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**AGGRESSION AND BRAIN ASYMMETRIES:
A THEORETICAL REVIEW**

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ABSTRACT

The relationship between aggression and brain asymmetries has not been studied enough. The association between both concepts can be approached from two different perspectives. One perspective points to brain asymmetries underlying the emotion of anger and consequently aggression in normal people. Another one is concerned with the existence of brain asymmetries in aggressive people (e.g., in the case of suicides or psychopathies). Research on emotional processing points out the confusion between emotional valence (positive-negative) and motivational direction (approach-withdrawal). Because of this, it is not clear whether the frontal asymmetry reflects the valence of the emotion, the direction of the motivation, or a combination of valence and motivation. Appetitive motivations are not always associated with positive affects. Anger (a negative emotion) has been associated with approach motivation and with aggression. Relative left-prefrontal activity is associated with state anger and with aggression. This information would lead to the conclusion that the more violent a culture, the higher the relative proportion of the right-handers. On the other side, there is an exaggerated structural asymmetry in the anterior hippocampus (R>L) in unsuccessful psychopaths. In suicidal persons, the functional insufficiency of the right hemisphere produces a compensatory shift to left hemisphere information processing, showing a reversed asymmetry of typical traits for suicidal people. These findings suggest, therefore, the existence of a certain correlation between brain asymmetries and human aggression.

Keywords: Brain asymmetry Aggression; Violence; Anger, Emotion, Motivation

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1. INTRODUCTION

The history shows that humanity has the ability to allocate resources on several levels for starting and supporting wars. At the present time, western societies are living a moment of important terrorist pressure. The Basque terrorism in our own country (Ramirez & Sullivan, 1987) and the international terrorism on the Twin Towers in New York. in 2001 and more recently on trains in Madrid and London are only a few unfortunate examples of this fact. On the other side, newspapers report too often about fighting on the streets or domestic violence. All these actions refer to an unchained aggression that we must daily coexist with. It is important to emphasize that aggression refers to a specific behavior, namely a reaction to a situation, stimuli or particular emotion. According to these life circumstances, it seems logical to suppose that aggression is present in the human nature and, consequently, about a possible existence of relationships between human brain and aggression. Moreover, since scientific literature indicates the existence of brain asymmetries and laterality functioning, one could wonder whether there were any relation between these and aggression.

Our argument in favour of a possible relation between brain asymmetries and human aggression is based on three assumptions: a) Principles of neuroscience suggest a strong brain determinism on human behavior. b) According to the general theory of the cerebral function, there seems to exist unevenness on cortical activation; for example, introvert people show very high basic activation line and, because of this, they feel too much stimulation and tend to run away from social interaction, while extrovert people have low cortical activation and need more stimulation to avoid becoming boring (Carver & Scheier, 1997). These differences at the cortical activation level when talking about the dimension extroversion/introversion suggest that it could be possible to find similar differences among people with different levels of aggression display. c) According to Gray (e.g. 1987), all the behavior may be regulated by two cerebral systems: a behavioral approximation system (BAS), the activation of which moves the individual to approach a goal and to obtain rewards; and a behavioral inhibition system (BIS), which activates the individual to inhibit his movement to reach goals in order to avoid punishment. Gray's theory refers to behavior

and emotional experience, attributing positive feelings to the first system and negative ones to the second one. Moreover, the tendency to feel negative affects (NA) would be associated with a behavioral avoidance system partially localized at the right prefrontal area, whereas the tendency to feel positive affects (PA) would be associated with a behavioral activation system partially localized at the left prefrontal area. This conceptualisation of behavior corresponding to two cerebral systems is referred as the *reinforcement sensitivity theory*. Later, Davidson (1992a & b) showed the association of higher levels of rest at the right prefrontal area with negative feelings, whereas, on the contrary, higher levels of rest at the left prefrontal area indicate an association with positive feelings. This frontal asymmetry may be due to three different dimensions: a) to emotional valence (positivity/ negativity), b) to motivational direction (approach/withdrawal), and c) to a combination of both, emotional valence and motivational direction (positive-approach/negative-withdrawal). In this way, Davidson attends only to the emotional experience, as evidence in favour of a brain asymmetry on emotional processing.

If there are brain asymmetries on emotional processing, there could also be possible brain asymmetries related to aggression. This eventual association between both concepts could be analyzed from two different perspectives. One perspective tries to explain the existence of brain asymmetries underlying emotion processing and consequently aggression: brain asymmetries would modulate the emotion (anger) that produces aggression. The another one points out the existence of brain asymmetries in specific groups of people who can display an aggressive behavior as consequence of a mental illness, (e.g., in the case of suicidal people). In this case, brain asymmetries would cause or, at least, correlate with aggression without mentioning emotion.

At a general level, aggression has to do with emotional processing, as far as it may constitute a reaction to a particular emotion, anger. But aggression has also to do with brain activity, because it correlates with emotional processing. Finally, as we will see, the study of aggression may also have to do with cerebral asymmetries. The present review would try to revise the scientific literature in order to understand this eventual relationship.

2. METHOD

Data Sources: SCIECEDIRECT and MEDLINE-derived Online reviews of bibliographies were systematically searched for articles published during the last forty years related to brain asymmetries and aggression in humans. Only eleven different research works were found to be interesting for our purpose. Abstracted information of each research work will be presented in order to elaborate a summary referred to brain asymmetries and aggression.

Information selection: Among all these works, we found specially interesting the studies done by Harmon-Jones and colleagues (1997; 1998; 2001; 2003 a & b; 2004) because they

were specifically about anger and aggression, a relationship is very important for assessing brain asymmetries and aggression, given that most kinds of aggression are provoked by anger (Ramirez & Andreu, 2003, in press). Consequently, his work will be analysed more thoroughly.

