Infant Interest Expressions as Coordinative Motor Structures*

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Abstract:

Two opposing facial actions, raised and knit (contracted} brows, hove been considered expressions of the unitary emotion of interest. We examined differential relationships between these brow actions and accompanying head, eye, arm, and other facial movements in 5- and 7-month-old infants who were videotaped as toys were presented above or below eye level. Raised-brow movements significantly co-occurred with head-up and/or eyes-up movements for both ages. Knit-brows co-occurred with eyes-down at 5 months and head-down at 7 months. Frequency of arm movements was not systematically related to head, eye, or brow movements. Muscles that move the brows con be recruited when young infants move their head and/or eyes. Therefore, converging sources of evidence are needed before interest con be inferred from the brow actions of infants. Keywords: infant facial expressions motor coordination emotion interest

Article:

According to Izard and Malatesta (1987), infant facial expressions represent discrete emotions from the time of their appearance. In contrast, others (e.g., Campos & Barrett, 1984; Lewis & Michalson, 1983; Sroufe, 1979) have argued that facial expressions initially either are not tied to an emotion or are tied to diffuse, relatively undifferentiated hedonic states. Only during the course of development do facial expressions become linked to specific emotions. Despite such disagreement, all investigators agree that many facial configurations are present early in infancy and are highly organized and similar, though not identical (Oster, Hegley, & Nagel, in press) in form to adult facial expressions of emotion (Camras, Malatesta, & Izard, 1991; Malatesta, Culver, Tesman, & Shepard, 1989; Oster, 1978; Oster & Ekman, 1978; Rosenstein & Oster, 1988; Sullivan & Lewis, 1989). How might this early organization of infant facial "expressions" be explained without postulating control by underlying discrete emotions?

Darwin (1872/1965) proposed that many emotion-related facial expressions evolved from movements that served a noncommunicative function. For example, eye widening to increase the visual field when encountering a novel, unexpected object or event would serve the noncommunicative function of increasing acquisition of visual information as well as the communicative function of signaling the emotional state of the individual. Following Darwin, Peiper (1963) claimed that patterns of facial movements in neonates emerge as spreading reactions that tend to increase or decrease receptivity of stimuli. For example, Peiper observed that infants close their mouths as well as their eyes in reaction to bright light. Andrew (1963a, 1963b) suggested that primate facial expressions are derived from reflexes or combinations of reflexes having nonsocial basic functions connected with protection, respiration, vision, and so forth, and that the nonsocial functions would be present and apparent in the social contexts in which the expressions occur. Thus, Andrew seemed to maintain that emotional expressions are never emancipated from their non- communicative function.

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Other investigators (Ekman, 1979; Fridlund, Ekman, & Oster, 1987) also acknowledged that some of the individual facial movements involved in emotional expressions may not be completely emancipated from their non- communicative origins, especially during infancy. Hence, when produced in isolation, these movements may not always serve as expressions of emotional states. Nevertheless, unlike Andrew, they did consider instances of complete facial expressions to represent affective states fully emancipated from their noncommunicative origins.

Recently, investigators of infant motor development proposed a framework for characterizing the organization of infant action (cf. Prechtl, 1982; Thelen, Kelso, & Fogel, 1987) that may be of value in understanding the relation of infant facial expression to emotional state. Patterns of action during infancy derive from the formation of "coordinative structures." That is, any action is a component of larger ensembles of motoric and physiological variables that are constrained to cooperate to form patterns according to the rules of the system's dynamics. Although the variety of possible movement patterns is nearly infinite, the general level of effort involved in the activation of muscles, the environmental constraints on movement, the state of action of other muscles, and the biomechanical properties of the structures being moved all combine to constrain the variety to a small set of distinctly identifiable coordinative structures. These coordinative structures are not programmed by the nervous system but rather emerge from the dynamic of action itself.

