# Do brain lesions in stroke affect basic emotions and attachment?

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The aim of the current study was to investigate basic emotions and attachment in a sample of 86 stroke patients. We included a control group of 115 orthopedic patients (matched for age and cognitive status) without brain lesions to control for unspecific general illness effects of a traumatic recent event on basic emotions and attachment. In order to measure basic emotions and attachment style we applied the Affective Neuroscience Personality Scale (ANPS) and the Attachment Style Questionnaire (ASQ). The stroke patients showed significantly different scores in the SEEKING, SADNESS, and ANGER subscales of the ANPS as well as in the Relationship as Secondary Attachment dimension of the ASQ when compared to the control group. These differences show a pattern influenced by lesion location mainly as concerns basic emotions. Anterior, medial, left, and subcortical patients provide scores significantly lower in ANPS-SEEKING than the control group; ANPS-SADNESS scores in anterior, right, medial, and subcortical patients were significantly higher than those of the control group. ANPS-ANGER scores in posterior, right, and lateral patients were significantly higher than those in the control group; finally, the ANPS-FEAR showed slightly lower scores in posterior patients than in the control group. Minor effects on brain lesions were also individuated in the attachment style. Anterior lesion patients showed a significantly higher average score in the ASQ-Need for Approval subscale than the control group. ASQ-Confidence subscale scores differed significantly in stroke patients with lesions in medial brain regions when compared to control subjects. Scores at ANPS and ASQ subscales appear significantly more correlated in stroke patients than in the control group. Such finding of abnormalities, especially concerning basic emotions in stroke brain-lesioned patients, indicates that the effect of brain lesions may enhance the interrelation between basic emotions and attachment with respect to the control group.

Keywords: Stroke; Brain lesions; Basic emotions; Attachment.

Patients with stroke show a wide variety of different symptoms that, besides sensory, motor, and cognitive changes, often concern psychological distress (Intercollegiate Stroke Working Party, 2012). In particular, beside psychopathogical symptoms, emotional behavioral disorders and

dysregulations—for example, emotional lability (Morris, Robinson & Raphael, 1993), emotional intelligence impairment (Hoffmann, Bencs Cases, Hoffmann, & Chen, 2010), pathological laughing and crying, catastrophic reactions (Ghika-Schmid & Bogousslavsky, 1997), irritability, agitation, and disinhibition (Angelelli et al., 2004; Dafer, Rao, Shareef, & Sharma, 2008)—have also been investigated. These symptoms and dysregulations can hamper the rehabilitation process after the stroke and require specific and focused intervention.

Many studies were carried out aiming at evaluating the impact of brain lesions on emotions. In particular, the lesion method provides important insights into how the human brain generates emotion and feeling (e.g., Feinstein, 2013). A large body of literature examined emotions in patients with brain damage, focusing on impairment of emotion recognition, especially the negative emotions: These studies found a disproportionately severe impairment in recognizing fear, whereas others found evidence for a broader impairment in recognizing multiple emotions of negative valence in the face, including, fear, anger, disgust, and sadness (see the review by Adolphs, 2002). These studies on one side provide a general model of emotions and emotion recognition and, on the other side, can be of crucial importance to better understand changes and symptoms mentioned above after stoke event.

In the frame of a large body of studies devoted to study emotions across species (Anderson and Adolphs, 2014), Panksepp (1998, 2011a, 2011b, 2011c) developed a sophisticated concept of emotions where he distinguishes primary and secondary (and tertiary) emotions. Primary emotions are those that are evolutionarily ingrained, which we therefore share with other species, especially those with whom we share ancestral genetic relationships. These emotions include sadness, anger, fear, play, care, seeking, and lust, which Panksepp usually capitalizes, for basic neuroscience work, in order to indicate their genetically ingrained, primary-process mental character.

These primary emotions are associated with different neural networks in evolutionary old subcortical regions of the brain. In particular, neuroscientific evidence suggests that subcortical and medial regions of the brain could be associated to basic emotions (e.g., Northoff & Panksepp, 2008; Panksepp & Northoff, 2009). In this line, the study of brain-lesioned patients, and in particular the comparison of basic emotion features as a function of different locations of brain lesions, may allow new insight to be gained in this aspect. In one of our previous studies, we investigated the impact of subcortical and cortical lesions,

especially on SEEKING, which was consistently reduced in stroke patients, thus indicating their often elevated degrees of depression (Farinelli et al., 2013). This, however, left unexplored the impact of brain lesions on the other primary emotions, which was the key aim of the present study.

In addition to changes in their basic emotions, stroke patients can often be characterized by changes in their relationships with others, especially their attachment style (McWilliams & Bailey, 2010), which we sought to document in this study, as guided by basic attachment theory. Specifically, Bowlby (1969) hypothesized four interrelated behavioral systems that regulate emotions and human behavior: attachment, caregiving, exploration, and sex. In particular, Bowlby recognized the attachment system as being of primary importance in regulating the other systems.

The attachment system motivates children and adults to seek safety and security through close contact with attachment figures. These bonds aid the development and maintenance of mental representations of the self and others, also called "internal working models." Through these, individuals understand and predict their environment, engaging in survival-promoting behaviors such as physical and/or relational proximity maintenance, while experiencing a sense of security (Bretherton, 1985; Sroufe & Waters, 1977). At the same time, some studies have highlighted the role of attachment style on brain maturation in infants (Coan, 2010; Schore & Schore, 2008).

During the past two decades, an increasing interest in the role of the attachment behavioral system, its assessment, and its role in emotion regulation in life span has developed in addition to being also explored in the elderly (Cicirelli, 2010; Mikulincer & Shaver, 2003; Simpson & Rholes, 2010). Despite the fact that attachment styles developed early in life, some studies evidence changes in attachment style and figures in relation to development stages, life events, and age (Cicirelli, 2010; Van Ijzendoorn & Bakermans-Kranenburg, 2010; Zhang & Labouvie-Vief, 2004). For a full updating of recent attachment literature, see Hart, 2011; Mikulincer & Shaver, 2013; Narvaez, Panksepp, Schore, & Gleason, 2012).

Several studies have investigated the relationship of medical illness with attachment style (Ahrens, Ciechanowski, & Katon, 2012; Ercolani et al., 2010; Farinelli, Ercolani, Trombini, & Bortolotti 2007; Picardi et al., 2007; Picardi et al., 2013).

Concerning studies on patients suffering from neurological illness associated with brain lesions, Magai and Cohen (1998) explored the relation between premorbid attachment style and emotion characteristics of dementia patients (including

emotion regulation), dementia behavioral symptomatology, and caregiver burden. They found association between premorbid attachment style and emotion regulation in patients and that premorbid attachment style significantly affects symptom expression and burden of their caregiver.

A recent study on traumatic brain injury patients (Sela-Kaufman, Rassowsky, Agranov, Levi, & Vakil, 2013) found that attachment style and other premorbid personality characteristics affect occupational outcome. In particular, they found that neuroticism, extraversion, conscientiousness, and avoidant attachment style came out as significant moderators, and that these measures exerted a significant moderating effect on occupational functioning. Thus, attachment can be considered, with other motivational and emotional personality factors (Prigatano, 1992) as contributing to the "reserve" (Stern, 2002) and plasticity, to explain mismatch between brain pathology or damage and the clinical expression of that damage and adaptation after brain lesion consequences.

At the neural level, adult attachment cannot be considered a unitary construct (Coan, 2008, 2010). There are in fact several key neural structures associated with emotional responding involved in the formation and maintenance of adult attachment relationships, which play a role in social bonding and interaction (Coan, 2008; Insel & Fernald, 2004).

Further studies suggest that attachment is associated to neural activity in cortical regions such as some regions of the cortical midline structure (e.g., Northoff et al., 2006) and in particular the ventromedial prefrontal cortex (Schore & Schore, 2008). These areas are distinct from the subcortical networks more involved in basic emotions. This indicates a clear segregation of the two systems considered here (attachment and basic emotions), which should be affected in a different measurable way by lesion location. Again, comparing basic emotion configurations and attachment styles in patients lesioned in a different way (e.g., subcortical vs. cortical, medial vs. lateral, etc.) could link neural networks and psychological aspects.

The general aim of our study was to investigate basic emotions and attachment pattern in a sample of patients with such brain lesions ($n = 86$). In order to control for nonspecific effects of the illness itself on basic emotions and attachment, we included a control group ($n = 115$) of orthopedic patients matched by age that showed a recent traumatic event (an orthopedic one) without any accompanying brain damage. Considering this kind of control group allowed us to differentiate between specific effects related to brain lesions and those unspecific negative affective changes stemming from the occurrence of a recent traumatic illness and hospitalization in general.

