**Identifying and Classifying impulsive and non-impulsive aggressive behavior through Metaphorical Language analysis among adolescents.**

**Scientific Background**

Aggression is an observable behavior characterized by acts intended to harm another person who is motivated to avoid that harm. In the proposed study, the terms “aggression” and “aggressive behavior” are used interchangeably. Aggression includes verbal acts and physical acts with violence being an extreme form of aggression that can cause severe physical harm (e.g., serious injury or death) (Allen & Anderson, 2017; Anderson & Bushman, 2002; Hills, 2018). Each year over 1.6 million people worldwide lose their lives to violence, which is among the leading causes of death for people aged 15–44 years worldwide, accounting for 14% of deaths among males and 7% of deaths among females (World Health Organization, 2002). Aggressive behavior among adolescents age 14 – 18 years has been identified as a serious problem in European and American countries )[Organization for Economic Cooperation and Development, OECD, 2014](https://www.sciencedirect.com/science/article/pii/S1697260017300406" \l "bib0160)). School environment have been consistently linked to aggression problems in adolescence in the international scientific literature (Jiménez & Estévez, 2017; López et al., 2008, 2018). The aggressive behavior exhibited by some adolescents towards their peers and their teachers in the school setting may put them at high risk for emotional, psychological, and school difficulties, criminal offending and imprisonment, at the short and long term (López et al., 2018; Moffitt et al., 2002).

There is a distinction between two fundamental types of aggression: non-impulsive and impulsive aggression. Non-impulsive aggression is described as “instrumental,” and is characterized by calculated, controlled, and purposeful behavior lacking in emotion; it is used to achieve a desired goal, including domination and control of others. It is a planned behavior and is often prevalent in patients with psychopathic traits (Babcock et al., 2014; Dambacher et al., 2015; Raine et al., 2006 ). In contrast, impulsive aggression is described as “affective,” “reactive,” and “defensive,” and is characterized as emotionally charged, uncontrollable, and grossly disproportionate to a stimulus; it can lead to an agitated state in which verbally or physically aggressive acts are committed (Barratt et al., 1997; Blair, 2016; Liu, 2004; Miller et al., 2008). Impulsive aggression is closely related to poor information-processing, poor cognitive control and trait impulsivity; it is a social and psychological problem of substantial magnitude (Raine et al., 2006 ;Villemarette-Pittman et al., 2003). Notwithstanding, practically distinguishing between these two types of aggression remains difficult, presumably because of shared common characteristics underlying aggressive behavior, such as genes, personality traits, and sociological factors.

Predicting aggressive behavior is a major challenge for researchers, especially when it is unplanned (impulsive) and reactive. In the proposed study, we offer an innovative way to address this obstacle using linguistic analysis focusing on the use of metaphoric language. To date, exploration of language in the context of the study of aggression has most commonly been limited to examining verbal (syntactic and semantic) and non-verbal (prosody) dimensions of language and/or examining individuals with language disabilities (Cornwall & Bawden,1992; Leshem et al., 2020; Miller et al., 2008; Progovac & Benítez-Burraco, 2019). The ability to characterize an individual’s “linguistic profile” can offer clear theoretical and practical benefits for the study of aggression.

**Figurative language as a tool of perceptual and cognitive conceptualization and construction**

Figurative language is composed of different types of linguistic constructions, in particular: metaphors, idioms, proverbs, irony, indirect requests, and sarcasm. Figurative language is generally studied at the linguistic level; however, *understanding* figurative language requires the ability to process more than the literal meaning of the individual words and to go “beyond” in order to grasp the speaker’s intention in a given context (Giora, 1997; Shen, 1999). Both metaphors and idioms are prototypical forms of lexicalized nonliteral language and are remarkably frequent in everyday discourse (Gibbs, 1994). Indeed, metaphors have been estimated to occur in as much as 20% of spoken discourse (Steen et al., 2010). A metaphor forms a linkage between two seemingly unrelated domains of knowledge, creating a linguistic tool to transfer knowledge from one domain to another. There are several psycholinguistic theories explaining how metaphors are processed (Gentner, 1983; Ortony, 1979, 1993; Glucksberg & Keysar, 1990, 1993). For example, the class inclusion theory proposes that all metaphoric expressions are statements of categorization (Glucksberg & Keysar, 1990, 1993). According to this view, metaphoric expressions in the form of “A is B” (e.g., “This lawyer is a shark”), the target ‘A’ (lawyer) becomes a member of the category of the base term ‘B’ (shark) by means of mental construction of an ad-hoc *superordinate* *category* exemplified by the base term ("shark” representing *aggressive behavior*), and the target term becomes a new member of this superordinate category.