3. EMOTIONAL PROCESSING

A review of the recent research on emotional processing could be useful for the understanding of the focus of this review. An interesting work concerning the study of the relationship of individual differences in emotional behavior and brain function is done by Zald, Matson and Pardo (2001). They showed that NA correlates with high activity in a specific area of the brain, namely, the ventromedial prefrontal cortex (VMPFC). According with these authors, NA "is a technical name that includes a range of unpleasant mood states, ranging from irritability to anxiety to anger". This finding is very important for our review as far as we state that aggression can be a reaction to the emotion of anger.

Participants were 52 right-handed healthy subjects (24 males and 14 females age 19-55). A first questionnaire about the extent to which they had experienced unpleasant moods during the previous month was used to rate each individual on a "negative scale". Then they were scanned by positron emission tomography (PET). The levels of brain activity of all the subjects were compared with their NA, finding that the encountered differences at the NA scale agreed with the brain activity variation among the participants at the VMPFC. To ensure that the results were correct, the authors replicated the experiment with 38 subjects and the same was found. Even if these results agree with other works with similar aims in the same field, they refer only to a correlational relationship. In the future it should be researched, therefore, if this brain activity is the cause or the effect of NA.

In agreement with Zald and colleagues' work, it can also be suggested that approach-related positive emotions are associated with higher left frontal brain activity, whereas withdrawal-related negative emotions would be associated with higher right frontal brain activity (Carver & White, 1994; Davidson, 2000; Davidson et al, 1990). This research however seems to have confounded the concepts of emotional valence (positivity/negativity) and motivational direction (approach/withdrawal) and the theoretical explanation was muddled (Harmon-Jones y Allen, 1998).

Recent research supporting the motivational direction model (Harmon-Jones, 2004) has revealed that anger and cognitive dissonance, emotions with negative valence and approach motivational tendencies, are associated to a relatively higher left frontal activity, commonly implicated on positive emotions. However, these findings could be again product of a confusion between approach motivation and positive emotional valence, because appetitive motivations are not always associated with positive affects (e.g. Carver, 2001; Harmon-Jones, 2003 a). Anger, greed, lust, and mania are some examples of approach motivations that may have negative consequences. Given the eventual confusion between the valence of

the emotion and the direction of motivation, we are not able to find out whether the frontal asymmetry reflects the valence of the emotion, the direction of the motivation, or a combination of valence and motivation.

Supporting only the valence model, Smith and Bulman-Fleming (2004), addressing hemispheric asymmetries for the conscious and unconscious perception of emotional stimuli, have found a right-hemisphere advantage for conscious perception of negative information. Their starting point was the right-hemisphere hypothesis that posits emotional stimuli are perceived more efficiently by the right hemisphere than by the left one. Conscious perception was measured by using a subjective report-of-awareness measure reported by participants, and unconscious perception was measured by using an "exclusion task", a form of word-system-completion task.

As we have pointed out, positive emotion is often associated with approach-related motivation and with left frontal brain activity, whereas negative emotion is associated with withdrawal-related motivation and with right frontal brain activity. Indeed, according to most contemporary theories of emotion, positive emotion is always associated with approach motivation, and negative emotion is always associated with withdrawal motivation emotion (e.g., Watson, 2000; for a different point of view, see Carver, 2001). For this reason, it seems that a relatively higher activity in the left frontal cortical region would be psychologically and physically healthier than a relatively lower activity in the same region (Harmon-Jones, 2003 b).

Not all emotions however behave according to this presumed relationship between the valence of emotion and direction of motivation. One of the best examples of a violation of the relationship is anger: it is negative in valence (e.g., Lazarus, 1991; Watson et al., 1999), but it often evokes approach motivation (e.g., Berkowitz, 1999; Darwin, 1872/1965; Plutchik, 1980 and Young, 1943). By examining the emotion of anger, we are in a position to find out what are the emotional/motivational functions of asymmetrical frontal brain activity (it will be explained later). Furthermore, anger is associated with approach motivation and with aggression (Harmon-Jones, 2004).

We will present some behavioral evidences starting with animal research. The reason for considering aggression in animals to understand human aggression, lies in two facts: 1) "there is an evidenced evolutionary continuity between animals and people for aggression and fear and the major factors that control them" (Blanchard & Blanchard, 1984); and 2) there are ethical and legal constraints on human research to do specific aggression research. So, in animal behavior literature, a distinction has been made between offensive or irritable aggression and defensive aggression (Flynn et al, 1970; Moyer, 1976; Ramirez, 1981). Irritable aggression results from anger and it "involves attack without attempts to escape from the object being attacked" (Moyer, 1976, p. 187), whereas defensive aggression is associated with fear, and attack only if attempts to escape are impossible (Blanchard and Blanchard, 1984; Lagerspetz, 1969 and Moyer, 1976). Lagerspetz (1969) found that, under

certain conditions, mice would cross an electrified grid to attack another mouse, showing that organisms evidence offensive aggression and that this is an approach behavior. On the other side, Blanchard and Takahashi (1988) demonstrated that damage to the amygdala, a brain region involved in defensive behavior, reduced considerably defensive behavior in rats while it had no effect on offensive aggression. Indeed, when rats with bilateral lesions in the area of the amygdala were compared to controls by testing their coexistence with strange male intruders, no difference between both of the groups were found, while in the presence of a predator -a cat-, the injured group of rats showed a substantial reduction of their defensive behavior, that is, freezing. Similar results were shown by us in pigeons after specific lesions in their *archistriatum*, a homologous in birds of the mammal amygdala (Ramirez & Delius, 1978, 1979a & b). According to Blanchard & Blanchard, (1984), the two above mentioned emotions -fear and anger- are the emotional concomitants of defense and offense respectively and they are present also in human behavior. Evidence for such a statement comes from facial expression research, where Izard (1971) affirmed that subjects from a number of different cultures are capable of identifying through photography's fear versus anger emotional expressions on individuals. Animal research also seems to support the concept of anger as involving approach and not withdrawal motivation. According to the Blanchards (1984), anger motivates offensive aggression, whereas fear motivates defensive aggression.

