Assessing Physiological Differences in Reactive and Proactive Aggression Scenarios in Adolescent Boys with Mild to Borderline Intellectual Disabilities: The Use of Interactive Virtual Reality

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Abstract

Aggression in children, particularly those with mild intellectual disability (MID) and borderline intellectual functioning (BIF), is an important problem with profound individual and societal implications. This study investigates the physiological distinction between reactive and proactive aggression in adolescent boys with MID-BIF, using virtual reality (VR). VR provides an innovative method to simulate real-life social interactions and offers a more accurate assessment of aggressive behaviour compared to traditional vignettes. This study aims to determine whether adolescent boys with MID-BIF in reactive aggression scenarios exhibit increased heart rate and skin conductance compared to proactive aggression and neutral scenarios. Also, we hypothesize that the mean heart rate and skin conductance will change more for those who have an aggressive response than for those who do not. In this study, 43 Dutch boys aged 10 to 17 years old (M = 14.37, SD = 1.89), we asked to engage in VR scenarios provoking proactive or reactive aggression. The results did not provide evidence that heart rate differed significantly between the various scenarios or significant changes related to aggressive responses in either proactive or reactive scenarios. However, boys showed higher skin conductance during reactive aggression scenarios compared to neutral and proactive scenarios. Also, skin conductance varied depending on whether the boys showed aggression, although specific group comparisons were not significant. Further research should continue to understand differences in physiological expressions. This may lead to targeted interventions to reduce the negative consequences of aggression in this vulnerable population.

Keywords: aggression | physiological measures | Virtual Reality | boys | MID-BIF

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Aggression is a complex social phenomenon with many causes and expressions. It involves feelings of anger or dislike that result in hostile or violent actions (Im et al., 2018). Aggression has consequences for both perpetrators and victims. It is an important component of conflict that can lead to physical and mental harm (Russu, 2022). Additionally, the development of aggression is an ongoing process that begins in childhood and continues into adulthood, affected by individual differences and environmental factors (Buchmann, 2014). Moreover, children who exhibit aggressive behavior in early childhood have an increased risk of negative outcomes, such as difficulties in school, problems interacting with peers and symptoms of depression (Campbell et al., 2006; Evans et al., 2018). The consequences of aggression can be severe, including low socioeconomic status, unemployment, criminal behavior, and social isolation (Buchmann, 2014). Therefore, understanding and addressing the underlying causes of aggression is crucial for the well-being of individuals and the population.

A theory to explain aggressive behavior in children is the social cognitive theory (Van Der Ploeg, 2014). This theory looks not only at observable behavior but also at a child's cognitions. The social cognitive theory assumes that aggressive behavior is the result of maladaptive cognitive processing. The child does not process social information appropriately, which also causes him or her to make incorrect interpretations and choices. Social problem-solving difficulties are key factors which contribute to externalizing and aggressive behavior in children with mild intellectual disability (MID) or borderline intellectual functioning (BIF) (Van Nieuwenhuijzen et al., 2009).

Mild intellectual disability (MID) is characterized by an intelligence quotient (IQ) below 70, affecting the ability to understand abstract concepts and impacting academic achievement and social functioning. Individuals with MID also struggle with social cues and poor social judgment (Medicine, 2015; Mild Intellectual Disability, 2024). Borderline intellectual functioning (BIF) includes individuals with IQ scores between 70-85, who also face significant challenges. Children with BIF have difficulties in executive functions like working memory and problem solving, and often exhibit lower levels of Theory of Mind (ToM) development, affecting their social understanding (Fernell & Gillberg, 2020; Baglio et al., 2016). Both MID and BIF lead to challenges in cognitive abilities, academic achievement, and social functioning. Poor social judgment and limited social skills make children with MID or BIF vulnerable in social situations, potentially leading to aggressive behavior due to difficulties in social problem-solving and information processing (Van Nieuwenhuijzen et al., 2005; Arsenio & Gold, 2006; Dekker et al., 2002).

Indeed, research shows that aggressive behavior problems are the most prevalent mental health problems in youth, especially for youth with MID-BIF (Douma et al., 2007). Children with MID-BIF are more likely to display externalizing behavior, which often result in additional social costs such as increased delinquency rates and the need for extra educational support and caregiving (De Castro, 2004). These behavioral problems of children with MID-BIF maintain over time, unlike in peers with average intelligence (Einfeld et al., 2011). These problems have negative consequences for both the individual and their environment and place a significant economic burden on society (Dodge, Coie, & Lynam, 2006). Aggressive behavior in childhood has also been identified as the leading cause of antisocial behavior in adolescence and adulthood (Schaeffer et al., 2003). It is therefore important to understand the mechanisms behind aggressive behavior, as with increased knowledge there is more capacity to develop effective treatments, thereby reducing and preventing it. Additionally, understanding the specific type of aggression most frequently expressed by boys with MID-BIF allows us to formulate and implement appropriate interventions.

Boys and girls appear to have different etiologies, and differ in important ways for aggressive behavior (Crick & Zahn–Waxler, 2003; Leman et al., 2019, p. 437). Girls engage more in indirect aggression while boys engage more and more frenquently in physical aggression (Björkqvist, 2018). While indirect aggression, like spreading rumours about someone, is considered an internalizing problem, physical aggression is seen as an externalizing problem (Mash & Wolfe, 2018). Boys score higher than girls on aggression, delinquent behaviour, attention problems and overall externalising behaviour (Weine et al., 1995). Longitudinal studies show that individuals with externalizing behaviors in adolescence experience multiple social and health impairments throughout adulthood, including lower educational attainment, unemployment, and financial difficulties (Colman et al., 2009). Therefore, understanding and addressing physical aggression in boys is crucial due to its higher prevalence and its long-term negative social and health impacts.