The first specific aim was to investigate the impact of brain damage following strokes on basic emotions (Panksepp, 1998) using a specific inventory, the Affective Neuroscience Personality Scale (ANPS; Davis & Panksepp, 2011). Based on previous studies (e.g., Feinberg & Keenan, 2005; Turnbull, Evans, & Owen, 2005), we hypothesized that various primary emotions, especially negative ones such as anxiety, irritability, and separation distress—as monitored by the FEAR, ANGER, and SADNESS scales of the ANPS—are affected by lesions and, in particular, that lesions could adversely affect emotions—that is, that brain lesion patients may provide lower scores than our hospitalized orthopedic control group. Following previous results, such as those concerning SEEKING (Farinelli et al., 2013), FEAR, and other negative emotions (e.g., Adolphs, 2002; Feinstein, 2013), we expect that lesions in subcortical and medial regions of the brain could be more responsible for such impairment.

The second specific aim consisted in the investigation of attachment styles in these patients. For that purpose, we used the well-established Attachment Style Questionnaire (ASQ) to measure attachment and its different dimensions (Feeney, Noller, & Hanrahan, 1994). In general, due to the fact that several key neural structures seem to play a role in the formation and maintenance of adult attachment relationships, no lesion-specific effects are expected in stroke patients. However, we may expect that the attachment system may be activated after the stroke event. In particular, attachment is expected to play a crucial role in emotion regulation (Bowlby, 1969; Fonagy, Gergely, Jurist, & Target, 2002), in particular in early phases when a new configuration of basic emotions perturbed by lesion find a new adaptive equilibrium. We hypothesized mild effects of brain lesions on attachment dimensions while enhanced correlation is expected between stroke and control groups concerning attachment dimensions and basic emotions.

## METHOD

### The study group (stroke patients)

The present study was carried out across a span of two years, whereby 86 first-time stroke inpatients in the acute phase were recruited after written informed consent. They came from a stroke-unit to a rehabilitation hospital after the stabilization of the clinical situation (15 days to 1 month after the acute event). The communication of the diagnosis to the patient

was managed by the stroke-unit MDs before their admission to the rehabilitation hospital.

Exclusion criteria included the presence of aphasia as measured with the Token Test (De Renzi & Faglioni, 1978; Spinnler & Tognoni, 1987; Zaidel, 1977), with a score lower than 26. Patients with Mini Mental State Examination (MMSE) scores (Folstein, Folstein, & McHugh, 1975) less than 21, corresponding to moderate/high cognitive impairments, as well as patients with any previous stroke events or with concomitant neurologic disease (chronic, acute, or degenerative) were also excluded. The average MMSE score for the selected sample was 24.2 ($SD = 4.1$). In general, most stroke patients ultimately included in the study were elderly with a slight higher prevalence of women (about 57% of the group). Sociodemographic data and lesion characteristics of the study group are reported in Table 1.

In the following analyses, several possible differences in stroke locations were considered.

There are two main approaches to evaluate such lesions: qualitative (neuroradiological visual inspection) and standard tracing (gold standard).

The lesion location was first determined independently of clinical symptoms and psychological assessment by the same neuroradiologist on the basis of magnetic resonance imaging (MRI) or computerized tomography (CT) scan obtained during the acute phase (Gallucci, Capoccia, & Catalucci, 2005) by visual inspection. Anterior and posterior lesion locations were designated based on locations with respect to the sensorimotor cortex. Participants with "cortical lesions" were based on damage restricted to cerebral gyrus and sulcus areas, while "subcortical lesions" were restricted to damage below cerebral cortex. "Medial lesions" referred to damage that infringed on midline structures, which in subcortical regions typically involved the basal ganglia, while at the cortical level typically involved the cingulate gyrus. "Lateral lesions" referred to brain damage restricted to areas starting at least 30 mm from the midline.

A standard tracing computer-aided procedure was also considered to perform lesion analysis. This was carried on by using the free MRIcron software (Rorden, Karnath, & Bonilha, 2007, http://www.cabiatl.com/mricro/mricron/index.html). Native MR and CT images are in the DICOM (digital imaging and communications in medicine) format, whereas MRIcron works with the NIfTI (Neuro/maging Informatics Technology /nitiative) format. We then converted DICOM into NIfTI format using the dcm2nii tool, embedded in the MRIcron download.

As a necessary prerequisite for group comparisons, spatial normalization into a standard space is needed. So, before any volumetric analysis, each patient was spatially normalized into Montreal Neurological Institute (MNI) 152-space, using the software package FSL (FMRIB's Software Library, Jenkinson, Beckmann, Behrens, Woolrich, & Smith, 2012; Smith et al., 2004; Woolrich et al., 2009; http://www.fmrib.ox.ac.uk/fsl/). Briefly, the procedure consists in cutting off (cropping and skull-stripping) the non-brain structures in the raw NIfTI images, by means of the BET (Brain Extraction Tool) command (Smith, 2002), followed by the FLIRT (FMRIB's Linear Image Registration Tool) command (Jenkinson & Smith, 2001), which linearly aligns each image to match the MNI152 T1 template (coregister function). We used the "Affine (12 parameters)" warping transformation (rotations, translations, zooms, and shears, each in three dimensions) and a trilinear interpolation to resample the patients' images into the MNI space, with an isotropic spatial resolution of 1 mm × 1 mm × 1 mm (MNI152_T1_1mm.nii.gz). The normalizing procedure failed in nine patients, who were excluded from the subsequent analysis. The resultant images in the standard space were ready for the drawing of the brain lesions.

For each patient, the boundary of the lesion was manually outlined on each patient's normalized-MNI space image, for every single axial slice, by a single trained neuroradiologist. The circled lesion was, then, filled and verified as well (and corrected

**TABLE 1**
General statistics for the two samples considered

| Item | Stroke (N = 86) | Ortho (N = 115) | t; $x^2$ | P |
|------|-----------------|-----------------|----------|---|
| Age (years; average/SD) | 71.63/9.84 | 72.89/12.27 | 0.161 | .872 |
| Gender (M/F) | 37/49 | 31/84 | 5.674 | .017 |
| Education (primary/secondary/high/degree/unknown) | 56/9/16/0/5 | 42/32/27/14/0 | 33.224 | <.001 |
| Marital status (single/married/divorced/unknown) | 8/43/4/31 | 12/41/8/54 | 4.310 | .230 |
| Occupation (employed/retired/housewife) | 9/70/7 | 15/97/3 | 3.351 | .187 |

Note. Samples: neurologic (stroke) and control (orthopedic). Ortho = orthopedic; M = male; F = female. A t test has been used to evaluate differences in age and gender. A chi square test has been used to test differences in the other features. Significance p of the corresponding statistics is reported for each feature. Except for gender and education, no statistically significant differences are revealed in the two samples. However, a significant dominance of women and high education subjects in the control sample is observed (see boldface figures).

if necessary), both in coronal and in sagittal planes, so producing a contiguous 3D lesion volume (VOI = volume of interest). The resulting VOI was finally smoothed in $x$, $y$, and $z$ planes (3 mm full width at half maximum, FWHM). In order to assess a difference in the lesion locations, all lesion volumes were subsequently imported into the NPM (nonparametric mapping) software, a statistical tool for neuroimaging, distributed as part of the MRIcron software package (Rorden, Fridriksson, & Karnath, 2009).

Finally, multislice maps of the four groups were superimposed to the ch2bet.nii.gz brain, the single subject normalized brain distributed with MRIcron.

### The control group (orthopedic patients)

In addition to the stroke patients, we also recruited subjects for a control group of comparable age and clinical history. This control group is constituted by aged orthopedic patients group hospitalized in the same way as stroke patients. This control group was on purpose selected in order to control for the effects of a recent, unexpected, and disabling traumatic illness on both emotions and attachment that is shared by both group of patients. In this way, the effects reported here must consequently be considered specific to the patterns of brain damage in the stroke patients rather than to the unspecific effects of acute illness in general, as that should have been accounted for by the selection of our control group. Furthermore, in order to exclude possible differences in reactive emotional states, we matched our control group with stroke patients on the following basic features: age, duration of hospitalization, and recency of traumatic events. Thus, 115 orthopedic patients that were affected by a recent leg bone fracture were selected as a control group (Table 1). These patients came from an orthopedic unit and were treated in the same rehabilitation hospital as the stroke patients.

An overall exclusion criterion was patients having MMSE scores less than 21. The average MMSE score for the resulting control group was 25.5 ($SD$ = 4.7) and was not significantly different (at a two-sample two-tailed $t$ test with $p < .05$) from the one characterizing the stroke group. This result implies that cognitive status of stroke and control groups was matched. There was a prevalence of women (73% of the group). Most participants were married (36%) or widowed (47%), with only a small fraction never married (10%) or divorced (7%). Most subjects were retired (84%) with a minority still employed (13%) or active housewives (7% of the entire control group).

