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Psychology, Neuroscience and Human Sciences**



Revisiting The Balloon Analogue Risk Task In Ugandan and South African Adolescents

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Abstract

The Balloon Analogue Risk Task (BART) is a widely used laboratory measure of behavioural risk-taking. However, the BART has been predominantly studied in Western, Educated, Industrialised, Rich, and Democratic (WEIRD) samples, limiting the understanding of how performance on the task generalises across different environmental and cultural contexts. The present study examines BART performance and its associations with response processes, cognitive control, mental health, real world risk-taking, and socioeconomic characteristics among healthy adolescents in Uganda (N = 310) and adolescents with depressive symptoms in South Africa (N = 195). In both samples, participants displayed reasonable response processes, strategically adapting their risk-taking to the feedback they received, suggesting appropriate engagement with and comprehension of the task. Furthermore, in Uganda, higher risk-taking was associated with greater cognitive control and lower anxiety but was not significantly associated with real world risk-taking or socioeconomic characteristics. These associations were not observed in the South African sample. The findings suggest that higher risk-taking in the BART need not necessarily be interpreted as a marker of maladaptive behaviour, and may instead reflect decision-making under uncertainty. The findings provide evidence that the BART may be meaningfully used with adolescents in South Africa and Uganda, although its interpretation should be approached with caution among adolescents experiencing depressive symptoms.

1. Introduction

1.1 Adolescence as a Critical Period of Development

Adolescence is a time of rapid physical change and is considered an evolutionarily developmental phase characterised by hormonal, physiological, behavioral, and neural changes (Doremus-Fitzwater et al., 2010). Literature often describes adolescence as the transitional period between childhood and adulthood characterised between ages 13 to 19. It is well-recognised as a period defined by the emergence and progression of risk-taking behaviours such as drug and substance use, delinquency, unsafe sex behaviours, or gambling behaviours (Bozzini et al., 2021, Dougherty et al., 2015). This belief has been heavily present in both academic and public opinions (Willoughby et al., 2021). Nearly all developing organisms of mammalian species go through a similar transition from dependence to independence (Spear, 2008). For instance, similar to their human counterpart, adolescent rats exhibit elevations in peer controlled social interactions in risk-taking or novelty seeking, with significant changes in reward-related brain regions (Varlinskaya & Spear, 2002, 2008). Indeed, the neural regions modulating pleasure and reward-related behaviour reflects much similarity between human and mammalian species (Spear, 2008). Changes in adolescence in context of evolutionary brain motivation systems and reward-related neural activity may play a critical role in adolescent behavioural characteristics, which may include marked elevations in interactions with peers, sensation seeking, and risk-taking (Doremus-Fitzwater et al., 2010). Greater activation of the ventral striatum has been linked to responses to social rewards, thrill seeking, risk-taking behaviours, and the relevance of peer and peer influences (Somerville et al., 2010). With the transition into adolescence, younger people display increased value for and sensitivity to social

information, particularly from their peers. There are progressive changes in the way adolescents anticipate, receive, and respond to social stimuli and feedback, including stimuli that are rewarding, such as praise or positive feedback, and those that feel like disapproval or social rejection (Armstrong-Carter et al., 2025). The responses to these types of social feedback can be further amplified by the physiological and neurobiological changes that occur with puberty maturation.

1.2 Why Study Adolescent Risk-Taking?

Risk-taking behaviours are those that involve some potential for danger or harm while also offering the potential for reward. Risk-taking generally encompasses a broad range of behaviours that constitute both positive and negative effects. However, those that place individuals at risk for adverse health effects and negative safety outcomes have received notable attention in literature (Lejuez et al., 2002). Some research suggests that risk-taking behaviour often begins in adolescence and can result in short-term and long-term negative consequences (Resnick et al., 1997). Due to this, adolescence is described as a period of heightened risk-taking by both researchers and the general public (Willoughby et al., 2021).

Risk-taking is not assumed to be just an effect of adolescent development, but is considered a part of the developmental structure of adolescence (Kloep et al., 2008). Some research suggests that adolescence is not simply the period of development where risk-taking increases in comparison to other groups, but instead emerging adulthood is the age where risk-taking is more prevalent across multiple domains (Willoughby et al., 2021). One view is that the trend-level changes of heightened risk-taking is likely an endurance from earlier research when this line of reasoning was more appropriate. For example, from 1970 to 1990, there were increased forms of

crime or STD rates like the AIDS epidemic which peaked in adolescence and into emerging adulthood (Willoughby et al., 2021). This suggests that the prevalence of risk-taking is not static and should be studied in the context across type of risk-taking behaviour, age, and historical time to understand the changing nature of risk-taking behaviour during adolescence.