Metaphors, however, are not a homogenous class of expressions but instead vary along on a continuum, from novel metaphors at one end to “dead” metaphors (idioms) at the other (Fraser, 1998). Some scholars posit that the processing of a metaphor depends on its level of conventionality (e.g., Bowdle & Gentner, 2005). The meaning of a conventional metaphor is already lexicalized and stored in long term memory while novel metaphors involve base terms that refer to domain-specific concepts that have not yet been formulated (Gentner, 2005). According to the Career of Metaphors hypothesis (Bowdle & Gentner, 2005), novel metaphors are comprehended through a comparison process in which properties of the base and target terms are first extracted non-selectively and then exhaustively checked against each other (e.g., Gentner, 1983); once the properties that are relevant and informative have been identified, and the irrelevant properties of the base term are suppressed, those remaining properties are selected as the grounds for comparison (Bambini et al., 2011; Gernsbacher et al., 2001; Mashal, 2013).

Studies on metaphor comprehension tend to emphasize cognitive abilities but neglect the contribution of affect to metaphor processing. It is well-established that understanding novel metaphors requires cognitive abilities such as working memory, selective attention, divergent thinking, non-verbal intelligence, and mental flexibility (Beaty & Silvia, 2012; Chiappe & Chiappe, 2007; Kasirer & Mashal, 2016; Mashal, 2013; Menashe et al., 2020). However, Sopory (2005) adds to this picture by suggesting that our understanding of metaphorical expressions is achieved only by *also* accessing their affective meaning. According to this view, an affective attribute (usually a valence tag) can be associated with different cognitive elements such as a category, objects of a category, or features of a category. For example, in the metaphor “This lawyer is a shark” the base term (shark) has several valanced affective tags attached to it (e.g., a negative valence tag is associated with the merciless attribute of the base term). Further, in line with the class inclusion theory, the target term of the metaphoric expression (lawyer) inherits the affective valence of the base term (shark), hence contributing to full metaphoric comprehension. Consistent with this view, Mashal and Itkes (2013) demonstrated that emotional valence interacts with cognitive processes during familiar metaphor comprehension.

In addition to research relating to metaphor comprehension, exploration into the generation of metaphors also sheds light on their important communication role (Ortony, 1975). A metaphor provides a compact way of representing our experiences (the compactness hypothesis), a mechanism to talk about experiences that are hard to describe literally (the inexpressibility hypothesis), and a vivid way of perceiving or describing our experiences (the vividness hypothesis). Among several ways to elicit metaphor generation, it has been shown that describing subjective emotional states results in relatively higher incidence of metaphoric language use. Fainsilber and Ortony (1987) asked participants to provide verbal descriptions of emotional states they had experienced while involved in intense and mild emotional states. The findings showed that, in support of the vividness hypothesis, a greater tendency to use novel metaphors was found for descriptions of intense, over mild, emotional states. It appears that the more an experience was emotionally-charged, the more likely the participants were to generate rich and complex metaphors to explain how they felt (e.g., "a storm was brewing inside" to describe resentment). These findings emphasize that metaphors have a communication function that facilitates conveying one’s internal states. Thus, describing subjective internal states such as those occurring during the experience of intense emotions can be used as a tool to evoke metaphor generation.

Not mere figures of speech, metaphors can express and even shape thoughts, feelings, and behavior (Thibodeau et al., 2017). Indeed, the Conceptual Metaphor Theory (CMT; Lakoff & Johnson, 1980) posits that metaphors (e.g., *crime is a virus*) are not just linguistic devices, but also cognitive mechanisms through which the target domain (e.g., crime) can be understood in terms of the base domain (e.g., virus). The target domain is typically an abstract, less familiar concept whereas the base domain is usually more concrete and familiar. The structural mapping of the relations between the base and the target terms (Gentner, 1982) may shape the way people make inferences about the target domain. For instance, the metaphor “crime is a virus” elicits thoughts on fighting the crime problem similarly to a virus problem by, for example, vaccinating the city against crime (Thibodeau et al., 2017). Thus, according to the CMT, people may think, feel, and behave in metaphorical terms.

Conceptual metaphors are used to shape our understanding of subjective experience such as emotions (Barnden, 1997). In the view of the CMT, emotions like happiness and sadness are expressed as the conceptual metaphors of HAPPINESS IS UP and SADNESS IS DOWN, respectively, which yield metaphoric expressions like "happiness is being on cloud nine" and "sadness is feeling down”, respectively (Lakoff & Johnson, 1980). Another example is the conceptual metaphor EMOTION IS A HOT BODILY FLUID that yields metaphors such as “anger boiled up inside her” (Garkova & Soriano, 2014). Consistent with the inexpressibility hypothesis noted earlier (Ortony, 1975), we may use metaphoric language to describe affective experiences, especially intense ones, because literal language is sometimes insufficient to express the emotion.