### Psychometric evaluation

Psychometric assessment of emotions and of attachment style was performed in the acute phase close to the radiologic characterization of lesions.

The Affective Neuroscience Personality Scales (ANPS; Davis, Panksepp, & Normansell, 2003; with an Italian version provided by Andrea Clarici, University of Trieste, by personal communication, October 15, 2007) is a self-report questionnaire and includes three subscales concerning positive emotions (ANPS-SEEKING, ANPS-PLAY, and ANPS-CARE) and three concerning negative emotions (ANPS-FEAR, ANPS-ANGER, and ANPS-SADNESS):

- PLAY was conceptualized as having fun versus being serious, playing games with physical contact, humor, and laughter, and being generally happy and joyful.
- SEEKING was defined as feeling curious, feeling like exploring, striving for solutions to problems and puzzles, positively anticipating new experiences, and a sense of being able to accomplish almost anything.
- CARE was defined as nurturing, being drawn to young children and pets, feeling softhearted toward animals and people in need, feeling empathy, liking to care for the sick, feeling affection for and liking to care for others, as well as liking to be needed by others.
- FEAR was defined as having feelings of anxiety, feeling tense, worrying, struggling with decisions, ruminating about past decisions and statements, losing sleep, and not typically being courageous.
- ANGER was defined as feeling hotheaded, being easily irritated and frustrated, experiencing frustration leading to anger, expressing anger verbally or physically, and remaining angry for long periods.
- SADNESS was conceptualized as feeling lonely, crying frequently, thinking about loved ones and past relationships, and feeling distress when not with loved ones.

The whole questionnaire is composed of 110 items grouped in seven scales with each basic affect evaluated by 14 items (7 of which are positively scored, and 7 negatively/reverse scored, see Davis & Panksepp, 2011, p. 1956). The Spirituality scale consists of only 12 items. There are various "filler items" that evaluate deception and other potential issues of interest (which were not analyzed here). Administration of all tests was performed within the first week of admission by trained psychologists working in the rehabilitation hospital.

The ASQ by Feeney et al. (1994) comprises 40 items and allows the attachment style to be detected according to five important factors:

- *Confidence:* Low scores reveal mistrust in the expectation of consideration and respect for self on the part of others especially in basic and need conditions.
- *Discomfort with closeness:* High scores reveal discomfort in conditions of dependency on others and psychological closeness to others.
- *Need for approval:* High scores indicate fear in dealing with others and preoccupation for the disapproval of others.
- *Preoccupation with relationships:* High scores indicate fear in the goodness of one's own relationships and necessity for continual affective confirmation.
- *Relationship as secondary:* High scores indicate the inclination to attribute greater importance to factuality and concreteness rather than relationships.

The above dimensional measures can be recategorized within a categorical classification of attachment styles.

1. Scores in confidence: namely, secure (high scores) versus insecure (low scores) attachment in general.
2. High scores in discomfort with closeness and relationship as secondary: namely, insecure avoidant versus dismissing attachment.
3. High scores in need for approval and preoccupation for relationships: namely, insecure anxious-preoccupied attachment.

This questionnaire was also recently validated in Italy (Fossati et al., 2002) and seems to be a good screening instrument for discriminating attachment styles. It is possible, as noted by Feeney et al. (1994), to relate dimensions explored by the ASQ questionnaire with the three-dimensional classification of attachment style proposed by Hazan and Shaver (1987) and the four-dimensional one proposed by Bartholomew (1990) and Bartholomew and Horowitz (1991).

The Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983, provided in the Italian version by Costantini et al., 1999) is a self-report rating scale designed to estimate levels of both anxiety and depression in hospitalized subjects. It consists of two subscales (HADS-Depression and HADS-Anxiety), each containing seven items on a 4-point Likert scale (ranging from 0–3). The HADS is scored by summing the ratings for the 14 items to yield a total score, and by summing the ratings for the 7 items of each subscale to yield separate scores for anxiety and depression. The HADS-Depression subscale was considered to evaluate depression. Validity of this instrument to measure depression and its equivalence to alternative tools (e.g., Beck Depression Inventory; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) was determined in a number of studies involving patients with different pathologies, including stroke (Aben, Verhei, Lousberg, Lodder, & Honig, 2002; Loosman, Siegert, Korzec, & Honig, 2010; Preljevic et al., 2012; Sagen et al., 2009).

ANPS and ASQ and HADS questionnaires were administrated in their complete form.

## Statistical analysis

Statistically significant differences between control and patient groups for possible covariates (age, gender, education, marital status, and occupation) were evaluated with $t$ tests and chi-square comparisons, with a significance threshold of .05. The two groups did not differ except with regard to gender (more females exist in the control group) and education (educational level was slightly higher than in the brain-damaged group). The first aspect is of major importance since the original studies on healthy individuals (Davis et al., 2003) found significant sex differences in the average scores of some ANPS subscales; this possible biasing feature has to be accounted for. To this end, an analysis of covariance (ANCOVA) analysis considering gender as a covariate has been performed to enlighten differences in the average scores of stroke and control groups at each ANPS and ASQ subscale.

Whenever significant $F$ ratios ($p < .05$) were obtained, post hoc $t$ tests in the Tukey's form were used to determine specific effects on the considered scale. The same approach has been also used to evaluate the possible effect of lesion location on ANPS and ASQ scores. Since a number of ANCOVA analyses were performed (by considering the ANPS and ASQ subscales, control and stroke subgroups, etc.), the possibility that a number of "significant" outcomes will occur by chance and the lack of any significant difference between the relevant populations cannot be excluded. To evaluate this possibility, the binomial probability distribution has been used to evaluate what is the probability that the observed configuration of significant differences will occur by chance, simply due to the multiple testing (Type I error).

Pearson correlation analyses were used to evaluate relationships among the scores obtained by

stroke subjects at the ANPS and ASQ subscales. In this case also, correlation coefficients characterized by $p < .05$ (after the relevant Bonferroni correction) have been considered as significant. Furthermore, in order to compare correlation matrixes obtained for each group of patients (stroke and control) and evaluating statistical significance of observed overall differences, a specific test described in the Appendix has been applied.

Also in the case of correlation tests, the binomial probability distribution has been used to evaluate what the probability is that the observed configuration of significant correlations among the whole number of correlation matrixes computed will occur by chance.

## RESULTS

### Lesion characterization

Four possible lesion locations were identified (Table 1) by neuroradiologists via qualitative analysis: right/left hemisphere (52 vs. 31 patients), anterior/posterior region (27 vs. 29 patients), medial/lateral region (54 vs. 19 patients), and cortical/subcortical regions (12 vs. 34 patients). As one can see, except in the case of anterior/posterior subgroups, populations in the relevant subgroups are severely unbalanced with a relatively scarce presence of left, lateral, cortical lesions. It is worth noting that except in the case of right/left contrast, the number of cases considered in each comparison as a whole was considerably smaller than the total number of patients actually included in the global

sample: In fact, whenever lesions involved both brain regions/parts (e.g., bilateral lesion, etc.) or had uncertain diagnosis, patients were excluded from subsequent statistical analysis.

Standard tracing procedure resulted into four series of lesion maps, in concordance to the four groups previously defined by the qualitative analysis (Figures 1C, 1D, 1E, 1F). With this subdivision, a binary design was implemented in NPM/voxel-based lesion symptom mapping (e.g., left = 1, right = 0; cortical = 1, subcortical = 0, etc.), and a corresponding binary analysis was performed. Looking at the maps, it is immediately evident that left frontal cortical lesions were absent: This may be due to a bias in patients' selection; owing to the need for an answer to the administered psychometric tests, patients with left frontal cortical lesions were automatically excluded. At a more close inspection, lesions appear overlapped in many points and very wide in extension.