In research with adult humans, Baron (1977) demonstrated that angry individuals were reinforced positively by signs of their tormentor's pain. The participants, who had been deliberately provoked by another individual, had a sanctioned opportunity to assault him in return. They started hurting themselves, and their target led to intensified aggression, even though the unprovoked participants reduced the intensity of their punishment at learning of the other's pain. The initial signs of their victim's suffering showed that angry persons were approaching their aggressive goal and thus evoked even stronger assaults from them. Also Berkowitz et al (1981) pointed out results consistent with these findings. Two experiments were designed to demonstrate that painful environmental conditions evoked aggressive inclinations directed toward doing harm even when the available target was not responsible for the suffering. In both, 94 female undergraduates kept one hand in a tank of water that was either painfully cold or much warmer while they delivered rewards and punishments to another woman supposedly supervising their work. Half of the subjects in each condition were informed that their punishments might harm their partner, whereas the other ones were told that these punishments probably would be helpful. Subjects exposed to the warmer water tended to deliver the greatest number of rewards when they had been told punishment would harm, whereas those in the cold-water condition were least rewarding if they had been informed punishment would injure their partner. Results showed that the aversive stimulation evoked an instigation to do harm, and that the information about the possibility of hurting the partner served as a goal cue facilitating the overt expression of the instigation.

Research on testosterone (T) shows further evidence supporting the conceptualization of

anger as involving approach and not withdrawal motivation, although it is a negative emotion. T treatments would decrease withdrawal (fear) responses in a great number of non-human species (e.g. Boissy and Bouissou, 1994; Vandenheede & Bouissou, 1993). The wealth of evidence supporting the ability of T to facilitate aggressive behavior in a broad number of mammal species has led to wonder about its potential role in human aggression, expecting at least a positive correlation between both variables (Ramirez, 2003). Three meta-analyses conducted by Archer (1991), however, only found a weak, positive relationship between T and aggression; and other similar studies at pubertal and at a younger age (Scerbo & Kolko, 1994) yielded rather equivocal results, with a lack of links and less conclusive association between androgens and aggression.

Other evidence supporting the idea that anger is associated with an approach-orientation comes from research in patients with bipolar disorder. The emotions of euphoria and anger often occur during manic phases of bipolar disorder (Cassidy et al, 1998; Depue & Iacono, 1989; Tyrer & Shopsin, 1982). Both, euphoria and anger may be approach-oriented processes, and a dysregulated or hyperactive approach system may underlie mania (Depue & Iacono, 1989; Fowles, 1993). So, hypomania/mania involves increased left frontal brain activity and approach motivational tendencies. It has been also found that individuals who have suffered damage to the right frontal cortex are more likely to evidence mania (see review by Robinson & Downhill, 1995). These results are consistent with the hypothesis that mania may be associated with increased left frontal activity and increased approach tendencies, because of the approach motivation functions of the left frontal cortex, which are released and not restrained by the withdrawal system in the right frontal cortex. Furthermore, the fact that lithium carbonate treatment for bipolar disorder reduces aggression (Malone et al, 2000), also suggests that anger and aggression correlate in bipolar disorder. On the other side, trait anger has been found to relate to high levels of assertiveness and competitiveness (Buss & Perry, 1992). According to these lines of research, therefore, anger would be associated with a number of approach-related individual differences characteristics.

More recently, Harmon-Jones & Sigelman (2001) did an experiment that confirmed two hypotheses: 1) state-induced anger is associated with relative left-prefrontal activity; and 2) this prefrontal activity is also associated with aggression. Two additional individual differences studies were conducted in order to test whether trait anger was related to trait approach motivation, or more specifically, to trait BAS (approach behavioral system).

In the first study (Harmon-Jones, 2003 a), three questionnaires were administered: the BIS/BAS Questionnaire (Carver & White, 1994) to assess individual differences in BIS and BAS sensitivities, the anger subscale of the AQ (Buss & Perry, 1992) to assess trait anger, and the Positive and Negative Affect Schedule Questionnaire (PANAS-X) of Watson & Clark (1991) to assess PA and NA. Participants were asked to indicate to which extent they felt a list of emotions. Results confirmed that trait anger correlated with BAS, suggesting that higher levels of BAS were associated with higher levels of trait anger. In addition, trait

anger also correlated positively with BIS and general NA. This general pattern of correlations was replicated using the hostility subscale of the PANAS-X: BAS was positively correlated with PA and BIS with NA. A standard regression analysis, carried out in order to explore whether the relationships of anger to BAS and BIS were due to the overlap of general negative affect with BIS, revealed that only BAS and negative affect predicted anger for both scales: anger scale of Buss & Perry (1992) and PANAS-X hostility subscale of Watson & Clark (1991). The results indicated that individual differences in BAS would be related to individual differences in anger and that the positive association of approach motivation and was consistent with some contemporary approaches to emotion and motivation (e.g. Carver, 2001; Harmon-Jones & Allen, 1998; Harmon-Jones & Sigelman, 2001). It was also found that trait anger related to trait behavioral inhibition sensitivity at a simple correlation level.

