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FACIAL EXPRESSIONS IN VARIOUS EMOTIONAL STATES IN CONGENITALLY BLIND AND SIGHTED SUBJECTS

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ABSTRACT

Most of the studies comparing facial expressions of born blind and sighted persons that have been carried out up until now have involved children as subjects. Various studies claimed that the quantity and quality of facial expressions of congenitally blind persons deteriorate with increasing age. Here, we compared facial expressions of born blind and sighted individuals using adults predominantly. Facial expressions were documented in an individual interview inducing such emotions as think-concentrate, sadness, anger, disgust, joy, and surprise.

Common characteristics found amongst studied individuals were: similar repertoires* of movements over the entire interview, high-frequency and high-repertoire proportion of facial movements in concentration, sadness, and anger relative to those in disgust, joy, and surprise, similar distributions of a cumulative repertoire proportion of facial movements, and also common behavioral profiles of frequencies of facial movements in the emotional states discussed. Similar displays of eyebrow movements were found as well in concentration, sadness, and anger.

Our study indicates that most tested characteristics of facial movements are common to born blind and sighted subjects, except for different cumulative mean frequencies in different emotional states, which is possibly related to the lack of visual feedback in born blind persons.

Our study substantiates the hypothesis that facial expressions are innate and have important cues in the evolution of social communication.

*Repertoire in our study is a list of all facial movements we observed.

Keywords: facial expressions, born blind subjects, congenitally blind subjects, repertoire, frequency, innate

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Gili Peleg embodies the integration of theoretical studies and practical application. Her studies have ranged over many fields in the biological sciences, and her career—from her army service until today—has encompassed a variety of roles in psychological and human resources. All this is reflected in her interest in human facial expression, the subject of this paper, for which she has been awarded the first annual Naomi Bouskila Award for best student paper published in the *Israel Journal of Ecology & Evolution*.

INTRODUCTION

Facial expressions are important in communication between individuals (Darwin, 1872). The clues indicating that innate factors influence facial expressions are: the homology of human and non-human primate facial expression (Van Hoof, 1967, 1972; Chevalier-Skolnikoff, 1973; Givens and Nettleship, 1976), the universality of facial expressions and facial perception (Ekman and Friesen, 1971; Eibl-Eibesfeldt, 1973; Grammer et al., 1988; Brown, 1990; Ekman and Keltner, 1997; Keltner and Harker, 1998), and similar facial expressions in newborns and adults (Darwin, 1872; Ekman, 1973; Trevarthen, 1985).

One of the classical ways to unravel the innate patterns of facial expressions is to study them in congenitally blind individuals since they lack visual feedback. According to Darwin (1872): "The inheritance of most of our expressive actions explains the fact that those born blind display them, as I hear from the Rev. R.H. Blair, equally well with those gifted with eyesight". Recently, we demonstrated the existence of a hereditary family signature of facial expression (Peleg et al., 2006), which is expressed in similar facial movements in born blind individuals and their relatives.

NATURAL FACIAL EXPRESSIONS IN CONGENITALLY BLIND CHILDREN

Six basic emotional expressions of joy, surprise, sadness, anger, disgust, and fear have been recognized in the faces of congenitally blind individuals (Izard, 1977). Studies of congenitally blind infants (Thompson, 1941; Freedman, 1964; Fraiberg, 1971, 1974; Iverson and Goldin-Meadow, 1998a; Galati et al., 2001a) indicate that their smile is similar to that of sighted infants. According to Thompson (1941), displays of anger, annoyance, and sulkiness in born blind children resembled those of sighted children. Charlesworth (1970) showed that congenitally blind and sighted children showed the same facial expressions of surprise. Eibl-Eibesfeldt (1973, 1989) showed that the congenitally deaf-blind children, some of whom had mental retardation, had the same basic repertoire of facial expression as sighted individuals although the facial movements of children born deaf and blind are less refined than those of sighted children due to the lack of visual feedback.

Galati et al. (2001a,b) showed that negative expressions of born blind children are more difficult to recognize compared to those of sighted children. He also showed that there was no decrease in facial expressiveness of blind children in the same period of development. Cole et al. (1989) suggested that blindness did not preclude the spontaneous expressive control of negative emotion. Iverson and Goldin-Meadow (1997, 1998a,b) realized that blind children's gestures took the same forms as those of sighted children and concluded that gestures require neither a model nor an observant partner. They found that even congenitally blind speakers use their eyes and gesture when they speak to a blind listener. Parke et al. (1980) found that blind children used head nods appropriately in conversation, although the children produced those nods in a narrower range of circumstances than did sighted children. Parents of born blind persons participating in our study reported the same phenomenon.

DOES THE ABILITY TO CONTROL FACIAL EXPRESSIONS IN BORN BLIND PERSONS CHANGE WITH AGE?

Thompson (1941) found a decrease in smiling and laughter in congenitally blind children with age (whereas their negative expressions, such as crying, remained constant). Mistschenka (1933) claimed that the expressions produced by the congenitally blind deteriorate qualitatively and quantitatively with increasing age. Less deterioration was evident in children who became blind later in life. According to Ekman (1982) and Galati et al. (1997), this could be attributable to the absence of reinforcement via the facial expressions of others.

In spite of the above-mentioned results, there are reports saying that blind individuals showed no deficits in normal spontaneous expression of emotion. We found several common characteristics in studies carried out so far that compared facial expressions of subjects blind from birth and sighted individuals:

1. Most studies included only a small number of congenitally blind subjects (1–14).
2. In most studies, the subjects were children who were blind from birth.
3. Most studies included a few of the six basic emotions or a single emotional state.
4. Only one study (Rinn, 1991) included a non-standard emotional state (a concentration-like situation).
5. A decrease in facial activity with age was reported in subjects blind from birth in some studies.