There are two forms of aggression: reactive and proactive. Reactive aggression involves intense feelings of anger and frustration, acting impulsively in response to threats or provocation (Jambon et al., 2018). It is emotion-driven and associated with increased physiological arousal, including heightened skin conductance and heart rate (Hubbard et al., 2002; Thomson et al., 2021; Armstrong et al., 2019), which may represent the “hot-blooded” perception. In contrast, proactive aggression is goal-oriented, involving coercion or harm to ensure success, and is characterized by decreased physiological arousal and hypoactive sympathetic functioning, often described as “cold-blooded” (Jambon et al., 2018; Armstrong et al., 2019). Proactive aggression shows reduced skin conductance and heart rate.

To investigate in which way and in which situation children with MID-BIF might react aggressively, one can use simulated situations using virtual reality (VR). With VR, children wear goggles that replace perceptions from the real world with digitally generated perceptions, giving the feeling that you are in a new environment (Freeman et al., 2017). In such a VR environment, children can see and interact with others. Traditionally, aggressive responses were examined through hypothetical social situations using vignettes. Children had to imagine what they would do, think, or feel in the hypothetical situation (Gould, 1996). For children this a complex task, and for children with

MID-BIF even more (Mild Intellectual Disability, 2024). In this case VR can be beneficial for children with MID-BIF, as they often experience limitations in cognitive skills (Schuiringa et al., 2016). With VR, it is possible to examine real life behavior, improve ecological validity and create emotionally engaging social interactions. VR is an artificial, 3-dimensional reality created by a computer. VR interacts with the user and aims that the user experiences the virtual environment as reality and can participate in it (Lemley & Volokh, 2017). When using vignettes, only general aggression is assessed, but with VR it is possible to distinguish between proactive and reactive scenarios (Lobbestael & Cima, 2021).

This research, using VR is promising because it could highlight the underlying physiological mechanisms that distinguish reactive and proactive aggression in boys with MID-BIF. For measuring aggression, VR has not been used before and is therefore promising, because it potentially offers a new method that is more immersive and less dependent on reading or imagination skills. By using VR to simulate real-life social interactions, we aim to increase the ecological validity of our findings and provide insight into the nature of aggressive behavior in this population. Also, a better understanding of the physiological correlates of reactive and proactive aggression in adolescent boys with MID-BIF may lead to targeted interventions and support strategies aimed at reducing the negative consequences of aggression.

The aim of the current study is to investigate the physiological distinction between reactive and proactive aggression scenarios in adolescent boys diagnosed with MID-BIF, using VR as a research tool. We hypothesize that in reactive scenarios individuals will exhibit an increased physiological response (i.e. an increased heart rate [1a] or an increased skin conductance [1b]) compared to proactive scenarios and neutral scenarios. In addition, we hypothesize that individuals with aggressive responses in reactive scenarios will show a higher mean heart rate [2a] or a higher mean skin conductance [2b] compared to those who did not have an aggressive response.

Methods

Participants

Participants were 43 Dutch boys aged 10 to 17 years old ($M = 14.37$, $SD = 1.89$). Participants were excluded from the study if they suffered from car sickness, because it was likely they could start feeling nauseous in the VR-environment. Participants were recruited at two institutions for young people with mild intellectual disabilities.

From the original dataset that contained 43 children, three participants were removed. Two participants were excluded due to missing measurements, and one participant was excluded because there were measurements available for only two types of scenarios (neutral, proactive or reactive). Other missing values were imputed by using the mean outcome of the other participants, resulting in a final dataset of 40 children, of which the average age was 14.35, (SD = 1.94). The participants were predominantly Dutch (n = 32, 80%) and six participants had indicated to be non-Dutch (15%). Of two participants the nationality was unknown (5%).

Procedure

The proposal for this study was submitted to and approved by The Faculty Ethics Review Committee of the Faculty of Social Sciences at Utrecht University (FETC 24-0265). A detailed protocol was drawn up for this study to guide data collection. The protocol was designed for testing days in schools. Teachers and, in some cases, group leaders completed, online questionnaires prior to the test day. The data of this research has already been collected in a study about the use of virtual reality for assessing social information processing and aggressive behavior in adolescent boys with MID-BIF (Verhulp & Schuiringa, 2020).

VR test

When conducting the VR test, VR equipment was carefully checked and prepared, including watches, laptops, and VR glasses. The person conducting the test carefully followed the protocol, paying attention to instructing the participants and noting observations during the test. Since all boys were native Dutch speakers, the VR test was conducted in Dutch. All test administrators were also Dutch.

First, the participant answered questions about their country of birth, father, and mother. The participant put on the watch on the non-dominant wrist. Before starting the VR game, the participant was shown a neutral 2-minute video, starting from 03:01 (Nature Relaxing Milieu, 2021). This video showed iconic landscape locations of Germany. Before watching the video, there was an instruction given: *"You are now going to watch a piece of a video. It is important that you don't talk during the video and try to stay as still as possible."* Participants were shown this video to ensure they started the task relaxed. After watching the neutral video, the VR classroom was put on. If the participant got nauseous or dizzy, they stopped the VR test.

The VR environment was designed by CleVR as a virtual school classroom where participants could move freely (in a four-by-four-meter space), interact with virtual peers, and play games (see figure 1a & 1b; Verhoef et al., 2021). The participants wore an HTC Vive VR headset with a combined resolution of 2160x1200, a diagonal field of view of approximately 110°, and support for 6DOF tracking. The VR characters, portraying boys of the same age with varied appearances, had pre-recorded responses by theater school children. The test administrator controlled the pre-recorded responses, including standardized reactions, and general statements that allowed for natural interaction (e.g., "I'm 10 years old. How old are you?"). During all scenarios, VR characters displayed neutral facial expressions, except changing to anger when participants showed aggression. Instructions, game rules, and scores were provided within the VR environment on a digital whiteboard and explained using instructions previously recorded by a female experimenter.

