Exploring the Relationship between Aggression and Executive Functions

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Abstract

A growing amount of evidence supports the relevance of executive functions (EF) in explaining aggressive behaviors. However, the relationships between Cognitive Flexibility (CF) and inhibition, two core abilities of executive functions, and subtypes of aggression, such as reactive aggression (RA) and proactive aggression (PA), remain ambiguous. The current study hypnotized that weak performance on CF and Inhibition was negatively associated with RA while a good performance on CF and Inhibition was positively associated with PA. In this online study, thirty-nine male adults filled in the Reactive Proactive Aggressive Questionnaire (RPQ) and completed two EF tasks, the Wisconsin Card Sorting Test and the Go/No-Go Task. Two multiple regression analyses were performed to test the hypotheses, in which RA and PA were entered as dependent variables and the two EF tasks as independent variables. Contrary to our expectations, no significant associations were found between CF and Inhibition and RA and PA. Findings from this study highlight the ambiguity of the results regarding this topic and the importance of carrying out more research on this topic, focusing on the specific subtypes of aggression and individual EF components.

Introduction

Aggression is defined as any behavior directed towards another being with the intent to cause harm (Anderson & Bushman, 2002). The perpetrator must believe that their behavior is actually harming the victim, and the victim must be motivated to avoid being harmed (Anderson & Bushman, 2002). Although aggression can provide competitive advantages, it is time-consuming and potentially risky for the perpetrators themselves (Sgoifo et al., 2014). For example, the association between coronary heart disease and rage has been established numerous times (Sgoifo et al., 2014). A plausible explanation for this association could be found in several studies that suggest that aggression-induced stress may lead to tachycardia, hypertension, and atherosclerosis (Sgoifo et al., 2014). Furthermore, aggression is linked to unhealthy behaviors such as drinking and smoking (White et al., 1993).

Aggression is considered pathological when it is exaggerated, recurrent, or expressed out of context (Nelson & Trainor, 2007). Aggression is present at all developmental stages, but while it is a part of the normal developmental process in early childhood (Greydanus et al., 1992), as toddlers and pre-school children display aggressive behaviors by screaming, throwing objects, or crying (Greydanus et al., 1992) aggressive behavior in adulthood could have devastating consequences. Some examples of exaggerated aggressive behavior include domestic violence, homicide, and physical or sexual abuse (Liu et al., 2012). Apart from injuries that could result from physical aggression, victims could also suffer from psychological consequences such as post-traumatic stress disorders, phobias, depression, and panic attacks (Liu et al., 2012). These are some of the reasons why it is crucial to better understand aggression, especially in males, since they are generally more aggressive than females in terms of physical aggression (Björkqvist, 2018).

Most authors tend to differentiate between different types of aggression. The first dichotomy that should be made relies on the causes of aggressive behaviors. Personological causes encompass anything that the individual brings to the current circumstance, such as characteristics, beliefs, and traits (Anderson & Huesmann, 2003). Situational causes are provided by the current situation that could enhance aggressiveness, such as a threatful object (a knife or a gun) or an insult (Anderson & Huesmann, 2003). Situational and personological together influence the behavior of the individual. Most people can be provoked to act aggressively in the proper setting, but some people are far more inclined to do so than others (Anderson & Huesmann, 2003). Trait aggression refers to a person's dispositional tendency to engage in physical and verbal aggression and experience aggressive cognitions or outbursts of anger (Buss & Perry, 1992). It is possible to derive two subtypes of aggressive traits from trait aggression: proactive and reactive aggression (Wrangham, 2017).

Proactive aggression (PA) is characterized by well-planned aggression to obtain an external (e.g., money) or internal reward (e.g., status or self-confidence) (Weinshenker & Siegel, 2002). It is characterized by a commitment to a victim, usually not preceded by a provocation, and, in many cases, it is characterized by a lack of arousal. Proactive aggressors may act because they believe they have a chance of achieving their objectives (Weinshenker & Siegel, 2002). This type of aggression is associated with personality traits such as psychopathy and stimulation-seeking tendencies (Cima et al., 2009). Bullying and stalking can be regarded as two examples of PA.

Reactive aggression (RA) is aggressive behavior occurring in reaction to a threat or frustration aimed at removing the threat or the cause of frustration (Weinshenker & Siegel, 2002). Perception of danger and feeling anger are considered important causes of RA (Dodge & Coie, 1987). Examples include bar fights and crimes of passion committed directly following the revelation of infidelity.