OBJECTIVES

Taking into account the data mentioned above, the main objective of our study was to compare the frequency and the repertoire of *spontaneou*s facial movements shown by congenitally blind subjects, mostly *adults*, with those of sighted individuals in *various* emotional states, including think-concentrate.

MATERIALS AND METHODS

DATA SETS

Blind from birth individuals (BI) and their sighted close relatives (SI) were chosen to be the subjects in our study since BIs never imitate facial expressions by visualization. Fifty-four (54) individuals, belonging to 21 families, participated in our study. This group included 24 BIs and 30 SIs who were the BIs' close relative. Informed consent was obtained from all subjects. All BIs had no known cognitive emotional, or physical impairments besides blindness. All SIs had no cognitive or emotional impairments, and were matched to the BI participants on the basis of kinship. The 24 BIs belonged to 21 families. Eighteen families included only one person who was a BI, and 3 families included 2 persons who were BIs. Information on subjects participating in our study (sex, age, and family relationships) is provided in Table 1.

Table 1

a. Age and sex of subjects

Age (years)	1–10	11–20	21–30	31–40	41–50	51–60	61–70	Total
BI females	0	6	5	3	2	0	0	16
BI males	2	2	3	1	0	0	0	8
SI females	0	2	3	6	1	11	1	24
SI males	1	1	0	1	2	1	0	6

b. Family relationships of BIs and their relatives

Relatives of BI	Mother	Father	Sister	Brother	Non-identical twin sister	First cousin
No.	18	3	2	3	2	2

INDUCTION OF FACIAL EXPRESSIONS OF VARIOUS EMOTIONAL STATES

Spontaneous facial movements were chosen to be studied since they are more relevant to studying emotions (Ekman, 1982). A special interview was planned to elicit the following emotional states: think-concentrate, sadness, anger, disgust, joy, and surprise. Each subject was interviewed individually. Induction of sadness, anger, disgust, and joy was carried out in two ways: 1. Actively by the interviewer ("induced"). The interviewer told the subject a story that elicited a specific emotional state. The subject was then asked to tell about his feelings regarding this story. 2. Autobiographical interview: the subject was asked to imagine, as vividly as possible, an occasion during which he felt a strong emotion in the past, and talk about this personal experience concerning a specific emotional state ("self") (Rosenberg et al., 1998).

The "induced" stage was carried out in order to more easily elicit the "self" reaction. The "self" induction of each of the emotional states discussed was carried out as follows:

Think-concentration: the subject was asked to solve a few puzzles. The difficulty level of each consecutive puzzle was elevated gradually.

Sadness, anger, and joy: each subject was asked to think about an experience he had, in which he felt one of the emotions discussed (sadness, anger, joy) in a very intensive manner, and to relate his experience, causing him to feel the specific emotion. He was requested to give as much detail as possible, to relive the emotions he had experienced. According to Ekman (2003), spontaneous behavior is natural when some part of life itself leads to the behavior studied.

Disgust: the subject listened to a story that included disgusting details.

Positive surprise: the subject was asked to solve a difficult puzzle. While concentrating on the details, trying to clearly remember the data of the puzzle, he was asked a question in gibberish.

In order to verify that subjects experienced the intended emotion, self-reported emotional data were collected during the elicitation of emotions and during the autobiographical interview.

PHOTOGRAPHING

The camera (Sony model DSR-PD100AP) was placed in front of the subject at a distance of 1.5–2 meters. The BIs were told they were being filmed, and they were informed about the camera's position. Each subject was filmed throughout the entire interview, lasting about 55 minutes. The interviewer met each subject for a one-hour session before photographing them in order to complete a standard document of personal details and reduce the embarrassment of the subject when being photographed. All subjects chose to be photographed at home.

INDEX OF FACIAL MOVEMENTS

We created an index of facial movements (see Appendix), including all the movements observed while watching videos of 54 subjects. This index includes 43 facial movements that were used to document the videos. Nine out of 43 facial movements included 2 movements that appeared continuously, one immediately after the other. These movements are called "complex movements" and include movements 8, 10, 19, 35, 36, 37, 38, 39, and 40.

DOCUMENTING FACIAL MOVEMENTS

The process of documenting facial movements was carried out in several steps:

1. Watching the full length of the film (at a speed of 25 frames per second).
2. Documenting in writing *all* facial movements belonging to the "self" reaction. These analyzed video segments included segments in which each subject:
   A. Answered *all* the puzzles (think-concentrate);
   B. Told about a life experience that caused him to feel a particular emotion (sadness/anger/joy). The analyzed segments included the entire description given by the subjects;
   C. Listened to the entire story that included disgusting details (disgust);
   D. Was asked to solve a difficult puzzle and, while concentrating on the details, was unexpectedly asked a question in gibberish (surprise).

The video segments we took for analyzing joy, for instance, were only those where the subject gave a self report that says he felt joy in a very intensive manner (4–5 on a scale of 1–5, where 1 is a weak degree of feeling and 5 is a strong one). This is right for all emotions discussed. Each video segment was observed at least three times. In each observation we concentrated on a specific area of the face: the eyebrow area, the nasal area, and the lip area.

The coding procedure was carried out by a single coder. The results are based on watching 50 hours of video (55 min/subject*54 subjects, i.e., each subject was interviewed individually for 55 minutes), and the analysis of 18.5 hours of video segments that included "self" reactions. Video segments that served for analysis consisted of 436 minutes of think-concentrate, 266 minutes of sadness, 246 minutes of anger, 34 minutes of disgust, 115 minutes of joy, and 13 minutes of positive surprise.