Figure 1a & 1b

The classroom within the VR-environment

Participants engaged in one main activity: knocking down cans with a ball. This game was chosen to increase emotional engagement and was enhanced with high scores and bonuses to control gains and losses experimentally (Verhoef et al., 2022). Before entering the VR, participants were briefed by the research assistant about the classroom rules (e.g., being friendly and respectful). Participants were told they would interact and play games with boys from other schools participating simultaneously in the study.

In the VR environment, participants experienced six scenarios in a predetermined fixed order: practice, neutral, object acquisition, competition, social provocation, and object provocation. The practice scenario allowed them to get used to the VR environment, and learn the rules. The neutral scenario consisted of a short interaction with a VR character to familiarize participants with answering questions. The following two scenarios (object acquisition and competition) focused on instrumental gain, with the goal to provoke proactive aggression. In the object acquisition scenario, participants had the choice to steal a ball from the VR character to earn additional points. In this scenario, the VR character walked away leaving his balls unattended. The participant had the choice to steal a ball to gain more points for himself. In the competition scenario, they could win by playing unfairly and reducing the virtual peer's score. The final two scenarios (social and object provocation) focused on provocation, and the goal is to provoke reactive aggression. In the social provocation scenario, two VR characters refused to let the participant join a game. In the object provocation scenario, the VR character ruined the participant's game by knocking over their tower. The provocation scenarios were presented last because it was possible that participants would react strongly, which could lead to spillover effects if presented first.

Measurements

The physiological measures, heartrate and skin conductance, will be assessed during 5 different scenarios. First the neutral scenario, where nothing is provoked, and the participant can get used to the VR environment. The neutral scenario is seen as the baseline condition. Then two scenarios where proactive aggression is provoked, by object acquisition and competition. After that, two scenarios where reactive aggression is provoked, by social exclusion and cheating. Skin conductance reactivity and heart rate reactivity will be calculated separately for each participant in each of the different conditions. This will be measured, within the VR-test, through a watch.

Physiological arousal

The physiological data, in this case heart rate and skin conductance, were measured by means of a biosensor worn on the wrist, the Empatica E4. This was specially designed for research so that it measured physiological signals in real time. This biosensor was designed as a watch. The watch had no display, so participants could not be influenced by the measurements. However, the watch did have a time marker button. All data were extracted from the watch and stored using Empatica E4 software.

Skin conductance. From the Empatica E4 software, the raw skin conductance level (SCL) was provided. This SCL consisted of a combination of tonic and phasic levels, which could be associated with arousal and stress. The electrodermal activity (EDA) thereby had a sampling frequency of 4 Hz and could be decomposed into several parameters. The EDA data tracked spikes, or non-specific skin conductance responses (NSCR) linked to stress and arousal. Using the software EDAExplorer, the correct peaks and artifacts (incorrect measurements) were identified within this data. The skin conductance was measured for each scenario, resulting in a minimum, maximum and a mean per scenario. In this research we used the mean skin conductance, where each mean of the reactive scenarios was compared to the other scenarios (that is, the neutral and proactive scenarios).

Heart rate. To measure heart rate, a photoplethysmography sensor was used, with a sampling frequency of 64 Hz. Heart rate was expressed in beats per minute. The Empatica E4 measured both heart rate and heart rate variability. Heart rate was measured for each scenario, within the time frame of a specific scenario. For each scenario the minimum, maximum and mean heart rate was conducted. In this research we used the mean heart rate of each scenario. Like skin conductance, each mean heart rate for reactive scenarios is compared to the other scenarios (that is, the neutral and proactive scenarios).

Aggressive response

In this research, we were interested in when the participants reacted aggressively. That is why we mainly looked at the aggressive responding after the proactive or reactive aggression trigger. This observation was coded using zero, one, and two. Where zero stood for: no aggression (prosocial behavior, solution-focused behavior, avoidance behavior); one stood for: mild aggression (coercion, verbal aggression); two stood for: severe aggression (physical aggression, destructive aggression, object-related aggression). Coded observations allowed us to link aggressive responses to different scenarios for each participant. This allowed us to see whether an increased heart rate or skin conductance was associated with an aggressive response.

Results

Data-analyses

Participant data for heart rate and skin conductance were initially stored separately in IBM SPSS Statistics (version 27). These data were combined into one long dataset, with each participant's scenarios in order. The long dataset was then restructured into a wide format, with the average heart rate and skin conductance for each participant across the scenarios juxtaposed. This way a repeated measures Analysis of Variance (ANOVA) could be performed. In addition, demographic information (age, nationality of participant and parents) and behavioural observations (aggressive reactions categorised as 0 = none, 1 = mild, 2 = severe) were merged into the broad dataset for comprehensive analysis.

Assumption checks

Before the main analyses were performed, the assumption of normally distributed variables was checked. For heart rate, the Shapiro-Wilk test indicated that all scenarios, except for scenario 4 ($p = .012$) and scenario 7 ($p = .024$) were normally distributed. Inspection of the histograms and Q-Q plots showed that all heart rate variables were approximately normally distribyted. For skin conductance (EDA), however, all scenarios appeared not normally distributed ($p < .001$). The histograms showed a positive skew with most participants having a low skin conductance and only few participants with high levels of skin conductance. To limit the deviation of normality, the EDA values were log-transformed to achieve a normal distribution, thereby meeting this assumption as well.

The descriptive statistics of the the average heart rate and skin conductance for all the scenarios are presented in Table 1.

