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Department of Brain and Behavioral Sciences (DBBS) MSc in Psychology, Neuroscience and Human Sciences

Validation of the Automatic Balloon Analogue Risk Task in Adolescents of Peri-rural Uganda

Supervisors:

Dr. Gabriele Chierchia

Dr. Serena Lecce

The thesis written by

Merve Uçar

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Contents

Abstract

Background: Risk-taking behaviors are a known source of vulnerability for people of all ages, but they are known to disproportionately affect young people, especially adolescents. To investigate this, psychologists have developed the Balloon Analogue Risk Task (BART), one of the most widely used measures of risk-taking in adolescents. The Bart is an internally consistent measure that has also been found to relate to real-world risk-taking, as well as mental health outcomes. Problematically, this has almost exclusively been studied in WEIRD (Western, Educated, Industrialized, Rich, Democratic) participants. The current study aims to validate the Bart and investigate these associations in adolescents of peri-rural Uganda.

Methods: A total of 310 adolescents, aged 15-19 years (mean age = 17.01), from peri-rural Uganda participated in the study. The BART was used to measure risk-taking behavior, and participants completed self-report questionnaires assessing real-world risky behaviors and mental health. After addressing the Bart's internal consistency and response processes, we tested for the association between risk taking in the Bart and both, real world risky behavior and mental health outcomes, using a combination of factor analytic and regression analyses.

Findings: Split-half reliability analyses showed that Bart had good internal consistency, and response processes were in line with what is known from WEIRD samples.

Also, in line with WEIRD samples, on average participants took less risk than is optimal in the BAR, suggestion they are risk averse. Despite an adequate sample size, we observed no significant associations between Bart and real-world risky behaviors. However, we found that the Bart was oppositely associated with two independent latent factors of mental health: adolescents who took more risks in the Bart were those with greater emotional well-being and less anxiety.

Conclusions: These findings suggest that the Bart is a valid measure of risk-taking in peri-rural Uganda, and they provide new important insights into the relationship between risk-taking and mental health during adolescence.

1. Introduction

1.1. Moving beyond WEIRD psychology in adolescents of peri-rural Uganda

In 2008, Arnett highlighted a significant concern about the overrepresentation of research from the United States in top psychology journals, revealing that 68% of the samples were drawn from the United States population. This issue extends to much of the research in psychology and related fields, which predominantly centers on Western countries, such as those in Europe, North America, Australia, and Israel (Rad et al., 2018). This has led to a limited global perspective in scientific findings. As a result, our understanding of human behavior often reflects a narrow, Western-centric view, leaving out much of the world.

Psychology, sociology, and the humanities have been heavily influenced by research that primarily focuses on Western perspectives. This imbalance in research has led some to argue that these fields have been shaped in a way that reflects the dominance of Western cultures, similar to the effects of colonization. This influence can limit our understanding of human behavior by overlooking diverse perspectives from other parts of the world (Arnett, 2008; Rad et al., 2018). Decolonizing psychology involves questioning and critically examining the dominance of Western theories and methods in psychological research and practices (Adams et al., 2015). This focus gained momentum after the introduction of the WEIRD acronym, which highlighted that much of psychological research while claiming to represent humans in general, was predominantly based on participants from Westernized, Educated, Industrialized, Rich, and Democratic societies (Henrich et al., 2010). Towards the beginning of the 21^{th} century, after the publication titled 'The Weirdest People in The Word?' mentioned the limitations and generalizability problems in behavioral and psychological research arise from an over-reliance on the WEIRD population.

With the introduction of the WEIRD concept (Western, Educated, Industrialized, Rich, Democratic), there has been a gradual increase in non-WEIRD research. Thalmayer and colleagues revisited the same six journals analyzed by Arnett and found about a 10% decrease in research focused on the American population. While this suggests that attention to non-WEIRD populations is growing, it also underscores the need for researchers to be cautious in drawing conclusions, as much of the global population remains underrepresented.

In a 2016 scientific symposium in Mwanza, Tanzania, a debate arose over whether concepts of adolescence from the Global North are appropriate for Africa. Ngwenya and colleagues explored this issue, emphasizing the importance of considering sociocultural norms, standards, and legal structures in adolescence. One proposal argued that neurocognitive development is similar across countries and that cultural rites, rather than geography, should be the focus when differentiating the adolescent period. However, some participants contended that defining adolescence solely by its biological transition to adulthood overlooks the importance of communal values and social roles, which are more prominent in the African context. The debate also called for the decolonization of global health and a shift away from perspectives dominated by the WEIRD countries.

To address the differences between WEIRD and non-WEIRD groups, it's more important to understand the underlying reasons behind these differences, rather than just focusing on what can be seen or measured (Kanazawa, 2020). To illustrate, one of the most famous economic decision-making games, Ultimatum Game has shown the differences in the decision to accept the lower/unfair offers in the non-WEIRD sample than the WEIRD population. The difference in acceptance decisions can be attributed to the contrasting perspectives on private property, with the Tsimane and Machigenga from non-WEIRD, horticulturalist societies having a different understanding compared to the capitalist views prevalent in Westernized countries (Baumard & Sperber, 2010). However, it's important to note that not all variations in the ultimatum game can be solely explained by horticulturalist societies.

Another importance of the increasing non-weird studies, understanding the differences in maintaining the best-fit intervention methods for the samples. Cross-cultural studies help us understand how information typically associated with WEIRD populations is represented in non-WEIRD countries. To illustrate, cross-cultural research that collected university students in the WEIRD sample, Switzerland, and in the non-WEIRD sample, India led to underlining different sensitive protective factors in students with symptoms of physical pain and mental health markers. According to a network analysis maintaining central factors in mental health to experience physical pain was different in the WEIRD and Non-Weird samples, which were found essential while targeting sample-specific interventions (Tandon et al., 2024). When developing targeted interventions for adolescents, it's crucial to focus on middle-income countries, where the majority of adolescents—around 90%—live (Erskine et al., 2015). According to the World Population Data Sheet, all around the world, Africa has the highest projected population growth and fertility where Sub-Saharan Africa subregions and Northern Africa are included (‘Population Trends in Africa’, n.d.). Indeed, 23 % of the population of South Africa, is expected to have the largest adolescent population worldwide in 2050 (UNICEF, 2020).

Despite the significant adolescent population and the high prevalence of risky behaviors in South Africa, including risky sexual behaviors and high daily reported HIV rates (WHO, 2018; Finer et al., 2016), research on risk-taking in non-Western cultures remains limited. This gap is concerning given the universal characteristics of adolescent development and the two primary sources of vulnerability during this period: risky behaviors and mental health challenges.

Adolescence is a critical phase characterized by significant brain development, including changes in brain volume. For example, grey matter volume increases until adolescence, peaks, and then starts to decrease, while white matter volume and subcortical volumes continue to increase throughout adolescence, along with cortical thickness (Bethlehem et al., 2022). These neurological changes are crucial for cognitive and emotional development, making adolescence a particularly sensitive period. This increased plasticity is noteworthy because adolescence is a period marked by both vulnerability and considerable growth and development (Fuhrmann et al., 2015). Developmentally, it differs from any other stage, offering more mobility and autonomy than childhood. This autonomy provides adolescents with the freedom to choose their experiences, which can lead to engaging in behaviors that may be risky and potentially harmful, yet appealing and enjoyable.

For example, risky behaviors could be the consequence of degraded decision-making processes linked to specific mental health problems, or they might be a maladaptive coping method used by youth experiencing emotional dysregulation (Romer, 2010). On the other hand, engaging in risky behaviors basis regularly might raise the chance of mental health problems. Concurrently, this period also sees an increase in the diagnosis of mental health issues.

Mental health is a global concern with potentially long-lasting effects throughout an individual's life. The prevalence of mental health disorders typically begins in early adolescence, with adolescents in low-income countries being particularly vulnerable. Factors such as poverty, malnutrition, and exposure to violence significantly increase the risk of developing mental health problems in these populations (Ridley et al., 2020).

According to a recent systematic review on the prevalence of mental health issues among adolescents in Sub-Saharan Africa, out of a total of 97,616 individuals studied, over 40% were found to have emotional and behavioral difficulties, more than 35% had anxiety disorders, and nearly 30% experienced depression, based on research published between 2008 and 2020 (Jörns-Presentati et al., 2021). There remains a significant gap in research on validating the Balloon Risk Taking Task, a key tool for measuring risk-taking behavior, among adolescents in peri-rural Uganda, which is crucial for developing effective mental health interventions (Moffett et al., 2022). Validating the BART on this sample, which will allow bridging gap between behavioral measurement of risk taking and relation to the real-life risk behavior, mental health of adolescence.

1.2. The age of adolescence: definition and adolescent - "typical" traits

Adolescence is a sensitive period in human development characterized by changes in the social, biological, and psychological domains (UNICEF, n.d.; Fuhrmann et al., 2015). Adolescents take many risks during this time. In part, this heightened risk-taking is likely to be an important component of adolescent development (Steinberg & Duell, 2020; Ciranka & Van Den Bos, 2021) but it can also have serious adverse consequences, such as in the context of reckless driving, substance use, unsafe sex etc. (Mirman et al., 2012; Aklin et al., 2005; Nathan et al., 2023). This developmental phase marks a higher sensitivity to rewards and heightened emotional experiences, often manifesting as sensation-seeking behavior. Sensation-seeking, defined as the pursuit of novel and stimulating experiences, can lead to both beneficial and harmful outcomes, making adolescents particularly vulnerable to risk-taking behaviors (Zuckerman, 1994).

This heightened sensation-seeking and risk-taking behavior during adolescence has been observed across cultures (Steinberg et al., 2017; Silva et al., 2016), even across species, such as mammalians (Galván, 2013; Spear, 2000; Laviola et al., 2003). Indeed, there are studies which show similar hormonal and brain activation on the animal models, such as heightened Ventral Striatum activation in adolescence (Galvan, 2013; Stansfield et al., 2006; Sturman & Moghaddam, 2011). Although this might lead to unfavorable outcomes sometimes, it might also lead favorable outcomes. In other words, while the desirability of the risk outcome may change, the behavior itself remains risky.

Adolescence is an essential period for development. This period is commonly defined as turbulent, due to many challenges that adolescents face. There are many definitions of adolescence, starting from the age period. With the growing understanding of the interaction between brain development and behavior, the adolescent period is now recognized to extend until at least the age of 25. It is important to acknowledge that brain development and decision-making processes become more mature as the myelination and pruning of the prefrontal cortex (PFC) progress (Casey et al., 2008; Giedd, 2004; Steinberg, 2008). Various models have begun to address these developmental changes, with the imbalance model being one of the first to be introduced.

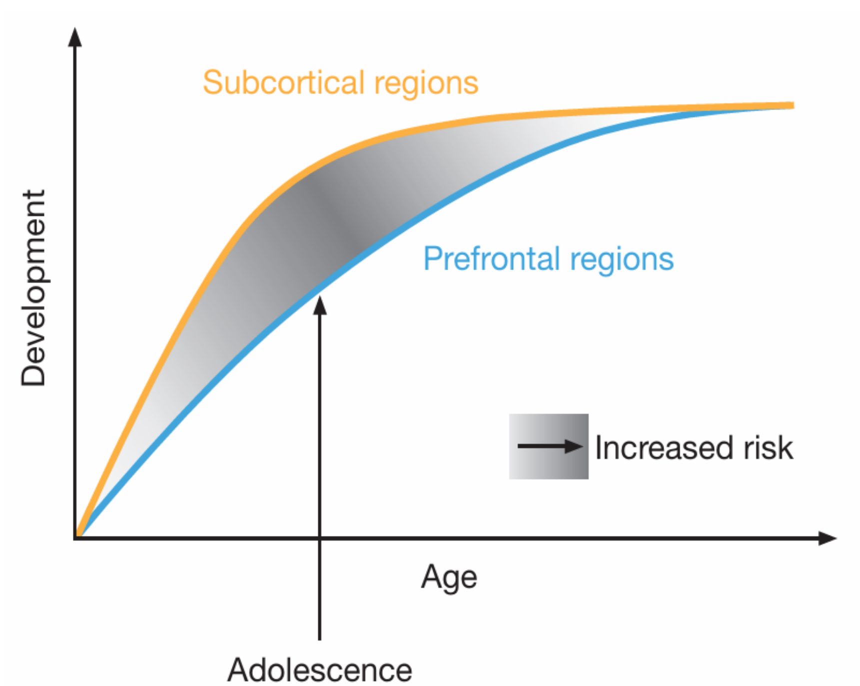

Figure 1. Dual Systems Model. Casey's dual systems model (Casey et al., 2008; Somerville et al., 2010) presents a framework that highlights the extended development of cortical

prefrontal regions (blue line) in contrast to the more rapidly maturing subcortical limbic regions (yellow line), such as the amygdala and ventral striatum. This developmental mismatch is thought to contribute to adolescence being a particularly vulnerable period for engaging in risky behaviors and experiencing heightened emotional responses. The figure adapted from Somerville et al. (2010) illustrates this concept.

The imbalance models suggest that adolescent-typical behaviors, such as risk-taking, could be explained by relatively fast development of limbic cortices (ventral striatum) coupled with slower development of brain systems associated with cognitive control (prefrontal cortex). According to the imbalance model, adaptive decision-making in adolescence is limited by the not fully developed PFC. Research has indicated that risk-taking behavior during adolescence is associated with exploration and learning, which are often accompanied by increasing independence and self-sufficiency, factors that may play a role in supporting brain development. (Luna et al., 2015; Murty et al., 2016; Spear, 2013). This perspective acknowledges the overestimated perception of stereotypical risk-taking behaviors, which has overshadowed the importance of promoting healthy and adaptive forms of risk-taking among adolescents (Reyna et al., 2015; Romer, 2010).