Some researchers raised doubts about the distinction between RA and PA, arguing that there is no need for such distinction (Bushman & Anderson, 2002). Other scholars have argued that the two subtypes would be challenging to distinguish in some cases, for example, when a person who is frustrated by a confrontation becomes angry (RA) and then plots an act of revenge (PA) (Bushman & Anderson, 2002). However, there is significant evidence supporting the view that RA and PA are not triggered by the same causes (Blair, 2016). Moreover, the neural mechanisms underlying reactive and proactive aggression are distinct (Blair, 2016; Dambacher et al., 2015).

This classification of aggression has been regarded as applicable to aggression exhibited by children, adolescents, and adults (Cima et al., 2013). In their study on correlates of the subtypes of aggression, Raine et al. (2006) showed that this bimodal classification of aggression fits their results considerably better than the one-factor model. Similarly, Cima et al. (2013) found that the reactive and proactive aggression subscales revealed a good balance between convergent and discriminant validity, indicating that these two aggressiveness subtypes have separate correlates. Moreover, they noticed that reactive aggression appears to be associated with impulsivity. Meanwhile, proactive aggression seems to be significantly associated with callousness, which is consistent with the view that proactive aggressiveness is premeditated and cold (Cima et al., 2013). However, most researchers have used children and juvenile samples (for example, see Cima et al., 2013; Raine et al., 2006). According to their findings, adolescents with high traits of proactive aggressiveness are likely to have more psychopathic traits. In contrast, the reactively aggressive adolescent is more impulsive and apprehensive (Raine et al., 2006).

Since trait aggression is defined as one's predisposition to act aggressively, it is important to investigate the factors that may alter this predisposition. One neuropsychological factor that might play a role in determining this predisposition is Executive Functions (EF). EFs are cognitive processes that integrate thoughts, movements, ideas, and actions during situations that necessitate problem-solving or inhibit improper behaviors (Ogilvie et al., 2011). Researchers gathered empirical support for a three-factor EF model (Diamond, 2013; Miyake & Friedman, 2012). This three-factor model entails three core functions: inhibition, working memory, and cognitive Flexibility (Diamond, 2013). Inhibition is the ability to control one's attention, actions, feelings, and emotions to overcome an internal or external lure. Inhibition allows one to selectively listen, concentrating on what they want while blocking attention to other stimuli. Working memory is the capacity to retain knowledge and use it later on when the information is no longer present (Smith & Jonides 1999). Cognitive flexibility is the last core function of EF; it refers to adapting to a continuously changing environment in a flexible manner (Cools, 2015). People persist in using specific behavioral strategies as long as these are perceived as optimal for goal attainment. However, they may also modify their approaches flexibly when there is a clear need for change (Cools, 2015). Cognitive flexibility suggests a learning process, implying that it may be acquired with experience. Finally, it entails that after executing a task for some time, one would be able to adjust to new and unforeseen environmental changes (Cañas et al., 2005).

Evidence on studies between EF and aggressive behavior points toward a negative relationship, meaning that the higher the executive functions, the lower the aggression levels (Nazmie et al., 2013). Nazmie et al. (2013) studied the impact of neuropsychological factors, specifically executive functions, and their relationship with aggressive behavior recidivism rates. They found out that poor executive function and aggressiveness may be linked to poor strategy formulation, impairments in cognitive flexibility, and impulsiveness. Furthermore, there are prospective studies suggesting that performance on EF tests may be useful in predicting future aggressive behavior (Brower & Price, 2001).

However, most of the literature on this association focused on clinical samples without investigating it in healthy individuals (Nazmie et al., 2013; Brower & Price, 2001). Research on non-clinical samples is scarce. One example is the study of Hoaken et al. (2003), who chose healthy individuals based on their performance on EF tasks. They found that participants with poorer executive functions had higher levels of laboratory-induced aggression.

Interestingly, other studies on healthy subjects did not find significant relations between EF and aggression (for example, see Gianicola et al., 2004; Krämer et al., 2011). For example, in a study conducted by Krämer et al. (2011), EF was measured by administering multiple tests for each core function and a questionnaire to measure aggression. No significant relationship was found between EF and aggression. One reason for these mixed findings could be that the type of studied aggression moderates the relation between EF and aggression.

Support for this explanation comes from several studies that have found distinct associations between EF and PA and RA. For example, studies have linked RA to executive functioning deficits (Ellis, Weiss, & Lochman, 2009), poor response inhibition (Feilhauer, Cima, Korebrits, & Kunert, 2012), and greater levels of impulsivity (Dodge et al., 1997). Meanwhile, other studies found a positive association between PA and improved response inhibition (Feilhauer et al., 2012). Furthermore, PA was not found to be significantly associated with decreased levels of self-control (Latzman & Vaidya, 2013).