Table 1

Descriptive statistics for heart rate and skin conductance

Variables	*M*	*SD*	*Min*	*Max*
Heart rate neutral	87.27	11.99	69.85	130.70
Heart rate pro-active I	89.28	10.54	70.79	124.12
Heart rate pro-active II	88.83	12.04	68.10	123.60
Heart rate reactive I	84.90	8.96	69.65	107.10
Heart rate reactive II	86.51	7.87	71.41	108.29
Skin conductance neutral	0.04	1.41	-2.32	2.65
Skin conductance pro-active I	0.09	1.44	-2.24	2.60
Skin conductance pro-active II	0.13	1.40	-2.19	2.73
Skin conductance reactive I	0.33	1.48	-2.10	2.99
Skin conductance reactive II	0.51	1.35	-2.01	2.99

Reactive versus proactive and neutral scenarios

Two repeated measures ANOVAs were conducted to investigate differences between the scenarios. Heart rate and skin conductance as the dependent variables, respectively. For heart rate and the log-transformed EDA values, Mauchly's Test of Sphericity indicated that the sphericity assumption was violated ($p < .001$), so sphericity was not assumed. Consequently, the Greenhouse-Geisser corrected results were interpreted.

Heart rate

The effect of scenario was not significant indicating that the average heart rate did not differ between the five scenarios, $F(2.7, 105.5) = 2.56$, $p = .065$, $\eta_p^2 = .061$, indicating a medium effect size. As the omnibus effect was not significant, the post-hoc tests were not interpreted. Using complex contrasts, it was found that there was no significant difference in average heart rate between neutral and proactive scenarios ($M_{diff} = -1.79$, $se = 1.23$, $p = .153$; see Table 2), and between the neutral and reactive scenarios ($M_{diff} = 1.57$, $se = 1.83$, $p = .396$). There was, however, a significant difference in average heartrate between proactive and reactive scenarios ($M_{diff} = 3.36$, $se = 1.32$, $p = .015$). This indicates that the heartrate was significantly higher in the combined proactive scenarios than in the combined reactive scenarios. Therefore, we reject Hypothesis 1a, as we expected that individuals would exhibit an increased heart rate in reactive scenarios compared to proactive and neutral scenarios. However, the results indicated the opposite, with heart rate being higher in proactive scenarios than in reactive scenarios.

Table 2

Complex contrast results of different scenarios for heart rate

	neutral vs proactive	neutral vs reactive	proactive vs reactive
Contrast estimate	-1.79	1.57	3.36
Std. Error	1.23	1.83	1.32
P	.153	.396	.015

Skin conductance

The Greenhouse-Geisser corrected results were used, which revealed a significant main effect of scenario, $F(2.2, 84.0) = 9.30$, $p < .001$, $\eta_p^2 = .061$. Pairwise comparisons showed that reactive scenario II ($M = 0.51$, $SE = 0.21$) resultated in a significantly higher average skin conductance than the neutral scenario ($M = 0.04$, $SE = 0.22$; $p = .071$). Proactive scenario I ($M = 0.09$, $SE = 0.23$) significantly differed from reactive scenario I ($M = 0.33$, $SE = 0.23$; $p < .001$) and reactive scenario II ($p = .004$). Also the average skin conducatance during pro-active scenario II differed significantly from reactive scenario I ($p = .006$) and reactive scenario II ($p = .007$).

The complex contrast for EDA (Table 3) comparing the average skin conductance between the neutral, the combined proactive and the combined reactive scenarios, showed significant differences between neutral vs. reactive (M_{diff} = -0.38, *se* = 0.11, *p* = .002) and between the proactive vs. reactive scenarios (M_{diff} = -0.31, *se* = 0.07, *p* < .001), but no significant difference in skin conductance was found between the neutral and the combined proactive scenarios (M_{diff}= -0.07, *se* = 0.09, *p* = .419; Table 3). Therefore, we accept Hypothesis 1b, as we hypothesized that individuals would exhibit increased skin conductance in reactive scenarios compared to proactive and neutral scenarios. The results confirmed this, showing significantly higher skin conductance in reactive scenarios compared to both proactive and neutral scenarios.

Table 3

Complex contrast results of different scenarios for skin conductance

	neutral vs proactive	neutral vs reactive	proactive vs reactive
Contrast estimate	-0.07	-0.38	-0.31
Std. Error	0.09	0.11	0.07
P	.419	.002	<.001

Aggressive responses

During the study, participants were observed for aggressive responses during the VR sessions. No aggressive responses were observed in the neutral scenario. In the proactive scenarios, six participants showed mild or severe aggression. In the reactive scenarios, 15 children exhibited aggressive responses. Due to the low number of aggressive responses, no distinction was made between mild and severe aggression. Two mixed ANOVAs were performed to determine whether individuals who displayed an aggressive response in reactive scenarios also displayed a higher mean heart rate (hypotheses 2a) or mean skin conductance (hypotheses 2b) than individuals who did not have an aggressive response.

For both hypotheses, two seperate mixed ANOVA were conducted with the mean heart rate or the mean skinconductance as the dependent variable. The within-subject factor was the scenario (neutral vs. reactive I vs. reactive II), and the between-subject factor was the aggressive response (no aggression vs. aggression). Within both ANOVAs the assumption of sphericity was tested using Mauchly's test of sphericity, which was significant (*p* < .001). This indicates that the assumption of sphericity was violated. Therefore, the results with the Greenhouse-Geisser correction were used to interpret the results. The Levene’s test showed that the variance is comparable between the two groups (aggression vs. no-aggression), indicating that the assumption of equal variances was met.

Heart Rate: aggressive response versus no aggressive response

The mixed ANOVA (see Table 4) showed that the main effect of scenario was not significant, $F(1.5, 55.9) = 0.78$, $p = .428$, $\eta_p^2 = .020$). There are no differences in the mean heart rate between the baseline scenario, reactive I, and reactive II across all children. The main effect of the aggressive response is also not significant, $F(1, 38) = 0.26$, $p = .615$, $\eta_p^2 = .007$, indicating that the heart rate of children who did not show an aggressive response does not differ from the heart rate of children who did show an aggressive response. The interaction effect between the scenario and the aggressive response is also not significant, $F(1.5, 55.9) = 1.32$, $p = .270$, $\eta_p^2 = .033$). This means that the difference in mean heart rate between the baseline and the reactive scenarios is comparable between the aggression and the no-aggression group. So, hypotheses 2a is rejected.