For many years, psychologists have believed that reckless behavior in teenagers can be explained by cognitive differences between adolescents and adults. This idea is backed by cognitive neuroscience research, including structural and functional brain imaging, behavioral studies, and observations of risky behaviors in the real world. There are some inconsistent functional Magnetic Resonance Imagining (fMRI) findings, on supporting heightened risk-taking behavior might related to increased reward sensitivity during adolescence. While Ernst and colleagues (2005) revealed increased feedback activation in reward-related regions, such as the nucleus accumbens, on the other hand, adolescents were more risk aversive on the monetary gains compared to young adults by showing lower activation in the nucleus accumbens. Paus and colleagues used to them as less risk aversive biological responses to explain increased substance abuse during adolescence, which seen also in the adolescent rodent models (Doremus et al., 2003; Silveri et al., 2002; White et al., 2002)

The Dual System model was introduced to explain how adolescents make decisions, focusing on the interaction between two distinct brain systems: one that drives reward-seeking and another that is responsible for cognitive control (Steinberg, 2008; Casey et al., 2008). Adolescents' risky behavior can be better understood through the lens of different developmental trajectories of brain systems. One of the brain systems involved in adolescent decision-making is primarily localized in the medial and orbital prefrontal cortices, as well as the striatum. This system is crucial for responding to rewarding stimuli, driving the desire for immediate gratification. The other brain system is situated in the lateral prefrontal, lateral parietal, and anterior cingulate cortices, which are essential for inhibiting impulses and supporting cognitive control. These two systems interact to influence the balance between reward-seeking and impulse control, which is particularly significant during adolescence (Casey et al., 2008; Steinberg, 2008).

An alternative interpretation of risk-taking during adolescence comes from the Life-Span Wisdom Model (LSWM). This model highlights the beneficial aspects of adolescent risk-taking by emphasizing the role certain risks play in adolescent exploration. According to this model, by age, the tendency to risk-taking has differentiated into subtypes of risk-taking as adaptive risk-taking and maladaptive risk-taking behavior. Adaptive risk-taking involves behaviors motivated by a desire to explore, rather than by a lack of impulse control. This type of risk-taking can result in experiential learning, where past experiences inform and guide future decisions (Khurana & Romer, 2019). Therefore, adaptive risk-taking is associated with exploration and learning. It is likely to continue in late adolescence and young adulthood. In contrast, maladaptive risk-taking involves actions taken without sufficient consideration of possible negative consequences (e.g., not wearing a helmet). This type of risk-taking frequently results in harmful outcomes, such as substance use disorders, and is particularly common in a subset of youth with poor impulse control (Khurana et al., 2017).

The Life-Span Wisdom Model (LSWM) posits that the innate drive for exploration and learning during adolescence often leads to risk-taking behavior. However, the critical difference between adaptive and maladaptive risk-taking lies in cognitive control. Cognitive control is essential as it helps adolescents adjust their behavior, either by integrating necessary precautions or avoiding risks in future situations, thereby determining whether their risk-taking behavior is advantageous or detrimental. The heightened sensation seeking during adolescence has been supported by the empirical evidence from Steinberg and colleagues (2017) as seen in Figure 4, this peak is consistent with both models.

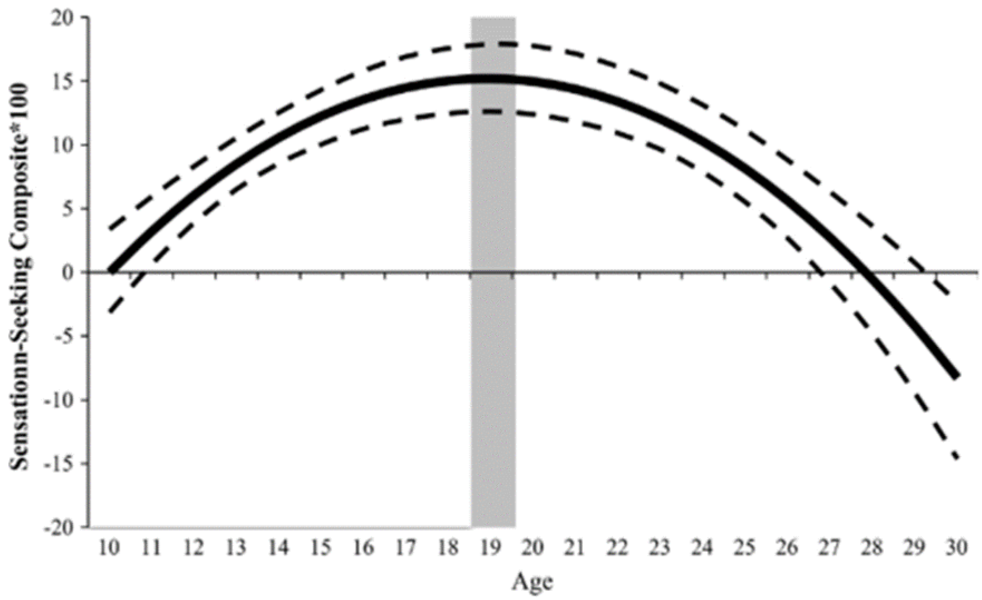

Figure 2. Inverted U-shaped curvilinear age pattern of risk-taking. Results for sensation seeking revealed a significant, inverted U-shaped curvilinear age pattern in 7 of the 11 countries: China, India, Italy, Kenya, the Philippines, Thailand, and the United States. Reprinted from Steinberg, 2017.

In summary, the dual systems model, the imbalance model, and the LSWM have all sought to explain the heightened risk-taking during adolescence by examining behavioral patterns. Their interpretations have evolved to take into account how exploration and learning influence changes in risk-taking behavior outcomes. A key focus is on cognitive control, where self-control plays a critical role in distinguishing between adaptive and maladaptive risk-taking.

Risk is one of the main concerns of behavior in developmental. When looking into the developmental aspects, hormonal changes, brain structural changes and relation to social interaction might help to explain adolescence. Heightened risk-taking behavior has been mostly seen during high school. Students start to drop out of courses, start to use alcohol, smoking. Many of these behaviors can be associated with exploration behavior, and some others are related to impulsivity. Although risk-taking might have serious health-related consequences for the future development of adolescents yet it is not investigated well in all the adolescent population. Understanding the risky behavior would help to identify the features of negative consequences of this behavior, which can be a pre-intervention step.

Adolescents living in environments with limited resources, such as low socio-economic countries, are more likely to engage in harmful behaviors, as noted by Patel and colleagues (2018). These heightened risky behaviors during adolescence are influenced by the unique challenges faced in low-resource populations, like those in non-WEIRD countries. This study focuses on peri-rural adolescents in Uganda, who are particularly vulnerable to these risks. By investigating risk behaviors within this context, we aim to address the specific needs of this population and develop interventions that are tailored to their geographical and socio-economic circumstances. Therefore, it is important to investigate and validate measures of risk-taking across cultures, and to understand if these only relate to negative outcomes, or also to positive ones. There has been a lack of focus on non-Western countries, especially on the adolescents of Peri-rural Uganda.

2. Risk-taking and mental health during adolescence

2.1. Types of risk-taking

Risk-taking behavior involves making decisions that could result in a reward but also come with the risk of loss in uncertain situations, as highlighted in neuroeconomic decision-making studies (Duell and Steinberg, 2019). Although the first thing comes to mind is more likely to be illegal or dangerous behaviors, it is not restricted to it. Risk does not imply specific behaviors (Frey et al., 2017), and the act itself has potential to have either positive or negative consequences (Crone, van Duijvenvoorde, & Peper, 2016; Hertwig et al.,2019). Duell and Steinberg refer to these types of risks as negative risks, and they point out that, even though negative risks can sometimes be harmful, they might also play a role in personal growth (Chassin et al., 1989).

Positive risk outcomes are more desirable in terms of social acceptability and legal perspectives. In the literature, the terms "adaptive" and "prosocial" are sometimes used to describe positive risks (Fischer & Smith, 2004; Hansen & Breivik, 2001).). Risk taking can be constructive for development, to help youths explore and learn about the world and themselves, as well as enable them to interact with their future environment positively (Van den Bos et al., 2018). The significance of this becomes clear during adolescence, a period when risky behaviors increase as part of exploring environments and preparing to live independently from caregivers (Sandseter & Kennair, 2011). The sensitive period of development also implies that higher-level cognitive functions happen with increased plasticity during adolescence. Although heightened risk-taking during adolescence has frequently been related to negative outcomes, recent literature presents its role in development by acknowledging the positive and adaptive aspects of risk-taking behavior through adolescence. Since it is not only looking for excitement; they are exhibiting positive relationships between emotional control, and cognitive development (Steinberg et al., 2020).

The increased tendency to explore new and novel experiences, observed from childhood to adulthood, is often associated with negative outcomes (Eaton et al., 2012; Moffitt, 2018). For example, discovering a new restaurant can be risky since it may end up as a negative experience or a rewarding, fulfilling experience. While many aspects focus on the negative aspects of risk-taking and novelty-seeking, these behaviors are also important for bridging adolescence to adult life, in terms of independence. Heightened risk-taking can allow adolescents to learn from experiences, and take fewer risks for the future (Spear, 2009). This aligns with the evolutionary function of adolescence for many mammals. Contrary to common belief, risk-taking behavior plays an adaptive role in the transition from adolescence to adulthood, helping boost reproductive success according to both developmental and evolutionary theories (Ellis et al., 2012; Mata et al., 2015).

2.2. The Mental Health

As mentioned in the previous chapter of this dissertation, adolescence is a special period not only for heightened sensation-seeking and exploratory, risk-taking behavior but also concerning mental health. From birth through young adulthood, the brain undergoes developmental changes that become evident in observable behaviors. Adolescence is an important age for the clinical prevalence of psychological disorders. According to the World Health Organization, %50 of mental disorders starts to be seen by age 14 (2018). One of the most prevalent psychological disorders is anxiety, followed by schizophrenia, major depressive disorder, and bipolar disorder. Major depressive disorder is the leading cause of illness and disability (WHO, 2017), and the second most common cause of death during adolescence (Bernaras et al., 2019). A recent meta-analysis of 192 epidemiological studies revealed the age of onset of mental disorders peaks at 14.5 proportion, decreasing in the mid-twenties.

Paus, Keshavan, and Giedd published a review on why many psychiatric disorders emerge during adolescence. They highlighted the importance of neurobiological changes during this period and linked these to emerging psychopathology, mood disorders, anxiety, eating disorders, and substance abuse. In synthesis, they suggest that profound alterations in hormonal and receptor function can contribute to the emergence of anxiety- and depressive disorders during adolescence, also by increasing emotional reactivity to social cues promoting rapid shifts in motivational and reward systems (Paus et al., 2009). The systems that undergo the most marked development in adolescence are those subserving higher cognitive functions, reasoning, and social interaction (Crone & Dahl 2012), as well as emotional control/motivation (Steinberg et al. 2008) being major ones here. These activations on the reward circuits are important as well as hormonal, and neurotransmitter (increased GABA activity, inhibitory neurotransmitter) changes happening during adolescence, which might be key to understanding risk factors on the merging mood and anxiety disorders.

Stress-related hormones may contribute to depression and anxiety, with alcohol and other substances potentially exacerbating or influencing these effects (Shen et al. 2007).

For example, risky behaviors could be the consequence of degraded decision-making processes linked to specific mental health problems, or they might be a maladaptive coping method used by youth experiencing emotional dysregulation (Romer, 2019). On the other hand, engaging in risky behaviors basis regularly might raise the chance of mental health problems, creating a vicious cycle that can be challenging to stop without the right interventions. For developing the intervention, it is also crucial to understand the environment-specific needs.

It is well-known that mental disorders need to be diagnosed by the health professional, and need to receive appropriate psychological, and psychiatric treatment to overcome remission in the following years. The first reason to prioritize mental health during adolescence is its role in limiting the individual's daily functioning.

The second reason is related to the risky behaviors. Hooshmand and colleagues shared findings related to depressive symptoms and health-risk behaviors from the longitudinal data collected from high-school students from ages 11 to 23 (2012), the results were interesting because they highlight the importance of peer influence on engaging in risky behavior. During adolescence, peer influence and the social environment become increasingly important and are closely tied to the activation of reward circuits in the brain (Gardner & Steinberg, 2005; Siraj et al., 2021). Also, Marijuana use is influenced by peer substance use and lower levels of depressive symptoms. Despite engaging in risky behaviors like marijuana use, peers may still play a protective role against depression (Hooshmand et al., 2012). Moreover, peer support and social environment supports the self-esteem of the adolescence, which indirectly positive impact on well-being, and improve social understanding (Arnett, 2014), and positive adaptation skills (Ungar & Liebenberg, 2011).

Results from the National Comorbidity Survey of 2016 shared that anxiety and depression have a leading role in the starting of substance use in mid to late adolescence (Conway et al., 2016). Supporting that, rumination as a transdiagnostic mental health variable is related to the later onset of the substance use disorder (Adrian et al., 2014). One of the most common explanations of risky behaviors, like substance use is the self-medication hypothesis. According to this hypothesis, stressful/distressing situations are followed by maladaptive coping strategies. Clinical studies also point to the self-medication model to explain alcohol use disorder (AUD) and comorbidity with other psychological disorders, such as posttraumatic stress disorder (PTSD), anxiety, and depression (Kessler et al., 2005; Hawn et al., 2020). It is relatively common to have comorbidity for mental health conditions.

Previous research indicates that % 60 of adolescents who have a mental illness are likely to display comorbidity with a second disorder (Essau and De la Torre-Luque, 2019). Among young people, anxiety and depression have been the focus of comorbidity studies, in addition to internalizing and externalizing behaviors, substance use, and violent/aggressive behaviors (Gomez & Vance, 2014; Liu et al., 2017).

Low-income neighborhoods and stressful life events are important risk factors for developing mental health problems during adolescence (Webb & Mendelson, 2021). These risk factors are especially prominent in Uganda, where a substantial portion of the population lives in poverty and suffers everyday obstacles such as restricted access to healthcare, education, and basic supplies. Youth in Uganda's peri-rural areas are particularly at risk because they frequently deal with high-stress levels brought on by poverty, exposure to violence, and the demands of subsistence living. During this sensitive period of development, the challenging environment in Uganda may further increase the likelihood of mental health problems among adolescents. This is already evident, as high HIV rates, coupled with inadequate mental health resources, contribute to significant psychological issues in Ugandan youth (Knizek et al., 2017). For instance, as Kamau et al. (2012) highlight, the high prevalence of HIV in Uganda is linked to increased psychological distress among adolescents, exacerbated by the lack of adequate support and mental health services. Acknowledging these environmental risk factors plays an essential role in the mental health of adolescents.