DEFINITIONS

Frequency: *Mean frequency* = the total number of times a given facial movement was observed during a given period of time divided by the observation duration (in minutes). *Cumulative mean frequency* = the sum of the mean frequencies of all facial movements of all subjects observed in a certain emotional state.

Repertoire proportion: *Repertoire of facial movements of a subject* = the total number of facial movements observed during all analyzed video segments of the particular subject (including: think-concentrate, sadness, anger, disgust, joy, and surprise). *Repertoire proportion* = the proportion of the facial movements shown by a subject in a particular emotional state, out of his facial movements' repertoire. *Cumulative repertoire proportion* = the sum of the repertoire proportion of all subjects in a certain emotional state.

PRINCIPAL COMPONENT ANALYSIS

The Principal Component Analysis (PCA) of data (Watkins, 1991) detects major directions of data variability in an initial coordinate space and reduces the dimension of the space for adequate data presentation. Principal components of n × m data matrix indicate orthogonal directions of maximum data variability (n—number of data points, m—number of coordinates). They originate from singular value decomposition of matrix of rank r:

$$X = U\begin{bmatrix} \Lambda^{1/2} & O \\ O & O \end{bmatrix} V^T$$

where U is n × m column orthonormal matrix, V is m × m column and row orthonormal matrix, $\Lambda^{1/2}$ is the r × r diagonal matrix with elements $\sqrt{\lambda_i}$, and λ_i are the r nonzero eigenvalues of the associated matrix $X^T X$. Rows of matrix V are eigenvectors (principal components) of $X^T X$. For real applications r = m was used.

In our case, the initial space has six dimensions, which are the six emotional states: think-concentrate, anger, sadness, joy, surprise, and disgust. Every data point of the space ("profile") represents a normalized facial movement with six coordinates that are the normalized frequencies of this movement at corresponding emotions. The procedure of normalization was carried out in two steps: (1) The average of the profile was deducted from every profile value. (2) Each profile value after average deduction was divided by SD of the profile.

The aim of the normalization is to provide the same range of variability for all facial movement profiles. All profiles of all facial movements for all subjects (426 profiles) were classified by a hierarchical clustering algorithm. The data set of profiles was clustered to 8, 16, and 32 clusters. The applied clustering was nested: every cluster of clustering-16 consists of clusters belonging to clustering-32, and every cluster of clustering-8 consists of clusters belonging to clustering-16.

RESULTS

A. SIMILAR REPERTOIRE OF FACIAL MOVEMENTS IN BIs AND SIs

We examined whether BIs and SIs show the same repertoire of facial movements. We found that BIs (n = 24) show 84% of the set of facial movements that serves as the description of facial expressions in this study (36 facial movements out of 43). SIs (n = 30) show 93% (40 facial movements out of 43) of this set.

B. THE FREQUENCIES AND REPERTOIRE PROPORTION OF FACIAL MOVEMENTS IN VARIOUS EMOTIONAL STATES

B.1. Different cumulative mean frequency and similar cumulative repertoire proportion of facial movements in various emotional states in BIs and their SI relatives

We examined if BIs and their SI relatives show the same distribution of cumulative mean frequency and cumulative repertoire proportion of facial movements in various

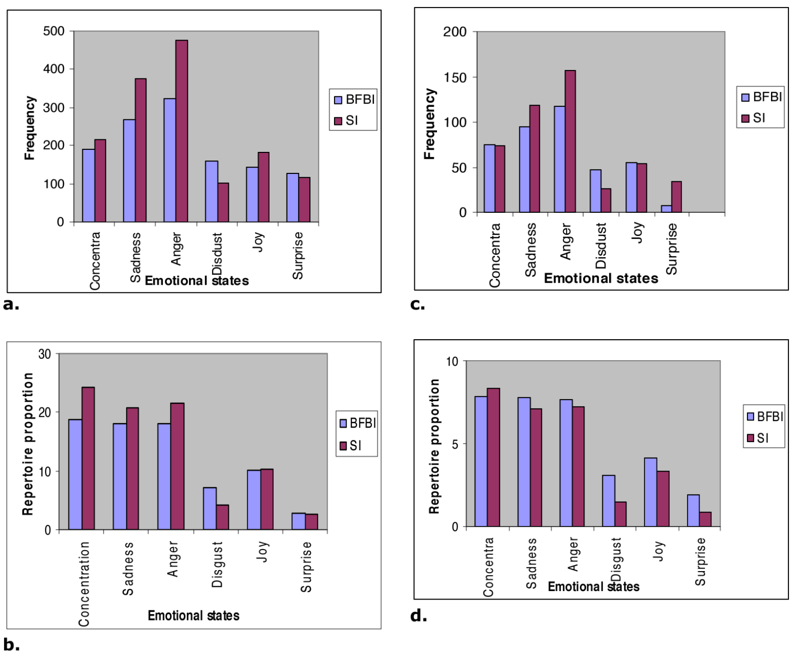

Fig. 1. (a) The cumulative mean frequency in various emotional states in BIs (n = 24) and their SI relatives (n = 30). (b) The cumulative repertoire proportion in various emotional states in BIs (n = 24) and their SI relatives (n = 30). (c) The cumulative mean frequency in various emotional states in BIs (n = 10) and SIs (n = 10) who are not family relatives. (d) The cumulative repertoire proportion in various emotional states in BIs (n = 10) and SIs (n = 10) who are not family relatives.