Coordinative structures can arise because movement of one set of muscles recruits the involvement of other muscles (Michel, 1991). The pattern of recruitment depends on the effort exerted in the moving muscle and the relation of its neural control to that of other muscles. Coordinative structures emerge from the associated movements accompanying the action of any particular muscle group. Perhaps infant facial expressions are components of larger ensembles of motoric and physiological variables constrained to cooperate to form different patterns depending on which ensemble of motoric and physiological variables is operative (Fogel & Reimers, 1989). If so, then, organized infant facial expressions could occur without linkage to any emotional state, and unlike the Darwinian framework, the coordinative structures upon which the infant's facial configurations depend need not be presumed to be adaptive.

If infant facial expressions represent coordinative structures evoked as components of larger movement ensembles, then specific facial actions ought to be associated with the movement of muscles controlling the head, eyes, limbs, or trunk. Consistent with this argument, Legerstee, Corter, and Kienapple (1990) reported that specific facial and hand movements are associated with states of distress or pleasure in social and nonsocial contexts in 9- to 15- week-old infants. However, the notion of coordinative structures makes no assumptions about essential emotions or emotional expressions; therefore, it may provide a means for examining the development of infant facial expressions without postulating that each occurrence of an expression necessarily reflects a discrete emotional state of the infant.

This experiment was designed to illustrate how a focus upon coordinative structures can alter both the empirical examination of infant facial expressions and their interpretation, Specifically, we examined the proposition that certain facial expressions during infancy can occur as components of coordinative movement structures that include the head and eyes.

Facial expressions of "interest" were chosen because several rather diverse patterns have been described as expressions of this emotion by Izard (1977). These include either knit and/or contracted (i.e., drawn together and slightly lowered) or raised brows accompanied by a relaxed open mouth or puckered or pursed lips (Izard, Dougherty, & Hembree, 1983). According to differential emotions theory (Izard, 1977), these different patterns are tied to a single primary emotion. However, it is not clear why interest, if it is a single unitary emotion, should be expressed by such different facial movements. Furthermore, whether or not interest is a primary emotion, the circumstances under which one versus the other of the alternative interest facial expressions is produced must still be specified.

Other interpretations of the raised-brow or knit-brow facial expressions have been proposed. Darwin suggested that lowered (knit) brows reflect concentration or determination evoked by difficulty in thought or action. More recently, Oster (1978) proposed that knit brows in young infants may reflect an effort to "assimilate a complex pattern of stimulation" (p 70). Peiper (1963) included raised and lowered brows in a description of receptive and defensive spreading reactions. In addition, Peiper suggested that the brows may be lifted when the gaze is directed upward by an ocular frontalis reflex.

We propose that the raised-brow pattern is part of a larger coordinative structure and is synergistically related to head and eye movements that lift the chin above the horizontal plane. Thus, when infants raise their heads, they will produce the raised brow expression of interest irrespective of whether we assume they are in such an emotional state. We also examine the possibility that the knit-brow expression of interest is part of a coordinative structure that includes downward head movements.

METHOD

Subjects

Ten 5-month-old (5 males) and 10 7-month-old (6 males) healthy infants, recruited from Columbus Hospital (Chicago) birth lists, participated in the experiment.

Procedure

Each infant was seated on the mother's lap facing a small table whose surface was between the infant's chest and navel and a Panasonic videocamcorder 2 m distant. The mother was instructed to hold her infant's waist and chest. Then, the infant received 20 presentations of toys (10 toys were presented once and 5 toys were presented twice). Half of the presentations were from above the infant's line of sight and half were placements on the table, below the line of sight. The toys were presented to the infant's midline. The presenter stood slightly to the right for about half of the infants and slightly to the left for the remainder to avoid blocking the camera. The toys included rattles, keys, beads, concentric rings, balls, chains, and cubes. Five toys (a cube, beads, chain, key set, concentric rings) were presented twice: once from above and once on the table. The order of presentations was random and the toy was removed 10 s after the infant had touched it or 15 s after presentation. Each session lasted fewer than 10 min.