Since previous research indicated an association of aggression with an increase in the left frontal cortical activity (Harmon-Jones & Sigelman, 2001), which has been found to be associated with the BAS (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997), a second study also included measures of individual differences in aggression, such as the full AQ (Buss & Perry, 1992), in order to assess whether aggression would relate to BAS (Harmon-Jones, 2003). The hypothesis was that if individual differences in physical aggression were due to differences in approach motivation, then physical aggression should relate to individual differences in BAS. Results showed again a positive correlation of BAS with trait anger and with physical aggression; but BAS did not correlate with the hostility subscale of the PANAS-X. Trait anger correlated also positively with general NA.

In both studies, general NA was statistically controlled, because its association with anger may lead to the association of BIS and anger (Berkowitz, 1999; Berkowitz, 2000; Watson, 2000). That is, the affect of anger has two subcomponents: a non-specific one that reflects the contribution of general NA, and a more specific subcomponent that reflects the unique qualities of anger (Watson, 2000). Results supported the prediction that anger may be associated with BIS at the simple correlation level, but when controlling for NA, anger will be only associated with BAS. Additional results revealed that physical aggression was positively related to BAS, negatively related to BIS, and positively related to NA. The hypothesis that anger is related to approach motivation is therefore supported, challenging strongly theoretical models that assume that approach motivation is only associated with PA.

Smits and Kuppens (2005), studying the relation between anger and BIS/BAS, replicated these results: anger may be associated with BIS at the simple correlation level. They argued that anger and BIS were related due to the overlap of both of them with neuroticism. Their start point was the hypothesis that anger, amongst other things, consists of a component related to NA and an approach action-related component, resulting in positive relations between trait anger and both BIS and BAS. Based on the fact that both, anger and BIS, have been associated with general NA or neuroticism (Berkowitz, 2000; Carver & White, 1994;

Costa & McCrae, 1992; and Watson, 2000), that anger is considered an emotion that is accompanied by a negatively valenced hedonic tone (Lazarus, 1991), and that BAS may play a role in anger because the latter is accompanied by a clear approach motivation. All these different dimensions -trait anger (TA), BIS, BAS and neuroticism- were measured in 323 psychology students, finding that TA was primarily correlated with BIS and BAS and that TA and BIS were both associated with neuroticism. A series of regression analysis confirmed this expectation: the association between TA and BIS was primarily due to the fact that both were associated with negative emotionality or neuroticism.

On the other side, an emotion can be felt and expressed by any person. In this sense, and according to Smits & Kuppens (2005), anger can be expressed and consequently copied in two ways: outwardly, usually directed at the target of one's anger, that is with an antagonist reaction (the term *anger-out* is usually employed for this type of anger coping style); and inwardly, implying anger regulation by suppression (*anger-in*) (Greenglass, 1996; Julkunen, 1996; Schwenkmezger & Hank, 1996). The relationship between these anger coping styles and BAS/BIS may be different than the one between anger experience and BAS/BIS. While anger correlates strongly positive with BAS and only at a correlational level with BIS, because of the overlap of BIS and anger with NA, anger-out coping style is correlated with BAS and the anger-in coping style with BIS.

Smits and Kuppens (2005) did a second study to exam this. Individual differences in BIS and BAS activity were assessed in 261 first year psychology students with the Dutch translation of Carver and White's (1994) BIS/BAS questionnaire (Smits & De Boeck, submitted for publication). The anger coping-styles were measured with an adaptation of the Anger Expression Scale (Spielberger et al., 1982), the Anger-out and Anger-in scales of the Self-Expression and Control Scale (SECS), (Van Elderen, Maes, Komproe, & van der Kamp, 1997). The tendencies to display physical and verbal aggression were also measured with the corresponding scales from the Dutch adaptation of the AQ (Buss & Perry, 1992; Claes et al., 1999), which included a TA scale, called the Anger scale. The results showed that the anger-out and the two aggression variables were negatively correlated with BIS, and positively with the BAS scales, whereas the anger-in displayed an opposite pattern of correlations: it was positively correlated with BIS and negatively with the BAS scales. Furthermore, anger-out and both aggression variables were strongly correlated with the Anger scale.

4. ASYMMETRICAL FRONTAL BRAIN ACTIVITY AND ANGER

Baseline frontal asymmetrical activity during resting has been found to predict emotional responses (Harmon-Jones, 2003 b). For example, individuals with relatively higher right-than-left frontal activity during baseline recording sessions exhibited larger NA responses to negative emotion-inducing films, and smaller PA responses to positive emotion-inducing films (Tomarken, Davidson & Henriques, 1990). Since anger is an emotion which can

produce aggression behavior, this behavior can be considered as forming part of the whole of the emotional response of anger. Consequently, if baseline frontal asymmetrical activity during resting could predict emotional responses, it would be theoretically possible to predict anger through brain activity measurement.

One of the first studies examining the relationship between anger and asymmetrical frontal brain activity (Harmon-Jones and Allen, 1998) tested whether dispositional anger, an approach-related motivational tendency with negative valence, would be associated with higher left-than-right anterior activity. Trait anger was measured using the AQ (Buss & Perry, 1992) and alpha activity by EEG. Trait anger was positively related with higher left-than-right frontal brain activity. Moreover, additional analyses revealed an association of high levels of trait anger with increased left frontal activity and with decreased right frontal activity. These results suggest that the frontal asymmetry is associated with motivational direction (approach versus withdrawal) rather than with emotional valence (positive versus negative). In addition, general activated PA and NA, assessed by the Positive and Negative Affect Schedule Children's version (PANAS-C) (Laurent et al, 1994), were related to the frontal asymmetry in similar magnitude to those found in previous research (Sutton & Davidson, 1997). That is, PA was related to relative left frontal activity and NA to relative right frontal activity. Presumably, PA and anger are related to left frontal activity because both emotions are approach-related. Moreover, controlling for PA and NA, separately and together, did not alter the magnitude of the anger-frontal asymmetry relationship. These results suggest that the relationship of anger to relative left frontal activity is independent of general activated PA and NA. According to Harmon-Jones (2004) the relationship between trait anger and left frontal activity might be entirely correlational and consequently subjected to the interpretational difficulties associated with correlational results.