2.3. The association between risk taking and mental health

The relationship between mental health and risk behaviors has been explored through data obtained from national epidemiological studies on adolescent risk-taking behaviors. Research has found associations between depression and various forms of risky behavior, including violence (DuRant et al., 1996; Simantov et al., 2000), substance use (DuRant et al., 1996; Simantov et al., 2000), and unsafe sexual practices (Kowaleski-Jones and Mott, 1998). Negative consequences of risk-taking behavior can be a danger to self and others, low self-esteem, and negative mental health symptoms (Aklin et al., 2005; Gullone et al., 2000). These studies highlight the strong link between mental health issues, particularly depression, and the likelihood of engaging in behaviors that pose significant risks to adolescents' well-being.

Brooks and colleagues (2002) highlighted that psychological stress and stressful life events are likely contributors to risky behavior. Their research suggests that depression and stress may serve as mediators for risk behaviors and even suicidal attempts. This indicates that adolescents experiencing high levels of stress are more vulnerable to engaging in risky behaviors as a means of coping, potentially leading to severe outcomes such as suicide attempts, especially in the scenario of clinical depression. Furthermore, Pine and colleagues (2002) approached mood disorders and risk behaviors by mentioning the definition of emotion as mental states brought on by stimuli that an organism would either actively seek out (rewards) or actively try to avoid (punishments). Moreover, self-esteem is another important indicator of mental health, which is defined as feelings about self-worth. Hardy and colleagues showed psychological well-being and risky health behaviors among college students (2013). They found risky sexual behaviors negatively correlated with self-esteem, anxiety, and depression significantly.

To understand adolescent risky behavior, it is essential to underline what might be the potential gain from the behavior, and the psychosocial functions of that behavior. Lavery and colleagues highlight two psychosocial mechanisms behind risky behaviors: self-centered justification, where individuals prioritize personal desires like stress relief, and social justification, which is driven by the need for social acceptance. These examples illustrate that risky behaviors can arise from different underlying motivations, reflecting the complex and varied functions that risk-taking can serve during adolescence.

The motives behind risk-taking behaviors have been expanded into four categories: irresponsible behaviors (which focus on immediate gratification; Loewenstein & Schkade, 1999), audience-controlled risk-taking (such as peer pressure in substance abuse or reckless driving; Levitt, Selman & Richmond, 1991), calculated risks (taking risks to achieve a desired goal), and thrill-seeking (engaging in exciting or sensation-seeking activities; Kloep & Hendry, 1999). This categorization highlights that not all risk-taking behaviors are driven by the same motivations.

Recent research has also begun to emphasize the positive consequences of risk-taking behavior on adolescent development. According to Romer (2010), risk-taking behavior is essential for becoming adaptive and flexible in changing environments, making it a key component of adaptive behavior. Ciranka and Van Den Bos (2021) further categorized risk-taking into two types: reactive and reasoned. Reactive risk-taking involves poor response inhibition and heightened reward sensitivity (Rosenbaum et al., 2018; Shulman et al., 2016; Steinberg, 2008), which is common in adolescent behavior. However, it is important to recognize that not all adolescent risk-taking is purely reactive.

Reasoned risk-taking, on the other hand, is strategic, premeditated, and driven by sensation-seeking alongside increased cognitive control (Romer et al., 2017). This type of risk-taking is associated with improved executive functions, such as enhanced working memory, future orientation, and higher levels of sensation seeking, as supported by Maslowsky and colleagues (2019). This distinction underscores the complexity of adolescent risk-taking, where both reactive and reasoned forms play significant roles in development.

In conclusion, understanding the diverse motivations and forms of risk-taking behavior in adolescence is crucial, as it reveals both the potential risks and the adaptive benefits that contribute to healthy development during adolescence.

3. The current study: validating the Balloon Analogue Risk-Taking task (BART) in peri-rural Uganda

3.1. Internal consistency and response processes

3.1.1. Internal consistency

Internal consistency is perhaps the most important preliminary validation measure of a task. Correspondingly, Lejuez et al., (2007) used split-half reliability analysis to address this for the BART. Specifically, the authors compared the first half and second half of the trials compared with each other. Previous validation studies of the BART have shown that has good internal reliability with split-half measurement, $r > .70$, and re-test reliability (Lejuez et al., 2002; 2003; 2007; White et al., 2008).

The accuracy of measuring risk propensity has been critically questioned, with doubts about whether self-reported questionnaires or even laboratory tests can truly capture real-life risk-taking behaviors. The Balloon Analogue Risk Task (BART) was developed by Lejuez and colleagues (2002; 2007) as an alternative to self-report questionnaires and traditional economic tasks. Unlike these methods, the BART was specifically designed to offer a more concrete and adolescent-friendly behavioral measure of risk-taking. The task simulates real-life risk-taking by requiring participants to make decisions that balance potential rewards against the possibility of negative outcomes, making it a more engaging and less abstract tool for assessing risk-taking behaviors in adolescents.

In the BART, participants decide how many times to inflate a virtual balloon. Each successful pump adds points. However, if the balloon pops, no points are earned. Since participants do not know when a balloon will pop, deciding to pump is potentially rewarding but also risky. Alternatively, they can choose to collect the total amount before the balloon bursts. In every BART scenario, excessive pumping is maladaptive because it increases the risk of the balloon exploding. On the other hand, insufficient pumping is also maladaptive, as it results in missed opportunities. Therefore, the relationship between the number of pumps and overall performance usually follows a U-shaped pattern (see Fig. 5). Expected earnings gradually decline after 64 pumps because the risk of the balloon popping outweighs the possible rewards. Therefore, BART measures the risk-taking behavior with the presence of immediate rewards (avoiding the balloon exploding) and future rewards (collecting as many points as possible) across the trials.

Moreover, the neuroscience of decision-making studies also supports this theory. The prefrontal cortex (PFC) is known to be responsible for higher-order cognitive functions, and executive functions such as planning, memory, emotion regulation, reward-learning, and decision-making (Chayer & Freedman, 2001; Clark et al., 2004; Krawczyk, 2002). It has been linked to risk-taking behaviors under risk and uncertainty. The specific roles that the anterior insula/posterior gyrus (IFG/AI) and ACC play in risk assessment were examined by

Fukunaga et al. (2012). By including longer pauses between choice and feedback, they slightly altered Rao et al.'s (2008) BART experiment. It has been seen that participants who increase the pumping (increase popping probability) are more reward-seeking and show increased activation of vmPFC (Fukunaga et al., 2012). Compared to them, participants who are more likely to accept the money on the early pumps are more likely to be loss-aversion and showed more activation on ACC and bilateral IFG/AI.

Moreover, several studies have found associations between risk-taking in the Bart and real-world risky behaviors (Lejuez et al., 2003), such as delinquency (Aklin et al., 2005; Lejuez et al., 2007), smoking (Bornovalona et al., 2005), MDMA use (Hopko et al., 2006; Hanson et al., 2014); cocaine and heroin use (Bornovalona et al., 2005). In the original study, the BART was shown to be associated with self-reported real-life risky behaviors related to the addictive, health, safe, and risk-related constructs. Two latent components were derived from the self-reported risk behaviors. Drinking, gambling, and theft are included in the first component, delinquent risk behaviors. The second element is sexual risk behaviors and substance use, which are assessed by looking at things like daily cigarette consumption, drug use, and using condoms during sexual intercourse in the past year. The results of the study show that the adjusted BART is a useful tool for understanding risk behaviors since it significantly contributes to explaining variance in both categories *(Delinquency Risk Behaviors R square .448 and, Substance Use & Sexual Risk Behaviors, R square .370)* of risk behaviors.

Historically, in the Balloon Analogue Risk Task (BART), the average adjusted pumps across trials have been commonly used as the primary measure of risk-taking behavior. The adjusted average pump refers to the number of pumps on balloons that did not burst throughout the trials. However, more recent research has begun to incorporate all average pumps, including both burst and non-burst balloon pumps, as this approach captures the dynamic nature of the BART and provides insight into how learning and feedback influence pumping behavior (Pleskac et al., 2008; Rao et al., 2008; Sebri et al., 2023).

The BART-Y (Balloon Analogue Risk Task for Youth) differs from the standard BART in that the overall gain is measured in points rather than in monetary rewards. This adaptation is designed to be more suitable for younger participants, focusing on the accumulation of points instead of money, which helps in maintaining engagement while reducing the potential ethical concerns related to monetary incentives (Lejuez et al., 2007; Lejuez et al., 2002). The BART has been used with different trial levels in different studies, so one might be careful about whether it affects the outcome. Some argued that fewer trialscan lead to lower pumping, so it has been compared to 30 trials and 90 trials, but it could not find a significant difference (Lejuez et al., 2003).

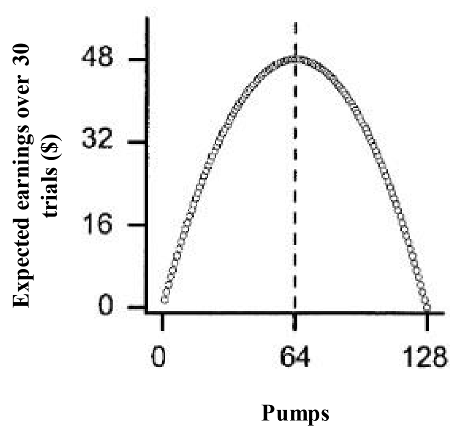

Figure 3. Expected earnings in the BART. Performance (i.e., expected earnings) in the BART is influenced by the number of pumps. Since the explosion points are randomly set

between 1 and 128, pump levels below 64 indicate risk-averse behavior, while pump levels above 64 suggest risk-seeking behavior. Reprinted from Lejuez et al., 2002.

3.1.2. Response processes

Investigating response processes is a crucial method for validating a task (Hubley, 2021). Although the Balloon Analogue Risk Task (BART) is primarily recognized as a measure of risk-taking behavior, it encompasses additional aspects that can be interpreted from participants' performance. Throughout this dissertation, the term "response process" is used to describe how participants follow specific patterns during the task. It is well established that people respond differently to the probabilities of losses and gains (Tversky & Kahneman, 1981). This concept, known as loss aversion, refers to the tendency for individuals to be more sensitive to losses than to gains. According to the value function described by Tversky and Kahneman (1979), this sensitivity is represented by an s-shaped curve, where the curve is convex for losses and concave for gains, illustrating that losses are perceived as more impactful than equivalent gains.

The way a problem is framed—whether as a gain or a loss—affects decision-making, with losses typically attracting more attention than gains (Hardman, 2009; Rolison et al., 2012; Yechiam & Hochman, 2013). This heightened attentional saliency suggests that learning from visual objects associated with gains or losses influences future decisions (Boroujeni et al., 2022). Specifically, learning which objects lead to higher gains increases the likelihood of selecting those objects in the future to maximize rewards, while learning which objects result in losses typically leads to their avoidance to minimize further losses

(Collins & Frank, 2014; Maia, 2010). While this approach aligns with rational decision-making, experimental evidence indicates that the effects of gains and losses on behavior are more complex, leading to adaptive responses that are not always straightforward or predictable.

A key behavioral pattern of interest in response processes is how individuals adjust their behavior after experiencing gains or losses. Specifically, research shows that people tend to increase their pumping after gains and decrease it after losses in subsequent trials. The exact nature of how past experiences influence risk-taking behavior remains unclear. Some studies indicate that individuals tend to be more risk-seeking following success (Thaler & Johnson, 1990; Liu et al., 2010; Ludving et al.,2015), while others suggest that risk appetite increases after experiencing losses (Thaler & Johnson, 1990; Andrade & Iyer, 2009). It is proposed that individuals make different investment decisions after similar experiences (e.g., a win or loss) depending on whether they hold a position of power. This proposal is grounded in extensive research demonstrating that power influences how individuals respond to rewards and losses, as well as their perception of risk (Brown & Smart, 1991; Di Paula & Campbell, 2002). Sekścińska and Rudzinska-Wojciechowska (2021) further emphasize the impact of power on decision-making in contexts of loss and gain, noting that individuals with high self-esteem and social power are more likely to increase risk-taking following potential losses. Consequently, sequential risk-taking behavior may vary significantly due to individual differences, including mental health factors, which will be focused in the section on the association of mental health.

A "gain" occurs in the BART when the balloon is pumped without bursting, providing positive reinforcement to continue pumping in the next trial. Conversely, a "loss" occurs when the balloon bursts, delivering negative feedback that discourages further pumping. Schmitz et al. (2016) demonstrated that using adjusted pumps in the BART correlates with positive feedback, as unburst balloons represent successful risk-taking, while the number of balloon bursts correlates with negative feedback, reflecting failed risk-taking attempts. Therefore, the total number of pumps during the trials reflects the influence of both positive and negative feedback on participants' performance in the BART.

Response processes in the Balloon Analogue Risk Task (BART) are significantly influenced by individual differences in sensitivity to reward and punishment. While sensitivity to punishment is crucial in guiding risk-taking behavior, by helping individuals avoid harmful activities and reduce potential punishment, it also has an adaptive component. This sensitivity can lead to safer decision-making in uncertain situations, thus lowering the chances of engaging in risky behaviors with negative consequences. However, high punishment sensitivity can interfere with effective reward-based learning strategies, inhibiting an individual’s responsiveness to rewards. This inhibition occurs because the increased focus on avoiding punishment can overshadow the potential benefits of reward-based decisions. Neuroimaging studies have shown that punishment-based learning is associated with increased activation in the insula and lateral orbitofrontal cortex, regions implicated in the processing of punishment (Elliot et al., 2010; Xue et al., 2013).