In alignment with the CMT (Lakoff & Johnson, 1980), emotions are conceptualized in more concrete terms by referencing bodily sensory-motor experiences. For example, as the experience of anger increases skin temperature, ANGER is more likely to be associated mentally with a HOT than a COLD feeling; (Wilkowski et al., 2009). In addition, temperature-related words are used to describe cognitive-emotional and behavioral functions. As such, words associated with coldness typically indicate that the person acted with forethought, whereas words associated with heat typically indicate that the person acted spontaneously and impulsively.

Metaphors may also provide insights into personality. In this respect, the use of body-related metaphors has been linked to personality traits (Fetterman & Robinson, 2014). For instance, two body parts were particularly highlighted in previous research: the head and the heart (Swan, 2009) with the heart conveying emotion (“one has a big heart,” “follow one’s heart”) and the head conveying logic (“have one’s head on straight”). People who selected the head as the body part best representing themselves (i.e., the head as the locus of the self, “head-locus”) described themselves as more logical and their interpersonal relationships as “colder”. Those who selected the heart as the locus of their self (“heart-locus”), described themselves higher on measures of emotionality and interpersonal “warmth” (for a review, see Fetterman & Robinson, 2014). Interestingly, a link between identification with these particular body parts and aggression was also found: head-locus individuals were more interpersonally hostile, and, in comparison to heart-locus individuals, demonstrated greater aggressive behavior that included arguing and yelling (Fetterman & Robinson, 2014). A study that analyzed batterers’ metaphors found three main themes describing their aggression: metaphors of war (in terms of victory or defeat); metaphors of body as a dangerous space (anger is liquid that floods in the body); metaphors of deescalation (Eisikovits & Buchbinder, 1997). **Thus, mind-body connections, i.e., mappings of mind to body, appear to be reflected by the linguistic metaphors we use.**

According to the CMT, abstract concepts are understood as an analogy to concrete, embodied experiences represented by base terms (Lakoff, 1987; Lakoff & Johnson, 1980). These concrete concepts are linked to “image schemas” based on experiences across modalities (Johnson, 1987; Lakoff, 1987). The processing of abstract concepts can activate these image schemas directly, without even using metaphoric language. According to this perspective, language is merely the expression of such activation, not the cause of it (Pecher et al., 2011). Furthermore, it has been suggested that metaphors can potentially express thoughts and feelings that reside outside of awareness (Fine et al., 1973). Metaphoric language may thus reflect individual differences in the expression of image schemas associated with aggression.

**Aggression in adolescents – metaphoric language of aggression**

As a part of typical development, adolescents are often characterized by sensitivity to reward, threats, emotionality, and impulsivity, with a tendency to act in the spur of the moment regardless of the consequences (Dahl, 2004; Scott & Steinberg, 2008; Spear, 2000). This makes mid-adolescence a time of heightened vulnerability to aggressive behaviors. Some adolescents, however, appear to be more responsive to and more easily influence by their peers (Chein et al., 2011; Somerville, 2013), and more likely to engage in impulsive and reckless behaviors, particularly in emotional and social contexts (Hwang et al., 2016; Leshem & Rose, 2021).

There are various theoretical frameworks that attempt to characterize and categorize the risk factors for aggression based on a range of factors. For example, the general aggression model (GAM; Anderson & Bushman, 2002) is a widely-used, integrative, comprehensive theoretical framework for understanding human aggression. The GAM considers the role of social, cognitive, personality, developmental, and biological factors on aggression, and incorporates elements from many domain-specific theories of aggression, including cognitive neo-association theory, social learning theory, script theory, excitation transfer theory, and social interaction theory (see Allen et al., 2018 for an in-depth description). According to the GAM, attitudes, and the use of schemata and other knowledge structures related to hostility, anger, and aggression comprise an individual's readiness to aggress (Anderson & Bushman, 2002). Another framework to understand aggression is the ecological systems theory of human development (Bronfenbrenner,1977). In accordance with this framework, school aggression needs to be explained by taking into account mutual adaptation of the characteristics of the developing adolescents and the properties of their immediate surroundings, such as family.