Table 2

a. Chi square of the distributions of the cumulative mean frequency of facial movements in various emotional states in BIs and their SI relatives

Emotional state	BIs' cumulative mean frequency of facial movements	SIs' cumulative mean frequency of facial movements	Sum of cumulative mean frequency per emotion	Chi square
Concentration	190.85	217.08	407.93	0.399
Sadness	266.99	375.05	642.04	3.44
Anger	323.11	475.85	798.96	7.39
Disgust	158.07	101.15	259.22	25.96
Joy	144.24	182.16	326.4	0.14
Surprise	128.62	116.32	244.94	5.24
sum	1211.88	1467.61		*42.58*
p value				**4.5E-08**

b. Chi square of the distributions of the cumulative mean frequency of facial movements in various emotional states in BIs and SIs who are not relatives

Emotional state	BIs' cumulative mean frequency of facial movements	SIs' cumulative mean frequency of facial movements	Sum of cumulative mean frequency per emotion	Chi square
Concentration	74.58	73.41	148	0.0014
Sadness	94.42	118.59	213	2.98
Anger	117.57	156.77	274.37	5.99
Disgust	47.77	26.72	74.49	5.75
Joy	55.26	53.48	108.74	0.015
Surprise	78.34	34.5	112.84	16.62
sum	467.94	463.5		*31.35*
p value				**7.99E-06**

The shading includes the values that cause the 2 distributions (of cumulative mean frequency of BIs and SIs) to be different.

emotional states. We found that the distributions of *the cumulative mean frequencies* for BIs and their SI relatives are significantly different according to chi-square criterion (*p* value < 4.5E-08).

The difference between the distributions in BIs and in SIs is expressed by (A) high cumulative mean frequency in anger in SIs compared to those in BIs, and (B) high cumulative mean frequency in disgust and surprise in BIs compared to those in SIs. These results are expressed in Fig. 1a. and Table 2a. We found that the distributions of the cumulative repertoire proportion in BIs and their SI relatives are similar according to chi-square criterion (chi-square *p* value > 0.92). These results are expressed in Fig. 1b.

B.2. Different cumulative mean frequency and similar cumulative repertoire proportion of facial movements in various emotional states in BIs and SIs who are not family relatives

We examined if kinship influences the similarity/dissimilarity of the distributions of cumulative mean frequency and cumulative repertoire proportion of facial movements in various emotional states in BIs and SIs. In order to absolutely eliminate the component of kinship in the comparison between facial movements of BIs and SIs (since each of the 24 BIs had at least one sighted family relative belonging to the 30 SIs), we compared the cumulative mean frequency and the cumulative repertoire proportion of BIs to those of SIs who are *not* their relatives. Using computational methods, we have created 3,003 different combinations, each combination including 10 BIs and 10 SIs who are not relatives. The distribution of the *average* of cumulative mean frequency and cumulative repertoire proportion of facial movements in different emotional states of BIs and SIs were compared.

We found that the distributions of *the cumulative mean frequency* in BIs and SIs who are not their relatives are significantly different according to chi-square criterion (p value < 7.99E-06).

The difference between the distributions of the cumulative mean frequencies for BIs and SIs who are not relatives is expressed in (A) high cumulative mean frequency of anger in SIs compared to those in BIs, and (B) high cumulative mean frequency in disgust and surprise in BIs compared to those in SIs. These results are expressed in Fig. 1c. and Table 2b. We found that the distributions of the cumulative repertoire proportion in BIs and SIs who are not relatives are similar according to chi-square criterion (p value > 0.97). These results are expressed in Fig. 1d.

Table 3

p values for the deviation of the number of BI profiles from the expected number (according to the number of BIs participating in our study) in 12 clusters consisting of 85% of the entire data analyzed

Cluster	Binom_pval	mLN(Binom_pv)	AvSD_normalized
2	0.09	2.39	0.02
4	**0.045**	3.09	1.48
5	0.18	1.73	–1.34
6	0.14	1.99	–0.80
7	0.09	2.43	0.11
8	0.08	2.58	0.42
9	0.06	2.81	0.91
10	0.19	1.66	–1.5
11	0.14	1.98	–0.83
14	0.08	2.58	0.42
20	**0.018**	4.02	3.42
22	0.055	2.91	1.11

The bold numbers represent clusters in which the number of BI profiles is not as expected, according to the number of BIs and SIs participating in our study.