Moreover, heightened punishment sensitivity has been linked to depressive symptoms, suggesting that individuals with greater sensitivity to punishment may be more vulnerable to mental health challenges (Hevey et al., 2017; Eshel & Roiser, 2010). In summary, the response process in the BART is a vital component that is closely tied to real-world risk-taking behaviors and mental health, emphasizing the complex interplay between reward, punishment sensitivity, and psychological outcomes.

The Balloon Analogue Risk Task (BART) is one of the best-known risk-taking measures in Westernized countries, but it has rarely been studied in different cultural settings. The main goal of this research is to validate the BART in adolescents of peri-rural Uganda by means of internal consistency and response processes. Also, investigate its relationship to real-life risky behaviors and mental health. The findings of this study will be useful for interventions aiming to foster better mental health and modulate risk-taking behaviors in regions of sub-Saharan Africa. It will also help understand how risk-taking can contribute to mental health.

3.2. Association with different types of real-world risky behavior

There are many other tasks have been used in the literature to investigate the risky decision-making mechanisms (i.e., Iowa Gambling Task (IGT), Delay Discounting Task, Cambridge Gambling Task (CGT), Columbia Card Task (CCT) and Bechara gambling Task (BGT)). Some of these tasks are better at measuring different aspects of risky behaviors, for example, effective decision-making with IGT (Bechara et al., 1994) and CCT (Figner et al., 2009). According to the explanatory factor analysis conducted on the most used risk-taking tasks, the Iowa Gambling Task (IGT), Columbia Card Task (CCT), and Balloon Analogue Risk Task (BART), these tasks were found to measure different dimensions of risky decision-making in adolescent samples (Buelow & Blaine, 2015). Beyond the primary factors that were analyzed, these tasks also differ in other significant ways, such as the specific risk-taking indicators they assess, the nature of the decisions involved, and the instructions provided to participants. For example, the IGT is more focused on long-term decision-making and learning from feedback, the CCT emphasizes risk evaluation under different conditions, and the BART assesses risk-taking in a more immediate and dynamic context. These variations highlight the complexity of measuring risk-related behavior and the need to consider multiple approaches to fully understand adolescent risk-taking.

The BART has been focusing on decision-making studies by valuing the predictability of real-life behaviors, and tasks as closer to the real-life context. Numerous studies have validated the Balloon Analogue Risk Task (BART) as an effective measure of real-life risk-taking behaviors, particularly impulsivity and substance use. The BART has been widely used to assess risk-taking propensity, showing strong correlations with impulsivity in various studies (Andrews et al., 2011; Lejuez et al., 2002). This task has been particularly valuable in alcohol research, where it has been used to study binge drinking behaviors in adolescents (Bourque et al., 2016) and adults. Specifically, the number of balloon pumps in the BART has been positively correlated with alcohol consumption in studies involving both adolescent and adult participants (Lejuez et al., 2002; Weafer et al., 2011; Fernie et al., 2010).

A meta-analysis by Biernacki et al. (2016) further confirmed the BART's effectiveness in detecting substance use and decision-making deficits, highlighting its predictive validity for substance use as initially demonstrated by Lejuez et al. (2002).

Additionally, the BART has been linked to other risky behaviors, including gambling (Mishra et al., 2017) and HIV-related risky sexual behaviors, as shown in a study with 96 African American adolescents using the BART-Y (Bornovalova et al., 2007). These findings collectively support the BART as a robust tool for assessing various forms of real-world risk-taking behavior, making it a valuable instrument in both research and clinical settings.

Besides the correlation of the self-report risk-taking measurement and BART, many researchers have started to investigate real risk-taking behavior rather than showing the predictive association with the self-report ones. Many studies conducted on BART and its relation to unhealthy risk behaviors. Self-report risk behaviors, such as gambling, risky sexual behavior, drug addiction, and smoking (Lejuez et al., 2003, 2005). Problematic drug and alcohol use is associated with increased risk-taking in the BART in asymptomatic adolescent groups (Lejuez, et al., 2002; MacPherson et al., 2010; Aklin et al., 2005).

Although the BART is a widely used measure of risk-taking across various samples, recent studies have increasingly reported conflicting findings. Campbell, Samartgis & Crowe (2013) shared interesting findings from their experimental study which compared the risk-taking levels between alcohol users and nonusers; they showed long-term alcohol usage leads to less risk-taking compared to nonusers; suggesting risky behavior can impair the risk-taking behavior. It is interesting because it is just one of the controversial findings related the risky behavior and BART relations. A study on smokers and non-smokers found that BART was able to identify a link between smoking behavior and sensation-seeking scores, whereas the BGT did not show a difference between the groups (Lejuez et al., 2003). Moreover, a systematic review of Canning, Schallert, and Larimer revealed the BART in the recent literature of alcohol research (2022). In alcohol research, BART was used to measure three different aspects to verify different levels of alcohol use engagement in risk-taking behavior.

Also, Acheson and de Wit (2008) could not find differences between smoker and non-smoker groups in terms of smoking behavior and BART pump levels. These results might be related to the low power of the study; number of the smokers was 10 and the nonsmokers were 20. According to Ray and Ashenhurst, 2010 risk-taking behavior has shown a negative correlation between the problematic alcohol level and the pumps within 51 participants who have alcohol use disorder.

Bell, Laws, and Petrakis, (2017) study measured the after-cognitive remediation intervention of individuals who had a substance abuse history and showed increased risk-taking behaviors which correlated with heightened executive functions. Even though researchers expected to see decreased risk-taking behavior due to decreased substance use, results were surprising to show BART may measure the adaptive risk-taking behaviors as well as mentioned by Bell and colleagues (2019). These controversial findings may suggest that the BART is not solely a measure of maladaptive risk-taking, but can also capture adaptive risk-taking behavior.

3.3. Association with mental health

Since BART has been an important predictor of risk-taking behavior in adults, and adolescents, recent studies focused on the validity studies of BART measuring different samples with the mental health variables. The original study of Lejuez and colleagues in

2002, investigated the level of anxiety with the Anxiety Sensitivity Index (ASI) and depression with the Center of Epidemiological Studies Depression Scale (CES-D) besides measuring impulsivity as risk-taking indicators. Although the results did not find a significant correlation between the pumps as a risk-taking indicator and mental health behaviors, recent studies on the BART have drawn a link between risk-taking in the Bart and anxiety. For example, Pleskac and colleagues found a significant negative relationship between anxiety and performance on the BART (2008). This indicates that higher levels of anxiety are associated with lower risk-taking behavior.

Furthermore, adults who have anxiety tend to avoid risks (Lorian & Grisham, 2010; Maner & Schmidt, 2006; Maner et al., 2007) which can also lead to the risk avoidant behavior (Lorian et al., 2012). Therefore, it may be a potential predictor of developing anxiety symptoms (Tieskens et al., 2021, Lorian & Grisham, 2010; Maner et al., 2007). Literature mentions there is a bidirectional link between a lack of risk-taking, which is avoidance of risky behaviors, and the development of anxiety symptoms in adolescence, and adulthood. Although BART mostly looked into maladaptive risk-taking and psychopathology, it looks like overlooked investigating relation to the adaptive risk-taking.

The relationship between depression and risk-taking behavior is more complex. Some studies have found no significant correlation, indicating that depression might not directly influence risk-taking behavior in a straightforward manner (Pleskac et al., 2008). However, more nuanced approaches that examine the underlying response processes, such as punishment sensitivity, have revealed important findings. For example, Augsburger and Elbert (2017) found that BART performance was negatively associated with depressive symptoms in a group exposed to civil trauma. They suggested that exposure to stressors, which can significantly impact mental health, should be considered when evaluating risk-taking behavior. This highlights the importance of considering the broader context in which risk-taking occurs, particularly how mental health factors like depression might interact with environmental stressors to influence behavior.

Differently, Hevey and colleagues (2017) investigate the effect of clinical depression and punishment sensitivity. They found that the depressed group showed clear risk aversion, (M=50.83) lower than the healthy control groups (M=63.25) in the BART although instructed the optimal pump is 64. Therefore, individuals who have suffered from depression and anxiety might be punished, maximizing the rewards for the participants. In other words, individuals who are depressed have a punishment-avoidant strategy. Rewarding stimuli are not perceived as reinforcing for depressed individuals, which leads to missing opportunities. Esher and Roiser highlighted that depression level is associated with punishment sensitivity (2010). Kim and colleagues did a similar study on subclinical and undergraduate students to test whether depressive symptoms and BART correlate. However, they could not find a hypothesized relation between depressive symptoms and pumps. More interestingly, depression levels played a role in the subsequent trial whether previously was gain or loss. Higher depression level individuals showed risk-seeking after gain trials but not in loss. However, they were more punishment-sensitive after a loss (Kim et al., 2021).

The first objective of the study is validating the BART through internal consistency measurement and response process analysis among peri-rural adolescents in Uganda. The second is that examining the external correlations of the BART involves assessing its relationship with various real-world risk-taking behaviors mental health variables. This helps to determine how well the BART aligns with other measures of risk-taking and mental health outcomes, ensuring its validity as a tool for evaluating these behaviors and conditions.

4. Methods

4.1. Participants and Procedures

Adolescents in the pre-rural of Uganda (N= 310, 155 females, M age=17.01, SD= 1.4, participants ranged: 15-19) participated in the study. The participants had an average of 8.67 years of education (SD = 2.15), and a mean poverty score of 60.03 (SD = 10.15), see Table 1. The sample size estimated per variable ensures enough participants (n=10) for reliable correlation analysis. The inclusion criteria for participation were being fluent in English or Luganda, and being aged 15-19 years. The informed consent was completed directly from participants aged ≥ 18. Assent from the parent or legal guardian was required for young participants. All tasks and questionnaires were administered by bilinguals.

Fieldworkers were specifically trained for this study and recruited participants by visiting households during random walks within each catchment area across 10 villages in Uganda. Participants were tested individually, with each completing all items in a single session on an electronic tablet in their homes. Data on risky behaviors were collected using Audio Computer-Assisted Self-Interviewing (ACASI) software. Participants listened to prerecorded survey questions through headphones and selected their responses on the tablet, ensuring privacy for sensitive behaviors, such as drug use and risky sexual behaviors.

To compensate participants, they received small "in kind" goods like soap or wheat, consistent with the standard procedure followed by BRAC for research purposes in Uganda. The Balloon Analogue Risk Task (BART) was incentivized with the chance to win a small amount of mobile airtime (up to 5,000 Ush / £1.05). Each testing session lasted approximately two hours, with an option for a break to rest and have a snack if needed during the mid-study visit. Data collection occurred between March 2020 and February 2021. All data were entered into an encrypted Qualtrics database at the BRAC Uganda Office.

The study was conducted under the principles of the Declaration of Helsinki and was approved by the Institutional Review Boards in the United Kingdom (Oxford Tropical Research Ethics Committee) and in Uganda (Makerere Review Boards in the United Kingdom (Oxford Tropical Research Ethics Committee) and in Uganda (Makerere University School of Public Health). University School of Public Health).

	N	**Age Range**	**Age Mean (SD)**	**Education Mean (SD)**	**Poverty Score Mean (SD)**
Adolescents	310	15-19	17.01 (1.4)	8.67(2.15)	60.03(10.15)

Table 1. Participants’ demographics table

4.2. Materials and Measurements

4.2.1. The BART

In total, there are 20 trials excluding the practice trials. Participants had to inflate a virtual balloon between 0 and 128 pumps. With each pump, participants' potential earnings increased, but there was also a chance that the balloon would burst and lose the earnings. Therefore, each trial included a measure of risky decision-making as participants made choices about how much to pump the balloon to potentially boost wins, even if doing so could result in them losing everything they had earned so far on that trial (points earned on previous trials were not lost). Participants were not informed about the explosion points of the balloons, and each participant was randomly assigned to one of three lists of balloons. The average explosion point was always 64, across the lists, and each list also had comparable variance. These lists were only introduced to eliminate possible order effects that might have emerged through randomization.

Pleskac and colleagues (2008) developed the automatic BART as an improved version of the Balloon Analogue Risk Task (BART) to address limitations in the original task that could influence participants' risk-taking behaviors. Unlike the original BART, where participants manually pumped the balloon by pressing a key, the automatic BART asks participants to decide upfront how many times they want to inflate the balloon. This change aims to reduce bias in measuring risk-taking decisions.

The study found that the automatic BART measures risk-taking propensity using a target score, which is the average of the indicated pumps. This score showed similar correlations with self-reported risk behaviors as the original BART, thus maintaining external validity (Pleskac et al., 2008; Lejuez et al., 2002). The automatic version also offers benefits like shorter administration times and less physical effort, making it a more efficient tool for assessing risk-taking behavior. The variation in balloon explosion points across trials further ensures an unbiased measurement of risk-taking.

The current Automatic BART is a modified version of Pleskac et al. (2008), incorporating feedback by indicating the explosion point of the balloon at the end of each trial, and showing the number of pumps relative to the explosion point. The feedback in the BART was innovative, providing explicit feedback on how many pumps the balloon would burst later or earlier.