Table 4

Mixed ANOVA results of aggressive responses for heart rate

	Aggressive	Heart rate	
Scenario	response	M	SD
Neutral	No	87.95	13.76
	Yes	86.14	8.84
Reactive I	No	84.29	10.25
	Yes	85.90	6.46
Reactive II	No	85.03	7.13
	Yes	88.96	8.65
Factor	*F*	*p*	η_p^2
Scenario	.777	.428	.020
Aggressive response	.257	.615	.007
Scenario * aggressive response	1.32	.270	.033

Skin conductance: aggressive response versus no aggressive response

The mixed ANOVA (see Table 5) showed that the main effect of scenario is significant, $F(1.49, 56.83) = 10.87$, $p < .001$, $\eta_p^2 = .222$ meaning there are differences in skin conductance between the baseline scenario, reactive I, and reactive II across all children. Pairwise comparisons with Bonferroni correction showed that the skin conductance in the neutral scenario ($M = -0.05$, $SE = 0.23$) was significantly lower than in the reactive I scenario ($M = 0.25$, $SE = 0.24$; $p = .028$) and the reactive II scenario ($M = 0.48$, $SE = 0.22$; $p = .002$). There was also a significantly higher skin conductance in reactive II than in reactive I scenario ($p = .027$). The main effect of the aggressive response is not significant, $F(1, 37) = 1.42$, $p = .240$, $\eta_p^2 = .036$, indicating no significant difference in skin conductance between children with and without aggressive responses. The interaction effect between the scenario and the aggressive response is also not significant, $F(1.49, 56.83) = 2.38$, $p =$

.115, $\eta_p^2 = .059$, indicating comparable differences in skin conductance between scenarios for both groups. Therefore, we reject hypothesis 2b, as we expect that individuals with aggressive responses in reactive scenarios will show higher mean skin conductance compared to those without aggressive responses. However, the results do not support this expectation.

Table 5

Mixed ANOVA results of aggressive responses for skin conductance

Scenario	Aggressive response	Skin conductance M	Skin conductance SD
Neutral	No	0.30	1.47
	Yes	-0.39	1.22
Reactive I	No	0.56	1.49
	Yes	-.07	1.41
Reactive II	No	0.60	1.36
	Yes	0.36	1.36
Factor	**F**	**p**	**η_p^2**
Scenario	10.87	< .001	.222
Aggressive response	1.42	.240	.036
Scenario * aggressive response	2.38	.115	.059

Discussion

The present study aimed to investigate the physiological responses of adolescent boys diagnosed with MID-BIF during reactive and proactive aggression scenarios using VR as a research tool. The primary hypotheses were that these adolescents would exhibit an increased heart rate [1a] or skin conductance [1b] in reactive scenarios compared to proactive scenarios and neutral scenarios. Also, we hypothesized that in reactive scenarios the mean heart rate [2a] or skinconductance [2b] would be higher for those who showed an actual aggressive response than for those who did not.

Contrary to our hypothesis [1a], we did not find evidence that individuals exhibit an increased heart rate in reactive scenarios compared to proactive or neutral scenarios. On the other hand, in line with our hypothesis [1b], we did find evidence that individuals exhibit increased skin conductance in reactive scenarios compared to both neutral and proactive scenarios. Additionally, we did not find evidence that individuals with aggressive responses in reactive scenarios show a higher mean heart rate [2a] or higher mean skin conductance [2b] compared to those without aggressive responses.

The lack of significant findings for heart rate might be attributed to individual differences in baseline heart rate, or the nature of the VR scenarios used. Some children found the VR experience very exciting, which may have led to an increased heart rate from the beginning of the session.

Another possibility is that the novelty and excitement of working with VR itself may have caused an increase in heart rate. Research consistently shows that engaging in exciting and new activities can lead to a higher heart rate. This is evident in various contexts, such as gambling (Wulfert et al., 2005), movie watching and adventure riding (Tsai, 2015). These findings suggest that the body's physiological response to excitement often includes an increase in heart rate. Thus, these factors may bias heart rate measurements, making it difficult to attribute changes in heart rate specifically to the aggression scenarios. Also, research shows a link between excitement and increased skin conductance. Wegner et al. (1990) showed that both thinking about and suppressing thoughts about exciting topics such as sex increased skin conductance levels compared to neutral topics. These findings suggest that individuals thinking about something aggressive could experience higher skin conductance, without necessarily pursuing aggression. This means that the observed effect may be biased, as boys might have been thinking about something exciting rather than experiencing aggression. This can be confirmed by the second hypothesis, which found no effect in skin conductance between reacting aggressively or not. Another issue that could lead to biased results in skin conductance measurements is temperature differences in the room. Sigrun Doberenz et al. (2011) observed that various factors, including temperature and physical activity, affect different EDA measures in different ways during 24-hour recordings. This could explain why there is a significant difference in skin conductance between different scenarios, whereas heart rate does not show such differences.

A notable strength of this research is its ecological validity, which refers to the extent to which research findings correspond to everyday practice. Unlike traditional vignettes where children need to imagine how they would react, interactive VR allows children to experience and respond to emotionally engaging situations involving virtual peers. To enhance the realism of the interactions and ensure ecological validity, participants were informed that the VR-characters were real, well-known children from other schools who were simultaneously logged into the VR environment. A sensitive aspect of ecological validity in this context is the assessment of participants' aggressive behavior. It is crucial that children understand that their actions in the VR environment can negatively impact their virtual peers. However, ensuring participants understood the consequences of their actions proved challenging, given their familiarity with video games where interactions with fictional characters are common. Despite our efforts, some boys recognized the virtual nature of their interactions. For instance, one participant stated, "I wanted to see if I could hit him, but not in real life. I didn't hurt him," indicating a clear distinction between the virtual and real-life consequences of their actions. Another strength of this research is that VR can be used flexibly to expose children to different scenarios, allowing researchers to assess individual differences in aggressive behavior. Interactive VR enables realistic scenarios in this study, facilitating observation of children's reactions in an experimental and controlled setting, thereby allowing for experimental control. Researchers can ensure standardisation of scenarios for different participants and adhere to ethical guidelines by carefully controlling the sequence and content of events in VR.