Coding

The video records showed the faces and upper bodies of both the mother and infant. The infant's facial expressions, direction of head movement (up and down), direction of eye movement (up and down) and arm movements were coded in a manner designed to provide information about their temporal co- occurrence. The coding procedure involved two steps: (l) identification of coding cues (CCs), that is, head, gaze, and facial movements designated for further coding; and (2) identification of co-occurring movements (COMs), that is, head, gaze, facial, and arm movements co-occurring with the cue item.

Based on Ekman and Friesen's (1978) anatomically based Facial Action Coding System, the categories of facial movements were: (1) raised brows or brows-up (i.e., contraction of m. frontalis); (2) knit brows or brows-down (i.e., contraction of m. corrugator with or without depressor glabellae, and depressor supercilli); and (3) "other" facial movements (i.e., contraction of other facial muscles producing expressions such as lip presses, oblique brows, etc.). This other category is composed of a diverse set of movements, each of which was relatively rare in our data. Although each was independently coded, they were grouped together for most analyses. The head movement categories were: head-up (i.e., chin lifted 45° from horizontal plane) and head-down (i.e., chin lowered 45° from horizontal plane). The eye-movement categories were: eyes-up (i.e., the appearance of white between the irises and the lower lids) and eyes-down (i.e., occlusion of parts of the irises and pupils by the lower lids). Head and eye movements were coded independently of one another in the sense that either had to reach apex, at least, before the other began to move. Often head and eye movements occurred entirely independently of one another. Arm movements were recorded as reaches (extensions of shoulder and elbow in the direction of the object) and other.

Identification of CCs proceeded in the following manner. The first three instances of the infant's raised brows were identified and marked. Then, without rewinding, the coder continued until three instances of knit brows were identified and marked. Continuing this procedure, three instances of each of the following categories were identified: head-up, head-down, eyes- up, eyes-down, and other facial movements produced when both head and eyes remained level with the horizon. Because the other facial expressions had to occur in conjunction with level head and gaze, they are labeled "LHGother." Occasionally, head and eye movements began after onset of the LHG-other cue and the movements reached apex before the end of the cue. Therefore, there are a few instances in which head or eyes did not remain level throughout the duration of the other cue. If the video record ended before three exemplars of each category were identified, the coder proceeded to re-view the tape from the beginning but omitted movement episodes previously selected as exemplifying another category. Although this procedure made coding more efficient, it was not completely comprehensive and allowed the possibility of failing to note a co-occurrence of some items. In sum, three exemplars of each of seven CCs (brows-up, brows-contracted, head-up, head-down, eyes-up, eyes-down, LHG-other) were identified for each infant.

Next, co-occurring facial, head, eye, and arm movements (COMs) were identified for each CC exemplar. Co-occurrence was defined in terms of the temporal relationships among movement apexes, based on rules presented in Ekman and Friesen (1978). Movement apexes were points of maximal muscle contraction (for facial movement categories) or points of maximal deviation from resting position (for head and eye movements). According to the co- occurrence rule, if Movement 1 reached apex before Movement 2 began to offset (i.e., began to decline or deviate from the apex position) the two movements were considered to co-occur. However, if Movement 1 had not reached apex before Movement 2 began to offset, the two movements were not considered to co-occur.

Reliability for CC identification was assessed by having a second coder identify CCs (n 42) for two infants. Reliability (number of agreements divided by agreements plus disagreements) was .77, conventionally acceptable for the coding of facial movements (Ekman & Friesen, 1978). Reliability for coding of COMs was assessed by having the second coder examine 54 CCs and code them for COMs; reliability was .76.

RESULTS

For each CC, the frequency with which each type of facial and nonfacial movement co-occurred was determined for each infant and summed across infants within each age group. Each of these sums was converted to relative frequencies (i.e., frequency of each COM divided by 30, the frequency of the CC for further comparisons, see Table 1). To identify significant relationships among movement categories, the relative frequency of co-occurrences for each CC was compared to the average relative frequency calculated for the remaining five CCs. For example, the relative frequency with which brows-up co-occurred with head-up (when head-up served as the CC) was compared to the mean of the relative frequency with which brows-up co-occurred with the five other CCs. If the relative frequency of brows-up co-occurring with head- up was more than two standard deviations greater than its average relative frequency with the five other CCs, then brows-up was considered to co-occur significantly with the head-up CC.