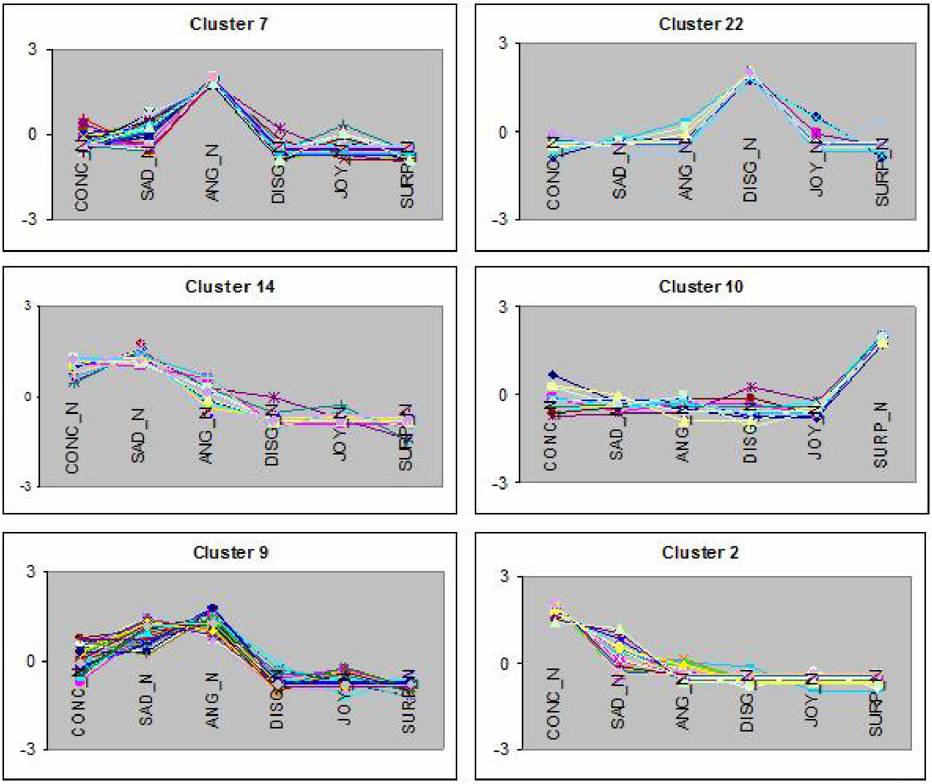

Fig. 2. Clusters 2, 7, 9, 10, 14, and 22 including expected number of BIs' profiles. Each line (colored differently) represents a profile of six normalized frequencies of a specific facial movement of a certain subject in the six emotional states discussed.

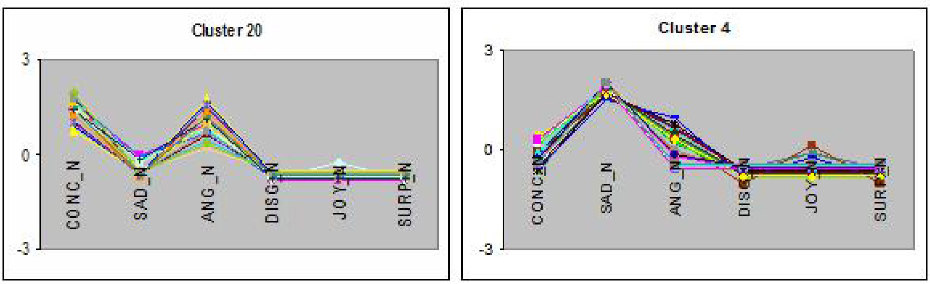

Fig. 3. Cluster 20, including lower number of BI's profiles than expected, and cluster 4, including higher number of BIs' profiles than expected. Each line (colored differently) represents a profile of six intensities of a specific facial movement of a certain subject in the six emotional states discussed.

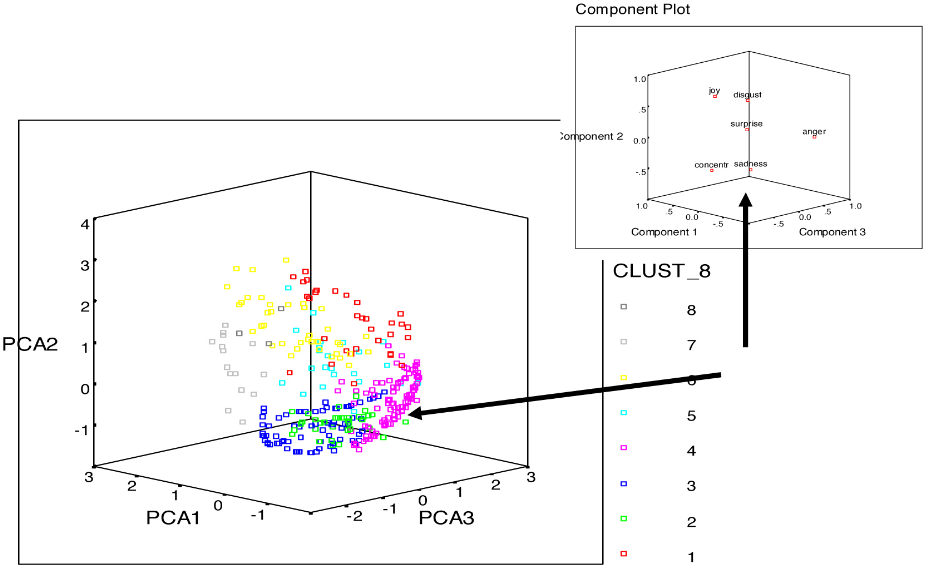

Fig. 4. CSA-manifold (concentration–sadness–anger manifold) consists of clusters of profiles including a peak(s) of facial movement frequency in concentration and/or sadness and/or anger. The profiles that create the CSA-manifold cover 67% of data variability. The 2D PC plane could explain 84% of the variability of the point distribution in initial three-dimensional concentration–anger–sadness space. The form of the manifold resembles a circle.

C. PRINCIPAL COMPONENT ANALYSES RESULTS

C1. BIs and SIs show the same profiles of frequencies of facial movements in various emotional states

We examined if BIs and SIs show the same profiles of frequencies of facial movements in the various emotional states (a profile of a facial movement consists of six normalized frequencies of this movement in the six emotional states discussed).

We found that 85% of all the profiles (n = 362) are united in 12 clusters. Every cluster consists of a number of profiles with a common frequency of facial movement behavior for the emotional states discussed: all profiles of the cluster have the same peak/s of mean frequency of facial movements in the same emotional states. The 12 most populated clusters included 6 clusters with a single peak in a specific emotional state, 5 clusters including two peaks in 2 different emotional states, and a single cluster including three peaks in 3 different emotional states.

In 10 out of the 12 clusters the number of BIs' profiles is as expected according to the number of BIs and SIs participating in our study. These results are expressed in Table 3.