Consequently, these research trends have been evolving in more recent literature, challenging the assumption that adolescents engage in more risk-taking than all other age groups. In addition, across many cultures, adolescence is associated with increased independence and greater opportunities for engaging in risk-taking behaviours (Arnett, 1992; Silva, Shulman, Chein, & Steinberg, 2016). As adolescents gain autonomy and encounter novel situations, opportunities for exploration may increase. As a result, risk-taking may reflect not only individual differences but also developmental and social changes that occur during adolescence.

From a developmental perspective, adaptive risk-taking allows adolescents to explore new environments, acquire cognitive skills, and enhance future decision making. Following this idea, not all risk takers can be considered reckless. Instead, certain forms of risk-taking might suggest careful and deliberate cognitive processing and thinking. Individuals with stronger cognitive abilities may rely more on reflective or controlled processing which can lead to more advantageous forms of risk-taking. Previous research has suggested a weak yet significant relationship between cognitive ability and risk aversion (Donati et al., 2014), suggesting that adolescents with higher cognitive ability are less risk averse, particularly in gain domains. This perspective challenges the idea that increased risk-taking is linked to impulsivity or poor self-regulation. Instead, higher risk-taking in artificial paradigms like the BART may indicate that participants are engaging in greater cognitive thinking and logical reasoning. Furthermore, anxiety and higher sensitivity to losses has been linked to reduced risk-taking, suggesting that

less willingness to engage in risk may, sometimes, reflect avoidance rather than reasoned decision making (Lilleholt, 2019).

1.3 Such a WEIRD Problem

In 2008, Arnett et al., published the landmark paper that challenged most of the existing body of literature in psychology by investigating exactly who was studied in behavioural science research. They found that it was mostly Western, more specifically American undergraduate students, who formed a large part of the data pool in most experimental branches of psychology, cognitive science, economics, and related fields. A study found that across six sub-disciplines in psychology, a significant number of participants came from North America, Europe, Australia, and Israel. This phenomenon led to coining the term WEIRD; samples from western, educated, industrialised, rich, and democratic countries (Henrich et al., 2010). Scientific belief and understanding about human behaviour is largely drawn from this knowledge, begging the question of how representative these samples are to current experimental theories of human behaviour and thought. Apart from selecting a very small representative sample across behavioural sciences research, this research also assumes that the inferences drawn about human behaviour from these samples can be applied to wider groups. By relying on WEIRD samples, researchers may miss out on important and interesting variations in human behaviour that arise in global contexts (Henrich et al., 2010). Even amongst Western samples, there is inter-cultural variation. For example, studies investigating performance on the Ultimatum Game, which studies the human specific evolved capacity for fair and punishing behaviour in situations with substantive influence, found that Americans relative to other Westerners stand out on phenomena that are associated with independent concepts and individualism. In addition, US

offers were nearly double that of compared countries including forager samples from Tanzania and horticulturalists from the Bolivian Amazon (Henrich et al., 2010). A decision-making task among small-scale farmers from Uganda found deviations from expected utility behaviours that is typically seen among American under-graduates (Henrich et al., 2010). Similarly, studies have observed substantial differentiation in people's motivations and preferences in relation to altruism, fairness, reciprocity, risk, and patience (Falk et al., 2018). A study investigating the cultural differences in risk-taking behaviours found that Turkish responders generally scored lower than Welsh responders in tasks of risk-taking (Kloep et al., 2008). The rise of artificial intelligence systems and language learning models such as ChatGPT has reflected a continuation of these findings. Studies have found that language learning models performed as human-like on various measures. Researchers compared ChatGPT's responses to global survey questions and psychological tasks to representative samples around the world and found that ChatGPT's responses presented as psychologically WEIRD, most similar to samples from the United States, Germany, and New Zealand, and was most dissimilar to samples from the Middle East and Africa (Atari et al., 2023).

In addition, many experimental findings suggest that there is considerable variation among human samples across many cognitive domains which is in line with the idea that people from WEIRD samples are highly psychologically unusual. This presents a challenge to the understanding of human psychology and behaviour because most data that forms the basis for psychology comes from WEIRD samples (Henrich et al., 2010). However, the positive reception of the concept of WEIRD samples has raised the question of how to investigate variances in key aspects of psychology across time and culture and has led to efforts to seek out new data sources (Henrich, 2024).

1.4 The Balloon Analogue Risk Task

One of the most widely used instruments to measure risk-taking is the Balloon Analogue Risk Task or the BART (Lejuez et al., 2002). It is a computerised laboratory instrument that involves simulating actual risky behavior where riskiness is rewarded until the point where riskiness leads to poorer outcomes. During the task, participants decide how many times they want to inflate a virtual balloon. Each successful pump earns points, but if the balloon bursts, then all points are lost (Lejuez et al., 2002). A near miss on the BART is defined as a failure that is close to being successful. For example, trials where participants successfully pumped enough to reach larger amounts, but then had their balloons burst can be perceived as a near miss. Since participants do not know when the balloon will burst, increased pumping can be perceived as potentially rewarding but also risky. The BART task also reflects the learning and response dynamics that underlie decision-making processes, including exploration, feedback, or learning. Behaviour on the BART may be influenced by the outcome of the previous trial. If the balloon burst in the previous trial, individuals may pump less in the next trial. This suggests that feedback can reinforce learning behaviours on the BART (Sebri et al., 2023).