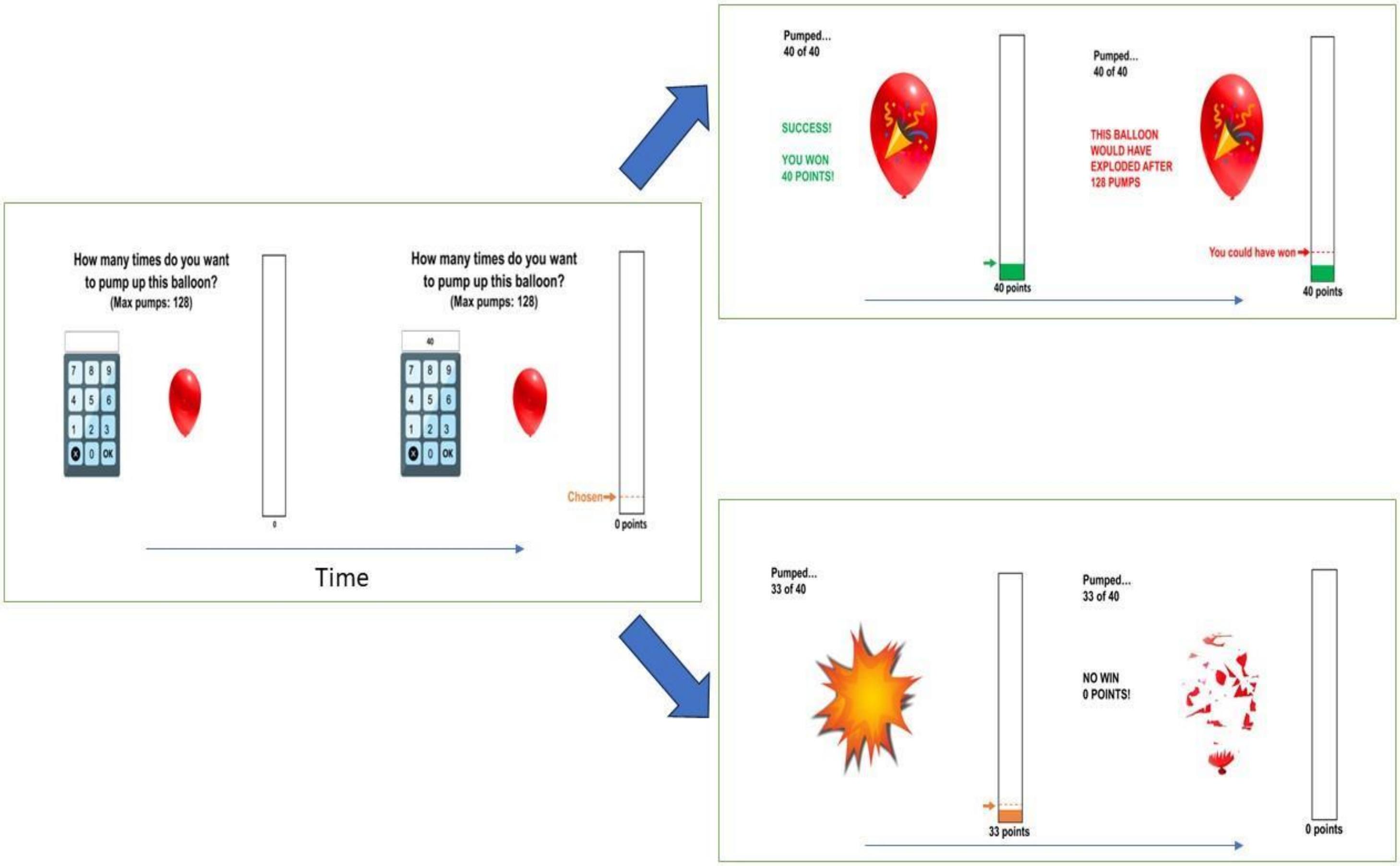

Figure 4. The Balloon Analogue Risk Task

4.2.1.1. Calculation of previous trial-related variables: win vs. loss

4.2.1.1.1. Change:

$$(pump.t\ -\ pumpt.t - 1)$$

4.2.1.1.2. Distance:

$$(pump.t - 1\ -\ expl.pt.t - 1)$$

4.2.1.1.3. Real-Word Risky Behaviors

4.2.1.2. Substance use

To screen substance use, the ASSIST-Y (Alcohol, Smoking, and Substance Involvement Screening Test for Youth) questionnaire was utilized for adolescents aged 15-17. In contrast, an adapted version of the ASSIST was used for the remaining age range of participants (South Australian Health, 2013). Structured questionnaires were used and participants were asked to self-report/rate their involvement in a wide range of risk behaviors.; ASSIST-Y Opioids, Tobacco, Alcohol, Cannabis, Cocaine, Amphetamines, Inhalants, Sedatives, Hallucinogens.

Participants were asked whether they ever had used these substances, if so during the past 3 months or not in the last three months and how often. They were also questioned about substance use on its own, including whether it resulted in issues, affected their daily activities, or worried other people.

4.2.1.3. Other Behaviors

Other behaviors hit and damaged variables measured by the questions that measure physical aggressiveness, trespassing, property damage, and theft were among the other risky behaviors covered in the questionnaire. In the last thirty days, participants stated if they have engaged in these behaviors.

4.2.1.4. Gambling

Gambling was assessed by asking participants to report the amount of money they had won or lost from betting or gambling during the specified period.

4.2.1.5. Risky Sexual Behaviors

The questions on risky sexual behaviors include topics such as unintended pregnancy, whether the participant has ever been pregnant unintentionally, unsafe sex (e.g., sex without a condom), risky sex (e.g., sex while drunk or high), and transactional sex (e.g., paying for sex), with responses recorded as yes or no.

4.2.1.6. Delinquency and Gambling

Delinquency was assessed by asking adolescents about their participation in delinquent activity over the past 30 days. This measure ranged from hitting or smacking somebody, entering a building without the permission of someone in control, and causing real damage to another person's property by stealing something.

Additionally, the gambling question asked whether participants had engaged in gambling within the past 30 days.

4.2.2. Mental Health

4.2.2.1. Depression

Depressive symptoms were measured using the Patient Health Questionnaire Adolescent (PHQ-A) a questionnaire that measures (Kaggwa et al., 2022). The PHQ-A is a reliable and widely used tool that consists of 9 items designed to measure adolescent depressive symptoms over the past two weeks. The total score of the PHQ-A ranges from 0 to 27 and can be calculated by adding all the responses of the items, which are ‘’0’’ (not at all) to ‘’3’’ (nearly every day). The PHQ-A has subcategories showing the depression levels, starting from 1-4 as minimal depression, 5-9 as minor depression, 10-14 as moderate depression, 15-19 as moderately severe depression, and 20-27 indicates severe level of depression as a total score. In Uganda, the PHQ-A is a validated and reliable measurement (Kaggwa et al., 2022), and has shown a good level of Cronbach’s alpha =.78 in the current study population.

4.2.2.2. Resilience

Resilience is measured by the Connor-Davidson Resilience Scale (CD-RISC), is a questionnaire that measures the degree of resilience by asking to think about the last month (Davidson, 2018). The CD-RISC has 10 items that are scored from ’0’ (not true at all) to ‘4’ (true nearly all of the time). The total score of the scale is the sum of all the items. The CD-RISC has good validity and reliability scores shown in various cultures and characteristics of the samples, as well as in Uganda adolescents (Klasen et al., 2010). In the current study, the scale has shown good reliability, with *a Cronbach's alpha of .83*.

4.2.2.3. Anxiety

Generalized Anxiety symptoms measured by the Generalized Anxiety Disorder (GAD-7), is a questionnaire that measures the generalized anxiety symptoms past two weeks (Spitzer et al., 2006), with responses of '0' (not at all) to '3' (nearly every day). The total score of GAD-7 is the sum of responses to all the 7 items, ranging from 0 to 21. The increased total score indicates a higher anxiety level which can be subcategorized with 0-5 as minimal, 6-10 indicates moderate, 11-15 reflects moderately severe anxiety and 15-21 suggests severe anxiety level. The GAD-7 showed good internal consistency with, Cronbach a score = .87 in the current study.

4.2.2.4. Behavioral Activation

The Behavioral Activation for Depression Scale (BADS) is a questionnaire that measures how well someone functions while feeling sad by considering the past week, including today. The BADS has 25 items with 5 subscales: Activation, Avoidance/Rumination, Work/School impairment, and Social Impairment (Kanter et al., 2007). The total score of the BADS is calculated by the overall sum of the seven-point scale ranging from '0' (being very untrue) to '6' (very true) in each subscale. Except for the activation scale, all the items in other subscales were reverse-coded (6=0, 5=1). An unweighted sum was calculated to compute the total scale score. In other words, an increase in the total score indicates higher activation although an increase in the social impairment subscale indicates higher social impairment. The BADS shows good internal consistency Cronbach's alpha =.84.

4.2.2.5. Emotional Well-being

The Warwick- Edinburgh Mental Wellbeing Scale (WEMWBS) measures the emotional well-being of the participants (Tennant et al., 2007). Items focus on the psychological functioning, and emotional well-being of participants by asking them to think about the last two weeks. The total score of WEMWBS ranges from 14-70, by the sum of all responses of 14 items on a 5-point scale of '0' (none of the time) to '4' (all the time). Including Uganda and many countries, the WEMWBS has seen good reliability and validity and has shown excellent internal consistency *with Cronbach's alpha score =.91*

4.2.2.6. Rumination

The Ruminative Response Scale (RRS) is a self-administered questionnaire that measures rumination by asking to think of the statements when they are sad, or depressed. The RRS has 10 items and has two subscales reflection and brooding. The total score is the sum of each item ranging from a 4-point scale of '1' (almost never) to '4' (almost always) (Treynor et al., 2003). In the current study, rumination was measured by the five items of the RRS, which are the factors of brooding e.g. ''Think "Why do I have problems other people don't have?"'. It showed enough level internal consistency coefficient, Cronbach's alpha score = .69.

4.2.3. Sociodemographic

4.2.3.1. Food Insecurity

The Item Short Form of the Household Food Insecurity Scale is a questionnaire that estimates household food insecurity by asking 6 questions considering the last 12 months, developed by the National Center of Health Statistics (USDA, 2012). For example, have you ever needed to skip your meal because there wasn't enough money for food, answer by choosing an appropriate statement between often true, sometimes true, never true, or yes, no, and don't know. The total score is the food insecure index, categorized by high or marginal food security, low food security, or very low food security.

4.2.3.2. Poverty Score

The Simple Poverty Scorecard Poverty-Assessment Tool, Uganda **is** a questionnaire that estimates how likely it is that a household is living in poverty in Uganda. It is a low-cost tool, which consists of 10 questions that assess the number of people in the household, education level, and what items the household owns. The total score is used to classify whether the household is in the range of poverty line (Schreiner, 2015).

4.3. Statistical Analysis

4.3.1.1. Internal consistency and response processes

4.3.1.1.1. Internal consistency

To assess the internal consistency of the BART, we adopted a rigorous approach inspired by Lejuez and colleagues. Instead of simply comparing the average number of pumps in the first and second halves of the task, we employed a bootstrapped split-half reliability analysis. This method involves randomly sampling trials multiple times and calculating the average pumps for each sample. Specifically, we used the “splithalf” package in R, which provides a more robust assessment by comparing the average pumps across 5,000 randomly sampled trials.

The R function used for this analysis is part of the "splithalf" package, which includes functions such as splithalf that automate the process of calculating split-half reliability with bootstrapping. This approach enhances the reliability estimation by considering a wide range of possible splits, thereby reducing the likelihood of a biased estimate that could arise from a single arbitrary division of trials.

In addition to the bootstrapped split-half method, we also performed traditional reliability analyses, such as calculating Cronbach’s alpha, to further assess the consistency of the task. The split-half method specifically compared responses from the first 10 trials to the remaining 10 trials out of the total 20 trials, aligning with the validation and reliability methods used in the original BART-Y by Lejuez and colleagues (2007). Measures of reliability that exceed a threshold of .70 are considered adequate, providing a benchmark for the consistency of the task.

4.3.1.1.2. Response processes

Response processes were examined in two ways: first, by analyzing whether changes in pump behavior from one trial to the next varied depending on whether the previous trial resulted in an explosion or not; and second, by investigating whether the extent of this change was influenced by how close the pumps were to the actual explosion point.

For the first question, a trial-level analysis was conducted. A mixed model was used to predict the change in pumps (the dependent variable) across all trials except the first (since no change can occur after the first trial). The key independent variable was a 2-level dummy factor coded as "win" or "no-win," indicating whether the previous trial ended without an explosion. To account for repeated measures, the model included participants' IDs as random intercepts.

4.3.1.1.3. Exploratory Factor Analysis

The exploratory factor analysis was done to reduce the data complexity of the self-reported mental health and real-life risk variables. For both sets of variables, as a preliminary step, the Kaiser-Meyer-Olkin score was computed as a (KMO) measure of sampling adequacy (Field, 2012). The KMO ranges between 0 to 1, with values closer to 1 indicating reliable correlation patterns for factor analysis. KMO is recommended to be higher than >.05, .5-.7 are mediocre, .7-.8 are good and values between .8-.9 are great, and above .9 are superb (Hutcheson and Sofroniou, 1999).

4.3.1.2. Real-World Risky Behavior

Several real-world risk behavior measures were used, including rating scales from the ASSIST-Y, which assessed the use of substances such as opioids, tobacco, alcohol, cannabis, cocaine, amphetamines, inhalants, sedatives, and hallucinogens. Additionally, questionnaires were administered to evaluate risky sexual behaviors, behaviors involving "hit and damage," delinquency (indicating "delinquent behaviors"), and gambling. For more details, refer to the materials and measurement section under the real-world risky behaviors subsection. Since few participants provided any response higher than 1, the responses of most real-world risky behavior variables were binarized, with 0 indicating that participants did not self-report taking in the behavior, and responses larger than 0 indicating that they did. This approach yielded a reasonable number of non-zero responses, ranging from 9 for amphetamines and cannabis to 76 for alcohol and 199 for substance use in the past 3 months. Moreover, we required a minimum of 10 non-zero responses to be included in the analysis. This resulted in the following variables: "ever tried substances" (174 participants), tried substances in the past 3 months (111 participants), alcohol use (76 participants), opioid use (48 participants), sedative use (31 participants), and tobacco use (14 participants). The gambling variable had 168 missing values, making it unsuitable for inclusion in the analysis as more than half of the data was missing.

Although the factor analysis was designed to follow the methodology used in the BART-Y study by Lejuez et al. (2007), we did not observe a reliable factor structure for the real-world risky behavior variables. This was due to a combination of missing data, high uncorrelated variables, and the presence of Heywood cases, see Appendix, page 71.

A mixed-effects logistic regression model (GLMER) was conducted to predict whether participants self-reported engaging in a risky behavior or not. This outcome variable was modeled based on the type of risk, a factor with 10 levels indicating the type of risk-related variables, the average level of risk in the BART, modeled as a continuous predictor, and the interaction between these factors.