On the other side, it is not known yet how state anger relates to asymmetrical frontal brain activity. For this purpose it would be convenient examining whether manipulated anger would increase relative left frontal activity, *maxime* when previous research found asymmetrical frontal activity to be responsive to manipulations of positive-approach and negative-withdrawal states. Brehm (1999) and Frijda (1986) have also suggested that emotions such as anger could be conceived of as having motivational functions and as generating action tendencies. Moreover, anger often generates approach-related action tendencies that are generally aimed to resolve the anger-producing event. We will be back to this later, when brain asymmetry and aggression will be commented. However, anger not always increases left frontal activity; for instance, “when individuals believed there was nothing they could do to rectify an angering situation, they still reported being angry but did not show an increase in relative left frontal activity” (Harmon-Jones, 2003 b).

Above-mentioned research data also suggest that anger is a negative and approach-oriented emotion, associated with relative left frontal activity, and that state anger produces aggressive behavior (see Ramirez, 2003). But before analyzing how aggression correlates with anger-related asymmetrical frontal activity, we would like to mention another recent

study related to asymmetrical frontal brain activity (Hewig, Hagemann, Seifert, Naumann & Bartussek, 2005). Their aim was to clarify the empirical association between BAS, BIS and cortical trait activity, assuming that the behavioral systems would have a different relationship with brain cortical activity (Hewig et al, 2004). The withdrawal system and the approach system would be subsystems of the behavioral activation system related to bilateral frontal cortical activity (right/withdrawal and left/approach). This suggestion was inspired by Harmon-Jones and Allen (1997), who reported on a relation of higher bilateral frontal cortical activity and higher scores on the BAS scale. Behavioral activation comprising approach and withdrawal motivation would also be in line with Wacker et al's (2003) arguments in favor of a relation of the BAS with behavioral activation irrespective of the direction of behavior. So, they had two hypothesis to test: the BIS/BAS model, and the bilateral BAS model. Broad band alpha activity under rest was used for quantifying cortical activity. A total of 59 right-handed German university students defined the sample: 29 males and 30 females. A German version of the BIS/BAS scales (Carver & White, 1994) was assessed individually at four occasions, each separated by four weeks. Extraversion and neuroticism were measured using the German version of the revised Eysenck Personality Questionnaire (EPQ-R) (Eysenck et al., 1985; German version: Ruch, 1999). EEG was recorded with the ECI-Electro cap system. Results showed a relation between higher left anterior temporal cortical activity and BAS, in line with previous findings (for example, Harmon-Jones & Allen, 1997). A positive association between the BAS and approach motivation may well explain it. However, there was no relation with asymmetry for frontal target sites: the correlation with anterior temporal asymmetry was specific for the CSD data, and the respective GLM follow-up tests did not corroborate the regional specificity of that relation. Furthermore, the BIS/BAS model may also not account for the findings of an association of higher bilateral frontal cortical activity and BAS. Finally, there was no significant relation between higher right anterior cortical activity and BIS. In few words, these findings provide rather weak support for the BIS/BAS model.

The *bilateral BAS model* proposed that both, the approach system and the withdrawal system, are related to the behavioral activation system (BAS), i.e. that BAS is related to behavioral activation irrespective of motivational direction. This hypothesis implies that higher bilateral (left and right) frontal cortical activity would be related to higher BAS scores. The analysis revealed that this was the case (via BIS/BAS scales). According to the GLM analyses, this finding was independent of the derivation method. In summary, Hewig et al (2005) findings are in line with Harmon-Jones & Allen's (1997) who also reported on a positive relation between bilateral frontal cortical activity and BAS. There were also revealed some correlations between BAS strength and bilateral as well as asymmetric anterior cortical activity, which may be difficult to be explained by the BIS/BAS and the bilateral BAS models. However, these results could be explained by third variables (see the discussion section of their paper). Consequently they don't lead necessarily towards a rejection of the BIS/BAS model.

5. BRAIN ASYMMETRIES AND AGGRESSION IN NORMAL POPULATION

In their above mentioned study on the relationship of asymmetrical prefrontal activity to aggression, Harmon-Jones and Sigelman (2001) suggested that anger would be a negative and approach-oriented emotion, that trait anger would be associated to relative increased left-prefrontal activity, and, consequently, that state anger would be associated with increased left-prefrontal activity. Moreover, anger would generate approach-related action tendencies that are generally aimed to resolving the anger-producing event. Their tested hypothesis was: if anger-related relative left prefrontal activity is involved in approach motivational processes, then higher anger-induced left-prefrontal activity may relate to increased aggression. In the case of an insult, the action tendency may be aggression. To assess it, forty-two right-handed men were randomly assigned to a condition in which they were insulted or not insulted. Subjects were told that another participant was in another room with another experimenter, and that the study would be conducted in connection with this other participant's study. Then they were also told that there were two perception studies, the first involving person perception and the second involving taste perception. In the first study, some participants wrote an essay on a social issue they found important (e.g., legal drinking age), and they argued in its support. Other participants read and evaluated their essay. Finally, participants read the feedback provided by the later ones. EEG was recorded immediately after the feedback, which manipulation was designed to be insulting or not.