Importantly, BART performance does not necessarily reflect stable tendencies to take risks. The BART consists of repeated decisions and outcomes based on probabilities, and participants can learn from the outcomes of their previous choices and modify their behaviour accordingly. Such changes in responses indicate that performance on the BART involves processes of feedback sensitivity, learning, and deliberation in an addition to willingness to accept risk (Sebri et al., 2013). Therefore, examining only the mean number of pumps on the BART may not provide a complete account of how participants make decisions during the task.

One way of examining whether a task captures a consistent pattern of risk-taking behaviour is through measures of internal consistency. Good internal consistency indicates that participants' responses are sufficiently consistent across the task to suggest that the BART captures certain common aspects of decision-making. Simply, if participants' responses are increasingly inconsistent across each trial, it becomes difficult to interpret an overall measure such as mean pumps to be reflecting any meaningful individual differences in risk-taking. However, internal consistency does not imply that participants should respond to every trial in an identical manner. The BART provides changing outcomes and probability-related feedback, and such variation in responses may be an important feature of deliberate task performance. Participants may differ in how strongly they respond to task paradigms, such as whether a balloon burst or if it didn't. Therefore, examining internal consistency can be complemented by examining response processes that capture how participants adjust their behaviour across trials.

Previous literature has increasingly examined response processes in order to examine the learning mechanisms underlying performance on the BART, including the extent to which participants modify their pumping behaviour following successful or unsuccessful trials. For example, research with children and adolescents found that participants can develop more consistent response strategies and adapt their behaviour to the probabilistic nature of the task (Éltető et al., 2019; Blair et al., 2018). Similarly, research investigating response-based feedback has shown that BART performance can reflect behavioural differences to guide subsequent behaviour (Lee, 2017). More recent computational approaches have established learning into models of BART performance, conceptualising learning as adjustments in strategies for pumping following wins and losses (Zhou et al., 2021). Thus, examining both internal consistency of the task responses and changes in responses following changing outcomes can provide additional

information about BART performance, distinguishing a general tendency in responding to adaptations in behaviour based on previous experiences.

Such a distinction is particularly interesting when interpreting BART performance in adolescents. Higher pumping may not reflect simply greater willingness to accept risk, but it may also reflect exploration of the task environment, learning about the outcomes of varying decisions, or the use of strategies intended to maximise rewards and minimise losses. Likewise, decreased pumping may reflect risk aversion but may also indicate strategies of consistently prioritising an avoidance of losses. Examining both the consistency of responses and changes in responses following outcomes may provide a more comprehensive assessment of BART performance than mean pumping alone.

Furthermore, studies have suggested the BART to be an ecologically valid measure. Specifically, riskiness on the BART has been shown to correlate significantly with measures of real world risk-related constructs and the occurrence of risk related behaviours (Lejuez et al., 2002). In some adolescent samples, increased pumping on the BART has been shown to be associated with increased detrimental alcohol and drug consumption (Fennie, Cole, Goudie, & Field, 2010; Lejuez et al., 2002; MacPherson et al., 2010). This suggests that BART scores can be used as a potential predictor of risk-taking.

However, in recent years, many studies have found that risk-taking in the BART may not relate to real-world risk behaviours in the way that was always expected. For example, one study found that risk-taking in the BART is negatively correlated with severity of clinical alcohol use (Ashenhurst et al., 2014). Another study found similar results and saw that long term alcohol users took less risk overall in the BART compared to nonusers (Campbell, Samartgis & Crowe, 2013). Similarly, smokers were found to pump less on the BART compared to nonsmokers. In

addition, the degree of tobacco dependence was negatively correlated with risk-taking on the BART as well (Dean, Sugar, Hellemann, & London, 2011). These mixed findings raise important questions regarding exactly what the BART measures and whether associations with real-world risk behaviours can be generalised (Ashenhurst et al., 2014). One potential explanation for these inconsistencies could be that the BART reflects underlying processes rather than stable risk-taking paradigms. Since the BART requires individuals to balance potential rewards against losses while simultaneously learning from previous outcomes, performance on the task may not just reflect risk-taking but also reward and loss sensitivity, feedback response, learning processes, or loss aversion (Sebri et al., 2023; Zhou et al., 2021). Another criticism of the BART comes from the notion that much of the existing data concerning the ecological validity of the task comes from WEIRD samples (Ashenhurst et al., 2014). There is comparatively little evidence exploring behavioural risk-taking in non WEIRD samples or in samples that experience high levels of adversity.