4.3.1.3. Mental Health

Kaiser-Meyer-Olkin factor adequacy (KMO) was 0.64, which shows mediocrity for mental health variables loaded for each variable; depression (PHQ-A) = 0.65, anxiety (GAD-7) =0.61, (CD-RISC) = 0.78, rumination (RRS)= 0.68, emotional well-being (WEMWBS)= 0.54, behavioral activation for depression scale =0.78.

Furthermore, Bartlett's test of sphericity was used to find out if the data was suitable for factor analysis. With a significant test result of χ^2 (15) = 331.59, $p < .001$, it was determined that the data was suitable for factor analysis and that the correlation matrix was not an identity matrix. Most of the indicators, including the Kaiser rule (eigenvalues), parallel analysis, optimal coordinates, and the acceleration factor, suggested a two-factor solution. Consequently, a two-factor structure was retained. The overall six mental health variables have recovered %43 by the two-factor structure and demonstrated satisfactory fit (RMSE= 0.067; TLI=0.934). Factor 1 was named "Anxiety" (gad7_total) and loaded 0.91, although Resilience negatively loaded on it, Depression and Rumination also positively loaded on it.

Factor 2 was named "Emotional well-being" (wemwbs_total) loaded 0.80, and resilience also positively loaded on this factor, see Table 2.

To investigate the association between risk-taking in the BARTt mental health we used a similar statistical model as we did for the real-world risk-taking behavior. In this case, the outcome variable was the latent mental health score. This was predicted based on risk-taking in the Bart, again modeled as a continuous predictor, the type of mental health score, modeled as a two-level factor (Emotional well-being vs. Anxiety) and the interaction between these predictors.

	Depression	**Anxiety**	**Behavioral Activation**	**Rumination**	**Resilience**	**Emotional Well-being**
Anxiety	0.622	0.913	-.401	0.465	-	-.124
Well-Being	-0.193	-	0.178	0.133	.507	0.7396

Table 2. Two-Factor Structure of Mental Health Variables.

5. Results

5.1.1. Measures of Reliability

Split-half reliability measurement showed, BART has r=.81, which is good for internal consistency. The grand mean of pumps in the Bart was 58.71. A t-test showed that this was significantly less pumping than risk neutrality, namely, 64 pumps (95% CI [57.25 60.17], t (309) = p < .001), see Figure 5, Panel A for the overall results, and see Appendix,

Figure 7 for the gender breakdown version. Comparison with risk neutrality which is 64, is significant $p<.001$.

5.1.2. Response Processes

A mixed model revealed a significant omnibus effect of the previous outcome (gain vs. loss) on the extent of change in the next trial (X^2 (1) = 821.77, $p < .001$). Post-hoc analysis showed that while changes after a win were significantly positive, indicating that participants increased their pumps relative to the previous trial (mean = 9.72, CI [8.64 10.8], $p < .001$), they were significantly negative, indicating a decrease in pumping, after a loss (mean = -14.01, CI [-15.22 -12.8], $p < .001$). Correspondingly two means also differed significantly from one another (mean = -23.7, CI [-25.4 -22.1], $p < .001$), refer to Figure 5, Panel B for the overall results, and see Appendix, Figure 8 for the gender breakdown version. Results of a mixed revealed a significant trend of distance on the amount change (omnibus result). Trend analysis suggested this was due to a negative association between distance and change (slope = -.33, 95% CI [-.349, -.316], $p < .001$), refer to Figure 5, Panel C. This could be explained by how participants adjusted their pumping behavior based on their proximity to the balloon's explosion point, either increasing or decreasing their pumping proportionally as they neared the potential explosion. Similarly, their behavior changed depending on how far they had already gone beyond the explosion point.

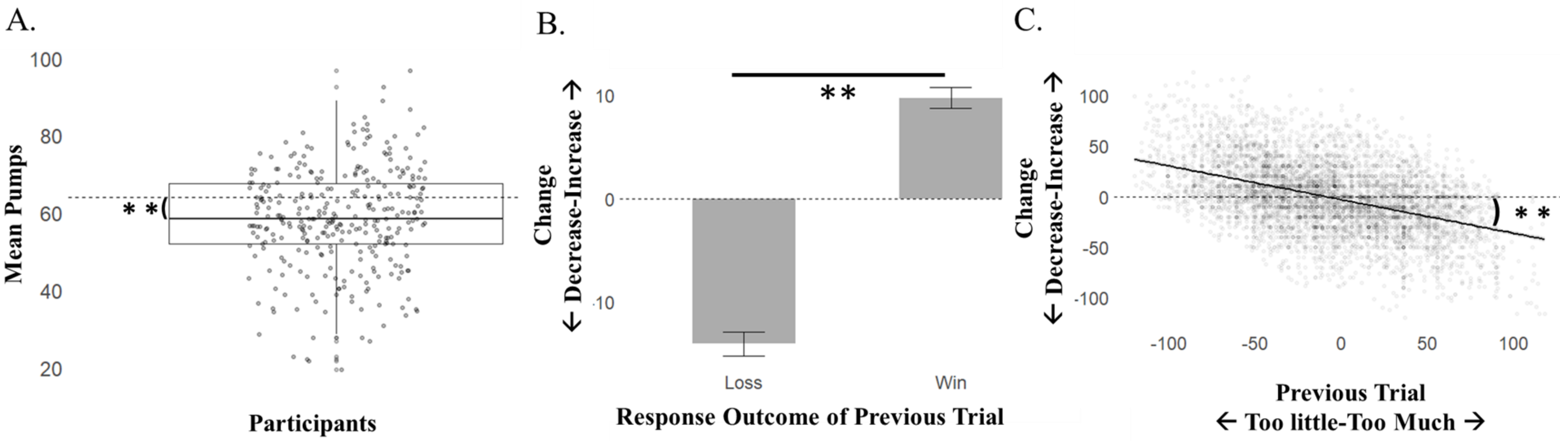

Figure 5. Response Processes in the BART. Panel A, the first graph on the left, is a boxplot displaying the average number of pumps in the BART. Panel B and Panel C represent the response processes. Panel B, on the right, the bar graph shows the average change in pumping (y-axis) following the previous trial outcome in the BART (x-axis), whether it was a loss or a win. According to the bar graph, individuals are more likely to increase their pumps following a win and decrease them following a loss in consecutive trials. The change between loss and win trials is significant (p < .001). Error bars represent a bootstrapped confidence interval of %95. Panel C, positioned in the middle, the scatter plot illustrates the relationship between the previous pumping distance (x-axis) and the change in pumping in BART (y-axis). The x-axis is labeled previous, under the arrow entering the 0, to the left as too little, and to the right as too much pumping in the previous trial; the y-axis presents the direction of the change, decreasing to the left and increasing to the right. The black linear regression line on a dashed horizontal line at y=0. The slope of the black line is = -.33, p<.001, indicating a negative relation between the distance of the previous trial and the change in a pump.

**p < .01, * p < .05, p < .1.

5.1.3. Association Between BART and Mental Health

Anova revealed that the mean number of pumps interacted with the type of latent factor (Anxiety vs. emotional well-being) in predicting the latent factor scores of mental health (F (1. 616) = 10.10, p = .002). Trend analysis suggested that this was due to a positive correlation between risk-taking in BART and emotional well-being (r =.015, p = 0.0064), but a marginally significant negative association with anxiety (r =-.01, p =0.071).

5.1.4. Association Between BART and Real Word Risky Behaviors

A mixed effect logistic regression showed that there was no significant association between risk-taking in the real world and risk-taking in BART ($\chi2(1, 310) = 0.09$, $p = .765$): the slope was slightly positive but non-significantly different from 0 (slope = 0.002, 95% CI [-0129 0.0175], p = .765), see fig. 6, Panel B. There was also no significant interaction between risk-taking in the BART and the type of risk-taking, in predicting real-world risk-taking (($\chi2(9, 310) = 9.7036$, $p = .375$). Even highly exploratory post-hoc trend analyses on the same model showed that there was no association between risk-taking in the Bart and risk-taking in any of the 10 dimensions of risky behavior tested here (all ps > 0.06, uncorrected, see Fig 12 in the Appendix).

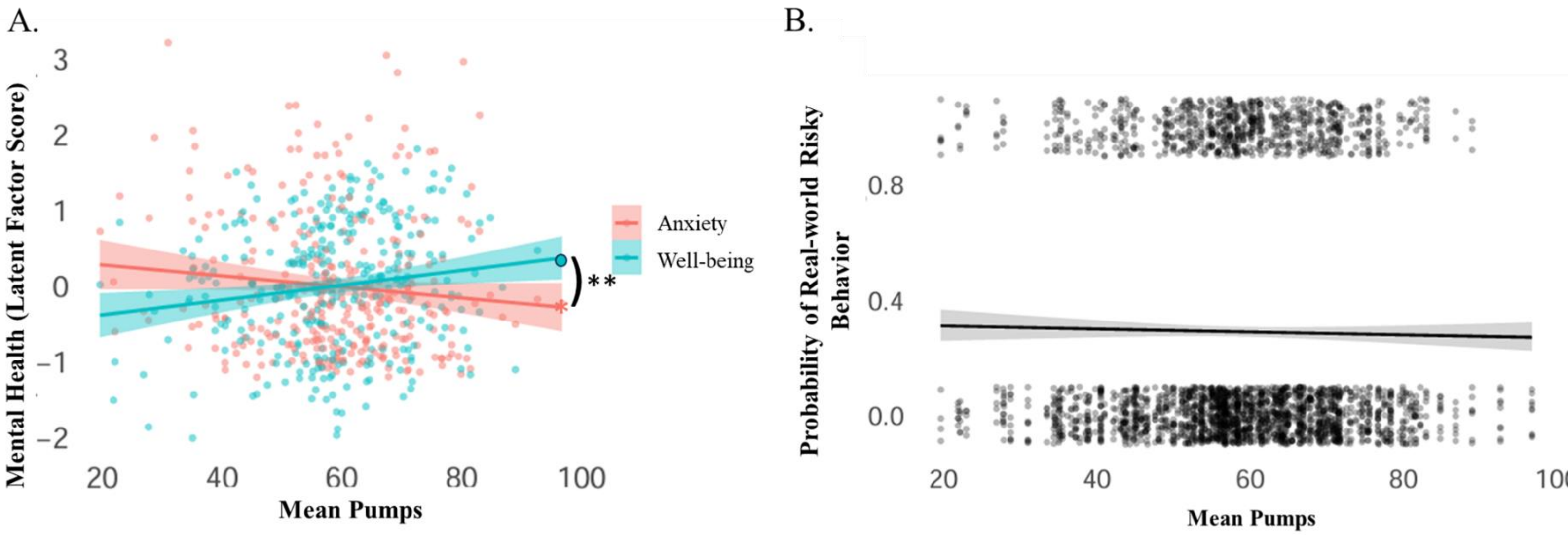

Figure 6. **Associations of BART.** The scatterplot illustrates the association between risk-taking in the BART (mean pumps on the x-axis) and two latent factors of mental health on the y-axis: well-being (green) and anxiety (red). The interactions are statistically significant, as indicated by the arc between trends. **p < .01, * p < .05, p < .1

6. Discussion

This study aimed to validate the BART among adolescents in peri-rural Uganda, an underrepresented group in psychological research. Split-half reliability analysis showed that risk-taking in the Bart was highly consistent among participants despite high heterogeneity between participants. Response processes analysis also showed that participants adapted their risk-taking strategies based on whether they previously won or lost. They were found to increase their risk-taking behavior after a gain and were likely to decrease after a loss. Further analysis of the response processes revealed a negative association between the change in behavior between trials and the distance effect. As the distance between the actual outcome (balloon explosion point) and the expectation (pump) increases across trials, adolescents tend to adjust their risk-taking behavior in the BART by reducing the number of pumps.

Lastly, while the BART did not correlate with any of the self-reported real-world risky behaviors examined in this study, it was found to be differentially associated with two distinct latent factors of mental health, showing a negative association with anxiety and a positive association with emotional well-being.

Internal consistency is an essential preliminary test when applying any psychological measure in a new cultural context. Likewise, evaluating response processes is important to confirm that the target population is properly engaging with the task. Our findings suggest that, in both regards, the BART is well-suited for use with adolescents in peri-rural Uganda.

Moreover, the response processes showed that people become more cautious after a loss compared to a risk. This signals the learning effect, both positive and negative effect. It might be interesting the see whether the magnitude of the changes after loss are larger than gains. Although we do not further analyze it since it did not align with the objectives of this validation study, it might be expected to see participants react more to loss than gains, as known loss aversion (Tversky & Kahneman, 1984).

6.1. Associations of BART and Real-World Risky Behaviors

6.1.1. Inconsistencies in the BART

We did not find any associations between real-world risk-taking and risk-taking in the BART. This may have occurred due to several reasons, first, one is the point is methodological variations in BART by the original study (Lejuez et al., 2002). Historically, BART has been a risk-taking task that predicts real-world risk behaviors, and maladaptive risks. Some studies have failed to find a relationship between real-world risky behavior measurements and BART performance (Acheson et al., 2007; Acheson & de Wit, 2008; Cross et al., 2011; Reynolds et al., 2006). Additionally, a systematic review of alcohol consumption and BART performance highlighted that the relationship varies depending on the specific measurement used (Canning et al., 2021). Some studies found no correlation between alcohol consumption, gambling, and BART (Ledgerwood et al., 2009; Ashenhurst et al., 2011), some studies identified a negative relationship with the frequency of alcohol use (Courtney et al., 2012). Interestingly, another study found that the relationship was negatively correlated with the frequency of consumption but positive with the quantity consumed (DeMartini et al.,2014). This suggests that the connection between BART and real-world risk behaviors may depend on how those behaviors are measured. Therefore, recent literature has also raised concerns about BART's ability to capture real-world risk-taking.

