965). Via direct enervation of the face by cranial nerves, expression allows direct signaling of the subcortical activation of A/W relevant brain regions. This is more readily observable in young infants, whose expressive behaviors have not yet been socialized to cultural rules and whose experience is limited.

Considering facial expression as a signal of A/W behavior acknowledges its social-communicative function. Viewing infant expressions as "read-outs" of A/W neural activation treats them as external signs of the internal interactions among core, organized neural processes responding to perceived contextual cues of threat or nonthreat. For, example, rapid transitions between expressions and the composites of basic expressions in the upper and lower face are commonly observed in individual infants (Camras et al., 2007; Matias & Cohn, 1993). Co-activation of and rapid transitions between approach and withdrawal behavior are possible and essential to how the infant's emotion/behavioral system is regulated in context. Shifts between approach and withdrawal would be critical to promote context-appropriate, flexible disengagement and may be an important mark of good emotion regulation.

Expression to context mapping**.** One to one mapping of expression to specific contexts or elicitors is not required in the A/W model. Izard (2004) postulated approach and withdrawal may each have a "family" of related contexts for which a modal action tendency and sets of expressions can be identified. Contextual variation may alter the predominance or sequencing of expressions and therefore, shifting action tendencies in the A/W model. A child might express interest in and approach a stranger initially, but display wariness and inhibt action if the stranger comes too close or speaks directly to the child. Mixed or composite emotions are also possible, and can be understood as reflecting competing inhibitory or excitatory influences between neural processes. For example, mixed anger and sad expressions in young infants may reflect either anger inhibiting distress/panic, or high or rapidly rising distress/panic may excite anger in spreading excitation. In either case, the co-occurrence or mix of approach and withdrawal facial responses is driven by dynamics at the level of brain systems rather than at the level of motor processes, unlike a DST account of expressions (Camras & Fatani, 2008). Since mixed or composite expressions in the A/W model signal emotion processes, rather than self-assembled facial muscle displays, the A/W model is consistent with the notion of constructed or emergent emotion (L F. Barrett & Wager, 2006).

What you see is what you feel. As stated above, the A/W model is agnostic with regard to whether feeling states are uniquely linked to specific emotion expression. Feeling has been defined as either emotion-specific, qualitiative, differences in tone or global brain-body state differences (Izard, 1977; Panksepp, 1998). Data thus far suggest that a one to one correspondence between specific expression and state is unlikely for most of the contexts that have been studied in infants (Barrett, Linquist, et al., 2007; Bennett et al. 2004; Camras, 1992; Camras et al., 2007; Izard, 2007b). In a compromise between DET's position and DST adherents who typically favor no feeling-expression linkages, Camras & Fatini's (2008) version of DST allowed for limited correspondence such that positively valenced expressions are linked to generalized positive feeling tone and negatively-valenced expressions are linked to generalized negative tone. However, "modal" expressions for a number of common emotion-relevant stimulus contexts have been identified and show some stability over the first years (Bennett, et al., 2005; Buss et al., 2004) along with expected physiological correlates (Lewis, Hitchcock, & Sullivan, 2004; Lewis et al., 2006), suggesting that face/state correspondence might exist or emerge for these modal expression/context mappings. This cannot be confirmed directly since infants and young children are incapable of self-report or conscious awareness of feelings much before the age of 2-3 years (Lewis & Michalson, 1983). Technology opened the "black box" of the emotional brain to reveal its wiring, but the nature of the current yet elude us. Understanding correspondence between expression and feeling states will require further sophisticated integration of our measurement systems and better understanding of the complex interactions between subcortical emotion centers, cardiac and HPA axis function and cognitive processes.

Even then, face/state relations may be somewhat modest, or observable only at extremes of approach or withdrawal. If perceived feeling-expression links are learned, rather than innate, the field will be challenged to show when in development and how such learning occurs.