Example of clusters including a single peak and two peaks of facial movements in different emotional states, in which the number of BIs' profiles is as expected, is expressed in Fig. 2. The exceptional clusters including an unexpected number of BI

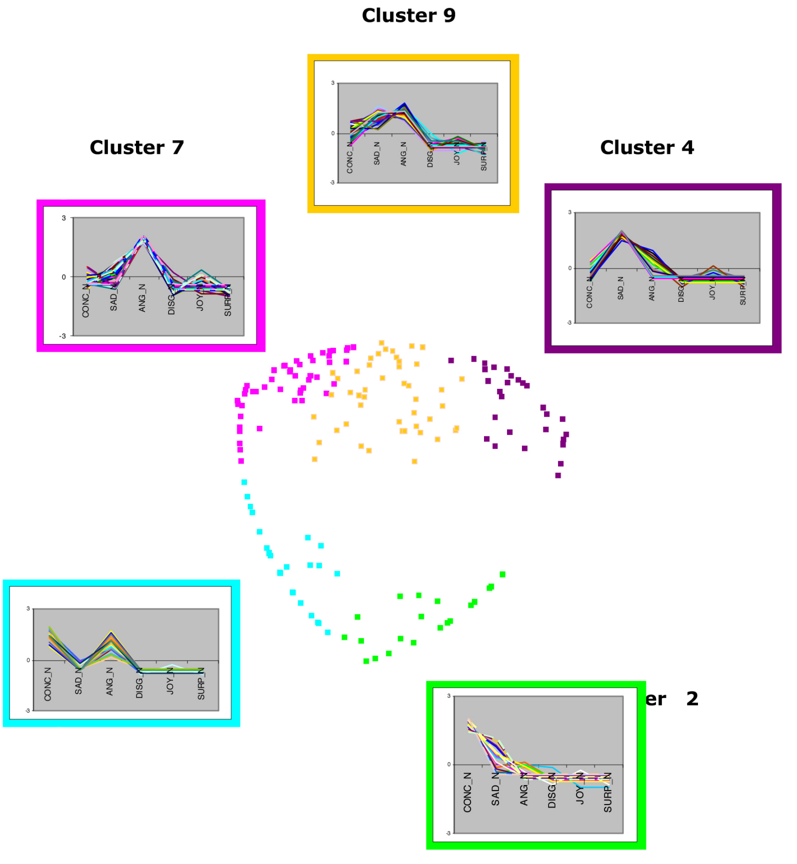

Fig. 5. The CSA-manifold's boundaries consist of five clusters. Each of these clusters includes a single peak/two peaks of frequency of facial movements in a single/two emotional states.

profiles are cluster 20 and 4. In cluster 20, which contains the high mean frequencies of facial movements in think-concentrate and anger, the number of BIs' profiles is lower than expected according to uniform distribution of BIs' profiles over all clusters (p value < 0.02). In cluster 4, which contains high mean frequency of facial movements in sadness, the number of BIs' profiles is higher than expected (p value < 0.05). These results are expressed in Fig. 3.

C.2. 3D Think-concentrate–sadness–anger manifold

We examined the distribution of the profiles of facial movements' frequency in three-dimensional (3D) space. The Principal Component Analysis (PCA) was used to visualize the 426 profiles at 3D space. The three first Principal Components (think-concentrate, sadness, and anger) cover 67% of data variability. The visual inspection of data distribution in 3D PCA space reveals the obvious concentration of dots in a ring-like manifold (Fig. 4). This manifold is almost two-dimensional and mostly defined by diversification of points across three emotional states: concentration, anger, and sadness.

The PCA analysis of the concentration–anger–sadness space demonstrates that the 2D PC plane could explain 84% of the variability of the point distribution in the initial three-dimensional concentration–anger–sadness' space.

Figure 5 demonstrates the position of the five clusters that created the CSA manifold's boundary (clusters: 2, 4, 7, 9, and 20). Three (3) out of the five (5) clusters (clusters: 2, 7, and 9) include the expected number of profiles of BIs. We examined if BIs and SIs use the same facial organs in concentration, sadness, and anger by analysis of the CSA-manifold's data. Almost all clusters of the CSA-space include an expected number of eyebrow movements (E) and lips, tongue, and nose movements (LTN). The most outstanding clusters are 2, 7, and 9, and all of them include the expected number of BIs' profiles. The number of profiles of eyebrow movements (E) is lower than expected in cluster 2 (p value < 0.000001), which contains profiles that include a single peak of mean frequency of facial movements in concentration. Clusters 7 and 9, which contain profiles including a single peak of mean frequency in anger and two peaks of mean frequency in sadness and anger, respectively, are overpopulated with eyebrow movements (E) (p val < 0.00001 and p val < 0.005, respectively).

D. FREQUENT APPEARANCE OF RAISING AND LOWERING EYEBROWS IN BIs AND SIs

We examined the appearance of two facial movements: raising and lowering eyebrows (movements No.11 and 12) in BIs and SIs. Although the proportion of movement No.11 and movement No.12 from the 43 facial movements of our "index" is 2/43 = 4.6%, the proportion of movement No.11 and movement No.12 from our whole data (426 profiles) is 23% (movement No.11 = 12% and movement No.12 = 11%). Movement No.11 and movement No.12 were observed in 96% and 100% of subjects participating in our study, both in BIs and SIs, respectively.

DISCUSSION

GENERAL

In this study we compared the patterns of spontaneous facial movements in various emotional states between congenitally blind and sighted individuals, most of whom were adults. This comparison was based on data of the frequency and the repertoire of facial movements of BIs and SIs. To the best of our knowledge, Rinn's project (Rinn, 1991) is the only one involving the study of the frequency of spontaneous facial movements in congenitally blind adults compared to those of sighted adults, but he concentrated on a specific emotional state (concentration-like) and on brow movements only. The common characteristics of facial movements found in BIs and SIs will be discussed in the following.