A recent study by Howsley (2016) failed to find an association as well, between risk-taking behavior in real-world contexts and risk-taking in the BART. The author suggested that the concepts of risk-taking measured by each are fundamentally different stating developmental trajectories. Real-world risky behaviors are conceptually different because they often arise in highly arousing social environments, such as substance use with peers. In contrast, the BART is a computerized risk-taking task conducted in a relatively low-arousal, isolated setting, as was the case in the current study (Howsley, 2016). Moreover, real-world risky behaviors were observed more associated with impulsivity which heightened early adolescence and decreased towards md-adolescence, whereas risk-taking peaked in mid-adolescence. Due to developmental trajectory differences, many studies failed to find a relation suggest. This explanation aligns with our speculation that real-world risky behaviors, particularly those that lead to harm in maladaptive forms, are unlikely to be predicted by the BART, which primarily measures adaptive risk-taking.

6.1.2. Conceptual differences in risk-taking and BART

The second reason we may have failed to find a relationship between real-world risky behaviors and risk-taking in the BART could be due to methodological differences in how the task was administered compared to the original BART. For example, De Groot (2020) identified methodological issues within the BART literature, including the challenge of distinguishing between adaptive and maladaptive risk behavior. One issue is that the BART may not reliably differentiate between adaptive risk-taking, which involves maximizing earnings through strategic pumping, and maladaptive risk-taking, which could lead to negative outcomes. Additionally, De Groot suggested that providing additional feedback after each trial could enhance learning and subsequently affect performance on the task.

The difference in the design of the Automatic BART, used in the current study, might be important to understand these challenges. This version of the BART introduces a time delay between entering a pump and pressing the key to inflate the balloon, potentially leading to more cognitive (planned) and less impulsive (emotional) decision-making compared to the original BART (Pleskac et al., 2008). Therefore, it might be capturing the adaptive risk-taking behavior. Another study demonstrated that adolescents exhibited higher levels of risk-taking behavior in emotionally charged ("hot") contexts compared to adults (Figner et al., 2009). This design aspect is important when interpreting null findings on risky behaviors in the BART. In addition, the specific version of the BART used, along with the type of pumps considered (whether adjusted or all unadjusted pumps), likely plays a significant role in the outcomes observed. Adaptive risk-taking, which involves increasing the pump count to maximize earnings, should be differentiated from maladaptive risk-taking, which might be reflected by pump counts that are too high or too low, as seen in Figure 5.

6.2. Association of BART and Mental Health

The most intriguing finding is the relationship between risky behavior in the BART and mental health. No prior study has simultaneously examined both the positive and negative dimensions of mental health in this context. These results support the Life-Span Wisdom Model, suggesting that risk-taking is associated with higher emotional well-being. This finding aligns with earlier research that shows risk-taking can have both positive and negative outcomes. In this context, within a low- and middle-income country (LMIC), risk-taking appears to support resilience and emotional well-being, which contrasts with findings from WEIRD contexts where risk-taking is often linked to adverse outcomes like depression or behavioral issues.

6.2.1. Anxiety and Risk-Taking

The relationship between risk-taking behavior and mental health, as discussed in the introduction, highlights that depressive symptoms are often associated with risk aversion. Studies (Hevey et al., 2007; Kim et al., 2021; Chapman et al., 2007) suggest that individuals with depression show increased sensitivity to punishment but do not exhibit a corresponding increase in reward sensitivity. Aaron Beck who is an important name in the cognitive theories of psychopathology attributes this decreased reward sensitivity to anhedonia, a lack of enjoyment, which can lead to withdrawal and isolation (2008). As a result, even potential risk-taking might result in unfavorable outcomes, which could have a stronger impact on individuals with depression and anxiety due to their heightened sensitivity to punishment. This heightened sensitivity to threats is likely to decrease engaging in risk-taking behavior according to the approach-avoidance trait. This can lead to negative reinforcement and withdrawal from future risk-taking attempts, potentially exacerbating depressive and anxiety symptoms (Corr, 2002). On the other hand, the relationship between anxiety and risk-taking has shown inconsistencies in the literature. Some studies report a positive relationship between anxiety and risk-taking during adolescence (Reynolds et al., 2013; Richards et al., 2015), while others have found a negative relationship which aligns with our study results (Howsley, 2016; Broman-Fulks et al., 2014; Giorgetta et al., 2012). Some studies suggest that anxiety predicts risky behaviors among adolescents (Dahl, 2004; Woodward & Fergusson, 2001), such as risky driving and substance use, as discussed previously, the self-medication hypothesis. According to the approach motivation trait, individuals may attempt to regulate their anxiety by altering their risk sensitivity, which can lead to an increase in risky behaviors and a greater likelihood of engaging in harmful risk. Therefore, it is crucial to understand how individual differences in anxiety-related traits, such as approach or avoidance tendencies, can mediate engagement in risky behavior. These differences may manifest as either risk aversion or reduced risk sensitivity, influencing how adolescents navigate risky situations. Supporting evidence has shown that within the anxiety group, individuals with a higher approach trait exhibited increased risk-taking in the BART compared to the control group (Leota et al., 2023). It might be essential in helping individuals make better choices in the future rather than withdrawing from challenges. Learning to manage their anxiety would enable them to identify a balanced point of risk-taking, where they can engage in challenges constructively without being overwhelmed by fear or avoiding opportunities that will lead to growth. It might be essential in helping individuals make better choices in the future rather than withdrawing from challenges.

6.2.2. Well-being and Risk-Taking

In this context, understanding the concept of adaptive risk-taking becomes crucial for psychological well-being. Ciranka and Van Den Bos describe adaptive risk-taking as playing a protective role against negative experiences by fostering learning and reducing the likelihood of repeating the same mistakes. This makes adaptive risk-taking vital as it promotes learning, cognitive control, and exploration. as explained by the LSWM Model (Romer et al., 2017) discussed in section 1.2 of the introduction. This model provides a framework for understanding how these aspects of risk-taking behavior develop over time. Moreover, risk-taking has been positively correlated with cognitive ability (Dohmen et al., 2010).

While sensation-seeking refers to the socio-emotional system, self-regulation is often to cognitive control (Meisel et al., 2019; Smith et al., 2017). The Dual Systems Model and Imbalance Model, see Fig. 1, focused on the relationship between sensation-seeking and self-regulation with a lack of understanding. Self-regulation encompasses adaptive skills that are used throughout life, including the regulation of emotions, behaviors, and cognition (Sperduti et al., 2017; Hoffman et al., 2012). As such, understanding risk-taking and self-regulation is essential. Psychological disorders like depression and anxiety are often linked to poor emotional self-regulation, where individuals struggle to resolve distress (Hinshaw, 2002). Emotions, particularly fear, disgust, and anger, play a critical role in guiding decision-making processes (Lerner & Keltner, 2001). In anxiety, heightened negative thoughts influence predictions, leading individuals to behave in ways that minimize potential threats and negative emotions arising from decision-making. This risk-avoidant approach may explain how anxiety contributes to risk aversion (Maner et al., 2006). Additionally, difficulty in emotional self-regulation can cause individuals to avoid potential rewards. Conversely, those with higher emotional well-being may better regulate their emotions—such as fear or anger—resulting in more balanced risk-taking.

Furthermore, self-regulation is closely connected to resilience and coping strategies (Hinshaw, 2002). Resilience, defined as the ability to successfully adapt to situations of risk or threat, is a key protective factor for psychological well-being and is negatively correlated with depression and anxiety (Mesman et al., 2021). Huang and colleagues found that in non-Western sociocultural contexts, resilience is negatively related to emotional and behavioral problems among adolescents (2020). These findings support the relationship between resilience, emotional well-being, and adaptive risk-taking, as observed with the BART in the current study.

These findings contribute to ongoing discussions about the cross-cultural validity of psychological measures. Past research has underscored the limitations of generalizing results from WEIRD populations to non-WEIRD settings (Henrich et al., 2010). Our study supports the need for careful consideration of cultural and environmental factors when interpreting results from tools like the BART. The correlations found in this study suggest that risk-taking behaviors may serve different roles, potentially functioning as an adaptive response to adversity (Romer, 2017). This echoes findings from studies in other non-WEIRD settings, which have noted that risk-taking can sometimes enhance social and emotional well-being in challenging environments (Ellis et al., 2012).

Participants in this study displayed levels of risk-taking behavior and response processes adolescents in this study displayed significant levels of risk aversion, which is commonly observed in the literature on risk-taking (Lejuez et al., 2007; Pleskac et al., 2008), suggesting that the BART effectively captures risk-taking behavior across diverse cultural settings. Similar cross-cultural validation studies have shown that while BART can be reliably administered in different contexts, the interpretation of results may vary based on socio-cultural factors (Pleskac et al., 2008; Mishra et al., 2017).

One of the strengths of this study is its focus on a non-WEIRD population, addressing a significant gap in the literature concerning the cross-cultural applicability of the BART. The study's relatively large sample size and use of validated mental health measures lend robustness to the findings.

7. Recommendations for Future Research

The findings from this study suggest several avenues for future research. First, there is a need for longitudinal studies to establish the causal relationships between risk-taking behaviors, mental health outcomes, and real-world risky behaviors in non-WEIRD populations. Longitudinal research could help clarify how risk-taking behaviors evolve and their long-term impact on adolescent mental health and well-being in various cultural contexts (Steinberg et al., 2017).

Further research should explore the conditions under which risk-taking becomes adaptive rather than maladaptive, particularly in low-resource settings. The positive association between risk-taking and emotional well-being observed in this study highlights the need to understand these dynamics better. Additionally, cross-cultural comparisons involving diverse non-WEIRD populations could help delineate universal versus culture-specific aspects of risk-taking behavior (Rad et al., 2018).

Refining the BART and other risk-taking measures to account for cultural and contextual differences is also recommended. Modifying task parameters or incorporating culturally relevant scenarios could enhance the ecological validity of these measures across different populations (Pleskac et al., 2008; Lejuez et al., 2002).

8. Limitations

While this study provides valuable insights, it is important to acknowledge its limitations. Although the study demonstrated that the BART has strong internal reliability, it did not assess re-test reliability in this validation. Future research should incorporate a data collection process that allows for re-test reliability analysis.

The cross-sectional design restricts our ability to infer causality between risk-taking behavior, mental health, and real-world risky behaviors. Longitudinal research is necessary to understand better these relationships' directionality (Maxwell & Cole, 2007).

The reliance on self-reported data for real-world risky behaviors may introduce response bias, particularly concerning sensitive topics such as substance use or sexual behavior (Tourangeau & Yan, 2007). Future research could benefit from incorporating objective measures or multi-informant reports to validate self-reported data (Brener et al., 2003).

Another limitation is the study's focus on a single task (BART) to measure risk-taking behavior, which may not capture the full complexity of risk-taking in real-life situations. Incorporating a broader range of behavioral tasks or combining them with qualitative methods could provide a more comprehensive understanding of risk-taking behavior (Buelow & Blaine, 2015).

Furthermore, we did not account for real-world risky behaviors that are adaptive and more positive, such as standing up for bullied friends, trying a new sport or activity, public speaking, forming new friendships, and pursuing challenging academic goals (Duell & Steinberg, 2022). While these behaviors still involve risk, they typically lead to favorable outcomes, in contrast to maladaptive risk-taking, such as substance use. By including a broader range of real-life risky behaviors, we could have gained a more comprehensive understanding of their relationship to the BART.

Lastly, the specific socio-economic and cultural context of the peri-rural Ugandan population studied may limit the generalizability of the findings to other non-WEIRD populations with different socio-economic conditions or cultural norms (Patel et al., 2018). Additionally, we did not have a matched WEIRD sample for comparison, which further restricts the scope of our conclusions.

9. Conclusion

The findings enhance our understanding of BART, to the real-world risky behaviors and mental health expressed in a non-WEIRD population, particularly within a socio-economically challenged environment. The consistency and response process measures indicate that the BART is applicable in this sample, aligning with previous findings in WEIRD populations. However, this study extends the analysis by employing advanced methods, such as split-half reliability analysis and response process analysis.

This study contributes to the growing literature on the cross-cultural applicability of psychological measures by validating the BART among adolescents in peri-rural Uganda. The findings suggest that the BART is a reliable tool for assessing risk-taking behavior in this population, with observed patterns of risk aversion similar to those in WEIRD populations. However, the lack of significant correlations between BART performance and real-world risky behaviors raises questions about the universality of these associations (Lejuez et al., 2002).

Importantly, the study reveals a positive correlation between risk-taking in the BART and emotional well-being, as well as a negative correlation with anxiety, suggesting that risk-taking may have adaptive functions in low-resource environments (Ellis et al., 2012; Romer, 2010). These results challenge the traditional view that primarily links risk-taking to negative outcomes and underscore the importance of culturally sensitive approaches to understanding and addressing adolescent risk-taking.

In conclusion, this study highlights the need for continued research into the adaptive versus maladaptive nature of risk-taking across different cultural contexts and the importance of developing culturally tailored interventions to support adolescent mental health and well-being.

10. Appendices

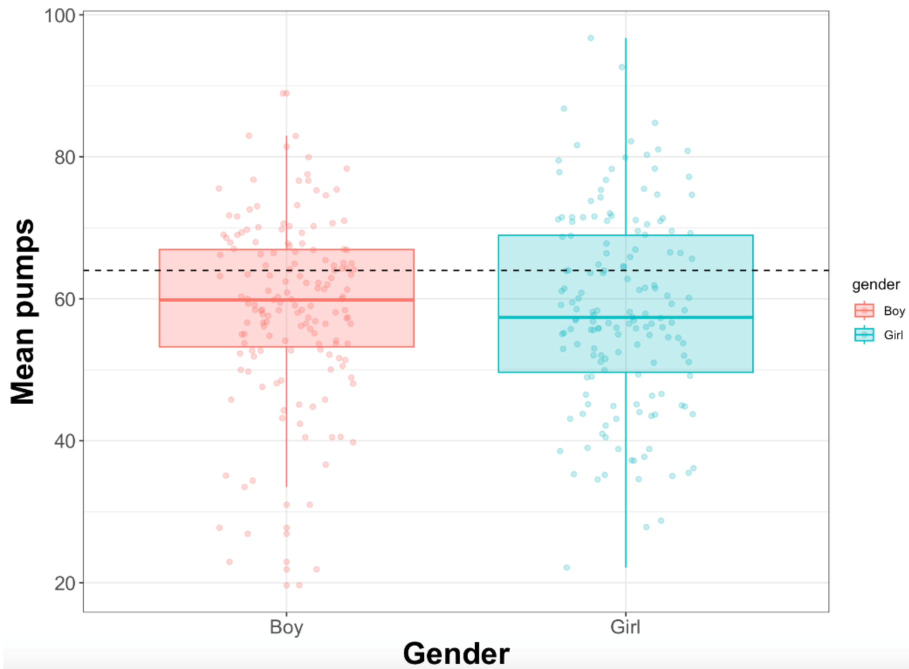

Figure 7: Boxplot displaying the average number of pumps in the BART, with a gender breakdown. The green line represents the mean pumps for girls, and the red line represents the mean pumps for boys.