### Impact of lesions on basic emotions

In order to replicate our previous results (Farinelli et al., 2013) and extend them to a larger sample (86 vs. 62 stroke patients and 115 vs. 76 orthopedic), we first focused specifically on the ANPS-SEEKING dimension. Comparison between the two groups (stroke, control) confirm previous results (Farinelli et al., 2013) in that ANPS-SEEKING scores were significantly lower in all stroke patients (regardless of lesion location) than in the control group (Table 2). The average ANPS-SEEKING scores were 33.66 and 34.87 for stroke and control groups, respectively,
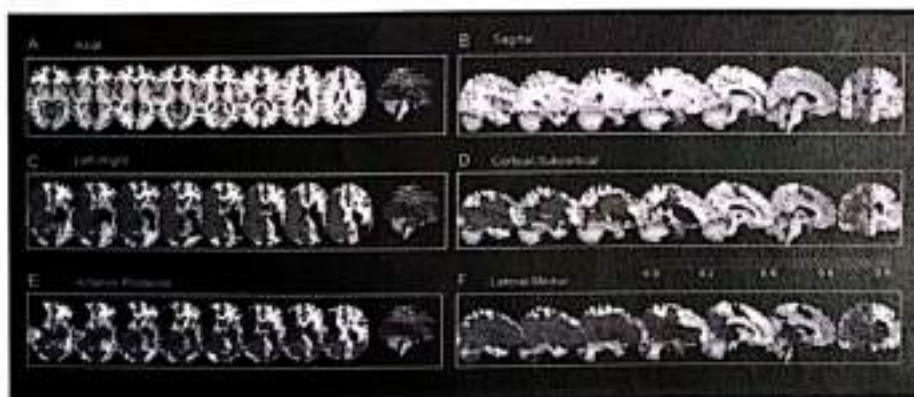


Figure 1. Lesion overlay maps of stroke patients, subdivided in the four binary partitions considered in the text. In each partition, colors associated to damaged points indicate the fraction of patients of the first considered subgroup having the relevant point damaged out of the overall number of patients having that point damaged. Lighter colors indicate that among the patients having that point damaged, the first subgroup dominates: The reverse is true for the darker colors. (A) and (B) show, respectively, axial and sagittal selected slices of the reference brain (ch2bet.nii.gz). (C) Left–right group; (D) cortical–subcortical group; (e) anterior–posterior group; (f) lateral–medial group. All axial and sagittal slices correspond, respectively, to −7, −2, 3, 8, 13, 18, 23, 28 and 39, 32, 25, 18, 11, 4 mm in the Montreal Neurological Institute (MNI) space.

TABLE 2
Comparison between the stroke and control groups at the ANPS subscales by the ANCOVA test by considering gender as a covariate

| Scale | Stroke (N = 85) Average (SD) | Ortho (N = 113) Average (SD) | ANCOVA (Stroke vs. ortho) F(df = 197) | $\eta^2$ | p |
|---|---|---|---|---|---|
| ANPS-SEEK | 33.66 (5.42) | 34.87 (4.83) | 5.504 | 0.0273 | .017* |
| ANPS-FEAR | 35.12 (6.38) | 36.70 (6.10) | 1.619 | 0.0081 | .174 |
| ANPS-ANGER | 32.66 (6.44) | 30.04 (5.59) | 7.458 | 0.0366 | .007* |
| ANPS-SAD | 37.42 (4.54) | 36.46 (4.59) | 4.570 | 0.0228 | .035* |

| Scale | Anterior (N = 27) Average (SD) | Posterior (N = 29) Average (SD) | ANCOVA (Ant vs. post) F(df = 54) | $\eta^2$ | p | ANCOVA (Ant vs. ortho) F(df = 138) | $\eta^2$ | p | ANCOVA (Post vs. ortho) F(df = 140) | $\eta^2$ | p |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ANPS-SEEK | 31.78 (6.16) | 35.07 (4.96) | 3.195 | 0.0568 | .080 | 7.888 | 0.0544 | .006* | 0.048 | 0.0003 | .827 |
| ANPS-FEAR | 36.82 (5.72) | 33.69 (6.25) | 4.771 | 0.0826 | .033* | 0.016 | 0.0001 | .900 | 4.649 | 0.0324 | .033* |
| ANPS-ANGER | 32.04 (7.15) | 34.31 (6.75) | 0.665 | 0.0124 | .418 | 2.758 | 0.0197 | .099 | 10.221 | 0.0685 | .002* |
| ANPS-SAD | 39.30 (4.01) | 35.79 (4.20) | 7.747 | 0.1275 | .007* | 8.960 | 0.0614 | .003* | 0.133 | 0.0010 | .716 |

| Scale | Right (N = 52) Average (SD) | Left (N = 31) Average (SD) | ANCOVA (Right vs. left) F(df = 81) | $\eta^2$ | p | ANCOVA (Right vs. ortho) F(df = 163) | $\eta^2$ | p | ANCOVA (Left vs. ortho) F(df = 142) | $\eta^2$ | p |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ANPS-SEEK | 34.25 (5.66) | 32.55 (5.14) | 1.440 | 0.0177 | .234 | 1.783 | 0.0109 | .184 | 6.895 | 0.0466 | .01* |
| ANPS-FEAR | 35.46 (6.15) | 34.84 (7.00) | 0.294 | 0.0037 | .589 | 0.384 | 0.0024 | .536 | 1.403 | 0.0099 | .238 |
| ANPS-ANGER | 32.94 (6.66) | 32.32 (5.86) | 0.126 | 0.0016 | .723 | 7.096 | 0.0420 | .009* | 3.022 | 0.0210 | .084 |
| ANPS-SAD | 38.14 (4.33) | 36.61 (4.57) | 3.664 | 0.0438 | .059 | 8.383 | 0.0492 | .004* | 0.228 | 0.0016 | .634 |

| Scale | Medial (N = 54) Average (SD) | Lateral (N = 19) Average (SD) | ANCOVA (Med vs. lat.) F(df = 71) | $\eta^2$ | p | ANCOVA (Med vs. ortho) F(df = 165) | $\eta^2$ | p | ANCOVA (Lat vs. ortho) F(df = 130) | $\eta^2$ | p |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ANPS-SEEK | 32.69 (5.46) | 34.84 (5.71) | 2.053 | 0.0285 | .156 | 11.599 | 0.0661 | .001* | 0.042 | 0.0003 | .837 |
| ANPS-FEAR | 35.69 (6.63) | 34.63 (6.44) | 0.308 | 0.0044 | .580 | 0.296 | 0.0018 | .587 | 0.965 | 0.0074 | .328 |
| ANPS-ANGER | 31.85 (5.98) | 33.84 (8.11) | 1.179 | 0.0166 | .281 | 2.555 | 0.0153 | .112 | 5.085 | 0.0379 | .026* |
| ANPS-SAD | 38.02 (4.55) | 36.58 (4.54) | 1.270 | 0.0178 | .264 | 6.981 | 0.0408 | .009* | 0.23 | 0.0018 | .632 |

| Scale | Cortical (N = 12) Average (SD) | Subcortical (N = 34) Average (SD) | ANCOVA (Cort vs. subcort) F(df = 44) | $\eta^2$ | p | ANCOVA (Cort vs. ortho) F(df = 123) | $\eta^2$ | p | ANCOVA (Subcort vs. ortho) F(df = 145) | $\eta^2$ | p |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ANPS-SEEK | 33.25 (8.21) | 32.74 (5.02) | 0.009 | 0.0002 | .926 | 1.659 | 0.0134 | .200 | 6.315 | 0.0420 | .013* |
| ANPS-FEAR | 33.08 (8.11) | 36.62 (6.19) | 1.840 | 0.0410 | .182 | 2.406 | 0.0193 | .123 | 0.051 | 0.0004 | .822 |
| ANPS-ANGER | 32.58 (7.42) | 32.62 (6.65) | 0.008 | 0.0002 | .928 | 1.387 | 0.0112 | .241 | 4.570 | 0.0308 | .034 |
| ANPS-SAD | 37.58 (5.79) | 38.29 (4.40) | 0.023 | 0.0005 | .881 | 1.184 | 0.0095 | .279 | 5.546 | 0.0371 | .020* |

Note. ANPS = Affective Neuroscience Personality Scale; ANCOVA = analysis of covariance. For each ANCOVA test, degrees of freedom (df), the F ratio, and the statistical significance p are reported. All the ANPS subscales were analyzed but only those showing any significant difference among subgroups are reported in the table. The size effect in the form of partial eta-squared ($\eta^2$), the size effect in the form of partial eta-squared is reported. ANPS-SEEK = SEEKING; ANPS-FEAR = FEAR; ANPS-ANGER = ANGER; ANPA-SAD = SADNESS; ortho = orthopedic (control group); ant = anterior lesion; post = posterior lesion; right = right lesion; left = left lesion; med = medial lesion; lat = lateral lesion; cort = cortical lesion; subcort = subcortical lesion.
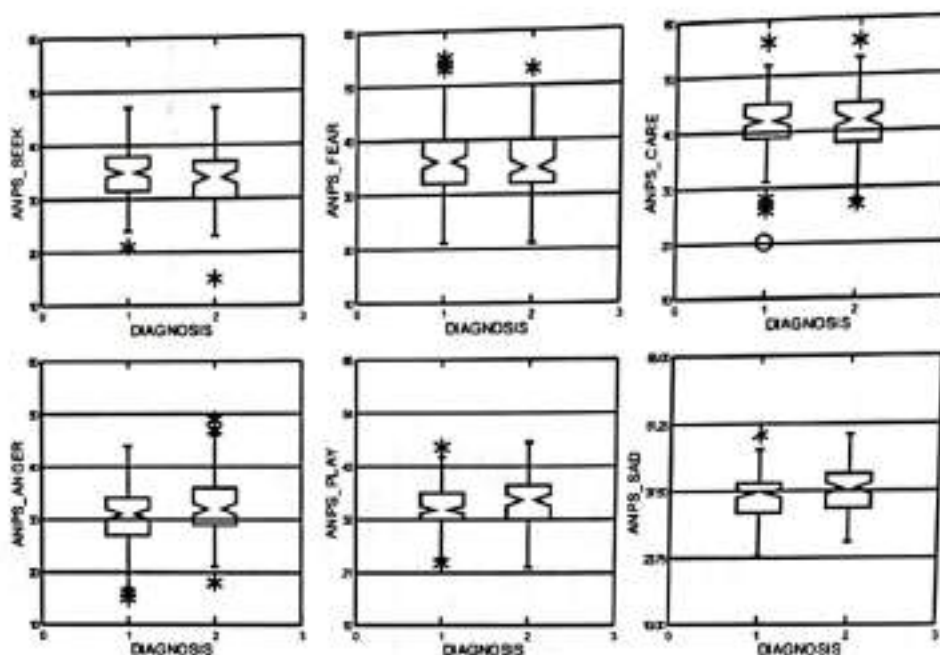*Significant differences, p < .05.