The second perception study involved taste perception. This allowed the authors to obtain a behavioral measure of aggression. Participants were told that it was very important for experimenters to remain blind to the type of tastes to which participants were exposed in taste perception studies. The experimenter explained that one way to keep experimenters blind to the tastes was to have one participant assign the tastes to the other participant, and that the other participant would have to drink all that he was given. There were six types of beverages, which consisted of 11 oz of water with 1, 2, or 3 teaspoons of sugar, apple juice, lemon juice, salt, vinegar, or hot sauce mixed into the water. Thus, each of the six types of beverages had three concentration levels. It was explained that most people find the sugar water most pleasant and the hot sauce most unpleasant, and that the other beverages were rated in between these two extremes, with those closer to sugar being more pleasant and those closer to hot sauce being more unpleasant (presented in the following order: sugar, apple juice, lemon juice, salt, vinegar, hot sauce). Participants had to select one of the six types of beverages for the other participant, to pour some of each of the three concentrations into cups, and to cover the cups with lids when done; they were also told to label the concentration level on the bottom of each cup. The experimenter indicated that the participants might choose which type of beverage to administer and how much to administer to the other participant. Participants were also given a black sheet to cover the unused beverages when they were finished administering the beverages, to keep the experimenter blind to the type of beverage they chose. Aggression was calculated by assigning each beverage a value that corresponded to its unpleasantness, measure similar to

the technique developed by other researchers (e.g. Lieberman et al, 1999; McGregor et al, 1998).

Participants in the insult condition reported feeling angrier and being more aggressive than participants in the no insult condition. More importantly, they evidenced higher relative left frontal activity. Within this condition, those who evidenced higher relative left frontal activity in response to the insult reported feeling angrier and behaved more aggressively and valued the beverages as more unpleasant. These results support the prediction that manipulated anger causes increased relative left frontal brain activity. In addition, it was suggested that relative left frontal activity during an anger-evoking situation was associated to increased aggression. Since anger is conceived of as evoking an approach motivational tendency that should be represented as in higher relative left-prefrontal activity, the anger-related relative left-prefrontal activity would be associated to behavioral manifestations of the motivation to approach and attack. The results confirmed the predictions (Harmon-Jones, 2004).

Another interesting work concerning asymmetries and aggression is Faurie and Raymond's research, at the University of Montpellier (Knight, 2004) examining the number of left-handed people as well as the homicide levels in unindustrialised cultures. They excluded industrialised cultures due to a lack of data and because, they argue, use of firearms was unaffected by handedness. A correlation between levels of violence and the proportion of the left-handed population was found: the more violent a culture, the higher the relative proportion of the left-handers. This strong correlation suggests that left-handers are more likely to survive a fight hand-to-hand combat. So, left-handed people may be better equipped for close range mortal combat than those who rely on their right hands. Left-handed people are more prone to some health problems, suggesting the trait ought to disappear naturally over many generations through natural selection, but they continue to make up a small proportion of the human population. Being left-handed could also have some evolutionary advantage. For instance, the ratio of left-handers to right-handers is higher in successful sports people than it is in the general population, suggesting there is a definitive advantage to favouring the left hand or foot in competitive games, such as tennis. Because of the advantage in sports there could be a similar advantage in fights: right-handed competitors are less accustomed to facing left-handers, making them a more difficult proposition. Knight's (2004) finding contradicts the research presented up till now, which states that human aggression seems to be associated with higher relative left-prefrontal activity. If that were the case, right-handed people should be more violent than left-handed people.

Finally, Pietrini, Guazzelli, Jaffe and Grafman (2000), assessing imaginal aggressive behavior by positron emission tomography in healthy subjects, observed that subjects that have committed crimes show a function reduction at the right orbitofrontal cortex.

6. BRAIN ASYMMETRIES ON AGGRESSIVE POPULATION

The information presented up till now refers to normal population and normal emotion processing. Other studies, however, have analyzed brain asymmetries in people with some clinical disturbances and displaying aggressive behavior. Because of their disturbances, their brain asymmetries may underlie or correlate with their aggressive behavior.

Since the hippocampus is involved in the regulation of aggression (Gregg & Siegel, 2000) and in contextual fear conditioning (LeDoux, 1996), abnormalities in the hippocampus and disruption of prefrontal-hippocampal circuitry could affect dysregulation and impulsive or disinhibited behavior of the type observed in psychopaths. In fact, a recent study demonstrated an exaggerated structural asymmetry in the anterior hippocampus (R>L) in unsuccessful psychopaths, when comparing with successful psychopaths and normal control subjects by signalling disruption to frontal-subcortical neural circuitry (Raine et al, 2004). Furthermore, disruption to circuits involving the prefrontal cortex have also been implicated in both disrupted emotion regulation and antisocial-aggressive behavior (Davidson, 2000; Davidson et al, 2000; Hoptman et al, 2002; Raine, 2002; Raine et al, 2000), whereas frontal and executive function deficits are frequently identified in institutionalized psychopathic and antisocial individuals (Moffitt, 1993 b; Raine et al, 1998).

Previous research with the same sample used by Raine et al (2004), found that unsuccessful psychopaths had executive dysfunction compared with successful psychopaths (Ishikawa et al, 2001). Hippocampal abnormalities, when combined with prefrontal impairments that decrease behavioral inhibition, may most likely predispose to aggressive, inappropriate, and psychopathic behavior. Disruption to prefrontal-hippocampal circuitry could therefore result in impulsive, disinhibited, unregulated, and reward-driven antisocial behavior, more prone to be detected in the unsuccessful psychopath.