Expressions as opponent processes. Thinking about expressions as co-ordinated, self-assembling emotion systems as in DST is an advance, but whether expressions themselves are organized in this way as not been demonstrated. The opponent process model is a dynamic account of the regulation of emotion (Solomon, 1980) that should be considered with regard to expression . It proposes that any given emotion process (*a*) does not simply decline over time, but concurrently elicits an opposite-valence (*b*) process that increases slowly until the net result is a return to homeostasis. Opponent processes explain emotional phenomenon including human attachment, separation and grief, as well as addiction and binging (Radke, Rothwell, & Gewirtz, 2011; Solomon, 1980). Although initially conceived within a valence-, rather than directional-framework of emotion, opponent processes might account for transitions between A/W emotions. Observation of bi-phasic processes of anger and distress in children's tantrum behaviors supports the idea that these emotions may be organized as opponent A/W processes (Potegal & Davidson, 2003; Potegal, Kosorok, & Davidson, 2003). Two emotions, anger-approach and distress-withdrawal, are involved in tantrum behavior. Behaviorally, the down-regulation of tantrums appears characterized by the "replacement" of anger with sadness/distress, which eventually dissipates. The *a* process, anger/approach, arises rapidly in response to a blocked goal or thwarted desire. As it does, the slower *b* process, sadness/distress, increments, remaining evident until the child eventually calms. Tantrum duration is effectively the sum of the duration of both emotional processes. Differences in tantrum behavior can be gauged then by the decline of anger/approach and the persistence of distress/withdrawal responses because both are activated as opponent processes. Oster's (2005) contention that sad expressions of young infants are attempts at distress regulation is consistent with this view.

Even if they are not opponent-processes, co-activation of A/W processes might be likely to occur when the context is ambiguous. In approach contexts, if access to a goal becomes blocked suddenly, competing action tendencies, either to continue approach with increased vigor or to withdraw, may be elicited until it becomes clear whether regaining the goal is possible or further action is fruitless. These hypotheses, one assuming homeostatic organization of emotion processes, and the other linked to contextually-based cognition, both allow that more than one action tendency may arise in a given context and "compete" with one another.

Cognition matters even in young infants. The influence of differences in perceptual-cognitive processes on emotion has not often been studied, especially below the age of 6 months. Perhaps because cognitions at this age are so basic, it is assumed that they have little influence. In the A/W model, perception of context *always* matters regardless of adult construal of that context. Perceptual-cognitive processes are linked with emotion from the outset and cannot be divorced from them (Lewis, Sullivan, & Michalson, 1985). Infants, who fail to learn a contingency, do not express anger to the degree that those who learned do (Crossman et al., 2009; Lewis et al., 1990). Infants who experience a stranger's contingent response to them overcome their wariness; the controllability of a potentially scary toy determines whether the infant avoids it or not (Gunnar-Vongnechten, 1978; Gunnar, 1980). Biases toward perceiving stimuli in a certain way, due to temperament or experience influence if and how, A/W emotions are expressed because few, if any, human emotions are bound to specific stimulus elicitors (Lewis & Michalson, 1983). Besides standardizing context, the history with that context should be controlled or otherwise accounted for in assessing emotional response to it. Infants limited social experience and their more basic cognitions make control of these less daunting than older children, but are often ignored in experimental work.

Aren't individual differences in A/W just temperament?

Temperament has been defined as a set of response styles presumed to reflect underlying physiological or other constitutional factors that vary across individuals (Putnam & Stfter, 2005; Putnam, Gartstein, & Rothbart, in press). Many different temperament types have been studied, from the dimensions of reactivity and regulation developed by Rothbart and colleagues (Rothbart & Derryberry, 1981; Putnam et al., in press) to behavioral inhibition (Fox et al., 2001) and sociability (Bates, 2000) to name some commonly described for infants. Biases toward approach and withdrawal have been studied as behavioral styles in adults and older children (Carver & White, 1994). Individual differences in infant approach and withdrawal may also be thought of as temperament, but have not been studied extensively across the "families" of context that would allow us to draw this conclusion (but see Bennett et al., 2005). Studying individual differences in approach and withdrawal in the very young may provide an opportunity to explore continuities in these response styles over the life span. For now, individual differences in approach and withdrawal may be best viewed as the raw material on which experience and environmental input operate to shape behavioral or later personality styles.