To date, empirical evidence broadly links impulsive aggressive behavior with language deficits. Specifically, poor language skills limit the ability to verbally resolve interpersonal conflict (thereby regulate aggressive behavior) (Brownlie et al., 2004; Snow, & Powell, 2011; Wood & Liossi, 2006). This difficulty is exacerbated when combined with an impulsivity trait. Miller et al. (2008) proposed a model that implicates language skills as central to the modulation of impulsive aggression. They argue that linguistic processing is key to helping inhibit aggressive impulses, via cognitive restraint and emotional control among other abilities. People with non-impulsive (proactive) aggression have been shown to possess higher verbal abilities and greater capacity to control anger (Arsenio et al., 2009; Ramírez & Andreu, 2006). The few studies that have studied figurative language in relation to aggression found that metaphoric language has a role in modulating and often diluting the emotional intensity of language (Dews & Winner, 1995; Gibbs et al., 2002). Indeed, use of aggressive metaphors was observed among male batterers in a study by Buchbinder (2018) in which participants were asked to give self-descriptions of different experiences in their daily life. Analysis of their responses identified metaphoric expressions such as “*I have a short fuse”* and *“I blow up without thinking*,” that were interpreted as impulsive and aggressive, reflecting how anger build up until a moment of uncontrollable rage. Aggressive men also tended to focus on negative feelings and transform a range of feelings to anger (Edleson & Tolman, 1992).

In a related vein, adolescents who are high in trait impulsive and tend to “act before thinking” may be more likely to engage in impulsive aggression. Trait impulsivity encompasses several cognitive components such as deficiencies in response inhibition, hasty and unplanned behavior, action without foresight, stimulus-driven behavior, and reckless decision making (Leshem, 2016). In contrast, individuals with proactive aggression are more calculated before they act and their behavior is more goal-oriented, controlled characterized often by a lack of emotional arousal (Stanford et al., 2003b; Wrangham, 2018). Accordingly, the type of metaphors (conventional and novel) and the content of the metaphors that aggressors will generate are likely to be differentially related to these two types of aggressions. That is, it is expected that content of generated metaphors from adolescents with impulsive aggression would be characterized by “warm” words and expressions associated with hot temperatures (*he is hot-tempered*) while those with non-impulsive aggression would be expected to generate more metaphors relating to coolness. Indeed, theoretical writings about the nature of impulsive and non-impulsive aggression have often included terms such as "hot-headed" and "cold-blooded," respectively (Hubbard et al., 2010). Furthermore, because *conventional* metaphors are based on *automatic* retrieval processes (Mashal, 2013), adolescents with reactive and impulsive aggression would be expected to generate more of this kind metaphor than adolescents with proactive and non-impulsive aggression since the spontaneous, automatic-response quality of impulsivity closely aligns with processing automaticity of conventional metaphors. In contrast, because novel metaphor processing is associated with more demanding cognitive processes such as cognitive inhibition, working memory, and mental flexibility (Beaty & Silvia, 2012; Chiappe & Chiappe, 2007; Kasirer & Mashal, 2016), adolescents with non-impulsive aggression would be expected to generate more novel metaphors than conventional ones, and more novel metaphors compared to impulsive aggressors.

**Pilot data**: In psychological priming terms, aggressive metaphors can actually activate aggressive cognitive and emotional schemes in memory, making aggressive responses more accessible. We tested the hypothesis that adolescents with aggressive behavior are more prone to choose responses with aggressive content (distractors) as compared to people without aggressive behavior. This hypothesis was examined in a **pilot study** conducted in our lab (unpublished data). We tested idiom comprehension in adolescents (age range 14-16 years) with and without aggressive behavioral problems, recruited from a boarding school. We used an idiom comprehension test in which participants were presented with seven idiomatic expressions (e.g., “nichneset lo la’vridim”, literally meaning “getting into his veins”). Each idiom was followed by four interpretations: a correct idiomatic interpretation (“interfering with his life”), a literal distractor (“injecting him with a shot”); an aggression-related distractor (“she cut his blood vessels”), and an unrelated interpretation (“entering the house”). Cronbach’s alpha (internal consistency) for the seven items was high: α = .82. The results showed that the adolescents with aggressive behavior chose more aggression-related distractors (*M* = 1.86, *SD* = 1.21) than their control peers (*M* =.16, *SD* = .40), *t*(11) = 3.23, *p* < .01. These findings support the notion that aggressive individuals are more prone to violent cues perhaps because they maintain aggressive-related schemata in memory, ready to be accessed (Kalmoe, 2014). It should be noted, however, that activating aggressive cognitions does not always lead to aggressive behavior, just as individuals who generate violent metaphors and/or interpret metaphors as violent will not necessarily exhibit aggression. Yet, when a person holds hostile cognitive and emotional attitudes and beliefs toward the other, it increases the chance that they will exhibit aggressive behavior, especially in stressful situations. When it comes to adolescents, who are characterized by emotionality, hypersensitivity to social stimuli, low cognitive control, impulsivity and aggression related traits – hostility and anger, can be easily become a trigger for aggressive behavior.