1.5 The Present Study

Most research examining risk-taking in adolescents has been conducted in WEIRD samples with little evidence from non-WEIRD samples. Measures such as the BART have shown associations between real-world risk behaviours and psychosocial outcomes in Western samples, yet it remains unclear whether these relationships generalise to adolescents growing up in contexts different than those of WEIRD samples. Adolescents in Uganda and South Africa may experience substantially different developmental environments compared to adolescents currently represented in existing literature. Therefore, the present study aims to investigate behavioural risk-taking among adolescents from Uganda and South Africa using the Balloon

Analogue Risk Task, and investigating the correlations between BART risk-taking, cognitive control, real-world risk behaviours, mental health outcomes, and socioeconomic characteristics.

The study examined whether participants demonstrated consistent and systematic responses on the BART. Internal consistency was assessed to examine whether participants showed reliable patterns of responses across the task, providing evidence that BART performance reflected meaningful individual differences in risk-taking behaviour. However, internal consistency alone does not capture how participants respond to changing task paradigms. Therefore, response processes were analysed to explore whether participants adapted their behaviour across trials in response to feedback and the changing probability of the explosion point. Evidence of systematic changes in behaviour across trials could indicate appropriate engagement in the task and would suggest that BART performance involves a degree of learning and strategic adaptation rather than simply risk-taking.

Two hypotheses were examined in relation to the interpretation of BART risk-taking. The impulsive risk-taking hypothesis predicted that greater risk-taking on the BART would be associated with poorer cognitive control, poorer mental health outcomes, and greater engagement in real-world maladaptive risk behaviours. More specifically, higher pumping on the BART was expected to be associated with lower cognitive control, higher levels of anxiety and depressive symptoms, lower well-being, and greater engagement in real world risk behaviours. In contrast, the deliberate decision-making hypothesis predicted that greater BART risk-taking would be associated with stronger cognitive control and more positive mental health outcomes, while suggesting limited or no association with real world risk behaviours. This pattern of outcomes would be more consistent with an interpretation of BART performance reflecting deliberate decision-making, learning and strategic adaptation. Table 1 visualises the predicted associations

with measured outcomes based on these two hypotheses. The study also examined whether socioeconomic characteristics were associated with BART performance based on theories proposing that environmental conditions may shape preferences for risk and immediate rewards. However, given the mixed empirical evidence concerning the relationship between socioeconomic characteristics and behavioural risk-taking, such an association was considered more exploratory.

	Impulsive Risk-Taking Hypothesis	Deliberate Decision-Making Hypothesis
Cognitive Control	-	+
Negative Mental Health Outcomes	+	-
Positive Mental Health Outcomes	-	+
Real World Maladaptive Risk	+	NS

Table 1. Predicted Associations Based on Hypotheses. For each hypothesis and measured outcome, predicted associations are marked. Negative associations are denoted by the ‘-’ sign and the colour red. Positive associations are denoted with the ‘+’ sign and the colour green. Non-significant associations are denoted by NS.

Finally, although the study includes samples based on both Uganda and South Africa, the present study does not aim to directly compare BART performance or associations between the two samples. Differences in task organisation, data collection procedures, and participant recruitment, and participant characteristics result in the samples not being directly equivalent. Consequently, although the same analyses are conducted in each country, they are done so separately, and findings are interpreted independently within each country, rather than providing

evidence for a comparison between Ugandan and South African samples. Including both samples, however, provides an opportunity to examine whether the relationship between BART performance and the associated variables are observed across distinct study contexts and provides a broader scope of interpretation.

2. Literature Review

2.1 What is Risk-Taking?

Risk behaviors are broadly defined as actions that carry some potential for harm or danger while simultaneously offering the potential for a reward. Risk-taking may encompass a broad range of behaviors and outcomes that can fall between negative and positive dimensions, but much of existing literature has focused on behaviours that place individuals at risk for adverse health or safety effects. Among adolescents in particular, maladaptive risk-taking is given special consideration due to the vulnerability during this developmental time (Lejuez et al., 2002, Lejuez et al., 2007).