Among the studies that explored the relationship between single functions of EF and the two types of aggression, Hecht and Latzman (2018) tried to expand the pre-existing literature on this topic. The hypotheses of their study were similar to the ones of the present study, assuming a negative relationship between EF and RA and a positive relationship between EF and PA. They gathered a sample of 384 participants with ages between 18 and 52 years. The participants had to complete a questionnaire to assess their levels and types of aggression. Afterward, they were tested using the Delis-Kaplan Executive Function System, which measures different core abilities of EF. Once gathered the results, they concluded that reduced goal-directed inhibitory capacities were related to high levels of RA. In contrast, increased monitoring, but not cognitive flexibility, could explain PA.

Investigation on the relationship between cognitive flexibility and the aggression subtypes in adult samples is quite limited. Nonetheless, there is one interesting paper on this relationship when looking at children's samples. Thomson and Centifanti (2018) studied the role of executive functions in relation to aggressive subtypes. Their findings suggest that impaired inhibitory control and cognitive flexibility may be more present in children who engage in reactive aggression. Children displaying PA traits do not differ significantly from the control group in terms of cognitive flexibility.

The present study aims at extending the literature on the relation between EF and aggression in healthy adult males. In particular, it will examine this relation by investigating both proactive and reactive aggression. The research questions are i) is there a relation between reactive aggression and executive functions, and ii) Is there a relation between proactive aggression and executive functions? Based on the literature, two hypotheses are formulated: i) low performance on inhibition and cognitive flexibility is negatively associated with RA, and ii) high performance on inhibition and cognitive flexibility is positively associated with PA.

Methods

Participants

This study recruited 42 healthy adult males, including 21 undergraduate students from the Erasmus University in Rotterdam, the Netherlands, and 21 participants who were not students. The students were recruited via the ERAS system, while the other participants were recruited using social media and advertisements. From these 42 participations, two were considered not valid because the participants had participated previously. Another participant was removed because he did not complete the session. The final sample included 39 male participants, with an age range of 19 to 53 with a mean age of 24.21 (SD = 8.58). Exclusion conditions included a weak command of the English language, a physical or mental condition, visual impairments, and no Internet access or inability to download a free app needed for both sessions.

Measures

The Reactive and Proactive Aggression Questionnaire (RPQ) (Raine et al., 2006)

The Reactive and Proactive Aggression Questionnaire (RPQ) (Raine et al., 2006) measured reactive and proactive trait aggression (Cima et al., 2013; Dinic et al., 2020; Raine et al., 2006). It consisted of 23 items that are scored on a 3-point liker scale. Of the 23 items, 12 measured proactive aggression, while the other 11 measured reactive aggression. The RPQ includes a total score and proactive and reactive aggression scores (Raine et al., 2006). The English version's internal stability was good for both the reactive (11 items, $\alpha = .84$) and proactive aggression (12 items, $\alpha = .86$) subscales (Raine et al., 2006; Seals et al., 2012).

Go/No-Go task (Donders, 1969; Littel et al., 2012)

The Go/No-Go task (Donders, 1969; Littel et al., 2012) used in the present study consisted of 501 trials, 100 of which were No-Go trials. In each trial, a vowel (A, E, I, O, or U) was presented in white against a black background for 500 ms, followed by a randomly varying period lasting between 400 and 600 ms before the following vowel was shown. If the vowel presented was different from the previous one, participants had to signal a 'Go' by clicking a button with their right index finger as quickly as possible. When the vowel was identical, participants had to refrain from pressing any key. For this experiment, inhibition is operationalized as the number of correct No-Go trials.

The Wisconsin Card Sorting Test (WCST) (Heaton et al., 1993)

The Wisconsin Card Sorting Test (WCST) (Heaton et al., 1993) was used to measure EFs. The test consisted of a set of trials in which four key cards and a deck of response cards were presented to the participants. For every trial, the participants had to pair a response card to one of the four key cards displayed on the screen based on different colors, shapes, and number of figures. The participants had to identify which classification rule (color, shape, number of figures) they needed to follow in order to match the cards. It is made clear at the beginning of the task that the classification rule can change without warning, as it does after ten correct trials. The task ended after six categories were achieved (every category twice) or after 128 trials. Cognitive flexibility is operationalized as the proportion of correct trials on the WCST (WCST Proportion).

Other measures included in the procedure which were not used for the present study are: The Interpersonal Reactivity Index (IRI), assessing trait empathy (28 items); the Self-Report Psychopathy Scale – Short Form (SRP-SF), assessing psychopathic traits, including callous-unemotional traits (28 items); State-Trait Anxiety Inventory (STAI), assessing state and trait anxiety (40 items) visual analog scales (VAS) for assessment of mood and physiological state at the moment; the 20-item Positive Affect and Negative Affect Schedule (PANAS); The Read the Mind in the Eyes Test-Revised (RMET-R) and The Point Subtraction Aggression Paradigm (PSAP).