One relatively new approach to assessing and predicting human behavior is machine learning (Bleidorn & Hopwood, 2018). Machine learning (ML) is an emerging method used to identify empirical associations between textual data and established personality trait measures. Although non-theoretical, this approach is nonetheless an empirical method, and has led researchers to develop assessment tools that can be used to reliably predict individual differences in aggression. Therefore, the planned study proposes using ML methodology for the first time to classify adolescents with impulsive aggression as compared to non-impulsive aggression based on their use of figurative language in a large-scale sample of the population.

**2. Research Objectives and Expected Significance**

The overarching goal of the proposed study is to test, for the first time, metaphoric language use as a tool for characterizing adolescents with aggressive behavior. Metaphoric language, either its comprehension or its generation, can reflect thoughts, emotions, and cognitive processes underlying the impulsive and non-impulsive aggressive behavior. Through the use of metaphoric language, we attempt to identify adolescents who are prone to act in a more reactive than planned aggressive behavior. This may ultimately lead to the development of more effective educational programs that fully address both the reactive and proactive functions that adolescent’ aggression serves. To this end, we plan to form a model using ML techniques to characterize impulsive and non-impulsive aggression based on metaphoric language in a large sample of adolescents. In particular, the research objectives are:

1. Examination of the relationship between aggression and choosing aggressive distractors during metaphor and idiom comprehension tasks.
2. Classification of adolescents with impulsive aggression and non-impulsive aggression through their metaphoric language comprehension and generation (type and content of the generated metaphors).
3. Construction of a new model that will provide comprehensive picture of the contribution of figurative language in distinguishing between adolescents with impulsive versus non-impulsive aggression. The model will take into account demographic attributes to control their impact on group classification.
4. Establishment of a new interdisciplinary collaboration. Given the paucity of data in the criminology-and psychoeducation interface, the proposed study suggests systemic examination, for the first time, of the link between metaphoric language use and aggression using ML techniques. Exploring the relationships between these two domains is important as it may provide a tool to observe one’s thoughts *about* one’s emotions. Describing emotions may reveal individual differences in underlying image schemata associated with aggression. Thus, interpretation and generation of metaphors, combined with aggressive and impulsive traits, may be used as a fingerprint for predicting aggression**.**
5. Characterization of aggression among subgroups such as females, and different socio-economics groups.
6. Contribution toward the ability to use **indirect** ways to reveal aggression by examining patterns of metaphoric language use, instead of directly examining aggressive behavior or traits.

The proposed study may have several important **theoretical, clinical, and practical implications**:

1. Theoretical implications – At the linguistic level, the study may inform us about metaphoric language comprehension in adolescents with aggression. At the conceptual level, the proposed study may shed light on individual differences using conceptual metaphors associated with emotions and aggression and, conversely, may also extend the power to predict aggressive behavior by adding a novel perspective to aggression models.
2. Educational implications – **Expanding the use of metaphors in educational programs as a tool for describing one’s emotions, experiences, and inner world may promote therapeutic insights (e.g., Buchbinder, 2018).** That is, creating in the school setting, educational programs that will: a) focus on learning and developing use of prosocial discourse using non-aggressive metaphors and idioms, which in turn, may affect their behavior. b) Strengthening the ability to articulate aggressive feelings and thoughts instead of acting aggressively.
3. Practical implications – From a public safety standpoint, the outcome model can provide ML algorithms that can be applied to cyber-violence to detect adolescents with aggression or at high risk for violent acts.

**Potential pitfalls and alternative solutions**

The study design, measures, and procedures were chosen to address potential pitfalls. To avoid multiple possible confounding variables, it seems prudent to exclude clinical and marginal populations (e.g., psychiatric patients or prison inmates) initially, and focus on the normative population. There are also several confounding factors which are not the main variables of interest in the present study but may be associated with the study variables, such as socio-demographic status, gender, and culture. Therefore, if a significant contribution of these variables to the model will be found, we will analyze the data according the relevant subgroup (e.g., specific ethnic group or socio-economic status). Another potential pitfall may be the possibility that participants will not tend to choose aggressive distractors from metaphor comprehension testing and will score at ceiling in the metaphor and the idiom comprehension test. If so, then the metaphoric language analysis will include only the metaphor generation task and we will focus on the different patterns of generated metaphors. However, given the large scale design of the study and the high variability of respondents, we expect to find individual differences in the tendency to choose aggressive distractors.

As the present study plans to recruit a normative sample and base the assessment of aggression on participant self-reports. If a link is found between aggression and metaphoric language use, a future study should follow, and be conducted among a cohort of participants with aggressive behavior to validate the study’s findings. This future study is important because activating aggressive cognitions does not always lead to aggressive behavior, just as individuals who generate violent metaphors and/or interpret metaphors as violent will not necessarily exhibit aggression.