Kloep and Hendry (1999) proposed that adolescent risk-taking can be understood according to the functions that govern these behaviours, identifying three broad categories of risk-taking motives. The first is that some behaviours may be considered irresponsible risk-taking where individuals pursue immediate rewards despite the possibility of long term negative consequences. These behaviours may include such as alcohol use, unprotected sex, or gambling. They are not typically pursued because the behaviours themselves involve risk, but because of the desirable outcomes (Kloep et al., 2008). The second is that risk-taking may be socially

motivated. Peer controlled risk-taking may emerge from worries about social acceptance, belonging, and peer approval. The third is that risk-taking may serve thrill-seeking functions. Such behaviours involve challenges that may test personal limits, provide excitement, and satisfy desires for novelty or stimulation. Though these activities may involve some degree of harm or danger, they also promote development by encouraging exploration. Consequently, there could be some forms of risk-taking that may represent positive developmental experiences rather than purely maladaptive behaviours. This can be further explained by the notion that adolescents themselves may conceptualise risks differently from adults. Kloep and Hendry found that young people made a clear distinction between risks and challenges, where risks were viewed as situations where outcomes were difficult to control or uncertain, and challenges involve difficult but achievable goals with predictable outcomes.

Historically, risk-taking has often been viewed as a problematic or maladaptive behaviour. Maladaptive or impulsive risk-taking has been assumed to be an individual trait that increases vulnerability to negative outcomes (Zhou et al., 2021). However, existing behavioural tasks show inconclusive results regarding convergence of such risk-taking with self-report measures of risk-related constructs. Several studies have found associations between task-based measures of risk-taking and self-reported measures of real world risk-taking (Lejuez et al., 2002; Lejuez et al., 2003). For example, some studies found associations between increased pumping on the BART and increased alcohol and drug use in adolescent samples (Lejuez, Aklin, Bornovalova, & Moolchan, 2005; Fernie, Cole, Goudie, & Field, 2010). On the other hand, some studies have demonstrated contradictory results with limited associations between task-based risk-taking and real world risk behaviours. Ashenhurst et al., 2014 found that risk-taking on the BART was negatively correlated with the severity of alcohol dependence. A similar relationship was found

in a study of adolescent tobacco smokers where they found smokers were less risky on the BART compared to nonsmokers (Dean, Sugar, Hellemann, & London, 2011). This suggests that different methods may capture distinct aspects of risk-taking and that risk-taking on the BART may shed light on conceptually varying aspects of risk-taking not necessarily associated with maladaptive risk-taking or real world risk behaviours.

Understanding the nature of risk-taking is important when studying adolescent samples, especially across different cultural and socioeconomic contexts. Evidence has suggested that risk-taking motivation may vary across cultures and that adolescents may engage in risky behaviours for different reasons depending on their circumstances (Kloep et al., 2008). Cultural norms and values may influence how and which behaviours are considered acceptable, desirable, or harmful, as well as the social consequences associated with exhibiting such behaviours (Kloep et al., 2008). These differences may influence social rewards associated with particular behaviours and the extent to which adolescents are influenced by social norms and peers (Kwon & Telzer, 2022). These considerations are particularly relevant when interpreting BART performance in non-WEIRD populations. While the BART provides a relatively standardized measure of decision-making under uncertainty that reduces some of the contextual differences, the acceptance of risk on the BART may still depend on experiences and environments in which adolescents develop (Romer et al., 2017). Consequently, examining BART performance alongside measures of real-world risk behaviours, peer influences, mental health, and socioeconomic circumstances may help explore the different expression of risk-taking and decision-making processes across different cultures.

2.2 Theories of Risk-Taking

There are several foundational theories that provide a framework for understanding risk-taking behaviours. Prospect theory is one of the most influential psychological models of decision-making under uncertainty and suggests that individuals evaluate future outcomes in regards to a reference point rather than absolute gains or losses, and so decisions are strongly influenced by how situations are framed. Individuals tend to be risk-averse when confronted with losses (Kahneman & Tversky, 1979; Tversky & Kahneman, 1985). Furthermore, losses are more strongly experienced than gains, resulting in greater sensitivity to negative outcomes than positive outcomes. Therefore, prospect theory suggests that risk preferences, rather than being fixed traits, can change based on context and current circumstances. An individual's propensity for risk changes depending on the context of the decision. Decision-makers may become more ready to accept risks when they are trying to avoid losses, whereas they may avoid losses when they have already secured gains. These predictions are important when considering risk-taking in adolescents experiencing adversity. Individuals living in resource scarce or impoverished environments may perceive themselves as operating within loss domains, and as such may reflect adaptive responses to perceived losses rather than heightened impulsivity or poor self control (Abdellaoui, Bleichrodt, and Paraschiv, 2007).

Sensation seeking is the tendency to seek and experience novel or exciting events. Normative adolescent behaviour is characterised by increased sensation seeking, with adolescents displaying increased motivation to experience rewarding and simulation situations (Dahl, 2004). Since adolescents are eager to experience new and intense stimuli to receive rewards, the increase in sensation seeking during adolescence may reflect developmental changes in relation to reward sensitivity (Doremus-Fitzwater et al., 2010). Sensation seeking has been suggested to

function as an adaptive developmental process that promotes learning, independence, and social development by encouraging adolescents to explore new environments and experiences (Larsen & Luna, 2018). However, heightened sensation seeking may also increase vulnerability to risky behaviours, especially when opportunities for exploration involve harmful activities such as substance use. Due to its double edged nature, sensation seeking can often be viewed as both a developmental asset and a potential source for heightened risk-taking (Doremus-Fitzwater et al., 2010).

