



# Aggressiveness of martial artists correlates with reduced temporal pole grey matter concentration

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## ARTICLE INFO

### Keywords:

Martial art

Aggression

Violence

Magnetic resonance imaging (MRI)

## ABSTRACT

Perception and practice of violence have hedonistic aspects associated with positive arousal (appetitive aggression). Earlier studies have mainly investigated the aetiology of aggressive behaviour in forensic/psychiatric patients. The present study examined structural brain characteristics in healthy people practicing violent sports (martial artists) compared to controls not showing violent behaviour. Aggressiveness was assessed in 21 male healthy martial artists and 26 age-matched male healthy controls using the aggressivity factors questionnaire (FAF). Participants underwent structural T1-weighted MRI. Grey matter (GM) differences were analysed using voxel-based morphometry. Whole-brain analyses of the main effects of group and aggressiveness and their interaction were computed. An interaction effect between group and aggressiveness was evident in a brain cluster comprising the left temporal pole and left inferior temporal gyrus. In martial artists, aggressiveness was inversely related to mean GM concentration in this cluster while in controls the opposite pattern was evident. Since these temporal brain regions are relevant for emotion/aggression regulation and threat appraisal, the increased GM concentration in aggressive controls might reflect a stronger cognitive top-down inhibition of their aggressiveness. Lower GM concentration in more aggressive martial artists may indicate a reduced need of inhibitory cognitive control because of their improved self-regulation skills.

## 1. Introduction

From an evolutionary point of view, aggressive behaviour is a widespread phenomenon in animals and humans (Krämer et al., 2011; Pietrini and Bambini, 2009). Violence against the own species occurs in almost all mammals (Gómez et al., 2016; Porges and Decety, 2013). Lorenz (1963) has explained this remarkable abundance by reproductive advantages for more aggressive individuals and their aggression disposing genes. This kind of behaviour is a prerequisite for building and dominating hierarchies, which goes along with power and higher reproductive success (Elbert et al., 2010).

Human aggression has been defined as every kind of behaviour against other people/beings to hurt them or to cause harm (Anderson and Bushman, 2002; Perach-Barzilay et al., 2012). Aggression is a complex, heterogeneous and multifactorial construct (Dorfman et al.,

2014) with diverse motives and triggers (Wahlund and Kristiansson, 2009) and thus has a wide range of different expressions and aspects (Dambacher et al., 2015). Due to this heterogeneity a variety of categorizations have been proposed (Anderson and Bushman, 2002), with the most prominent one differentiating between *reactive/impulsive* and *proactive/instrumental* aggression (McEllistrem, 2004). The aim of proactive aggression is to get positive reinforcement by dominating, offending or killing the victim, whereas the one of reactive aggression is to defend from threat, provocation or frustration (Anderson and Bushman, 2002; Bogerts et al., 2011; Elbert et al., 2010; Schlüter et al., 2013).

Usually aggression is regarded to be associated with negative emotions and motives, like anger or anxiety (Crombach and Elbert, 2015). On the other hand, the observation or exercise of aggressive behaviour can also be experienced as fascinating and attracting

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(Porges and Decety, 2013). Therefore, another categorization into *appetitive aggression* and *facilitative aggression* is common. Appetitive aggression is defined by feelings of control, excitement and pleasure elicited by perception and infliction of aggression and violent behaviour (Crombach and Elbert, 2015). In contrast, facilitative aggression results directly and spontaneously from perceived exposure to an acute danger (Elbert et al., 2010). What is special is, that appetitive aggression appears in all societies and, for example, the interest in watching martial arts or competitive combat sports or even the practice of these sports are most probably a reflection of it (Weierstall et al., 2014).

Aggressive behaviour in general has been associated with structural alterations in diverse brain regions in psychiatric and forensic populations (Bufkin and Luttrell, 2005; Witzel et al., 2016). In his temporo-frontal model of escalation, Potegal (2012) describes that the temporal and frontal lobes modulate aggression through their connections with amygdala, hypothalamus and brainstem. Temporal brain areas are described as functioning on early stages in terms of appraisal of danger or provocation. On the other hand, frontal brain areas, especially the orbitofrontal cortex, rather function as an inhibitory system (Potegal, 2012). Some studies reported decreased regional grey matter (GM) volumes in prefrontal and medial temporal regions in aggressive psychiatric populations, for example patients affected by psychopathy (Ermer et al., 2012) or impulsive-aggressive personality disorder (Dolan et al., 2002).

Schiltz et al. (2013) compared CT and MRI scans of violent inmates, non-violent inmates and healthy controls, showing structural abnormalities in frontal, parietal as well as medial temporal areas in violent inmates. Another study found increased GM volume in the cerebellum and decreased GM volume in the dorsolateral prefrontal cortex in violent offenders as compared to controls (Leutgeb et al., 2016). Within high-risk violent offenders, Leutgeb et al. (2015) reported a positive correlation between (para)limbic (orbitofrontal cortex, insula) GM volume and antisociality as well as violence recidivism risk.