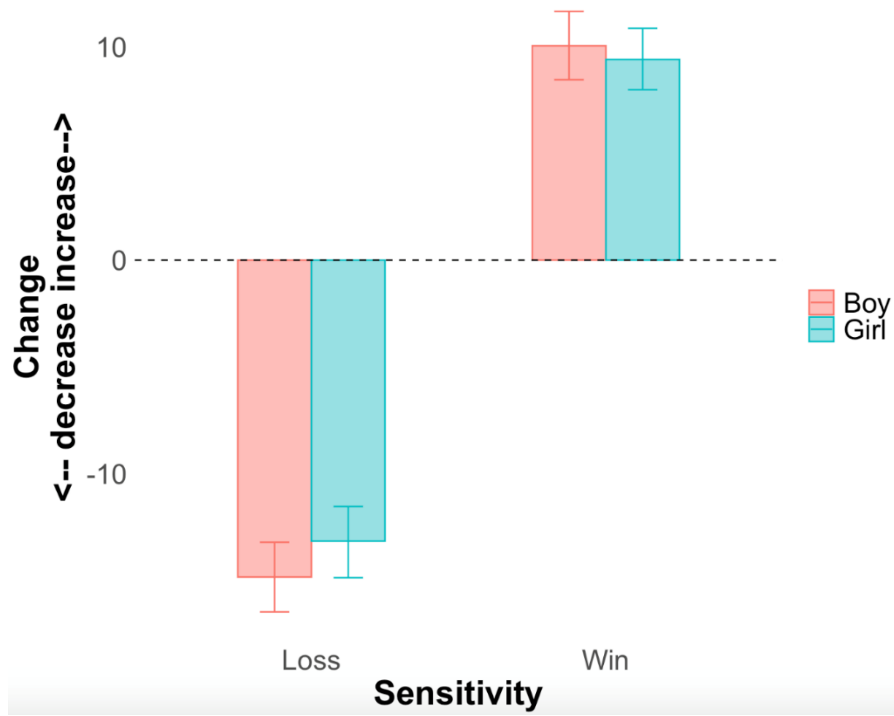

Figure 8: The bar graph with error bars shows a gender breakdown, with green bars representing girls and red bars representing boys. The bars illustrate the change in behavior following the previous trial, whether it resulted in a loss or a win. The graph indicates that after a loss, participants tend to decrease their pumping in subsequent trials, whereas after a win, they are more likely to increase their pumps. The difference in behavior between loss and win trials is statistically significant ($p < .001$).

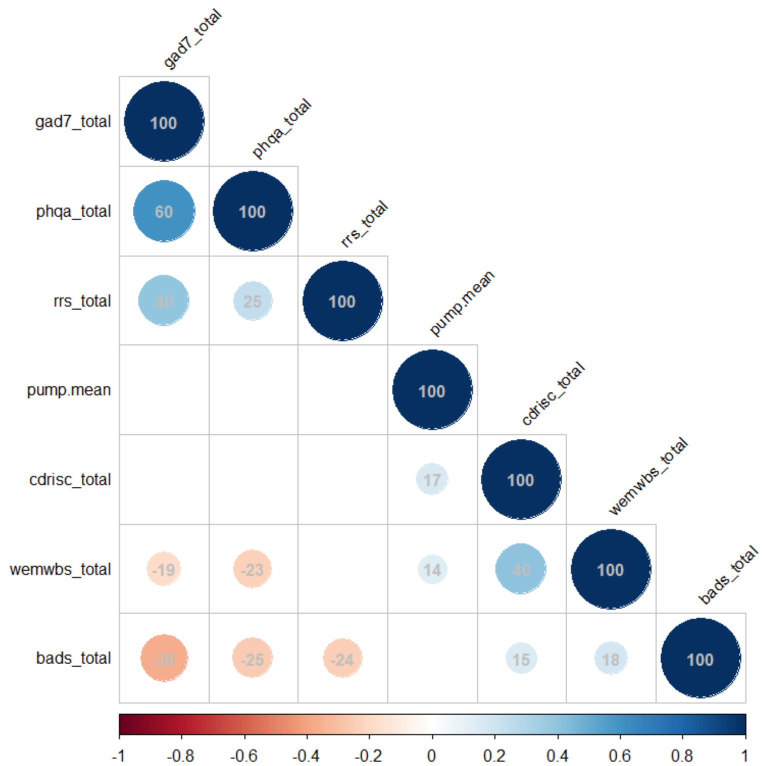

Figure 9. shows the correlation matrix between mental health variables and BART (pump.mean) using a corrplot. The x-axis represents the correlation values, ranging from -1 to 1. The intensity of the color indicates the strength and direction of the correlation: red tones represent negative correlations, with the intensity softening as the correlation approaches 0, while blue tones represent positive correlations, intensifying as they approach 1. The y-axis lists all variables included in the correlation matrix. Only significant correlations are displayed, with color gradients indicating the strength of these correlations.

10.1. Real-world Risky Behaviors Exploratory Factor Analysis

The Bartlett sphericity test ($\chi^2 = 335.6785$, $p < .001$) was statistically significant demonstrating that the correlation matrix is different from an identity matrix and it is suitable for factor analysis. However, an Ultra-Heywood case was detected due to the delinquency variable, which is why delinquency was eliminated from the factor analysis for risky behavior. Delinquency is eliminated from the factor analysis to solve the Ultra-Heywood case since the factor was extremely loaded on that variable >1.

Moreover, from the rest of the real-world risky behaviors, other_behaviours_damaged', 'other_behaviours_hit', 'assisty_opioids_score', 'gambled', "unsafesex" were also reduced, due to low loading on KMO rule, lower than >.5. For the rest of the real-word risky behaviors, eigenvalues and parallel analysis has suggested one-factor structure. Due to the one-factor structure's poor fit (RMSEA), the real-world risky behavior was not further pursued to analysis with factor structures. Even though a solution for factor analyzing the risky behavior variables was not identified, a similar statistical analysis was conducted as done with the mental health variables.

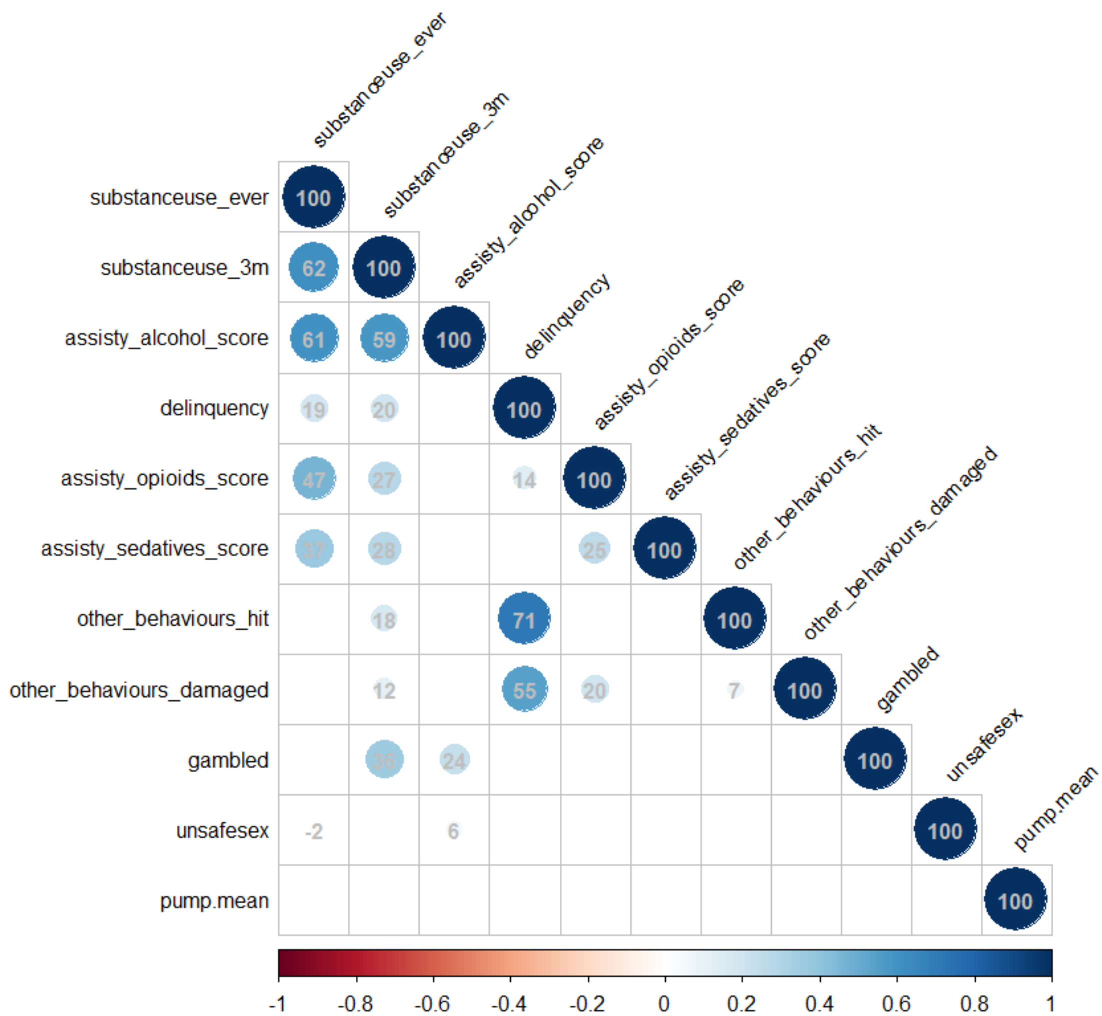

Figure 10. shows the correlation matrix between real-world risky behavior variables and BART (pump.mean) using a corrplot. The x-axis represents the correlation values, ranging from -1 to 1. The intensity of the color indicates the strength and direction of the correlation: red tones represent negative correlations, with the intensity softening as the correlation approaches 0, while blue tones represent positive correlations, intensifying as they approach 1. The y-axis lists all variables included in the correlation matrix. Only significant correlations are displayed, with color gradients indicating the strength of these correlations.

The pump mean did not correlate with any of the real-world risky behaviors. Other behavior hit and other behavior damage are strongly correlated with delinquency. Moreover, substance use ever and substance use 3 months have correlated with ASSITY- alcohol score.

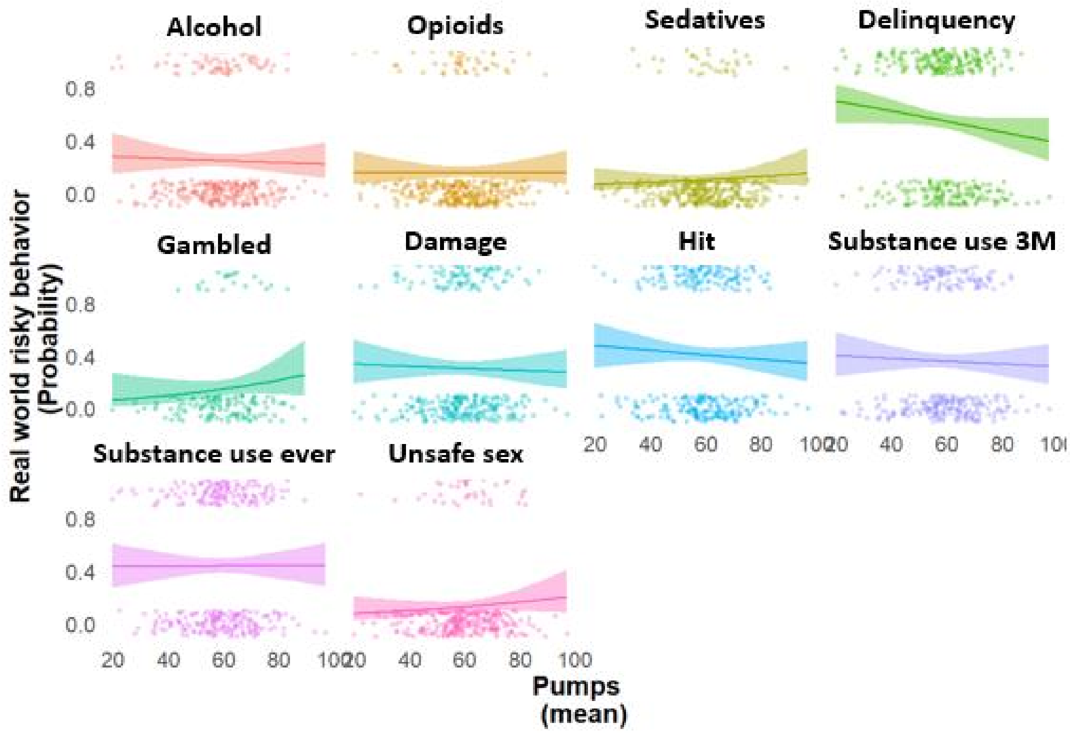

Figure 11. The scatter plot shows the relationship between the average number of pumps (x-axis) and the probability of engaging in real-world risky behavior (y-axis), with data points grouped by risk category. Each panel represents a different risk category, with a binomial smoothing curve indicating trends. The color and fill of the points correspond to the risk categories, and the jitter effect helps to spread out overlapping points. Printed in R- studio, ggplot function.

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