Using this criterion, significant relationships were found among head-up, eyes-up, and brows-up for both 5- and 7-month-old infants (Table 1). In addition, for both age groups, head-down and eyes-down were COMs for the eyes-down and head-down CCs, respectively. Last, brows-knit co-occurred with eyes-down at 5 months. Figure 1 (p. 354) shows the percent of co- occurrence of brows-up and brows-down (i.e., brows-knit) with each CC for 5- and 7-month-old infants.

To examine further the relations of brow actions with head and gaze movements, each brow movement's frequency of co-occurrence with each head and gaze CC was compared separately to its frequency of co-occurrence with the LHG-other CC using Fisher's exact test. In these comparisons, brow actions during head and gaze movements were compared with brow actions when head and gaze remained level rather than with their average relative frequency across all nontarget cues, including opposite-directed head and

TABLE 1
Relation (in Percent Co-occurrences) of Co-occurring Movements (COMs) With Coding Cues (CCs) at 5 and 7 Months of Age

Coding Cue	Co-occurring Movements H-U	E-U	B-U	H-D	E-D	B-C	Other
5 Months							
Head-up	—	100**	80**	—	0	10	10
Eyes-up	50*	—	77**	0	—	6	7
Brows-up	43*	80**	—	0	6	—	3
Head-down	—	0	3	—	90**	23	2
Eyes-down	10	—	10	0	—	40*	2
Brows-contr.	8	6	—	9	15	—	1
LHG-other	5	3	1	1	3	7	5
7 Months							
Head-up	—	93**	87**	—	13	10	8
Eyes-up	70**	—	73**	0	—	0	5
Brows-up	50*	67**	—	3	23	—	1
Head-down	—	3	3	—	97**	27*	3
Eyes-down	20	—	17	50*	—	10	2
Brows-contr.	20	7	—	20	60**	—	1
LHG-other	7	3	2	3	5	4	7

Note. H-U = Head-up, E-U = Eyes-up, B-U = Brows-up, H-D = Head-down, E-D = Eyes-down, B-C = Brows-contracted, LHG-other = Facial expressions in conjunction with level head and gaze.
*$p < .05$. ** $p < .01$.

gaze movments. Therefore, results indicating significant relations between upward brow and upward head and gaze movments could not be inflated artificially by the possibility that upward brow movements are related antithetically to downward head and gaze movements. Significant alpha levels for Fisher's test were set at .01 for the total probability for the observed distribution plus all the distributions needed to bring the distribution to its extreme (0 in two opposite cells).

For both 5- and 7-month-old infants, brows-up significantly co-occurred with head-up or eyes-up. The frequency of co-occurrence of brows-up with the remaining cues did not differ significantly from its co-occurrence with the LHG-other CC. Brows-down significantly co-occurred only with the head- down cue and only at 7 months. The frequency of co-occurrence of brows-knit with the remaining cues did not differ significantly from its co-occurrence with the LHG-other CC.

To determine whether the results for brow movements were associated with differences in general activity among CCs, the frequency of arm movements (reaches + other) was examined in an 2 x 2 x 7 (age x sex x CC) ANOVA. The analysis yielded no significant effects for age, sex, or their interaction. However, frequency of arm movements differed significantly

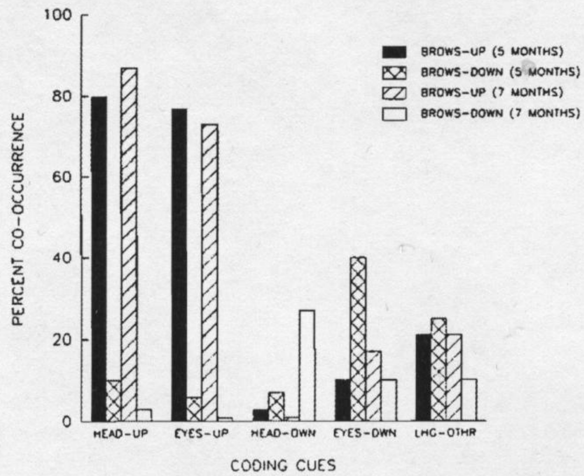

Figure 1. Percent co-occurrence of brows-up and brows-down (brows-knit) with each CC for 5- and 7-month-old infants.