These findings could aid in developing interventions or training programs to reduce aggressive behavior in children by using VR to practice and improve social skills in a safe, controlled environment. Schools and therapists can use VR to help children manage their emotions and responses to aggression. Existing interventions, such as the Virtual Reality Game for Aggression Impulse Management (VR-GAIME; Smeijers et al., 2021) and VR aggression prevention therapy (VRAPT; Tuente et al., 2020), use role plays and virtual environments to teach prosocial reactions and manage aggression. While studies found no significant differences between VR and control games, participants reported increased insight into their own and others' behaviors. VRAPT, specifically, shows potential in temporarily improving anger control and reducing hostility. Both studies underscore the need for further research to enhance VR tools for self-reflection in clinical settings. Further exploring and refining VR-based therapies could lead to more effective strategies for managing aggression in different populations.

Our study also had its limitations. First, the study only included boys aged 7-13 years with limited diversity in cultural and socioeconomic background, so the findings cannot be generalised to girls, other age groups or children from different cultural or socioeconomic backgrounds. Conducting similar studies in different cultural contexts is crucial not only for generalisability, but also because cultural differences can affect children's response to aggression and the effectiveness of interventions. Martin-Storey et al. (2009) emphasises the need to consider cultural factors when adapting Western interventions in non-Western settings. In addition, cultural differences have also been observed in emotional instability, aggression levels and prosocial behaviour in children and adolescents from different countries (Roa et al., 2004). Understanding differences can lead to the development of more effective, culturally appropriate interventions. Second, the children's responses and behaviors were coded by someone who might have been biased due to their knowledge of the research question. Additionally, the responses were coded only once and not reviewed by a second person. This raises uncertainty about the accuracy of the coded responses. Third, the use of VR is time-consuming and costly. It requires thorough training for personnel, which takes more time than usual, and developing the appropriate environments is expensive. Overal challenges of VR include technical issues, equipment costs, space requirements, and the need for trained personnel (Jakubowska & Kazimierska-Zając, 2020).

Future research should minimize external influences, such as VR-induced arousal, by acclimating children to the VR environment beforehand, using a control condition unrelated to aggression or ensuring that room temperature remains constant and can be monitored. Including self-reports of emotions and behaviors can provide a more comprehensive understanding of children's reactions. Also, longitudinal studies tracking boys with MID-BIF over time could reveal long-term effects of aggression and intervention effectiveness, enabling more targeted approaches for different ages. Additionally, using varied VR scenarios (differing in realism, aggression type, and context) can help identify specific triggers of physiological and behavioral responses. Understanding these triggers can structure the development of targeted interventions to teach children alternative reactions to aggression.

Conclusion

Our study found that while skin conductance increases in reactive aggression scenarios, heart rate did not significantly differ between scenarios. This suggests that skin conductance might be a more sensitive measure of physiological arousal in aggressive contexts for boys with MID-BIF. Despite the lack of significant findings for heart rate, the use of VR proved valuable in simulating realistic scenarios and understanding children's responses. These insights can inform the development of targeted interventions, emphasizing the importance of considering physiological responses beyond heart rate. Future research should focus on enhancing VR tools and exploring their long-term impact on aggression management.

References

Armstrong, T. A., Wells, J., Boisvert, D., Lewis, R. H., Cooke, E. M., Woeckener, M., & Kavish, N. (2019). Skin conductance, heart rate and aggressive behavior type. *Biological Psychology*, *141*, 44–51. https://doi.org/10.1016/j.biopsycho.2018.12.012

Arsenio, W. F., & Gold, J. M. (2006). The effects of social injustice and inequality on children's moral judgments and behavior: Towards a theoretical model. *Cognitive Development*, *21*(4), 388–400. https://doi.org/10.1016/j.cogdev.2006.06.005

Baglio, G., Blasi, V., Intra, F. S., Castelli, I., Massaro, D., Baglio, F., Valle, A., Zanette, M., & Marchetti, A. (2016). Social Competence in Children with Borderline Intellectual Functioning: Delayed Development of Theory of Mind Across All Complexity Levels. *Frontiers in Psychology*, *7*. https://doi.org/10.3389/fpsyg.2016.01604

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

Buchmann, A. F., Hohmann, S., Brandeis, D., Banaschewski, T., & Poustka, L. (2013). Aggression in children and adolescents. In Current topics in behavioral neurosciences (pp. 421–442). https://doi.org/10.1007/7854_2013_261

Campbell, S. B., Spieker, S., Burchinal, M., & Poe, M. D.; the NICHD EarlyChild Care Research Network. (2006). Trajectories of aggression fromtoddlerhood to age 9 predict academic and social functioning through age12.Journal of Child Psychology and Psychiatry,47,791–800. doi:10.1111/j.1469-7610.2006.01636.x

Colman, I., Murray, J., Abbott, R. A., Maughan, B., Kuh, D., Croudace, T. J., & Jones, P. B. (2009). Outcomes of conduct problems in adolescence: 40 year follow-up of national cohort. BMJ. British Medical Journal, 338(jan08 2), a2981. https://doi.org/10.1136/bmj.a2981