Procedure

Participants were be informed that the study consisted of two parts. Both sessions were conducted online. During the first session, participants filled in the questionnaires (the RPQ, the STAI, the SRPS-SF, the PANAS, the VAS, and the IRI) and executed the WCST after providing informed consent. Following that, they were advised to take a 10-minute break before proceeding with the final two tests, the Go/No-Go task and the Read the Mind in the Eyes test.

During the second appointment, participants rated their mood using the VAS and the PANAS. After that, they performed the PSAP. Next, they filled in the manipulation check questions.

Statistical Analyses

First, correlations between variables describing RA, PA, CF, and Inhibition were calculated. After that, a multiple regression was performed in which RA was entered as the dependent variable, and cognitive flexibility (WCST Proportion) and inhibition (Correct Rejects) as independent variables represent Model 1. Afterward, another multiple linear regression was calculated (Model 2), in which PA represented the dependent variable and the independent variables were the same as Model 1. Correlations were calculated between the following variables: RA, PA, Correct No-Go trials, and proportion of correct trials on the WCST. IBM SPSS statistics 27 program was used to conduct the analysis

Results

Before performing the analysis, the data were screened for outliers, and the multiple regression analysis' assumptions were checked for each multiple regression (see Appendix). The descriptive statistics of the variables of both models were presented in **Table 1.**

Table 1

Descriptive Statistics

	N	*Min*	*Max*	*Mean*	*Std. Deviation*
Age	39	19	53	24.21	8.51
RA score	39	1	14	5.92	3.61
PA Score	39	0	12	1.72	2.39
WCST Proportion	39	.71	10.17	4.122	2.28
No-Go Corr. Rejects	39	1	401	315.33	150.35

Next, correlations between all the variables included in the study were analyzed (**Table 2**). Only the variables PA and RA were found to be moderately correlated, $r = .46$, $p < .01$.

Table 2

Correlations between the main variables

	1	2	3	4
1. RA score	1			
2. PA score	.46**	1		
3. WCST Proportion	.18	-.14	1	

4. No-Go Corr. Rejects	-.15	-.18	.25	1

** Correlation is significant at the 0.01 level (2-tailed)

In order to answer the research questions, two analyses were carried out. Results from Model 1 are represented in **Table 3** and **Table 4.** The results of the multiple linear regression indicated that the two predictors explained only 7.6% of the variance (R^2=.076, F(2,36)=1.482, p= .241) in RA. There was no significant association between RA and the proportion of correct trials on the WCST, b = .375 , p = .160, as well as there was no significant association between RA and correct No-Go trials, b = .005, p = .209

Table 3

Proportion of Variance explained by Model 1

	R	*R^2*	*Adj. R^2*	*Std. Error*	*F Change*	*Df1*	*Df2*	*Sig*
Model 1	.276	.076	.025	3.571	1.482	2	36	.241

Table 4

Regression Analysis, RA predicted by CF and Inhibition

	B	*Std. Error*	*β*	*t*	*Sig.*
Constant	5.982	1.547		3.867	.000
WCST Proportion	.375	.262	.237	1.433	.160
Go-NoGo Corr. Rejects	-.005	.004	-.212	-1.280	.209

Afterward, the same analysis was performed for the dependent variable PA and the same two independent variables. Results from this second multiple linear regression showed no significant association was found between n the dependent variable PA and the two independent variables proportion of correct trials on the WCST (b = -.104, p = .558) and correct No-Go trials (b = -,002 p = .358) was found to be non-significant (**Table 5**). The results of the regression indicated that the two predictors explained 4.2% of the variance (R^2=.042, F(2,36)= .794, p= .460) (**Table 6**).

Table 5

The proportion of variance explained by the Model 2

	R	*R^2*	*Adj. R^2*	*Std. Error*	*F Change*	*Df1*	*Df2*	*Sig.*
Model 2	.205	.042	-.011	2.408	.794	2	36	.460

Table 6

Regression Analysis, PA predicted by CF and Inhibition

	B	*Std. Error*	*β*	*t*	*Sig.*
Constant	2.935	1.043		2.814	.008
WCST Proportion	-.104	.176	-.099	-.591	.558
Go-NoGo Corr. Rejects	-.002	.003	-.157	-.932	.358

Discussion

The present study was performed in order to better understand the mechanism behind aggressive behavior. A group of male participants was tested to determine whether Reactive Aggression and Proactive Aggression levels were related to cognitive flexibility and inhibition. In particular, whether low scores on CF and inhibition were negatively associated with RA while high scores on CF and Inhibition were positively associated with PA.