Figure 2. Box-whiskers plot comparing scores obtained by control orthopedic subjects (diagnosis = 1) and stroke patients (diagnosis = 2) at Affective Neuroscience Personality Scale (ANPS) subdimensions. In each plot, notches indicate medians and relevant confidence interval (95%). Upper and lower limits of the central box indicate the interquartile range around the median. Values exceeding 1.5 times and 3 times the relevant quartile (whisker) are considered as outliers and are indicated by asterisks or circles, respectively.

with a highly significant ($p = .017$) difference at the ANCOVA post hoc $t$ test.

To test the impact of other emotion dimensions in the ANPS, we then conducted similar analyses (Table 2 and Figure 2). Stroke patients showed significantly higher scores at the ANPS-ANGER (32.66 vs. 30.04, $p = .007$) and ANPS-SADNESS (37.42 vs. 36.46, $p = .035$). In sum, the emotion dimensions of SEEKING, SADNESS and ANGER differed between stroke patients and control subjects.

The next step in our analyses consisted in investigating the impact of lesion location on basic emotions as measured with ANPS. Post hoc $t$ tests relative to the 3 × 2 ANCOVA (anterior/posterior, medial/lateral, right/left, subcortical/cortical) revealed that patients with anterior lesions showed significantly higher scores at the ANPS-FEAR (36.82 vs. 33.69, $p = .033$) and ANPS-SADNESS (39.30 vs. 35.79, $p = .007$) dimensions than the patients with posterior lesions (see Table 2 for a general overview). With regards to SEEKING, differences emerged but were marginally significant ($p = .08$). Average scores in patients with anterior lesions were lower than those with posterior lesions (31.78 vs. 35.07). In sum, the emotion dimensions of FEAR, SADNESS, and SEEKING are specifically impacted by the lesion location.

Finally, we compared the ANPS scores in the different lesion groups with the ones in healthy subjects. In particular, the tendency of anterior, medial,

left, and subcortical patients to score significantly lower in ANPS-SEEKING than the control group was confirmed in our current larger sample (Farinelli et al., 2013). Furthermore, ANPS-SADNESS scores in anterior, right, medial, and subcortical patients were significantly higher than those of the control group. ANPS-ANGER scores in posterior, right, and lateral patients were significantly higher than those in the control group (see Table 2 for a general overview). Finally, the ANPS-FEAR showed slightly lower scores in posterior patients than in the control group. In sum, the emotion dimensions of SEEKING, SADNESS, FEAR, and ANGER show lesion-specific effects when compared to control subjects.

### Impact of lesions on attachment

We first compared the ASQ dimensions in the stroke group as a whole to those of the healthy controls. ANCOVA (5 × 2; 5 ASQ dimensions, 2 groups) revealed a significant effect only for the ASQ-Relationships as Secondary subscale (see Table 3). Post hoc $t$ tests revealed that stroke patients showed higher scores in this dimension than the control subjects (18.57 vs. 16.74, $p = .047$).

Concerning the subgroups (see Table 3), anterior lesion patients showed a significantly higher average score in the ASQ-Need for Approval subscale than the control group (21.52 vs. 18.59, $p = .026$).

### TABLE 3
Comparison between the stroke and control groups at the ASQ subscales by the ANCOVA test by considering gender as a covariate

| Scale | Stroke (N = 86) Average (SD) | Ortho (N = 113) Average (SD) | ANCOVA (Stroke vs. ortho) $\eta^2$ | $F(df = 197)$ | $p$ |
|---|---|---|---|---|---|
| ASQ-Conf | 33.51 (5.56) | 34.81 (5.25) | 0.0154 | 3.069 | .081 |
| ASQ-Sec | 18.57 (5.82) | 16.74 (4.95) | 0.0200 | 3.994 | .047* |
| ASQ-Need | 20.47 (5.32) | 20.70 (6.00) | 0.0002 | 0.045 | .833 |

| | Anterior (N = 27) Average (SD) | Posterior (N = 29) Average (SD) | ANCOVA (Ant vs. post) $\eta^2$ | $F(df = 54)$ | $p$ | ANCOVA (Ant vs. ortho) $\eta^2$ | $F(df = 138)$ | $p$ | ANCOVA (Post vs. ortho) $\eta^2$ | $F(df = 140)$ | $p$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ASQ-Conf | 33.26 (5.59) | 33.45 (5.66) | 0.0019 | 0.102 | .750 | 0.0131 | 1.824 | .179 | 0.0094 | 1.315 | .254 |
| ASQ-Sec | 18.30 (3.96) | 19.35 (6.01) | 0.0000 | 0.000 | .993 | 0.0155 | 2.158 | .144 | 0.0256 | 3.650 | .058 |
| ASQ-Need | 21.52 (5.24) | 18.59 (4.62) | 0.0898 | 5.231 | .026* | 0.0031 | 0.423 | .517 | 0.0240 | 3.422 | .066 |

| | Medial (N = 34) Average (SD) | Lateral (N = 19) Average (SD) | ANCOVA (Med vs. lat) $\eta^2$ | $F(df = 71)$ | $p$ | ANCOVA (Med vs. ortho) $\eta^2$ | $F(df = 165)$ | $p$ | ANCOVA (Lat vs. ortho) $\eta^2$ | $F(df = 130)$ | $p$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ASQ-Conf | 33.02 (5.21) | 32.84 (7.03) | 0.0002 | 0.017 | .897 | 0.0268 | 4.515 | .035* | 0.0164 | 2.146 | .145 |
| ASQ-Sec | 18.54 (5.82) | 18.47 (5.77) | 0.0001 | 0.010 | .920 | 0.0195 | 3.265 | .073 | 0.0058 | 0.756 | .386 |
| ASQ-Need | 20.24 (5.56) | 20.42 (5.54) | 0.0004 | 0.029 | .865 | 0.0008 | 0.131 | .718 | 0.0004 | 0.045 | .832 |

*Note.* ASQ = Attachment Style Questionnaire; ANCOVA = analysis of covariance. For each ANCOVA test, degrees of freedom (*df*), the size effect in the form of partial eta-squared ($\eta^2$), the *F* ratio, and the statistical significance *p* are reported. All the ASQ subscales were analyzed but only those showing any significant difference among some of the considered subgroups are reported. Conf = confidence; Sec = Relationships as Secondary, NEED = Need for Approval. Ortho = orthopedic (control group); ant = anterior lesion; post = posterior lesion; med = medial lesion; lat = lateral lesion.

*Significant differences, *p* < .05.

ASQ-Confidence subscale scores differed significantly in medial stroke patients when compared to control subjects (33.02 vs. 34.08, $p = .035$).

In sum, the ASQ dimensions of the ASQ-Relationship as Secondary, the ASQ-Need for Approval, and the ASQ-Confidence showed significant differences in the various comparisons between stroke patients and control subjects.

## Relationship between basic emotions and attachment

In order to test the relationship between basic emotions and attachment, we ran correlational analyses for ANPS and ASQ scores within each group—that is, in the control group and the stroke group. We first tested whether the lesion in the stroke patients impacted the relationship between basic emotional traits and attachment scores. Interestingly, we observed significant positive correlations between ANPS-PLAY and ASQ-Confidence, between ANPS-ANGER and ASQ-Relationship as Secondary trait, and between ANPS-FEAR and ASQ-Need for Approval trait (see Table 4 and Figure 3). A relatively high correlation (marginally significant with $p = .07$) also was found between ANPS-CARE and the ASQ-Need for Approval scores.