Risk-sensitivity theory proposes that individuals adjust their willingness to take risks based on environmental conditions and available resources. Rather than possessing stable risk preferences, individuals change their decision-making strategies depending on whether they perceive themselves to be in conditions of adversity or not. The theory argues that risk-taking reflects adaptive responses to uncertain futures. When available resources are enough to meet needs, individuals may focus more on long-term outcomes and future goals. However, when resources are limited, individuals may resort to riskier options that promise a larger reward and that becomes the more advantageous strategy. It provides the perspective that risk-taking should be understood as a context-dependent cognitive process rather than a trait that remains stable across time and environment (Song et al., 2017) .

In addition to existing theories, there are also neurodevelopmental models that seek to explore the mechanisms governing risk-taking behaviour with an emphasis on the role of adolescent brain development to explain risk-taking behaviour in contemporary literature. Many neurodevelopmental models exist that propose adolescence is characterised by the differentiated maturation of neural systems involved in processing reward functioning and cognitive control (Larsen & Luna, 2018). The Dual Systems Model proposed that reward related regions of the

brain mature earlier than brain areas involved in cognitive control and behavioural regulation. This imbalance leads to heightened sensitivity to rewards, combined with relatively less mature self-regulatory abilities. Similarly, neurodevelopmental imbalance models propose that maturation of limbic systems and prefrontal areas leads to increased novelty and reward seeking (Willoughby et al., 2021). This suggests that alterations in reward related neurocircuitry may contribute to adolescent risk-taking by increasing receptiveness to potential rewards while other cognitive systems are still maturing (Doremus-Fitzwater et al., 2010).

The Life-Span Wisdom Model offers an alternative to traditional neurodevelopmental accounts that interpret adolescent risk-taking as primarily an outcome of immature cognitive control systems. The model posits that some characteristics of adolescent risk-taking are adaptive and exploratory, allowing for adolescents to gain experience and develop systems to support decision-making later in life. From such a perspective, risk-taking is not inherently maladaptive but rather the consequences depend on the type of risk and the individual's ability to learn from experience and adapt their behaviour (Romer et al., 2017).

Altogether, these theories highlight that adolescent risk-taking is unlikely to reflect single, stable tendencies toward risk-related behaviors. Instead, risk-taking may reflect the interaction between decision-making under uncertainty, reward sensitivity, learning and cognitive control, and environmental circumstances, which is particularly relevant to the present study.

2.3 Cognitive Control

Cognitive control can refer to the ability to regulate thoughts and behaviour in relation with internal goals, allowing individuals to adapt flexibly to changing environmental demands. Rather than representing a single process, cognitive control comprises several related executive

functions, most notably the ability to shift between mental sets, update and monitor information held in working memory, and inhibit dominant or prepotent responses (Miyake et al., 2000). These executive functions will enable individuals to maintain goal-directed behaviour while adapting to changing task demands and environmental feedback.

Mental set-shifting refers to the ability to flexibly switch between different rules, tasks, or strategies where environmental rules change and update (Miyake et al., 2000). Updating involves continuously monitoring newly acquired information and replacing information that is no longer relevant held in working-memory with new, task-related information. Inhibition refers to the deliberate suppression of dominant or automatic responses in favour of behaviour that is more appropriate for current goals. Although these may be considered separate processes, these executive functions operate together to support flexible, adaptive behaviour and are considered central components of higher order cognition (Miyake et al., 2000).

Adolescence is an important period in terms of development, and can be characterised by substantial improvements in cognitive control. Although executive functions emerge during childhood, their efficiency and functionality continue to develop through adolescence into early adulthood (Crone & Dahl, 2012; Luna et al., 2015; Tervo-Clemmens et al., 2023). Improvements are observed across a range of executive functions, including inhibitory control, task switching, working-memory, and performance monitoring. This reflects the continued integration and refinement of distributed neural networks involving the prefrontal and parietal cortices (Crone & Dahl, 2012). Consequently, cognitive control development may reflect the gradual optimisation of existing cognitive processes rather than emergence of entirely new processes (Luna et al., 2015).