Dolan et al. (2002) investigated the frontal and temporal brain volume of personality-disordered offenders compared to controls, showing a 20% smaller temporal lobe volume in offenders. Furthermore, another research group studied the cortical thickness and brain volume of men with antisocial personality disorder (APD), male schizophrenic patients with and without history of violence as well as healthy non-violent men. Males with APD, compared to controls, showed reductions in whole-brain and temporal lobe as well as increases in putamen volumes. In male violent schizophrenic patients compared to non-violent patients decreased whole-brain and hippocampal as well as increased putamen volumes were observed (Barkataki et al., 2006). Moreover, patients (APD and schizophrenia) with a history of violence had lower anterior cingulate cortex volumes in comparison to healthy controls (Kumari et al., 2014). Furthermore, Narayan et al. (2007) reported an association between violence and cortical thinning in (particular right) medial inferior frontal and lateral sensory motor cortex.

Some research groups focused on the investigation of (former) prison inmates with psychopathy according to Hare (1991) compared to healthy controls in regard to their brain volume. Psychopathic forensic inpatients compared to controls had GM volume reductions in (pre)frontal as well as temporal brain regions (Müller et al., 2008; Yang et al., 2005). Ly et al. (2012) report cortical thinning (e.g. left insula, dorsal anterior cingulate cortex, bilateral precentral gyri, bilateral anterior temporal cortices, right inferior frontal gyrus) in psychopathic inmates compared to controls. Incarcerated men's psychopathic traits are further associated with decreased amygdala, orbitofrontal cortex, temporal pole (bilateral) and posterior cingulate cortex volumes (Ermer et al., 2013, 2012).

When studying psychiatric or forensic patients many potential confounds have to be taken into account, such as underlying mental disorders, hospitalization or imprisonment duration. Also, forensic samples tend to be heterogeneous, sometimes mixing APD and

psychopathy or sometimes excluding psychopaths (Leutgeb et al., 2016). For that reason it is important to study aggressiveness and its neural correlates in healthy subjects as well. Matthies et al. (2012) found in 20 healthy controls with normal lifetime aggression scores that participants scoring in the upper normal range showed a 16–18% reduction of the amygdala volume; however all subjects in that study had an aggression score that was still within the normal range. In a large multicentre investigation, Besteher et al. (2017) studied the correlation of irritability and brain structure (cortical volume, cortical thickness and gyrification) in 409 healthy adults from the community. The cortical volumes in the bilateral anterior cingulate cortex, the bilateral orbitofrontal cortex, the left lingual gyrus and the postcentral gyrus were positively correlated with self-reported irritability/aggression. Since the sample was recruited as healthy controls from the community, the aggression levels were low (Besteher et al., 2017).

Until now, violence and aggressive behaviour were mainly investigated within forensic or psychiatric populations (Anderson and Kiehl, 2014; Bogerts et al., 2011; Pardini et al., 2014). The two studies mentioned above investigated aggressiveness in a sample of healthy persons from the community. In these studies aggressiveness was only assessed by responses to a self-assessment questionnaire. Therefore, the present study specifically addressed brain structural correlates of aggression in two healthy experimental groups, matched for age, gender and education, who also differed in their involvement in violent acts. We chose martial arts as an indicator of an individual inclination to engage in (appetitive) aggression, which appears in an otherwise normal life style, but not in a forensic or psychiatric context. Martial arts are a widespread kind of leisure and competition sports (Hoffmann, 2006) that involve legally exercising violence. The impact of practicing martial arts on adolescents' aggression is controversially discussed (Lotfian et al., 2011). However, Endresen and Olweus (2005) showed that participants in these sports have more frequently already been involved in antisocial activities when they are beginning to train. They also found that practicing power sports, like boxing, wrestling and oriental martial arts, leads to an increased involvement in antisocial behaviour apart from sporting activity (Endresen and Olweus, 2005).

To our knowledge this is the first study to investigate neuroanatomical correlates of aggression by comparing structural MRIs of healthy martial artists and healthy controls. Therefore, GM concentration of healthy martial artists and healthy controls was compared on whole-brain level. As described in earlier studies (Besteher et al., 2017; Matthies et al., 2012), we hypothesized to find GM concentration decreases in martial artists compared to control subjects in frontal (e.g., orbitofrontal cortex, anterior cingulate cortex) and medial temporal (e.g., amygdala) brain regions that have been implicated in the temporo-frontal model of escalation (Potegal, 2012).

## 2. Material and methods

### 2.1. Participants

Twenty-one healthy martial artists were recruited from local fight clubs along with 26 healthy control subjects from the general population. Both groups did not differ in age (martial artists:  $M = 26.14$  years,  $SD = 6.00$ ; controls:  $M = 25.19$  years,  $SD = 5.90$ ;  $t(45) = .55$ ,  $p = .588$ ; see Table 1). All subjects were male and, apart from two controls, right-handed. For martial artists, type(s) of martial art and years of experience were recorded. Approximately half of the reported martial arts were Asian martial arts (e.g. Muay Thai, Judo, Jiu Jitsu, Karate), whereas the other half were competitive combat sports (e.g. boxing, free fight, mixed martial arts), partly with the help of weapons (e.g. Wing Tsun, Escrima). The reported experiences in practicing martial arts ( $M = 8.63$  years,  $SD = 5.20$ ) ranged from a few years of school sports up to almost 20 years of fighting experience.

Exclusion criteria were age under 18 years, history of neurological or psychiatric disorders including alcohol/ substance dependency

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