In contrast, Pearson correlation between ANPS and ASQ only revealed one significant correlation in the control group (see Table 4) concerning ANPS-CARE and ASQ-Need for Approval, as was seen in the stroke patients. However, it is also noteworthy that the correlation values were not significantly different in stroke and control patients (according to a $z$ test for independent samples with a significance threshold .05). This is not the case of the significant correlations found in the stroke group. In those cases, the overall comparison of the global correlation (Appendix) indicates that correlation values in the stroke group were
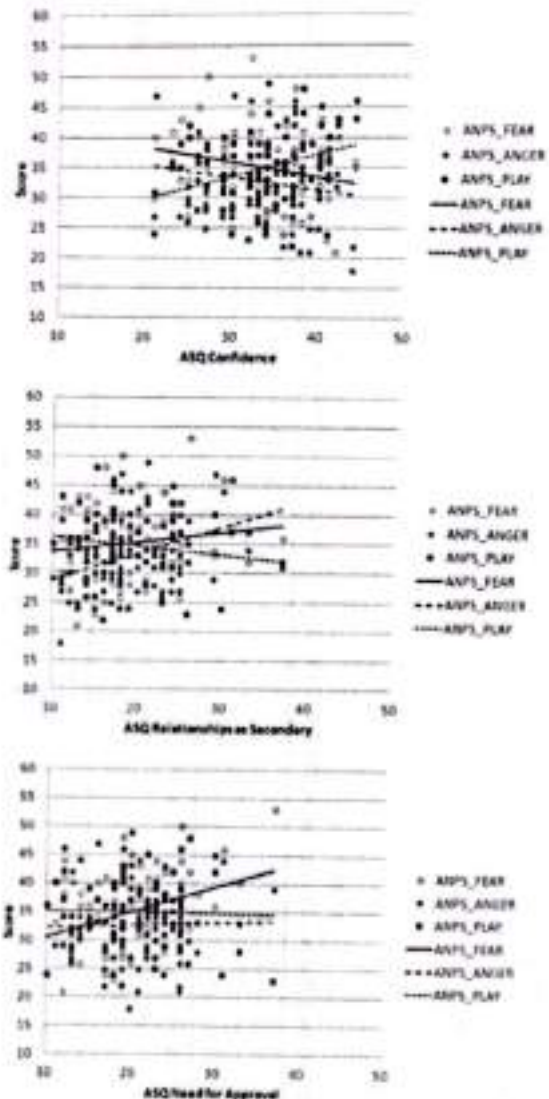


**Figure 3.** Correlation between Affective Neuroscience Personality Scale (ANPS) and Attachment Style Questionnaire (ASQ) in control subjects and stroke patients: Empty and filled circles respectively indicate ANPS-FEAR and ANPS-ANGER; squares indicate ANPS-PLAY.

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**TABLE 4**

Pearson correlation coefficients among scores obtained by control and stroke groups at the ASQ (rows) and ANPS (columns) subscales

| ASQ/ANPS | SEEK | FEAR | CARE | ANGER | PLAY | SAD | ASQ/ANPS | SEEK | FEAR | CARE | ANGER | PLAY | SAD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Stroke (86)* | | | | | | | *Ortho (113)* | | | | | | |
| Conf | .280 | −.216 | .261 | −.176 | .380* | −.119 | Conf | .146 | −.033 | .202 | −.077 | .138 | .087 |
| Dis | −.179 | .098 | −.207 | .058 | −.210 | −.028 | Dis | −.027 | −.042 | −.197 | .021 | −.249 | −.142 |
| Sec | −.061 | .148 | −.300 | .409* | −.168 | −.129 | Sec | −.131 | −.014 | −.307* | .194 | −.133 | −.085 |
| Need | −.092 | .369* | .323 | .039 | −.018 | .300 | Need | .041 | .224 | −.034 | .004 | −.105 | .164 |

*Note.* ANPS = Affective Neuroscience Personality Scale; ASQ = Attachment Style Questionnaire; ortho = orthopedic; SEEK = SEEKING; FEAR = FEAR; CARE = CARE; ANGER = ANGER; SAD = SADNESS; Conf = confidence; Dis = discomfort for closeness; Sec = relationships as secondary; Need = need for approval; Pre = preoccupation for relationships.

*Correlation values significantly ($p \le .05$ with the Bonferroni correction) different from 0.

significantly ($p < .05$) higher than those in the case of the corresponding ones in the control group.

This means that there is no statistical relationship between attachment and basic emotions in our control group, which suggests that, in the absence of brain lesions, attachment and basic emotions are basically two distinct separate processes, except concerning ANPS-CARE and ASQ-Relationship as Secondary.

These results also suggest that less secure attachments (lower scores at ASQ-Relationship as Secondary and ASQ-Need for Approval) tend to correspond to (perhaps enhance) negative emotions such as FEAR and ANGER (higher scores in ANPS), while more secure attachments (high scores in ASQ-Confidence) promote positive social joy emotions (higher scores in play).

The analysis of stroke subgroups (Table 5) revealed that the link between ANPS-ANGER and ASQ-Relationship as Secondary is most evident (and statistically significant) in patients with right and anterior lesions. Positive correlation between ANPS-FEAR and ASQ-Need for Approval was more significant in patients with right lesions, while the one between ANPS-PLAY

and ASQ-Confidence was larger for patients with subcortical lesions. Patients with lateral lesions also showed a significant positive correlation between ANPS-SEEKING and ASQ-Confidence subscales. Finally, patients with subcortical lesions showed the presence of a significant negative correlation between ANPS-PLAY and ASQ-Discomfort with Closeness scores (see Table 5).

In sum, the correlational analyses did not show any significant relationships between basic emotions and attachment in the control group, except as concerns ANPS-CARE and ASQ-Relationship as Secondary. In contrast, we observed various correlations between basic emotions and attachment style in the stroke group that also extended to specific lesion locations within the stroke group. As we discuss, these correlations may reflect a regression toward a more juvenile psychological pattern.

### Relationship of depression with basic emotions

With regards to both stroke and control groups, correlational analysis revealed the presence of

**TABLE 5**
Pearson correlation coefficients among scores obtained at stroke subgroups at the ASQ (rows) and ANPS (columns) subscales

| ASQ/ANPS | SEEK | FEAR | CARE | ANGER | PLAY | SAD | ASQ/ANPS | SEEK | FEAR | CARE | ANGER | PLAY | SAD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Right** | | | | | | | **Left** | | | | | | |
| Conf | .305 | −.059 | .344 | −.164 | .392 | .042 | Conf | .202 | −.507 | .013 | −.186 | .366 | −.458 |
| Dis | −.164 | .075 | −.263 | .150 | −.224 | .009 | Dis | −.232 | .122 | .01 | −.091 | −.162 | −.016 |
| Sec | −.135 | .180 | −.283 | .492* | −.214 | −.130 | Sec | −.002 | .093 | −.221 | .261 | .023 | −.034 |
| Need | −.096 | .430* | .278 | .011 | −.056 | .295 | Need | −.119 | .265 | .438 | .156 | −.003 | .176 |
| Pre | .050 | .283 | .210 | .163 | .001 | .098 | Pre | .046 | .207 | −.008 | .165 | .078 | −.026 |
| **Ant** | | | | | | | **Post** | | | | | | |
| Conf | .349 | .063 | .265 | −.223 | .420 | −.096 | Conf | .160 | −.199 | .217 | −.257 | .163 | .111 |
| Dis | −.233 | −.110 | −.220 | .169 | −.295 | −.166 | Dis | −.043 | .016 | −.285 | −.162 | .119 | −.149 |
| Sec | .062 | −.283 | −.329 | .593* | .088 | −.435 | Sec | −.089 | .311 | −.486 | .144 | −.147 | −.071 |
| Need | .020 | −.021 | .335 | .059 | .086 | .130 | Need | .090 | .446 | .426 | −.202 | .237 | .408 |
| Pre | .156 | .075 | .133 | .280 | .076 | .080 | Pre | .035 | .229 | −.017 | −.092 | .229 | −.110 |
| **Med** | | | | | | | **Lat** | | | | | | |
| Conf | −.008 | −.232 | .229 | −.246 | .262 | −.089 | Conf | .757* | −.081 | .321 | −.221 | .651 | −.159 |
| Dis | −.035 | .096 | −.190 | .091 | −.220 | −.113 | Dis | −.447 | −.002 | −.25 | .098 | −.231 | .156 |
| Sec | .007 | .162 | −.287 | .412 | −.175 | −.047 | Sec | −.246 | .068 | −.117 | .484 | −.041 | −.412 |
| Need | −.186 | .379 | .371 | .209 | −.105 | .315 | Need | −.131 | .52 | .431 | −.282 | −.037 | .447 |
| Pre | .115 | .213 | .138 | .296 | .036 | −.068 | Pre | −.152 | .559 | .461 | .01 | −.107 | .615 |
| **Cort** | | | | | | | **Subcort** | | | | | | |
| Conf | .479 | −.182 | −.023 | −.282 | .639 | .012 | Conf | .426 | −.336 | .258 | −.255 | .587* | −.206 |
| Dis | −.046 | .102 | .421 | .261 | .025 | −.116 | Dis | −.453 | .195 | −.078 | .045 | −.517* | .087 |
| Sec | −.154 | .164 | .186 | .550 | .066 | −.334 | Sec | −.029 | .039 | −.254 | .515 | −.176 | −.048 |
| Need | −.212 | .344 | .380 | −.759 | −.109 | .585 | Need | −.190 | .324 | .256 | .132 | −.002 | .383 |
| Pre | −.058 | .284 | .302 | −.074 | .256 | .299 | Pre | .088 | .218 | .037 | .363 | −.108 | .165 |