across CCs, F(6, 78) = 9.4, p < .001. Tukey's A test for differences among means revealed that arm movements occurred significantly (p < .01) more often with head-up, head-down, and eyes-down than with the LHG-other CCs (Figure 2). There were no significant differences (p > .10) among the brows-knit, brows-up, eyes-up, and LHG-other cues, although arm movement was significantly (p < .01) less frequent in each of them as compared to the head-down cue.

To examine the relation between interest expressions and coordinated motor structures involving the co-occurrence of head, brow, or gaze movements, AFFEX-specified interest configurations were identified in the coded

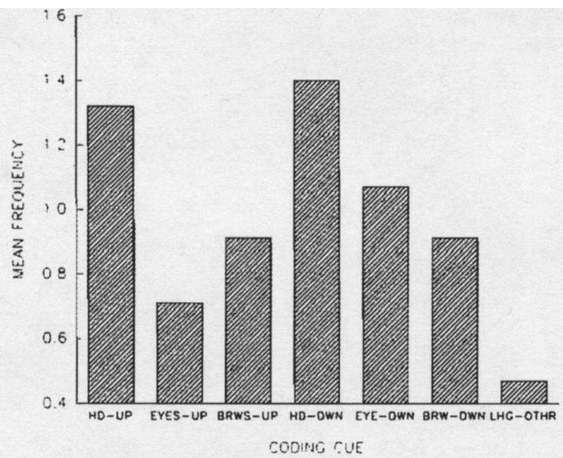

Figure 2. Mean frequency of arm movements, by both 5- and 7-month-old infants combined, for each CC.

TABLE 2

Relation Between AFFEX-Specified Interest Expressions and Coordinative Motor Structures

A. Percent of Coordinative Motor Structures Codable as Interest Expressions

Coordinative Motor Structures	Age	
	5 months	7 months
1. Brows raised with head-up and gaze-up	93	56
2. Brows raised and head-up or gaze-up	71	78
3. Brows knit with head-down and gaze-down	35	50
4. Brows knit and head-down or gaze-down	0	35

B. Percent of Interest Expressions Codable as Coordinated Motor Structures

Interest Expression	Head/Gaze Movement	Age	
		5 months	7 months
1. Brows raised with lips puckered/ pursed or relaxed open mouth	Head-up and gaze-up	72	43
	Head-up or gaze-up	22	36
	Total	94	79
2. Brows knit with lips puckered/ pursed or relaxed open mouth	Head-down and gaze-down	38	20
	Head-down or gaze-down	0	50
	Total	38	70

data. This required reviewing each instance of CCs to identify interest- relevant mouth actions (i.e., relaxed open mouth, puckered or pursed lips). Table 2 shows (a) the percent of coordinative motor structures that could also be codable as interest expressions of 5- and 7-month-old infants, and (b) the percent of interest expressions that could be codable as coordinative motor structures. For the latter calculation, CC exemplars from the raised and lowered head and gaze categories were not included in order to avoid artificially inflating the rate of co-occurrence.

Coordinated head and brow movements were not always coded as interest, and AFFEX-coded interest expressions did not always involve coordinated brow, head, and eye movements (Table 2). When coordinated brow, head, and eye movements were not AFFEX coded as interest, the infant usually had a relaxed closed mouth. These results show that although interest expressions can occur independently of head and/or eye movements, they are tightly tied to these movements. However, interest expressions are more likely to occur with upward than with downward head and/or eye movements.