Normal hippocampal functioning is critical for the retrieval of emotional memories and contextual fear conditioning; e.g. for remembering the situational context of previously experienced aversive events (Fanselow, 2000; LeDoux, 1996). Unsuccessful psychopaths have repeatedly shown poor fear conditioning (Patrick et al, 1994), Hippocampal impairments that disrupt learning the social context of a previously punished response would make such offenders relatively insensitive to environmental cues signalling danger and capture. These impairments consisted in a relatively reduced left hippocampal structure and also a reduced autonomic reactivity to a social-emotional stressor (Ishikawa et al, 2001). In contrast, successful psychopaths, who lack hippocampal impairments, may have relatively normal contextual fear conditioning, making them more sensitive to cues predicting capture. LeDoux (1996), in a perspective consistent with clinical features of caught psychopaths, suggested something similar: uncoupling of the hippocampus from the amygdala could result in the expression of emotions inappropriate to the social context and also in poor insight into emotional states.

The association between information processing and hemispheric asymmetry has also been studied in suicidal people. Suicidal behavior could be defined as an aggression against oneself. Weinberg (2000) suggested that suicidal people showed a compensatory shift to left hemisphere information processing, due to functional insufficiency of their right hemisphere. This shift would manifest a tendency to dissociation and other typical traits for suicidal people. The assumption was that the right hemisphere organizes information into polysemantic context, associated to a pronounced alpha-activity in that hemisphere (Rotenberg & Weinberg, 1999), while the left hemisphere is involved in the organization of monosemantic information in logical context. In healthy subjects tested under normal conditions, the left hemisphere is always more active than the right, as revealed by the frequency and the amplitude of the alpha rhythm, or by the alpha-index: the intensity and uniqueness of daydream images show a positive correlation with the alpha-index (Kripke & Sonnenschein, 1978). Vivid mental visualization does not decrease EEG synchronization for persons who have well-developed image thinking (De Pascalis & Palumbo, 1986). In meditation, which corresponds to the right hemisphere pattern of thinking, alpha waves have high amplitude and become generalized (Orstein, 1972). People with high ability to generate polysemantic contexts display high alpha-activity over the right hemisphere. Conversely, people with low potential for formation of polysemantic contexts demonstrate desynchronized pattern of EEG in the right hemisphere (Rotenberg & Arshavsky, 1991).

The left hemisphere data-processing pattern, contrary to that of the right hemisphere, requires a higher cerebral activity because it attempts to arrange the available information, distinguishing the few relevant links in a multitude of irrelevant relations. It has been found that while the left hemisphere activates only closely related information, the right one activates both closely and distantly associated information to the same degree (Beeman et al, 1994). According to this, Coney & Evans (1999) reported that the right hemisphere immediately and exhaustively activates various meanings associated with a word, while in the left hemisphere access is restricted to the dominant meaning. Emotions thus are closely associated with the right hemisphere (Gloor, 1960; Joseph, 1982; 1986; 1988; 1994; Kaada, 1967; Liotti & Tucker, 1995; Rotenberg, 1993; Rotenberg & Weinberg, 1999).

Emotional experience is essentially polysemantic and multidimensional. Words can name emotions, but they cannot convey the essence of emotional experience. The essence of personal experience is the continuous transformation of emotions themselves into other emotions. Only polysemantic context, formed by the right hemisphere, can sustain emotional experience in its uniqueness, inner complexity, and elusiveness (Rotenberg & Weinberg, 1991). Particularly, patients who suffer right-hemisphere damage are less facially expressive than patients who suffer left hemisphere damage and have impaired recognition of facial expression of emotions. The right hemisphere is responsible for predictions that extend beyond the actual statistics and thus come close to the experience brought about by insight. Its mechanism is yet to be identified. Right-hemisphere predictions may be kaleidoscopic in nature: many versions of the future exist simultaneously and are equally

probable. As a result, the occurrence of any event, even if it is improbable from the perspective of past experience, has the same weight as a product of reasoning (Rotenberg, 1993; Rotenberg, 1994). Furthermore, Borod (1992) demonstrated a close association between the right hemisphere functioning and emotions.

The development of the right hemisphere depends on the quality of the relationship with the caregiver during the first years of the development (Rotenberg, 1994; Schore, 1996). If these interactions are mostly positive and mutual, they enable the infant to explore his or her emerging capacities in the safe environment created by affirming interaction. These interactions generate PA while NA are regulated by the caregiver as well as by the growing abilities of the infant. Mutual PA are accompanied by elevation in such substances as dopamine and norepinephrine that stimulate neural tissue growth, increase mutual connections between cortical cells and enable further maturation of the right cortex (Schore, 1994; 1996; 1997). These enable the emergence of "the potential space", one of the most important abilities of the right hemisphere (Winnicott, 1971). However, severe traumata or repeated emotional stresses, which cannot be adaptively balanced by the emerging infant's capacities, lead to predominance of unmanageable negative affects that elevate corticosteroids (Schore, 1997). This increase in corticosteroids inhibits dendritic branching, reduces brain nucleic acid synthesis, and leads to axonal death (Joseph, 1994; Schore, 1997). Dopamine increases under stress (Bertolucci-D'Angio, et al, 1990) and induces neurotoxic inhibition of mitochondrial respiration and defective energy metabolism (Ben-Schaler et al, 1994), which may lead to programmed cell death (Margolis et al, 1994). These stress-induced neurochemical changes lead to structural and functional alterations in the right hemisphere, which become the general, non-specific predisposing factor for psychopathology. In fact, the right hemisphere dysfunction is involved in various forms of psychopathology (Cutting, 1992; Flor-Henry, 1969; Rotenberg, 1994). Early traumata experienced as the "psychic catastrophe" (Bion, 1962) lead to formation of functionally insufficient right hemisphere that cannot form polysemantic context and regulate affects. On the other side, the ability of the right hemisphere to generate polysemantic context makes possible perception of spatial information, pain, and music, representation of self- and body-image (Joseph, 1996; Rotenberg, 1985; Rotenberg, 1993), processing of emotions and emotionally laden memories (Rotenberg, & Weinberg, 1999), and affect regulation (Schore, 1997).