COMMON PATTERNS OF FREQUENCY AND REPERTOIRE PROPORTION OF FACIAL MOVEMENTS IN THE VARIOUS EMOTIONAL STATES IN BIs AND SIs

We found that the cumulative mean frequency and cumulative repertoire proportion in think-concentrate, sadness, and anger are higher relative to those in disgust, joy, and positive-surprise in both BIs and SIs. As a "better inducer", think-concentrate, sadness, and anger included an element of "stress" that may have evoked the expressivity of the face.

FREQUENCY OF FACIAL MOVEMENTS

Using PCA-analysis, we showed that 67% of our data variability concerning mean frequency of facial movements was found in the CSA-manifold (Concentration, Sadness, and Anger-manifold). Most clusters (five out of seven, which included 216 profiles out of the 289 profiles of the whole manifold) of this manifold included an expected number of BI profiles. This means that both BIs and SIs show a high frequency of facial movements in concentration, sadness, and anger relative to that in disgust, joy, and positive-surprise. This high frequency is expressed in similar patterns, i.e., in different combinations of concentration, sadness, and anger. Anger appears to be the "best" inducer of facial movements' frequency both in BIs and SIs. Our result showing that anger induces facial expressions is consistent with Kaiser's results (Kaiser et al., 1994), but she studied *sighted* subjects.

Using PCA analysis, we showed that, in most of the cases, BIs and SIs show the same pattern of frequencies of facial movements, including extreme frequencies (found in CSA-manifold's boundary) in different emotional states. Two exceptional cases include two clusters: one includes a high frequency of facial movements in concentration and anger and contains a lower number of BIs' profiles than expected (which can be related to the lack of visual feedback in BIs that can reduce the frequency of facial movements in anger), and the other includes a high frequency of facial movements in sadness and contains a higher number of BIs' profiles than expected. It may be possible that sighted subjects sometimes mask their facial expressions of sadness because such expressions are sometimes correlated with weakness.

It is important to emphasize that, contrary to the exceptional clusters mentioned above, there are clusters including peaks of frequencies in concentration, anger, and sadness that contain an expected number of BIs. That means that in principal, there is no difference between the BIs' and SIs' profile behavior. In both BIs and SIs we found that facial movements observed in anger and sadness included an abundance of eyebrow movements. Eyebrow movements were presented much less frequently in facial movements observed in concentration. Our results are consistent with those of Gouta and Miyamoto (2000), but they studied *sighted* subjects.

REPERTOIRE PROPORTION OF FACIAL MOVEMENTS

We showed that think-concentrate, sadness, and anger similarly elicit the expression of an individual repertoire of facial movements in both BIs and SIs. These results support those of Cohn and Katz (1998), showing that negative emotions (anger, disgust, fear, and sadness) were distinctly different from positive emotions (happy/calm, happy/

excited) but not from each other in diversity. Our results are also similar to those of Kaiser et al. (1994) who found a large range of facial expressions in anger. Cohn's and Kaiser's results were based on data from *sighted* subjects.

We found that the distributions of the cumulative *repertoire proportion* of facial movements in the emotional states discussed in BIs and SIs are significantly similar when BIs were compared to their SI relatives and when they were compared to non-relatives of SIs. These results support findings of Galati et al. (2001a,b) who studied congenitally blind and sighted *children* and showed similar facial profiles in anger, joy, disgust, surprise, interest, sadness, and fear with respect to the number and type of facial action units produced; however, in contrast to their results, instead of diversity we compared the cumulative repertoire proportion between BIs and SIs.

Reactions to different emotional states, which are expressed in different repertoire proportions, are innate because both blind and sighted individuals show similar reactions.

FREQUENT APPEARANCE OF RAISING AND LOWERING EYEBROWS

In our study we found that there are two facial movements that are "universal" (shown by almost all subjects in each emotional state discussed): movement No. 11 (raising both eyebrows at the same time) and movement No.12 (the eyebrows get closer to each other while being horizontal and sometimes lowered). These movements are identical to Au 1+2 + Au 4 of the FACS (Facial Action Coding System, Ekman and Friesen, 1978), respectively. Facial movements 11 and 12 are ancient movements and can be found in nonhuman primates (Darwin, 1872). Kaiser et al. (1994) showed that action unit combination AU1 + AU2 were shown by most of the subjects in their study. Eibl-Eibesfeldt (1989) writes that he observed raised eyebrows in mother–child interactions in every culture he visited throughout the world. According to Eibl-Eibesfeldt, the origin of rapid-brow-raising is probably a ritualized expression of friendly recognition that always occurs within the context of contact readiness. It also occurs in accompanying speech as an expressive movement of affirmation.

Rinn (1991), who studied brow movements of congenitally blind persons that accompanied normal conversation, found that these expressions were similar in blind and sighted individuals. The universality of eyebrow flash (a vertical brow movement) and brow movements suggests that it is an innate expressive movement.

FEEDBACK IN THE PROCESS OF LEARNING FACIAL EXPRESSIONS IN SUBJECTS BLIND FROM BIRTH

According to the theory that congenitally blind subjects are able to learn how to produce facial expressions, Eibl-Eibesfeldt (1989) showed that congenitally blind and deaf thalidomide children (having no arms) who are unable to touch their relatives' faces, are capable of adequate facial expressions. According to Iverson and Goldin-Meadow (1997), although blind speakers can learn something about the use of gesture from their own sensory experiences and from explicit instructions, the information they obtain from these sources is, at best, minimal. The possibility that the congenitally blind subjects had learned these expressions by sensing their relatives' faces through touch was excluded in a previous study (Peleg et al., 2006).