Approach/Withdrawal styles may involve clusters of emotions that co-occur frequently in some individuals; for example surprise followed by joy in some individuals, but surprise followed by annoyance in others. The A/W model as presented in this paper is concerned primarily with the processes themselves, although it may eventually be possible to describe variation in approach or withdrawal as biases characteristic of individuals.

Summary

Approach and withdrawal constitute a basic organizing framework of behavior and emotion processes. Facial expressions are hypothesized to be one component of A/W and can be thought of as a later overlay on more fundamental systems for eliciting and regulating behavior and affect in contexts broadly characterized as either threat or nonthreat. In this way, facial expressions contribute to the measurement of infants' action tendencies or "readiness" to approach or withdraw. Framing expressions and behavior in this way promotes thinking about how emotional behavior, rooted in coordinated neural systems, evolves with brain maturation and development to signal emotional/motivational dispositions to others. A/W neither requires discrete, independent emotions, nor close correspondence with a specific feeling state. Instead, infant emotion and behavior are conceived as arising from A/W behavioral systems which unfold over time and promote coherences among behavioral direction, expression, and physiology in context. A/W emotions are constrained by homeostatic internal, possibly opponent processes, experience, and socialization. Modal A/W emotions, including expressions, behavioral action and physiological support, are expected to occur in any given context, but will also exhibit individual differences. One key difference between current approaches to infant expression and A/W is its view of negative expressions. Negative expressions, in particular, are sometimes interpreted as reflecting negative reactivity or distress broadly, while the A/W model does not. The A/W model suggests that we may be able to unpack "negative reactivity" and "general distress" earlier in infancy than has been possible thus far possible by sensitive attention to context, infant history and perceptions of that context, and to the direction of infant behavior and expression. Thus, instead of talking about negative reactivity, distinctions between withdrawal responses in threat and nonthreat contexts (fear and sad expressions) and frustrated approach (e.g., anger expressions to goal blockage) may be possible. Although contexts themselves, and specific A/W behaviors and expressions elicited in any context, may change with development, individual differences will likely show some stability over time. Longitudinal work is needed to confirm these hypothesized differences.

An A/W framework should be useful in generating testable hypotheses about the classification of contexts and the occurrence, temporal sequence, and regulation of facially expressed emotion, behavior, and physiology within them over time as well as between individuals. The classification of contexts as either primarily approach or withdrawal, and studying the variation of expressive and behavioral actions and physiology systematcially within and across the context types over time, should allow a better understanding of how emotions arise and are regulated as well as with development. Consequently, an A/W model may move the field of emotional development forward without being limited by the idea that facial expressions are only assemblies of motor behavior or appear in some fixed developmental trajectory.

Table 1. *Dynamical Systems Theory: Constructs, Definitions and Example from the Locomotor System taken from Thelen & Urlich (1991)*