DISCUSSION

The results demonstrate that infant brow movements can occur as part of coordinated motor patterns involving actions of head, eyes, and brows by Sand 7-month-old infants. When head and eyes are raised as instrumental movements, the muscles that raise the brows can be recruited as well. There is some evidence to suggest that a downward movement of the head or eyes may recruit contraction of the brows.

When the results of the two types of data analyses are considered together, they show that raised brows co-occurred with upward head and eye movements more frequently than with level head and eyes and more frequently than with downward head and eye movements. Therefore, there is a significant positive relationship among upward movements rather than an antithetical relationship between upward and downward actions. Similarly, the analysis of arm movements showed that the up and down differentiated configurations of brow, head, and eye movements were not simply a consequence of generalized activity level, as measured by arm activity. High activity did not result in upward movements and low activity did not result in downward movements. Rather, brow movements appear to be recruited as part of coordinative motor patterns involving actions of the head and eyes during this age period.

Although interest expressions were not a CC, they were identifiable in the coding protocols. When interest expressions were examined in relation to head and/or gaze movements they appeared to be components of larger ensembles that include head and gaze movements. Brow-raised interest expressions are more likely to be recruited by, or to be components of, head and gaze movements than are brow-knit expressions. The reasons for this difference await further study. However, it should be noted that downward and upward movements of the head and gaze are not simply opposite actions. Downward movements involve different patterns of muscle activation and provide different stimulus field experience (downward movements brought a table surface into the infant's fovea) vision). Also, upward head movements have a greater range of motion than downward movements and upward head movements involve excitation of antigravity muscle use whereas downward movements involve some inhibition of antigravity muscle use.

One implication of our findings is that the brow movement configurations comprised by the facial expression of interest need not imply control by a discrete emotion program. Of course, some coordinative motor patterns involving facial expressions may be linked to basic emotions. This experiment has not disproved the presence of a link between infant facial expressions of interest and that emotional state. Rather, the results can be interpreted to mean that the muscle configurations comprised by facial expressions can arise from the dynamics of movement itself. Therefore, if brow raises can arise from dynamic relations among muscle actions, then upward head movements produced as part of stretching, directed glances in response to peripheral stimulation, or even upward glances produced in the course of avoiding a stimulus might be expected to produce the raised-brows interest expression.

It is difficult to speculate about how many of the other facial expressions exhibited during infancy may be components of larger coordinative motor structures. Based on naturalistic observations, Fogel (1985; Fogel & Reimers, 1989) argued that infant facial expressions are coordinative structures. The results of this experiment provide the first experimental demonstration that at least a subset of infant facial expressions may be the consequence of the actions of coordinative structures.

Considering brow raises as components of larger ensembles involving head movements can help clarify the somewhat conflicting reports about the relation of brow raises to visual search in 3- to 5-year-old children. Blurton-Jones and Konner (1971) reported that 2- to 5-year-old children exhibited more brow raises when the alarm of a hidden clock, as compared to a clock in view, sounded during story time. They proposed that brow raising results from visual search. In an attempted modified-replication experiment, Wheldall and Mittler (1976) found no brow raises when a bicycle horn was suddenly sounded in front of a group 3- to 5-year-old children. However, unlike the Blurton-Jones and Konner study, the concealed sound source was located directly in front of the children, and no "searching" behavior, including head and eye movements, was elicited by the noise of the horn. This suggests that brow raises are associated with motor action patterns rather than just an emotional state.

If facial expression can arise as coordinative motor patterns, then we must be cautious about interpreting all instances as expressions of emotions. Like other components of an emotional episode, the particular facial response produced will depend on extraemotional, nonfacial, contextual factors. Action theories based on dynamic systems notions of coordinative motor patterns (e.g., Fogel & Thelen, 1987), contend that behavioral development involves the formation, reformation, differentiation, and incorporation of coordinative motor patterns into larger systems of action. Because coordinative motor patterns are not "programmed" but rather emerge from the dynamic of action, they are available for recruitment by a variety of systems. Therefore, unique and exclusive ties between facial expressions and emotions may never be formed.

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