Finally, participants may prefer to use literal language instead of metaphoric language in the metaphoric generation task. Avoiding this is crucial in the proposed study because we aim to analyze patterns of metaphoric language use associated with aggressive and impulsive traits. To overcome this potential pitfall, a specific kind of metaphor generation task was chosen, based on a study showing that describing intense self-experienced emotional states enhances metaphor (and specifically novel metaphor) generation. It should be noted that the ML will analyze all responses (both metaphoric and literal).

**3. Detailed Description of the Research Program**

**3.1. Main Hypotheses**

Our overarching hypothesis is that the use of metaphors will be related to individual differences in type of aggression (reactive versus proactive). In particular, we predict that:

1. Because adolescents with high aggression may be more susceptible to violent cues (Kalmoe, 2014), and our pilot data indicated a tendency among those with high aggression to choose aggressive distractors on the idiom comprehension test, we hypothesize that higher aggression will be associated with greater selection of aggression-related distractors in the comprehension tasks for idioms and metaphors.
2. As the level of non-impulsive aggression related traits increases (i.e., proactive aggression), the number of novel metaphors generated will increase. Because proactive aggression, as compared to impulsive aggression related traits (i.e., reactive aggression) is characterized by greater inhibitory control (e.g., Stanford et al., 2003b; Wrangham, 2018; Zhang et al., 2017), and because novel metaphor processing is associated with adequate cognitive inhibition and executive functions (Beaty & Silvia, 2012; Chiappe & Chiappe, 2007; Kasirer & Mashal, 2016), adolescents characterized with non-impulsive aggression will likely generate more novel metaphors than conventional ones. Conversely, because conventional metaphors are based on automatic retrieval processes (Mashal, 2013), we predict that adolescents with higher levels of impulsive aggression will generate more conventional metaphors than those with non-impulsive aggression.

For hypotheses 3 and 4, participants will be divided into 4 groups by their aggression and impulsivity traits (see Table 1) and ML technique will be applied.

1. The content of metaphors generated by impulsive aggression group (group 1), as compared to non-impulsive aggression group (group 2), will differ. Consistent with Lakoff and Johnson’s (1980) account of conceptual metaphors, we hypothesize that individuals with higher impulsive aggression may generate more “heat”-related expressions while describing their emotions (e.g., “to be angry is like having a bonfire in the brain”; “I have short fuse”). Similarly, we hypothesize that classifying metaphoric content related to various body parts, using ML, may be associated with the type of aggression (Fetterman & Robinson, 2014). We predict that, metaphors related to the head will be associated with “cold” non-impulsive aggression whereas those related to the heart will be associated with “hot” impulsive aggression.
2. The comprehensive model: Adolescents with high impulsive aggression (group 1) will be characterized differently than those with non-impulsive aggression (group 2) by reactive and proactive aggression, the number of aggressive distractors chosen (on both the idiom and the metaphor comprehension test), the number of conventional and novel metaphors generated (Metaphor Generation Test), and the content of the generated metaphors (written description of eight emotions), taking into account the demographic factors. We predict that the content of the generated metaphors will differentiate impulsive from non-impulsive aggression.

**3.2. Study Design and Methods**

**3.2.1. Participants**

The sample will be comprised of 1280 native Hebrew speakers students in 7th to 12th grades (Age range 13 - 18 years encompassing the middle and late adolescence period to yield an age distribution designed to facilitate the examination of age differences). Multistage stratified random cluster sampling will be used for sample selection. The primary sampling unit will be the center of Israel (Tel Aviv-Yafo). This area was chosen because it is a large city including among the highest violent crime rates in Israel (Weisburd & Amram, 2014). The secondary units will be public schools, that will be chosen from a stratified list of schools in Tel Aviv, provided by the Israeli Ministry of Education. All will be state-run, non-religious schools from the Jewish sector, located in lower and higher socioeconomic status (SES) areas and with SES ratings on a scale between 1 (high SES, top 10th percentile) and 10 (low SES, bottom 10th percentile). Ratings are determined by the Ministry of Education, based on the following measures: parent education level, per capita income, location (central versus peripheral), student country of birth (emigration from poorer nations), and educational climate, including level of violence (<http://ic.education.gov.il/>). Once the schools have been identified random sampling of classroom by age group (13-14, 15-16, 17-18) will be performed. The sample will be evenly split between males and females.

The participants, both adolescents and their parents, will sign informed consent forms, explaining the demands of participation, remuneration and they will be informed that they can stop participation at any point. Participants will be excluded for any self-report of the following: born in another country than Israel, neurological disorder, significant head injury resulting in concussion, previously diagnosed learning disabilities, sensory-motor disability, current major depressive or manic/hypomanic episode, history of psychosis, developmental disorder in childhood (e.g., ODD, CD), and currently-prescribed antipsychotic, antidepressant, or anticonvulsant medications. Also, all participants will complete an anonymous socio-demographic questionnaire including age, gender, country of birth of the participants’ parents, and employment.