Results of the two multiple regression analyses showed that levels of inhibition and CF did not show any significant relationship with either RA or PA. In opposition with the hypotheses formulated for this study, results question the presence of a strong connection between aggression and EF in either positive or negative directions. Furthermore, RA and PA were moderately correlated in line with previous research, but this is considered normal as they are both subtypes of aggression (Cima et al., 2013).

Studies that have found a relationship between EF and aggression have used clinical samples, including participants suffering from neurological diseases or personality disorders. Xue et al. (2017) conducted a study exploring aggression in association with inhibition using a population of individuals with a history of childhood abuse and high levels of aggression. As for the present study, they took the Go/No-Go task as a measure for inhibition. The participants' brain activity during the task was measured using an Electroencephalogram (EEG). Performance on the task and the EEG revealed that inhibition was impaired in aggressive participants. Moreover, participants with a history of childhood abuse performed worse on the Go/No-Go task in comparison with the control group.

In another study by Meijers et al. (2017), aggressive offenders and non-aggressive offenders were evaluated on their performance on a set of EF (including both CF and Inhibition). Results of this analysis showed that violent offenders presented worse inhibition compared to non-violent offenders. Furthermore, worse CF was related to an increased chance of recidivism.

One behavioral study using healthy participants studying trait aggression and EF was performed by Kramer et al. (2011). Among the four EF measurements used in their research, high trait aggression was significantly associated with EF impairments only in one of them. The study of Kramer et al. (2011) is in line with the ones reported by the current study. An explanation for this could be that since all of the individuals in both studies were in good health, it is possible that the EF tasks used were not sensitive enough to detect minor differences in EF. Therefore, results from the present study do not indicate that there is no association between aggression and EF in general; it only stresses the fact that it is more difficult to find this relationship in healthy participants rather than in subjects displaying personality, behavioral or neuropsychological problems.

More support for this explanation comes from the review by Brower and Price (2001). According to their research, inhibition was significantly associated with frontal lobe impairment in subjects with both traumatic and neurodegenerative diseases. They found that these participants had higher aggressive and antisocial behaviors than subjects with no brain damage in the frontal lobe area. Studies including neuropsychological testing, Electroencephalogram (EEG)tests, and neuroimaging techniques have also found evidence of higher rates of prefrontal network dysfunction in aggressive and antisocial patients. The before mentioned paper from Kramer et al. (2011) included a second study that made use of an Electroencephalogram (EEG) to measure aggressive behavior in a laboratory setting using an aggression paradigm. Participants were divided into two groups based on their level of aggression. Although the high aggression and the low aggression groups were different in the way they responded to the provocations of the aggression paradigm, no evidence was gathered indicating that participants in the high aggression group showed poor EF. It appears that the type of population used for the study is crucial for the association between aggression and EF to be present.

Another explanation could be found in the fact that previous literature exploring the different subtypes of aggression (RA and PA) and different EF core abilities (Cognitive flexibility and inhibition) is limited. The studies mentioned above studied this relationship taking the concept of aggression as a whole without distinguishing between subtypes; this could also be an alternative explanation for the completely different findings of the current study.

The main limitation of this study is represented by the size of the sample. There were only 39 valid respondents; this made it difficult to determine the truthfulness of the outcome because of the low statistical power of the study. The consequences of low power are unreliability and low reproducibility of results (Button et al., 2013). One study that found a significant association between EF and RA/PA in healthy participants was recently performed by Hecht and Latzman (2017). While increased levels of RA resulted in being associated with decreased levels of goal-directed inhibition, high levels of PA were not found to be significantly related to cognitive flexibility. There are two main differences between the current study and the one performed by Hecht and Latzman (2017). The first stands in the number of participants recruited for the study, the 39 participants recruited for this research against the 384 participants recruited in their study. A third plausible explanation was given by the number of EF tests performed; they used the Delis–Kaplan Executive Function System, which measures the three EF components (inhibition, cognitive flexibility, and working memory) with multiple tasks. Differently, the present study only used two tasks, one to measure inhibition and the other to measure cognitive flexibility. The difference in sample size and the number of EF tests used could account for the significant difference between the findings.