*Note.* ANPS = Affective Neuroscience Personality Scale; ASQ = Attachment Style Questionnaire; SEEK = SEEKING; FEAR = FEAR; CARE = CARE; ANGER = ANGER; SAD = SADNESS; Conf = confidence; Dis = discomfort for closeness; Sec = relationships as secondary; Need = need for approval; Pre = preoccupation for relationships; ortho = orthopedic (control group); ant = anterior lesion; post = posterior lesion; right = right lesion; left = left lesion; med = medial lesion; lat = lateral lesion; cort = cortical lesion; subcort = subcortical lesion.

*Correlation values significantly ($p \leq .05$ with the Bonferroni correction) different from 0.

**TABLE 6**

Pearson correlation coefficients of scores obtained for stroke and control subgroups at the ANPS subscales and corresponding scores obtained at HADS-Depression subscale

| Scale | Ortho | Stroke |
|---|---|---|
| ANPS-SEEK | −.336* | −.323* |
| ANPS-FEAR | .355* | .578* |
| ANPS-CARE | −.028 | .075 |
| ANPS-ANGER | .019 | .023 |
| ANPS-PLAY | −.194 | −.321* |
| ANPS-SAD | .239 | .457* |

*Note.* ANPS = Affective Neuroscience Personality Scale; ASQ = Attachment Style Questionnaire; HADS = Hospital Anxiety and Depression Scale; ortho = orthopedic (control group); ANPS-SEEK = SEEKING, ANPS-FEAR = FEAR, ANPS-CARE = CARE, ANPS-ANGER = ANGER, ANPS-SAD = SADNESS.

*Correlation values significantly ($p ≤ .05$ with the Bonferroni correction) different from 0.

significant and relatively strong correlations of scores obtained in the HADS-Depression subscale with those relative to basic emotions (Table 6). These results confirmed, in a new larger sample, findings of our previous paper (Farinelli et al., 2013), which had highlighted the significant negative correlation between SEEKING and depression in both stroke and control groups. In that paper, this result was interpreted as an indication that reduction in SEEKING may predict depression. This last result also relies on a number of papers (e.g., Alcaro & Panksepp, 2011) stating that depression can be related to deficits in SEEKING. If this is the case, depression can be seen as an "effect" of SEEKING and possibly of other features of basic emotion systems. This last conjecture is partially confirmed in the present analysis where ANPS-Fear scores were found to significantly and positively correlate with HADS-Depression. Relatively high correlations were also observed as concerns ANPS-Play and ANPS-SADNESS (statistically significant only for stroke patients). Apparently, no relationship with HADS-Depression was found with ANPS-Care and ANPS-ANGER subscales.

The above-mentioned correlations do not mean causality, but only support the idea that there is bound to be causality somewhere in the nexus of unmeasured brain processes. In particular, it supports, from psychometric perspectives, the idea that a relationship exists among psychological and brain features. Furthermore, the number of basic emotions correlated with depression supports the idea that depression is a global affective disorder.

A further indication in this direction is also provided by repeating the ANCOVA analysis while considering depression as a covariate along with gender. When the effect of depression is removed (that is what happens when one uses depression as a covariate), all differences among groups described above become nonsignificant from a statistical point of view. The fact that one might lose differences if the critical brain substrate is taken away testifies that the role of the brain emotional system in depression is truly important.

## DISCUSSION

### Main findings

We report a behavioral study on the effect of brain lesions on basic emotions and attachment by comparing stroke patients with control group constituted by aged orthopedic patients group hospitalized in the same way as stroke patients.

Psychometric assessment of emotions and of attachment style was performed in the acute phase close to the radiologic characterization of lesions. This, according with clinical evidence, was very important because it is in this phase that phenomena associated with the reorganization of the self are activated, phenomena that can influence what follows. Three self-report questionnaires were administrated.

Our results show the following: (a) Brain lesions following strokes affect several basic emotions (SEEKING, ANGER, FEAR, and SADNESS) with specific lesion location exerting specific effects on particular basic emotions; in contrast, (b) brain lesions only mildly impact few subdimensions of attachment; and finally, (c) basic emotions and attachment correlate with each other more in the stroke patients than in the control subjects.

These results were obtained by performing a relatively large number of tests. One may wonder whether the number of significant differences revealed by the ANCOVA test (20 out of 148 performed comparisons) and correlations (significant correlations were revealed into 6 out of 11 correlation matrixes actually computed) may occur by chance (Type I error). To this purpose, by considering the significance threshold of .05 here considered both for ANCOVA and for the correlations test, one may compute by a binomial distribution what is the probability that the observed number (or larger) of significant differences (for ANCOVA) and correlations may occur by chance. In both cases of ANCOVA and correlation matrixes, this probability was much lower than .05, and this confirms the overall statistical robustness of the exploratory analysis here described.

## Stroke and basic emotions

Our previous study (Farinelli et al., 2013) investigated a smaller sample of stroke patients and focused on one particular basic emotion, namely SEEKING. The present study included a larger sample size (86 vs. 62), which made it possible to also consider the other basic emotions as defined by Davis and Panksepp (2011) and explored by the ANPS questionnaire. First and foremost, we again observed smaller SEEKING scores in our now larger sample of stroke patients with respect to the orthopedic control group in line with our initial hypothesis. Regarding other basic emotions, the analysis revealed a significant impact of stroke brain lesions on specific basic emotions like SADNESS, FEAR, and ANGER. This is confirmed by the different kinds of analyses, the comparison between all stroke patients and control subjects, the comparison between the different lesion locations within the stroke group, and the comparison between the different lesion locations (in the stroke group) and the control group. However, our findings are not entirely in line with initial hypothesis concerning the expected reduction of scores concerning basic negative emotions due to brain lesion impact. Thus we may infer that there is a more complex interaction of basic emotion systems, emotion regulation, and general poststroke factors.

Anyway, these results confirm the central role of specific intact brain functioning for regulating and/or generating basic emotions. While many studies have been conducted to investigate the impact of stroke and brain lesions on emotions (Gainotti, 2006, 2012), stroke-induced brain damage and induction of changes in basic emotions as defined by Panksepp (1998) and Panksepp and Biven (2012) are starting to be understood. Our study provides the first empirical evidence that basic emotions like SEEKING, SADNESS, FEAR, and ANGER are affected by stroke in general and specific lesion locations in particular. These results can find some correspondences with other studies relative to the motivational system of emotions in brain-damaged patients (e.g., Feinstein et al., 2013; Vijayaraghavan et al., 2013)

This is well in line with both neuroscientific and clinical evidence. Neuroscientifically, basic emotions have been associated with mainly subcortical and medial regions in the brain; this is congruent with the various emotional changes following specific lesion locations observed in our study. Clinically, many stroke patients show abnormal emotionality in both their experiences and their behaviors (Kaplan-Solms & Solms, 2000; Solms

& Turnbull, 2002). Especially negative emotions like SADNESS, FEAR, and ANGER seem to predominate in these patients (Turnbull et al., 2005), which corresponds well to our findings.

Most importantly, as our findings are based on the significant differences between stroke patients and hospitalized control patients, the changes in basic emotions must be related to specific effects of the stroke and brain lesions rather than just general negative effects of medical problems requiring hospitalization. However, for further clarification of issues, abundant additional research will be needed at both behavioral and neural levels.

## Stroke and attachment

Besides the basic emotions, our study focused on attachment styles in stroke patients and control subjects. Following our second main hypothesis, we observed few significant differences in attachment between the two groups. The dimension of ASQ-Relationship as Secondary proved to be significantly higher in stroke patients than in the control subjects. High scores in this specific dimension of attachment reflect an insecure/avoidant attachment style (Feeney at al., 1994; Hazan & Shaver, 1987), which has also been observed in stroke subjects in previous studies (McWilliams & Bailey, 2010). In this case, according to clinical practice, patients manifest abnormal behavioral styles tending towards avoidance, especially when negative emotions are more accentuated. In these cases, patients appear more withdrawn, they interact less with family members and healthcare workers, they seem more distrustful, the few requests for help concern practical and concrete aspects, and they tend to more easily express negative emotions through somatic–vegetative modalities.