DIFFERENCES IN THE DISTRIBUTIONS OF CUMULATIVE MEAN FREQUENCY OF FACIAL MOVEMENTS IN BIs AND SIs

The distributions of the *cumulative mean frequency* of facial movements in the emotional states discussed in BIs and SIs are significantly different in the cases where BIs were compared to their SI relatives and where BIs were compared to non-relative SIs. The differences are expressed in: (A) High cumulative mean frequency of anger in SIs compared to BIs. (B) High-cumulative mean frequency in disgust and surprise in BIs compared to SIs. Significant high-cumulative mean frequency in anger in SIs compared to BIs was also demonstrated in our study by using PCA analysis. (In cluster 20, which contains a high mean frequency of facial movements in concentration and anger, the number of BIs' profiles is lower than expected.) We assume that the reason for the differences mentioned above (A and B) is connected to the fact that BIs lack visual feedback, which contributes to eliciting/inhibiting facial expressions in person-to-person interactions.

A. HIGH CUMULATIVE MEAN FREQUENCY IN ANGER IN SIs RELATIVE TO BIs

When sighted subjects are exposed to positive and negative facial expressions, they unconsciously mimic facial stimuli (Dimberg and Thunberg, 1998; Dimberg et al., 2000). There is also a possibility that the BI's control of negative expressions (Cole et al., 1989) contributed to a greater discrepancy between the frequency of facial movements of anger found in BIs and SIs. Subjects born blind may consciously prefer to mask a clear reaction of anger in order to avoid rejection.

B. HIGH CUMULATIVE MEAN FREQUENCY IN DISGUST AND SURPRISE IN BIs RELATIVE TO SIs

Disgust is often considered to be a negative emotional state. We assume that the high cumulative mean frequency of disgust observed in BIs compared to SIs is related to the lack of visual feedback, i.e., BIs do not restrain their reaction to disgust. Concerning the high value of cumulative mean frequency of facial movements in surprise shown by BIs relative to SIs, we assume that surprise may elicit a more significant reaction in BIs because they cannot receive early visual cues for its onset or cessation. Additional support of the idea that the lack of visual feedback influences BIs' facial expressions is the fact that congenitally blind subjects participating in our study sometimes "lack the minute gradations of an expression" and "sometimes an expression suddenly appears or suddenly wanes" (Eibl-Eibesfeldt, 1973).

CONCLUSION

Patterns of facial expressions in BIs and SIs, most of whom were *adult, expressed in frequency and repertoire proportion in various emotional states, use of facial organs in particular emotional states, and frequent appearance of the eyebrow movements* are similar. The differences observed are probably associated with the lack of visual feedback in BIs. Our study supports the hypothesis that some components of facial expressions are innate.

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APPENDIX: INDEX OF FACIAL MOVEMENTS

The facial organ that moves	Codes for movements	Description of movements
Tongue	1	The tongue protrudes and touches both lips
	2	The tongue protrudes from one edge of the mouth, passes obliquely on the lips, and stops at the other edge of the mouth
	3	The tongue protrudes from the edges of the mouth
	4	The tongue protrudes while it touches the lower lip only
	5	The tongue protrudes after it rotates
	6	The tongue protrudes from the edges of the mouth, while the mouth is open
	7	The tongue moves inside the mouth but doesn't pass over any row of teeth
	8	The tongue protrudes and touches both lips and immediately after that the lower lip rolls inside
	9	The tongue is stable, a little bit up to the lower jaw, while the mouth is open
	10	The tongue protrudes and touches both lips and, immediately after that both lips roll inside
Eyebrows	11	Raising both eyebrows simultaneously
	12	The eyebrows move close together horizontally and sometimes are lowered
	13	The inner part of the eyebrows is higher than the outer part
	14	Raising the right eyebrow only
	15	Raising the left eyebrow only
	16	Raising the right eyebrow when the left eyebrow comes close to the right eyebrow
	17	Raising the eyebrows while they come close to each other
	18	The inner part of the eyebrows is higher than the outer, while the eyebrows come close
	19	The eyebrows get very close while they are horizontal or a little bit lower. The eyelids become very constricted. Sometimes the eyelids get close

Lips	20	Biting the lower lip when the upper lip is protruded
	21	Biting the lower lip (symmetrically)
	22	Biting the lower lip while the mouth shows left asymmetry
	23	Biting the lower lip while the mouth shows right asymmetry
	24	Rolling both lips inside
	25	Rolling the upper lip inside
	26	Rolling the lower lip inside
	27	Typical movements of the mouth while the lips touch; Appear while talking or not talking as if they are connected with swallowing
	28	The lips come close when they are constricted, until they touch each other (like kissing)
	29	The upper lip moves like a wave
	30	Typical movements of the lips while the lips touch each other (as if chewing)
	31	Friction of the upper teeth with the lower lip
	32	The lips roll out while talking
	33	The lower lip goes forward in a pouting motion
	34	Moving the lower lip from side to side while the lips touch each other
	35	The lips become close, touch each other, and become constricted. Simultaneously the chin also constricted
	36	Biting the lower lip after rolling the lower lip inside
	37	Typical movements of the lips while the lips touch each other as if chewing and, immediately after that, the tongue protrudes and touches both lips
	38	Rolling the lower lip inside and, immediately after that, the tongue protrudes and touches both lips
	39	Rolling the upper lip inside and, immediately after that, the tongue protrudes and touches both lips
	40	Rolling both lips inside and, immediately after that, the tongue protrudes and touches both lips
	41	A "U" shape is created in the area between the lower lip and the chin. The chin is stretched and goes forward. The edges of the mouth are embedded and the lower lip is stretched
	42	Pressed lips while they are touching each other
Nose	43	Constriction of the upper part of the nose

The 43 facial movements used for documenting facial movements. Movements 1–10 involve the tongue; movements 11–19 involve the eyebrow; movements 20–42 involve the lips; movement No. 43 involves the nose; movements 8, 10, 19, 35, 36, 37, 38, 39, and 40 are "complex movements".