Another limitation was that all the tests and questionnaires were administered online without any supervision nor assistance from an experimenter. It was impossible to account for any external factors such as distractions. This second limitation was caused by the lockdown restrictions, which made it impossible to perform the tasks on campus where the participants could have been surveilled while working on the tasks. Administering computerized neuropsychological tests online has both advantages and downsides. Among the advantages, there is the fact that researchers have the possibility to measures multiple dimensions of participants' performance which would be difficult to obtain by human observation (Feenstra et al., 2017). Online testing is overall more efficient as the costs in terms of time, money, and materials are reduced (Feenstra et al., 2017). It allows participants from everywhere to take part in the study (Feenstra et al., 2017); it also extends the possibility to participate to people with mobility issues or busy schedules as they are not required to travel to a test location (Feenstra et al., 2017). Nevertheless, there are also downsides to the use of online testing; there are both technical and contextual issues that could jeopardize test performance. The personal computer configuration of the participants, together with internet connection and speed, might represent a problem for stimulus presentation, recorded performance, and input processing (Feenstra et al., 2017). Among the contextual problems that might arise from the administration of an online study, there are differences in computer familiarity, stress, fatigue, poor task involvement, or anxiety (Feenstra et al., 2017).

Something that would be interesting to do in further studies would be implementing brain imagery and neurophysiological measures when studying EF and aggression. This could lead to new insights on the differences between individuals at the cerebral level. This could be useful, for example, to look at the contrasts between activity in either aggressive and non-aggressive people or between people displaying more RA and those showing more PA traits. It would be possible to see whether certain areas of the brain get activated in every participant.

In this study, the relationships between CF and Inhibition and subtypes of aggression, such as RA and PA, were explored. This paper highlights the ambiguity of the results regarding this topic; as a general relationship between aggression and EF, including CF and inhibition, seems to be established according to some studies, it did not seem the case of the specific subtypes of aggression and separate core function of EF. Future research should focus on further exploring the relationship between RA/PA and CF and inhibition, considering that in a healthy population, the link between these constructs seems absent.

References

Anderson, C. A., & Bushman, B. J. (2002). Human aggression. *Annual Review of Psychology*, 53(1), 27–51. https://doi.org/10.1146/annurev.psych.53.100901. 135231

Anderson, C. A. & Huesman, R. (2003). Human Aggression: A Social-Cognitive View. In M. A. Hogg & J. Cooper (Eds), *The Sage Handbook of Social Psychology* (pp. 297-232). Sage Publications.

Björkqvist, K. (2018). Gender differences in aggression. *Current Opinion in Psychology*, *19*, 39–42. https://doi.org/10.1016/j.copsyc.2017.03.030

Blair, R. J. R. (2016). The Neurobiology of Impulsive Aggression. *Journal of Child and Adolescent Psychopharmacology*, *26*(1), 4–9. https://doi.org/10.1089/cap.2015.0088

Brower, M. C., & Price, B. H. (2001). Neuropsychiatry of frontal lobe dysfunction in violent and criminal behaviour: A critical review. *Journal Of Neurology, Neurosurgery & Psychiatry*, 71(6), 720–726. doi:10.1136/jnnp.71.6.720

Burgess, P. W., & Simons, J. S. (2005). Theories of frontal lobe executive function: clinical applications. *The Effectiveness of Rehabilitation for Cognitive Deficits*, 211–231. https://doi.org/10.1093/acprof:oso/9780198526544.003.0018

Buss, A. H., & Perry, M. (1992). The Aggression Questionnaire. *Journal of Personality and Social Psychology*, *63*(3), 452–459. https://doi.org/10.1037/0022-3514.63.3.452

Button, K. S., Ioannidis, J. P. A., Mokrysz, C., Nosek, B. A., Flint, J., Robinson, E. S. J., & Munafò, M. R. (2013). Power failure: why small sample size undermines the reliability of neuroscience. *Nature Reviews Neuroscience*, 14(5), 365–376. https://doi.org/10.1038/nrn3475

Canas, J. J., Fajardo, I., & Salmeron, L. (2006). Cognitive flexibility. *International encyclopedia of ergonomics and human factors*, *1*, 297-301.

Cima, M., & Raine, A. (2009). Distinct characteristics of psychopathy relate to different subtypes of aggression. *Personality and Individual Differences*, 47, 835–840. doi: 10.1016/j.paid.2009.06.03

Cima, M., Raine, A., Meesters, C., & Pompa, A. (2013). Validation of the Dutch Reactive Proactive Questionnaire (RPQ): Differential correlates of reactive and proactive aggression from childhood to adulthood. *Aggressive Behavior*, 39, 99–113. doi: 10.1002/ab.21458

Dambacher, F., Schuhmann, T., Lobbestael, J., Arntz, A., Brugman, S., & Sack, A. T. (2015). Reducing proactive aggression through non-invasive brain stimulation. *Social Cognitive and Affective Neuroscience*, *10*(10), 1303–1309. https://doi.org/10.1093/scan/nsv018

Diamond, A. (2013). Executive Functions. *Annual Review of Psychology*, *64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Dinić, B. M., Raine, A., Vujić, A., & van Dongen, J. D. M. (2020). Cross–cultural Validity of the Reactive–Proactive Aggression Questionnaire Among Adults Across Five Countries. *Journal of Interpersonal Violence*, 088626052096667.