**Aggression and impulsivity assessment will be measured by a number of well-known and well-validated self-report:** 1) *Buss-Perry Aggression Questionnaire* (BPAQ) (Buss & Perry, 1992) that asses physical aggression, verbal aggression, anger, and hostility; 2) *Reactive Proactive Aggression Questionnaire* (RPQ) distinguishes between reactive and proactive aggression (Raine et al., 2006); 3) The *Barratt Impulsivity Scale – 11* that measure trait impulsivity that comprises three subscales: motor, cognitive, and non-planning. (BIS-11) (Patton et al., 1995).

**Aggressive metaphoric and idiom language assessment will be measured by:**

*Idiom comprehension.*This task examines idiom comprehension and the tendency to select an aggression-related response; *Metaphor comprehension questionnaire* that examines the comprehension of conventional metaphors and novel metaphors; *Metaphor Generation Task* that examines the ability to generate metaphoric text while describing intense self-experienced emotional states.

**Ethics Statement**

After complete description of the study to the participant, all participants will be asked to provide informed consent of their parents. The study will be reviewed by the research ethic committee of Bar-Ilan University and will be carried out in accordance with the Declaration of Helsinki.

* 1. **Data analysis**

**Sub-groups**

To test hypothesis 2, 3 and 4, participants will be first divided into high and low aggression groups based on the median of the BPAQ total (above or below the median). Then, each of these groups will be further divided into two subgroups (see Table 1): impulsive -aggression (group 1) and non-impulsive aggression (group 2) based on their scores in BIS-11 (above and below the median, respectively). Note that impulsive non-aggression (group 3), non-impulsive non-aggression (group 4) sub-groups serve as the comparison groups of the impulsive-aggression, non-impulsive aggression, respectively. The dependent variable (DV) in these regressions will be the reactive and the proactive subscales of the RPAQ.

**Table 1**: The four subgroups: impulsive-aggression, non-impulsive aggression, impulsive non-aggression, and non-impulsive non-aggression

|  |  |  |  |
| --- | --- | --- | --- |
| Low | High | **BPAQ** |  |
| Impulsive - Non-aggression (3) | Impulsive - Aggression (1) | High | **BIS-11** |
| Non-impulsive - Non-aggression (4) | Non-impulsive – Aggression (2) | Low |

***Sample size and power***: G\*power software was used to determine a priori the sample size (Faul et al., 2009). The saturated model contains 9 predictors for each of the four sub-groups (see Table 1). We propose utilizing different levels of power as follows: 1) The percentage of explained variance (R2) of the entire model will be different from 0. For linear multiple regression: fixed model, small-medium effect size = 0.10, α error probability = 0.05, high power (1-β probability) = 0.95 and number of predictors = 9, the total sample size required is 245 participants; 2) We will examine the unique contribution of the two predictor variables (in the third step) beyond the other 7 predictor variables. For linear multiple regression: fixed model, R2 increase with test parameters; small effect size = 0.05, α error probability = 0.05, high power (1-β probability) = 0.95, number of tested predictors = 2 and total number of predictors = 7. The total sample size required is 312 participants; and 3) We will examine the sample size required for one of the coefficients in the full model to be significant; small-medium effect size = 0.10, α error probability = 0.05, high power (1-β probability) = 0.95 and number of predictors = 9, the total sample size required is 133 participants. In light of the required sample size for each analysis and in order to increase the power and the sensitivity, the current study will be comprised of at least 320 participants for each model, with a total of **1280** participants.

**Hypothesis 1 and 2: Hierarchical regressions**

To test *hypothesis 1*, Pearson correlations between aggression scores (as will be assessed by the BPAQ) and the distractor variables (as will be assessed in the idiom and the metaphor comprehension test) and analysis of variance that will compare the number of aggressive distractors between individuals with high vs. low aggression will be performed. Then, to test the contribution of the aggressive distractors to the explained variance of the aggression scores (BPAQ) a three steps hierarchical regression will be performed with demographic attributes (3 parameters) at the first step, trait impulsivity and reactive/proactive aggression traits (3 parameters: 1 parameter - BIS-11; 2 parameters- RPAQ, respectively) and the distractors (2 parameters: number of distractors from the metaphor and the idiom comprehension tests) at the third step. The DV will be the score on the aggression traits (BPAQ).