Our results extend these findings by showing for the first time specific attachment styles in poststroke brain-damaged patients. Lesion location seems to affect only the ASQ-Need for Approval dimension since patients with anterior and posterior lesions showed significantly different scores. High scores in this dimension are associated to insecure/anxious/preoccupied attachment style (Feeney at al., 1994; Hazan & Shaver, 1987). In this case, patients manifest continual requests of presence and reassurance from their family members and, when they are absent, from the healthcare operators and assistants. When this occurs, negative emotions such as FEAR and ANGER are accentuated.

In general, however, brain damage seemed to weakly affect the attachment system, at least to a lesser degree than the measures of basic emotions.

This may suggest that the ASQ is measuring cognitive–conceptual issues more than underlying affective ones.

In addition to the attachment itself, we also investigated the relationship of attachment styles to basic emotions. We found relatively weak correlations among basic emotions and attachment styles in our control group. However, the attachment literature postulates a close psychological relationship between attachment and emotions (Shaver & Mikulincer, 2007), which then should have been evident in correlations between both variables as monitored with the ANPS and ASQ. However, that was observed in our data only with one subscale.

How then can we explain the weakness of relationships between emotions and attachment? Both the basic emotions and the attachment are assumed to be subserved by distinct and segregated underlying neural systems (Coan, 2010; Goldberg, 2001; Panksepp, 1998, 2011a, 2011b, 2011c). The basic emotions are associated with different neural systems in subcortical networks, while attachment is assumed to be related to neural activity in more cortical regions such as some regions of the cortical midline structure (Northoff et al., 2006) and, in particular, the medial orbital prefrontal cortex or the ventromedial prefrontal cortex (Goldberg, 2001; Schore & Schore, 2008).

Such neural segregation between subcortical and cortical levels may then be manifest on the psychological level that results in the absence of strong correlation between basic emotions and attachment. Indeed, that is what we observed. Accordingly, contrary to expectations from singular psychological perspectives, the weakness of correlations between basic emotions and attachment in our control group is well in line with their underlying neural distinction of different psychological processes.

Such neuronal segregation and independence find a correspondence in the psychological evolution of the individual. Development and maturation of attachment relational styles also supply a complex and integrated system of hierarchical emotion controls and regulations. Internal working models unconsciously regulate relationships with significant others and regulate social relations. Thus attachment styles through internal working models make relationships in general more independent of basic emotions especially during condition of bodily health and safety. As Bowlby (1969) and subsequent attachment researchers (e.g., Bretherton, 1985; Shaver & Mikulincer, 2007) highlighted, attachment style is especially evident in situations of physical and psychological distress and in particular is evoked during threats to physical or psychological integrity. Following these considerations, stroke,

due to lesions, should disrupt above all basic emotion systems. Consequently this disruption may reactivate distinct attachment styles developed in the first phases of early development as emotional regulators, putting in evidence the close relationship and interdependence between basic emotions and attachment.

How do such neurobiologically based, theoretical suppositions stand in relation to our empirically observed correlations between basic emotions and attachment in stroke patients? Due to the stroke damage, the neural networks underlying basic emotions and attachment may no longer be as independent and segregated (in functional terms) from each other as in the case of control patients. Such neural dependences may then be behaviorally manifest with a more evident relationship between basic emotions and attachment issues, which is what we observed in our data. We suspect that this may reflect a regression to an earlier style of psychological structure and functioning. However, future neural studies are necessary in stroke patients to lend further evidence to our assumptions.

## Limitations

As one can see, except in the case of anterior/posterior subgroups, populations in the relevant subgroups are severely unbalanced with a relatively scarce presence of left, lateral, cortical lesions, which may have hampered the possible search for significant differences in ANPS scores.

Another limitation of the present study concerns the decision to include patients with relatively low MMSE scores ($\geq 21/30$). With respect to this concern, our decision was to include only patients who, as a result of clinical assessments, could actively and successfully participate in our tests. Indeed, we would note that slightly higher and more conventional thresholds ($\geq 24/30$) do not necessarily exclude mild to moderate dementias, which may be problematic in this kind of work. Of course, expert clinical judgment may fail, and we cannot exclude possible biases induced by the declining motivation due to a multitude of interacting factors including the fact that older people simply do not have the skills to execute tasks and function in unstructured environments in which they previously might have performed well.

Furthermore, the cognitive status of the patients was only characterized by using MMSE. A full battery of neuropsychological measures and detailed standardized behavioral observations could possibly allow us to better evaluate the

influence of eventual specific cognitive deficits on self-awareness or conscious experience of emotions and feelings and their possible effect on questionnaire scores. However, in a statistical sense, these eventual biases affect in the same way both stroke and orthopedic groups, and this implies that observed differences could hardly be attributed to this possible distortion.

An unresolved critical aspect is the application of ANPS to target primary emotions. We must accept that the ANPS scales (indeed, perhaps all questionnaire scales) are assessing responding at a tertiary level of mentation (as defined by Northoff, Wiebking, Feinberg, & Panksepp, 2011; Panksepp, 2011a). This primary/tertiary slippage implies that in future studies it would be desirable to have measures other than the ANPS, including more direct behavioral testing of the underlying processes with various explicit tasks, but these may also only provide results representative of an integration of different levels of brain–mind functioning. As discussed by Coenen and colleagues (Coenen, Schlaepfer, Maedler, & Panksepp, 2011), reaching primary structures may require the use of specific neurological procedures (e.g., "deep brain stimulation"). Also, many future investigations are needed to study emotion and attachment in elderly healthy individuals and ill patients, especially considering how few studies have been devoted to such populations. Furthermore, such studies are needed since there is evidence that some peculiarities of attachment relationships and emotion regulations emerge in old age (Cicirelli, 2010).

The use of self-report evaluations to assess attachment and basic emotions may also represent a limitation of the present analysis. This kind of measure suffers from specific biases associated with, for example, social desirability, insight, and self-awareness problems (Philippi et al., 2012). To strengthen results obtained here, convergent measures should be employed in further studies, including suitable interviews and rating scales from the objective perspective of the investigator (e.g., Main & Goldwyn, 1994).

## CONCLUSIONS

We here investigated the impact of various forms of brain damage on basic emotions and attachment styles in a sample of stroke and orthopedic control patients matched for cognitive status and age. We observed significant differences in various basic emotion measures as well as attachment styles between stroke patients and control patients under comparable medical supervision. Our main

findings were that specific types of brain damage rather than nonspecific effects associated with general illness impact measures of basic emotions more than attachment styles. Most interestingly, basic emotions and attachment styles were mostly unrelated in our control group while they correlated significantly with each other in our stroke patients. This suggests that stroke impacts brain–mind dynamics in ways that are not as evident in individuals without such brain lesions. The weakness of correlations between basic emotions and attachment styles also suggests intriguing segregation and independence functions depending on the integrity of brain systems. In sum, our study reveals that brain damage arising from strokes affect not only the traditional or classical functions (cognitive, sensory, motor, social functions) but also basal survival functions like basic emotions and attachment processes in various distinct but specifiable ways. This highlights the psychosomatic relevance of brain damage arising from strokes, documenting mental changes in patients beyond traditional conceptions of neurological relevance.

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## APPENDIX. GLOBAL CORRELATION TEST

An overall comparison of the global correlation existing among the ANPS and ASQ scores in the subgroups of patients and the control group was also performed. To this purpose the correlation matrix $C_{ij}$ has been considered, whose elements are the Pearson correlation values obtained by considering the scores obtained at the $i$th subscale out of $I$ of ANPS and the $j$th subscale out of $J$ of ASQ. As a whole, any correlation matrix includes $K = I \times J$ elements. The correlation matrixes obtained by two subgroups ($n$th and $m$th, respectively) are then compared by computing the number $N_{nm}$ of times that $\left|C_{ij}^m\right| > \left|C_{ij}^n\right|$ for $i$ and $j$ in the ranges $[1, I]$ and $[1, J]$, respectively. If $N_{nm} \gg K$ one can state that in the $n$th subgroup scores relative to the subscales of the ANPS and ASQ are more correlated than in the $m$th subgroup.

In principle one can expect that the probability $p$ that $\left|C_{ij}^m\right| > \left|C_{ij}^n\right|$ and $\left|C_{ij}^m\right| < \left|C_{ij}^n\right|$ is the same and is .5. In this reasonable assumption, the binomial distribution with parameters $N_{nm}$, $K$, and .5 can be used to compute the statistical significance of the observed score—that is, the probability that a number of $N_{nm}$ or more exceedances is obtained by chance.