Dodge, K. A., & Coie, J. D. (1987). Social-information-processing factors in reactive and proactive aggression in children's peer groups. *Journal of Personality and Social Psychology*, *53*(6), 1146–1158. https://doi.org/10.1037/0022-3514.53.6.1146

Donders, F. C. (1969). On the speed of mental processes. *Acta psychologica*, 30, 412-431.

Ellis, M. L., Weiss, B., & Lochman, J. E. (2009). Executive functions in children: Associations with aggressive behavior and appraisal processing. *Journal of Abnormal Child Psychology*, 37(7), 945–956. doi:10.1007/s10802-009-9321-5

Feilhauer, J., Cima, M., Korebrits, A., & Kunert, H.-J. (2012). Differential associations between psychopathy dimensions, types of aggression, and response inhibition. *Aggressive Behavior*, 38, 77–88. doi:10.1002/ab.2012.38.issue-1

Feenstra, H. E., Vermeulen, I. E., Murre, J. M., & Schagen, S. B. (2017). Online cognition: factors facilitating reliable online neuropsychological test results. *The Clinical Neuropsychologist*, 31(1), 59-84.

Gelles, R. J., & Berkowitz, L. (1994). Aggression: Its Causes, Consequences, and Control. *Contemporary Sociology*, *23*(4), 575. https://doi.org/10.2307/2076412

Greydanus, D. E., Pratt, H. D., Greydanus, S. E., & Hoffman, A. D. (1992). Corporal punishment in schools: A position paper of the Society for Adolescent Medicine. *Journal of adolescent health*.

Heaton, R. K. (1993). Wisconsin card sorting test manual. *Psychological assessment resource*s.

Hecht, L. K., & Latzman, R. D. (2015). Revealing the nuanced associations between facets of trait impulsivity and reactive and proactive aggression. *Personality and Individual Differences*, *83*, 192–197. https://doi.org/10.1016/j.paid.2015.04.021

Hecht, L. K., & Latzman, R. D. (2017). Exploring the differential associations between components of executive functioning and reactive and proactive aggression. *Journal of Clinical and Experimental Neuropsychology*, *40*(1), 62–74. https://doi.org/10.1080/13803395.2017.1314450

Hoaken, P. N. S., Allaby, D. B., & Earle, J. (2007). Executive cognitive functioning and the recognition of facial expressions of emotion in incarcerated violent offenders, non-violent offenders, and controls. *Aggressive Behavior*, 33(5), 412–421. https://doi.org/ 10.1002/ab.20194.

Hoaken, P. N. S., Shaughnessy, V. K., and Pihl, R. O. (2003). Executive cognitive functioning and aggression: Is it an issue of impulsivity? *Aggressive Behavior* 29, 15–30.

Krämer, U. M., Kopyciok, R. P. J., Richter, S., Rodriguez-Fornells, A., & Münte, T. F. (2011). The Role of Executive Functions in the Control of Aggressive Behavior. *Frontiers in Psychology*, *2*. https://doi.org/10.3389/fpsyg.2011.00152

Latzman, R. D., & Vaidya, J. G. (2013). Common and distinct associations between aggression and alcohol problems with trait disinhibition. *Journal of Psychopathology and Behavioral Assessment*, 35(2), 186–196. doi:10.1007/ s10862-012-9330-5

Littel, M., van den Berg, I., Luijten, M., van Rooij, A. J., Keemink, L., & Franken, I. H. A. (2012). Error processing and response inhibition in excessive computer game players: an event-related potential study. *Addiction Biology*, *17*(5), 934–947. https://doi.org/10.1111/j.1369-1600.2012.00467.

Liu, J., Lewis, G., & Evans, L. (2012). Understanding aggressive behaviour across the lifespan. *Journal of Psychiatric and Mental Health Nursing*, *20*(2), 156–168. https://doi.org/10.1111/j.1365-2850.2012.01902.