Crick, N. R., & Zahn–Waxler, C. (2003). The development of psychopathology in females and males: Current progress and future challenges. *Development And Psychopathology*, *15*(3), 719–742. https://doi.org/10.1017/s095457940300035x

De Castro, B. O. (2004). The development of social information processing and aggressive behaviour: Current issues. *European Journal Of Developmental Psychology*, *1*(1), 87–102. https://doi.org/10.1080/17405620444000058

Dekker, M. C., Koot, H. M., Van der Ende, J., & Verhulst, F. C. (2002). Emotional and behavioral problems in children and adolescents with and without intellectual disability. Journal of Child Psychology and Psychiatry, 43(8), 1087–1098. https://doi.org/10.1111/1469-7610.00235

Doberenz, S., Roth, W. T., Wollburg, E., Maslowski, N. I., & Kim, S. (2011). Methodological considerations in ambulatory skin conductance monitoring. International Journal Of Psychophysiology, 80(2), 87–95. https://doi.org/10.1016/j.ijpsycho.2011.02.002

Dodge, K. A., Coie, J. D., & Lynam, D. (2006). Aggression and Antisocial Behavior in Youth. In N. Eisenberg, W. Damon, & R. M. Lerner (Eds.), Handbook of child psychology: Social, emotional, and personality development (6th ed., pp. 719–788). John Wiley & Sons, Inc.

Douma, J. C. H., Dekker, M. C., de Ruiter, K. P., Tick, N. T., & Koot, H. M. (2007). Antisocial and delinquent behaviors in youths with mild or borderline disabilities. American Journal on Mental Retardation, 112, 207-220. https://doi.org/10.1352/0895-8017(2007)112[207:AADBIY]2.0.CO;2

Einfeld, S., Ellis, L. A., & Emerson, E. (2011). Comorbidity of intellectual disability and mental disorder in children and adolescents: A systematic review. *Journal Of Intellectual & Developmental Disability*, *36*(2), 137–143. https://doi.org/10.1080/13668250.2011.572548

Evans, S. C., Frazer, A. L., Blossom, J. B., & Fite, P. J. (2018). Forms and functions of aggression in early childhood. *Journal of Clinical Child and Adolescent Psychology (Print)*, *48*(5), 790–798. https://doi.org/10.1080/15374416.2018.1485104

Fernell, E., & Gillberg, C. (2020). Borderline intellectual functioning. In *Handbook of Clinical Neurology* (pp. 77–81). https://doi.org/10.1016/b978-0-444-64148-9.00006-5

Freeman, D., Reeve, S., Robinson, A., Ehlers, A., Clark, D. M., Spanlang, B., & Slater, M. (2017). Virtual reality in the assessment, understanding, and treatment of mental health disorders. *Psychological Medicine*, *47*(14), 2393–2400. https://doi.org/10.1017/s003329171700040x

Gould, D. (1996). Using vignettes to collect data for nursing research studies: how valid are the findings? Journal Of Clinical Nursing, 5(4), 207–212. https://doi.org/10.1111/j.1365-2702.1996.tb00253.x

Hubbard, J. A., Smithmyer, C. M., Ramsden, S. R., Parker, E. H., Flanagan, K. D., Dearing, K. F., Relyea, N., & Simons, R. F. (2002). Observational, Physiological, and Self-Report measures of children’s anger: relations to reactive versus proactive aggression. Child Development, 73(4), 1101–1118. https://doi.org/10.1111/1467-8624.00460

IBM Corp. (2020). IBM SPSS Statistics for Windows (Version 27.0) [Computer software]. IBM Corp.

Im, S., Jin, G., Jeong, J., Yeom, J., Jekal, J., Lee, S. I., Cho, J. A., Lee, S., Lee, Y., Kim, D. H., Bae, M., Heo, J., Moon, C., & Lee, C. (2018). Gender Differences in Aggression-related Responses on EEG and ECG. *Experimental Neurobiology*, *27*(6), 526–538. https://doi.org/10.5607/en.2018.27.6.526

Jakubowska, L., & Kazimierska-Zając, M. (2020). Difficulties in conducting research with the use of virtual reality (VR). E-methodology, 6(6), 29–33. https://doi.org/10.15503/emet2019.29.33

Jambon, M., Colasante, T., Peplak, J., & Malti, T. (2018). Anger, sympathy, and children’s reactive and proactive aggression: Testing a differential correlate hypothesis. Journal of Abnormal Child Psychology, 47(6), 1013–1024. https://doi.org/10.1007/s10802-018-0498-3

Leman, P., Bremner, A., Parke, R. D., & Gauvain, M. (2019). Developmental Psychology, 2e.

Lemley, M. A., & Volokh, E. (2017). Law, Virtual Reality, and Augmented Reality. *Social Science Research Network*. https://doi.org/10.2139/ssrn.2933867

Lobbestael, J., & Cima, M. (2021). Virtual Reality for Aggression Assessment: The Development and Preliminary Results of Two Virtual Reality Tasks to Assess Reactive and Proactive Aggression in Males. *Brain Sciences*, *11*(12), 1653. https://doi.org/10.3390/brainsci11121653

Martin-Storey, A., Temcheff, C. E., Martin, E. K., & Stack, D. M. (2009). Interventions for Childhood Aggression in a Cross-Cultural Context. Psychology And Developing Societies, 21(2), 235–256. https://doi.org/10.1177/097133360902100204

Mash, E. J., & Wolfe, D. A. (2018). *Abnormal child Psychology*. Cengage Learning.

Medicine, N. A. O. S. E. A. (2015). Mental Disorders and Disabilities Among Low-Income Children. In National Academies Press eBooks. https://doi.org/10.17226/21780

Mild intellectual disability. (2024, 23 januari). University Of Gothenburg. https://www.gu.se/en/gnc/mild-intellectual-disability#:~:text=Mild%20intellectual%20disability%20occurs%20in,meet%20the%20criteria%20for%20ADHD.