Concerning the perspective of the functioning of the brain hemispheres, suicidal persons could show a functional deficiency of the right hemisphere, so this may increase suicidal tendencies. Under the burden of mental pain, the right hemisphere collapses. Consequently, the left hemisphere would largely determine the person's mode of experiencing and functioning. Mental pain coupled with decreased right hemisphere functioning determines the suicidal state of mind. Altshuler et al (1990) studied structural abnormalities in brains of 17 non-suicidal victims, 12 schizophrenics, and 10 psychiatric controls, demonstrating that, similarly to schizophrenics, suicidal people displayed a smaller area of the right parahippocampi than the controls did. Moreover, the shape of hippocampus and

parahippocampus was smaller on the right side of brains of suicidal people as compared to brains from two other groups. This demonstrates the existence of an association between the abnormalities in the right hemisphere and suicidal tendencies, but it does not clarify whether this relationship is causal or merely correlative.

In relation to neurotransmitters, a number of studies in suicidal persons have shown a reversed hemispheric asymmetry of serotonin functioning. Arato and colleagues (1991) compared the imipramine binding -the measure of activity of serotonin autoreceptors- in both hemispheres of brains of 23 suicide victims and 23 controls. The findings were clear-cut: non-suicidal persons had an increased binding in the right hemisphere as compared to the left hemisphere, whereas suicide victims showed elevated binding in the left hemisphere as compared to the right hemisphere. This asymmetry was more pronounced among violent suicides. This finding was supported by other studies (Demeter et al, 1989; Tekes et al, 1988); but not by Arona et al (1991). Another study (Joyce et al, 1992) showed that normal people displayed increased noradrenergic activity in the right hemisphere, whereas the young schizophrenics who committed suicide did not demonstrate such asymmetry.

Finally, another pioneer study (Graae et al, 1996) also pointed out a dysfunction at the right hemispheric among suicidal people. The EEG activity of 16 suicide attempters was compared to the one of 22 normal adolescents. Normal subjects showed higher alpha activity in the right hemisphere than in the left, instead of the trend in the opposite direction showed by the suicidal victims. Moreover, the non-depressed attempters, but not the depressed ones, displayed higher alpha activity in the posterior regions of the left hemisphere than in the right one. Alpha asymmetry over these regions was related to suicidal intent, but not to the depression severity. Although this study needs further replication, it clearly demonstrated a decreased alpha-activity in the right hemisphere of non-depressed suicidal attempters. Since decreased alpha-activity is a concrete expression of decreased ability to form polysemantic contexts (Ramirezdale, 1975; Rotenberg & Arshavsky, 1991), it may be concluded that suicidal persons have a diminished ability to generate polysemantic contexts. This difficulty affects personal experience of suicidal persons, their cognitive style, body and pain perception, and contributes to disintegrated self-perception, and to inability to regulate one's affects.

Taken together these results emphasize that non-suicidal people show increased right hemispheric functioning and decreased left hemispheric functioning, whereas suicidal victims are characterized by the reversed hemispheric activity.

7. FINAL COMMENTS

Since aggression -at least its more genuine type, the '*hostile-impulsive-reactive-hot blooded-defensive-affective*' one (Ramirez & Andreu, 2003)- is a behavior necessarily unchained for an anger-eliciting-event, we can not talk about aggression without assessing emotional

processing, anger. So, anger is a negative emotion that generates approach-related action tendencies that are generally aimed at resolving the anger-producing event, and that modulates aggression in humans (Harmon-Jones & Sigelman, 2001). In the case of an insult-event, the person will feel a state anger, and the action tendency may be aggression.

The anterior regions of the brain are specialized for expression and experience of positive (LH) and negative emotions (RH) respectively, and for approach and withdrawal processes, respectively. Although motivational direction has been confounded with affective valence in most of the literature, presumably PA and anger are related to relative left frontal activity, because both emotions are approach-related (Harmon-Jones & Allen, 1998). An increased left-prefrontal activity is associated with both, trait anger and state anger in normal and in pathological people. This evidence of the relationship between trait anger and left frontal activity, however, is entirely correlational and subject to the interpretational difficulties associated with correlational results.

The only work that provides some evidence of a brain asymmetry on aggression at more than a correlational level is Harmon-Jones and Sigelman's (2001). However, the relation between brain asymmetries and aggression in normal people has not been studied enough in order to find causal relations between both concepts. Aggressive normal subjects could reflect a hemispheric asymmetry, being the left prefrontal area, a typical area that is involved in emotional processing. Brain asymmetries were also found in psychopaths (Raine et al, 2004) and suicidal persons (Weinberg, 2000), providing evidence at a correlational level about their association with aggression. It might be expected therefore that the psychologically and physically healthier people would have a higher activity in the left frontal cortical region.

The present review finally leads to a suggestion for future research on the topic. Given that, according to the theory of brain asymmetries and laterality paradigms, there would be a specialization of functions -one hemisphere would be responsible for the faculties which have more to do with creativity and with artistic skills, whereas the other one for the faculties which have more to do with mathematics and with geometry; one would be primarily concerned with communication and intellectual activities, whereas the other one would serve chiefly emotions; one hemisphere would be prone to approach and PA, whereas the other one tends to withdrawal and NA- it would be appropriate to find out whether there would be real differences in the feeling of NA and PA between people with these different skills, or even between right-handed and left-handed subjects.

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