To test *hypothesis 2,* participants will be divided into four groups (see Table 1). A group by type of metaphor (novel, conventional) ANOVA will be performed on the number of generated metaphors. To test the contribution of the number of generated metaphors (novel, conventional) to the explained variance of the reactive and proactive aggression subscale scores (RPAQ) in each of the four subgroups a two steps hierarchical regression will be performed with demographic attributes (3 parameters) at the first step and the number of generated metaphors (conventional, novel) in the third step.

**Hypothesis 3 and 4: Machine learning analysis**

To test hypothesis 3 and 4 we will apply Machine Learning (ML) and Natural Language Processing (NLP) techniques. Specifically, we will base our work on distributed vector representations or embeddings that map variable length text to dense fixed length vectors as well as capture prior knowledge that have become the de-facto standard for text representation in deep learning-based NLP and in applications of NLP in social sciences (Pilehvar & Camacho-Collados, 2020; Kalyan & Sangeetha 2020; Goharian et al., 2021).

As we want to capture the semantic meaning of Hebrew words and texts, we will use available open source embedding resources (e.g., fast Text or Hebrew BERT) as well as train a model from available relevant Hebrew texts (e.g., Blogs or Twitter). These models will capture the semantic meaning of the participants’ texts and will be used as features for the ML models we will train.

Several computational analyses will be performed. First, we will try to build a computational model to identify metaphors and distinguish between novel and conventional metaphors. Metaphors will be characterized by semantic distance in vector space between the embedding vector of the emotional concept (e.g., happiness or anger) and the embedding vector of the phrase (the text participants will generate, i.e., the response). A metaphor will have a high semantic distance and will defined by a cutoff threshold. A novel metaphor will be defined based on co-occurrence probabilities in the general corpus of Hebrew between the words comprising the response (the generated text), and between the words in the response and the emotional concept (in the Metaphor Generation Test). We will manually tune the cutoff thresholds to obtain a computational model to identify metaphors.

Next, in order to test hypothesis 3 regarding “heat” and body-part related expressions, we will train a simple supervised model. We will manually assemble “heat”-related and “cold” expressions as well as body-part and neutral expression. Two simple classification models will be trained to distinguish between the annotated expressions based on their embeddings. These trained models will provide a "heat" or "body-part" score for any given expression and this score will be tested for correlation with the type of aggression as well as testing various thresholds for classification accuracy. If significant correlation is observed, these two scores will be used as features in the aggression and impulsivity classification model as described in the next step.

Apart from such directed heat and body-part features, we will also try exploratory methods to see if there are any other lexical or linguistic features that are highly correlated with aggression and impulsivity (e.g., words related to *war, victory, lose)*. Standard clustering methods will be run over all the Hebrew word embeddings to generate semantic word groups. We will then test to see if any of these word groups have high information gain scores with regards to the classification task (i.e., with aggression and impulsivity). A positive outcome would constitute an interesting and novel scientific outcome to be investigated further.

In order address hypothesis 4 and to distinguish between the various aggression and impulsivity traits, we will apply a standard deep learning classification model with all the various features as input – the embedding vectors of the different emotional concepts, the “heat” and “body-part” and metaphor usage features (as described above), as well as the various other non ML-based features such as trait impulsivity. We will assess the classification accuracy over a random held-out portion of the participants to see if the trained ML model is able to distinguish, with statistical significance, between impulsive and non-impulsive types of aggression among the held-out dataset. To better interpret the results of the supervised model we will apply explainable-AI methods (Burkart & Huber, 2021) to whiten the black box. For example, by listing the most contributing features or by highlighting the contributing words in the generated texts we will be able to shed light on our experimental results and gain insight into the factors that contribute to the classification.

**4. Provisions available to researchers for conducting the research**:

Prof. Mashal has vast experience studying metaphoric language processing and its underlying cognitive mechanisms. Her studies use behavioral and brain imaging techniques. Dr. Leshem has extensive clinical experience in adults with aggressive and impulsive behaviors, and research experience in the examination of aggression and impulsivity and their underlying cognitive and emotional mechanisms. The researchers have the full backing of a major research university with all of the administrative, academic, financial, and technical support required for the project.

We will collaborate with **Dr. Oren Glickman’s** laboratory in conducting the ML analyses. Dr. Glickman is a member of the Data Science Institute at Bar-Ilan University, and has access to the Institute’s computational resources, thus providing solutions for large-scale experimentation. The Institute’s flagship computational resources consist of 3 of NVIDIA’s latest DGX-1 servers, each consisting of 8 NVIDIA Tesla v100 GPUs. In addition, the Institute has additional GPU-based and CPU-based nodes dedicated for HPC - totaling over 350 CPU cores and over 50 GPUs. All servers have at least 128GB RAM. The cluster also has 120T 1T of fast storage available to member projects.  

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