Miller, J. D., & Lynam, D. R. (2006). Reactive and proactive aggression: Similarities and differences. *Personality and Individual Differences*, *41*(8), 1469–1480. https://doi.org/10.1016/j.paid.2006.06.004

Meijers, J., Harte, J. M., Meynen, G., & Cuijpers, P. (2017). Differences in executive functioning between violent and non-violent offenders. *Psychological Medicine*, *47*(10), 1784–1793. https://doi.org/10.1017/s0033291717000241

Nazmie, I. F., Nebi, M. R., Zylfije, H., & Bekim, H. (2013). Poor Executive Functioning Associated with the Risk of Aggressive Behavior Recidivism in the Forensic Community in Schizophrenic Patients. *International Journal of BioMedicine*, *3*(2), 94–99.

Nelson, R. J., & Trainor, B. C. (2007). Neural mechanisms of aggression. *Nature Reviews Neuroscience*, *8*(7), 536–546. https://doi.org/10.1038/nrn2174

Ogilvie, J. M., Stewart, A. L., Chan, R. C. K., & Shumd, D. (2011). Neuropsychological measures of executive function and antisocial behavior: A meta-analysis. *Criminology*, 49(4), 1063–1107. https://doi.org/10.1111/j.1745-9125.2011.00252.x.

Raine, A., Dodge, K., Loeber, R., Gatzke-Kopp, L., Lynam, D., Reynolds, C. ... Liu, J. H. (2006). The reactive-proactive aggression questionnaire: Differential correlates of reactive and proactive aggression in adolescent boys. *Aggressive Behavior*, 32, 159–171. doi: 10.1002/ab.20115

Reidy, D.E., Shelley-Tremblay, J.F., Lilienfeld, S.O. (2011) Psychopathy, reactive aggression, and precarious proclamations: A review of behavioral, cognitive, and biological research. *Aggressive Violent Behavior* 16:512–524

Sgoifo, A., Carnevali, L., & Grippo, A. J. (2014). The socially stressed heart. Insights from studies in rodents. *Neuroscience & Biobehavioral Reviews*, *39*, 51–60. https://doi.org/10.1016/j.neubiorev.2013.12.005

Smith, E. E. (1999). Storage and Executive Processes in the Frontal Lobes. *Science*, *283*(5408), 1657–1661. https://doi.org/10.1126/science.283.5408.1657

Thomson, N. D., & Centifanti, L. C. M. (2018). Proactive and Reactive Aggression Subgroups in Typically Developing Children: The Role of Executive Functioning, Psychophysiology, and Psychopathy. *Child Psychiatry & Human Development*, *49*(2), 197–208. https://doi.org/10.1007/s10578-017-0741-0

Weinshenker, N. J., & Siegel, A. (2002). Bimodal classification of aggression: affective defense and predatory attack. *Aggression and Violent Behavior*, *7*(3), 237–250. https://doi.org/10.1016/s1359-1789(01)000428

White, H. R., Brick, J., & Hansell, S. (1993). A longitudinal investigation of alcohol use and aggression in adolescence. *Journal of Studies on Alcohol, Supplement*, *11*, 62–77. https://doi.org/10.15288/jsas.1993.s11.62

Wrangham, R. W. (2017). Two types of aggression in human evolution. *Proceedings of the National Academy of Sciences*, *115*(2), 245–253. https://doi.org/10.1073/pnas.1713611115

Xue, J. M., Lin, P. Z., Sun, J. W., & Cao, F. L. (2017). Disrupted Executive Function and Aggression in Individuals With a History of Adverse Childhood Experiences. Journal of Nervous & Mental Disease, 205(12), 942–951. https://doi.org/10.1097/nmd.0000000000000743

Appendix

Assumption testing

An analysis of standard residuals was run for Model 1; this analysis showed that the data contained no outliers (Std. Residual Min = -1.61, Std. Residual Max = 2.40). A second analysis of standard residuals was carried out for Model 2; participant 39 was identified as an outlier (Std.

Residual = 3.89). Removing the outlier form Model 2 did not improve the model significantly; therefore, participant 39 was not taken out from the analysis.

Two scatterplots of the standardized predicted values showed that the data met the assumption of linearity and homoscedasticity when taking either RA or PA as dependent variables. Afterward, the assumption of multicollinearity was tested. When running the analysis with RA as the dependent variable, multicollinearity did not represent a problem (WCST Proportion, Tolerance = .94, VIF = 1.06; Correct Rejects, Tolerance = .94, VIF = 1.06), the same scores were registered when running the analysis with PA as the dependent variable. Thirdly, the Durbin-Watson test showed that the assumption of independence of residuals was met for both RA (Durbin-Watson value = 2.32) and PA (Durbin-Watson value = 2.03). The normal P-P plot of standardized residuals was performed for the models; in both cases, points were slightly deviating from the line, but not in a way that could compromise the reliability of the findings. Finally, there were not influential points biasing the models (Model 1, Cook's d Max = 0.295; Model 2, Cook's d Max = 0.764).