Nature Relaxing Milieu. (2021, August 8). *4K Drone Footage - Bird's Eye View of Germany, Europe - Relaxation Short Film with Calming Music* [Video]. YouTube. https://www.youtube.com/watch?v=MAn9WpsRrYc

Roa, M. L., Del Barrio, M. V., & Carrasco, M. Á. (2004). Comparación de la agresión infantil en dos grupos culturales. Revista de PsicologíA, 22(1), 29–43. https://doi.org/10.18800/psico.200401.002

Russu, A. S. (2022). AGGRESSION IN SOCIETY: TRENDS AND PROSPECTS. Materials of the All-Russian scientific and practical conference "Exponents of social aggression: general humanitarian discourses".

Schaeffer, C. M., Petras, H., Ialongo, N. S., Poduska, J. M., & Kellam, S. G. (2003). Modeling Growth in Boys' Aggressive Behavior Across Elementary School: Links to Later Criminal Involvement, Conduct Disorder, and Antisocial Personality Disorder. *Developmental Psychology*, *39*(6), 1020–1035. https://doi.org/10.1037/0012-1649.39.6.1020

Schuiringa, H. D., Van Nieuwenhuijzen, M., De Castro, B. O., Lochman, J. E., & Matthys, W. (2016). Effectiveness of an intervention for children with externalizing behavior and mild to borderline intellectual disabilities: a randomized trial. Cognitive Therapy and Research, 41(2), 237–251. https://doi.org/10.1007/s10608-016-9815-8

Smeijers, D., Bulten, E. H., Verkes, R., & Koole, S. L. (2021). Testing the Effects of a Virtual Reality Game for Aggressive Impulse Management: A Preliminary Randomized Controlled Trial among Forensic Psychiatric Outpatients. *Brain Sciences*, *11*(11), 1484. https://doi.org/10.3390/brainsci11111484

Tsai, H., & Yi, C. (2015). Wearable ECG for Tension Assessment in Movie Watching and Adventure Riding. 2015 11th International Conference on Mobile Ad-hoc and Sensor Networks (MSN), 23-30.

Thomson, N. D., Kevorkian, S., Blair, J., Farrell, A. D., West, S. J., & Bjork, J. M. (2021). Psychophysiological underpinnings of proactive and reactive aggression in young men and women. *Physiology & Behavior*, *242*, 113601. https://doi.org/10.1016/j.physbeh.2021.113601

Tuente, S. K., Bogaerts, S., Bulten, E., Vos, M. K., Vos, M., Bokern, H., Van IJzendoorn, S., Geraets, C. N. W., & Veling, W. (2020). Virtual Reality Aggression Prevention Therapy (VRAPT) versus Waiting List Control for Forensic Psychiatric Inpatients: A Multicenter Randomized Controlled Trial. *Journal Of Clinical Medicine*, *9*(7), 2258. https://doi.org/10.3390/jcm9072258

Van Der Ploeg, J. (2014). Theorieën over agressie. In *Bohn Stafleu van Loghum eBooks* (pp. 25–35). https://doi.org/10.1007/978-90-368-0635-0_4

Van Nieuwenhuijzen, M., Bijman, E. R., Lamberix, I. C. W., Wijnroks, L., De Castro, B. O., Vermeer, A., & Matthys, W. (2005). Do children do what they say? Responses to hypothetical and real-life social problems in children with mild intellectual disabilities and behaviour problems. Journal Of Intellectual Disability Research, 49(6), 419–433. https://doi.org/10.1111/j.1365-2788.2005.00674.x

Van Nieuwenhuijzen, M., De Castro, B. O., Van Aken, M. A. G., & Matthys, W. (2009). Impulse control and aggressive response generation as predictors of aggressive behaviour in children with mild intellectual disabilities and borderline intelligence. *Journal Of Intellectual Disability Research*, *53*(3), 233–242. https://doi.org/10.1111/j.1365-2788.2008.01112.x

Verhoef, R. E. J., Van Dijk, A., Thomaes, S., Verhulp, E. E., Van Rest, M. M., & De Castro, B. O. (2022). Detecting social information processing profiles of boys with aggressive behavior problems: An interactive virtual reality approach. *Development And Psychopathology*, *35*(4), 1843–1855. https://doi.org/10.1017/s0954579422000505

Verhoef, R. E. J., Van Dijk, A., Verhulp, E. E., & De Castro, B. O. (2021). Interactive virtual reality assessment of aggressive social information processing in boys with behaviour problems: A pilot study. *Clinical Psychology & Psychotherapy/Clinical Psychology And Psychotherapy*, *28*(3), 489–499. https://doi.org/10.1002/cpp.2620

Verhulp, E. & Schuiringa, H. D. (2020). Assessing Social Information Processing and Aggressive Behavior in Adolescent Boys with Mild to Borderline Intellectual Disabilities: The Use of Interactive Virtual Reality. [Ongepubliceerd manuscript]. Faculteit Sociale Wetenschappen, Universiteit Utrecht.

Weine, A. M., Phillips, J. S., & Achenbach, T. M. (1995). Behavioral and emotional problems among Chinese and American children: Parent and teacher reports for ages 6 to 13. *Journal Of Abnormal Child Psychology*, *23*(5), 619–639. https://doi.org/10.1007/bf01447666

Wegner, D. M., Shortt, J. W., Blake, A. W., & Page, M. S. (1990). The suppression of exciting thoughts. Journal Of Personality And Social Psychology, 58(3), 409–418. https://doi.org/10.1037/0022-3514.58.3.409

Wulfert, E., Roland, B. D., Hartley, J., Wang, N., & Franco, C. (2005). Heart rate arousal and excitement in gambling: Winners versus losers. Psychology Of Addictive Behaviors, 19(3), 311–316. https://doi.org/10.1037/0893-164x.19.3.311