Traditional neurodevelopmental models have argued that adolescent risk-taking reflects an imbalance between relatively mature reward-related processing systems and more slowly developing cognitive control systems, leading adolescents to prioritise immediate rewards over long-term consequences (Steinberg, 2008; Crone & Dahl, 2012; Figner et al., 2009). According to dual-system models, this developmental mismatch could contribute to increased impulsivity and risky behaviour during adolescence due to executive control not yet sufficiently mature enough to regulate affective drives (Marquez-Ramos et al., 2023). Subsequently, studies of adolescent risk-taking have frequently found greater behavioural control to be associated with lower levels of impulsive decision-making. Peeters et al. (2017) found that effortful behavioural control among young adolescents, especially those who displayed higher reward sensitivity, was a strong predictor of cannabis and alcohol use. Similarly, Botdorf et al. (2017), found that individual differences in cognitive control over emotional response conflict predicted adolescent risk-taking.

However, such assumptions have been increasingly challenged. Contemporary perspectives suggest that adolescent behaviour is better understood as the product of dynamic interactions between cognitive and affective processing, social context, and learning rather than simply reflecting frontal cortical functioning that is immature (Pfeifer & Guyer, 2011; Romer et al., 2017). Neuroimaging studies have produced inconsistent results for a straightforward pattern of delayed prefrontal maturation, with some reporting increases and others decreases in prefrontal activation across adolescence depending on the cognitive process being studied (Crone & Dahl, 2012). Such findings have shifted emphasis away from viewing adolescence as a period of impaired or weak cognitive control to understanding it as a period of increasing behavioural flexibility and adaptation (Luna et al., 2015).

Low self-control theories suggest that increased risk-taking during adolescence results in immature behavioural regulation and reduced inhibitory control (Willoughby et al., 2021). Adolescents may engage in risky behaviours because they struggle to regulate emotions and impulses and resist immediate desires. Models of impulsive choice suggest that adolescents prioritise immediate rewards over delayed outcomes, leading to preferences for short-term positive outcomes despite potential long-term costs (Tymula et al., 2012).

Such developments have important implications for the interpretation of behavioural risk-taking tasks such as the BART. Since performance on the BART requires participants to balance the possibility of loss versus the possibility of gains while continuously updating beliefs about previous explosion likelihoods, successful performance may depend not only on willingness to tolerate uncertainty but also on executive processes including performance monitoring, flexible updating, and adapting behaviour in response to feedback (Bogg et al., 2012; Luna et al., 2015). Rather than reflecting purely impulsive responses, greater pumping behaviour may represent deliberate exploration and learning about an uncertain environment (Romer et al., 2017).

These perspectives align with emerging theoretical accounts that distinguish maladaptive impulsive behaviour from adaptive exploratory risk-taking. Exploration during adolescence may facilitate learning about uncertain environments and contribute to the improvement of cognitive control systems, suggesting that increased behavioural exploration is not always indicative of poor self-regulation (Luna & Wright, 2015; Murty et al., 2016). Consequently, examining the relationship between cognitive control and BART performance provides an opportunity to further understand the cognitive processes underlying laboratory measures of risk-taking and

evaluation of whether these tasks can capture adaptive exploration rather than simple impulsivity.

Importantly, the direction of the relationship between cognitive control and risk-taking may depend on how risk-taking is defined. If risk-taking is primarily conceptualised as maladaptive behaviour, greater cognitive control would predict reduced risk-taking by aiding individuals in inhibiting impulsive responses and more strongly consider negative consequences. On the flip side, risk-taking need not necessarily be maladaptive, and some forms of risk-taking may be adaptive when they allow for exploration and learning (Romer et al., 2017). Consistent with such an approach, Blair et al. (2018), established that executive control functions, particularly working memory, were associated with strategic responses and better performance on the BART during adolescence. These findings suggest that executive functioning could contribute to adaptive forms of decision-making on the BART, rather than simply a reduction of risk-taking. Thus, the relationship between cognitive control and risk-taking may be positive, negative, or absent, depending on the type of risk-taking being measured, the way it is conceptualised, and even the cognitive demands of the task.

2.4 Mental Health and Risk-Taking

2.4.1 Anxiety and Risk Avoidance

Anxiety problems are characterised by excessive worry, fear, and avoidance behavior (Olatunji et al., 2010). It is well known based on previous literature that a balanced level of risk-taking is necessary for proper development and exploration (Sandseter & Kennair, 2011). However, avoidance of risk-taking behaviours has been found to be associated with anxiety symptoms in both adolescents and adults (Broman-Fulks et al., 2014, Lorian & Grisham, 2010,

Maner et al., 2007). Studies have shown that individuals with higher anxiety symptoms often display greater risk avoidant behaviour, leading some suggestions on interventions targeting anxiety to focus on reducing risk avoidance.