VARIABLE	**DEFINITION**	**Example: The Development of Walking**
Attractor	A stable state of the system that within and between individuals and to which the system returns when perturbed and to which all trajectories converge: the "steady" or homeostatic state.	An alternating step pattern.
Attractor subtypes: 1. chaotic 2.equilibrium 3. periodic 4. strange	Determined by the number of different patterns or trajectories the behavioral system goes through before attaining the stable attractor state. 1. Many different, mixed 2. limited set 3. continuous, repeats over time 4. continuous, nonrepeating	Alternating steps is a periodic attractor pattern.
Collective Variable	The measure that describes the behavioral result of the cooperative system.	The number of alternating steps is a measure of coordinated walking.
Control Parameters	Factor(s) constraining the emergence of a behavior or pattern or that limit its possibilities, usually aspects of the task, environment, or w/n organism.	arousal level; rate of muscular maturation; emergence of postural changes the fat to muscle ratio in the legs
Pertubation	An experimental manipulation of the control parameter that allows observation of the attractor state.	Varying the speed of a split-belt treadmill: Allows for measurement of alternating steps as speed increases.
Phase Shift	The point of transition between two different attractor states brought on by a critical change in one or more control parameters.	Transition between uncoordinated, unstable stepping to coordinated, invariant, alternate stepping. This occurred when all four control parameters listed above had dramatically increased.
Rate Limiting Variable	The slowest maturing component of the behavioral system's elements that, when it comes on-line allows the whole system to be functional (can also be a control parameter).	Fat to muscle ratio of the legs needs to mature for independent walking.
Scalar Change Threshold	The critical threshold of a control parameter that, when attained, causes behavior to shift out of the attractor pattern or state and a new state/behavior to emerge.	The specific fat to muscle ratio and/or flexor/extensor balance that marks the transition to independent walking.
Trajectory	Changes in a behavioral system changes over time; how attractor behavior/state is achieved.	Determined through repeated measures and longitudinal study.

List of Figures

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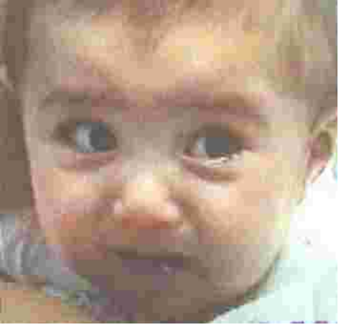
Table 1

Dynamical Systems Theory: Constructs, Definitions and Example

VARIABLE	DEFINITION	MOTOR SYSTEM: The Development of Walking
Attractor	Behavioral state of the system that is stable within and between individuals and to which the system returns when perturbed and to which all trajectories converge: the "steady" or homeostatic state.	An alternating step pattern. (Thelen et al. 1991)
Attractor subtypes: 1. chaotic 2.equilibrium 3. periodic 4. strange	Type is determined by the number of different patterns or trajectories the behavioral system goes through before attaining a stable attractor state. 1. Many different, mixed 2. limited set 3. continuous, repeats over time 4. continuous, nonrepeating	Alternating steps is a periodic attractor pattern (Thelen et al. 1991)
Collective Variable	The measure that describes the behavioral result of the cooperative system	The number of alternating steps is a measure of coordinated walking.
Control Parameter	Factor(s) constraining the emergence of a behavior or pattern or that limit its possibilities. Usually aspects of the task, environment, or w/n organism	arousal level; rate of muscular maturation; emergence of postural changes the fat to muscle ratio in the legs
Pertubation	An experimental manipulation of the control parameter that allows observation of the attractor state.	Varying the speed of a split-belt treadmill: Allows for measurement of alternating steps as speed increases.
Phase Shift	The point of transition between two different stable attractor states brought on by a critical change in one or more control parameters.	Transition between uncoordinated, unstable stepping to coordinated, invariant, alternate stepping. This occurred when all four control parameters listed above had dramatically increased.
Rate Limiting Variable	The slowest maturing component of the behavioral system's elements that, when it comes on-line allows the whole system to be functional (can also be a control parameter).	Fat to muscle ratio of the legs needs to mature for independent walking.
Scalar Change Threshold	The critical threshold of a control parameter that, when attained, causes behavior to shift out of the attractor pattern or state and a new state/behavior to emerge.	The specific fat to muscle ratio and/or flexor/extensor balance that marks the transition to independent walking.
Trajectory	The way a behavioral system changes over time; describes how attractor behavior/state is achieved.	Determined through repeated measures and longitudinal study.

List of Figures



Multiple Brain Systems for Emotion (adapted from Panksepp, 1998)