Research on the connection between childhood anxiety symptoms and risk avoidance is sparse. Some studies suggest that risk avoidance may be a precursor for the development of anxiety, while others such that anxiety symptoms later predict risk avoidance (Hartley & Phelps, 2012). Theories on behavioural inhibition propose that avoidance might be a precursor for anxiety problems (Lahat et al., 2011). Behavioural inhibition is a temperament characterised by withdrawal and restraint in response to unfamiliar situations or stimuli (Kagan et al., 1984). Individuals displaying higher behavioural inhibition are believed to exhibit greater sensitivity to potential threats and strong avoidance behaviours, indicating that adolescents displaying behavioural inhibition also show increased likelihood of developing anxiety disorders. Similarly, children showing behavioural inhibition are often overly preoccupied with threatening information, and this bias has been associated with later anxiety symptoms (Dodd et al., 2020, White et al., 2017)

However, alternative theories may suggest a reverse relationship, where anxiety symptoms act as a prerequisite to risk avoidance (Hartley & Phelps, 2012). Cognitive behavioural theories argue that anxious individuals demonstrate heightened attention to and monitoring of threats and fears, and despondent interpretations of uncertain outcomes. These biases may subtly influence decision-making, leading individuals to avoid risky situations and prioritize safety (Tieskens et al., 2021). This could lead to a perpetuating cycle where anxiety promotes avoidance, and avoidance maintains anxiety symptoms. Empirical evidence supports this notion. Longitudinal findings demonstrate that increases in anxiety symptoms precede decreases in risk-taking,

suggesting anxious individuals grow more risk averse over time. There is also evidence of a relationship between anxiety and risk avoidance in social settings. Peer-reported anxiety symptoms have been found to predict later risk avoidance more strongly than self reports, suggesting children may become increasingly concerned with how they are perceived by peers, and the possibility of negative social evaluations may contribute to both risk avoidance and anxiety symptoms (Tieskens et al., 2021). Sex differences may play a role in this relationship. During childhood, girls generally report higher levels of anxiety symptoms than boys (Zahn-Waxler et al., 2008). Though some studies have found that girls engage in lower levels of risk-taking, the findings remain inconsistent (MacPherson et al., 2010; Tieskens et al., 2018). Social expectations may further reinforce avoidance behaviour while encouraging boys to confront fears and suppress anxiety symptoms (Tieskens et al., 2021). These findings have important implications for adolescent decision-making as elevated anxiety may influence how adolescents evaluate uncertainty and perceive risky situations.

2.4.2 Depression and Risk-Taking

Depression is one of the most prominent causes of disability among young people worldwide and has been consistently associated with increased engagement in real-world risk behaviours (Pozuelo et al., 2022). However, some studies have found inconclusive results in the relationship between depression and risk-taking (Wang et al., 2025). One potential discrepancy between real-world and laboratory measures of risk-taking may reflect social contexts in which these risk behaviours occur.

Adolescence is characterised by heightened sensitivity to social influence and scrutiny, especially in peer relationships. Social sensitivity could refer to an individual's desire for social

connections and heightened emotional reaction to social feedback and scrutiny by others (Somerville, 2013). Excessive social sensitivity has been linked to elevated depressive symptoms, especially during adolescence when peer relationships become increasingly important.

The Social Risk Hypothesis of Depression suggests that depression develops when individuals believe themselves as having low social value within their social groups (Allen & Badcock, 2003). Social burden reflects the perceived costs that an individual imposes on others, while social value reflects the benefits an individual contributes to the group. When individuals perceive their social value to be lower than their social burden, they may experience increased belief of social exclusion (Allen & Badcock, 2003). Consequently, the theory suggests that depressive symptoms function as adaptive responses that could manage the possibility of further social losses. Depression could encourage risk averse behaviour, reduced willingness to engage in social situations, and social withdrawal in an attempt to avoid situations that could possibly lower social standing even further (Allen & Badcock, 2003).

Evidence supporting this hypothesis has emerged from studies using behavioural measures of risk-taking. On several experimental paradigms, including the BART, reduced social risk-taking has been observed among adults with depression (Lejuez, C. W. et al., 2002). Follett et al. (2023) found that adults with depression exhibited significantly lower levels of risk-taking than non depressed control subjects when completing the BART in a social context where gains and losses were affected in a group outcome but not for tasks involving individual rewards.

2.4.3 Trauma and Risk-Taking

Exposure to traumatic events and adverse experiences has been consistently associated with alterations in risk-taking behaviour. However, the extent of this relationship remains inconclusive, especially because different forms of trauma appear to influence different mechanisms of risk-taking (Ben-Zur & Zeidner, 2009). Traumatic experiences, particularly childhood maltreatment and exposure to violence, has been linked with a wide range of risky behaviours, including criminal behaviour, risky sexual practices, and substance use (Tull et al., 2016). Childhood maltreatment has been shown to predict heightened sexual risk-taking during both adulthood and adolescence, with history of sexual abuse acting as a strong risk factor (Moore, 2016). One study found among adolescents exposed to armed conflict in northern Uganda there were associations between risk-taking and traumatic experiences, mediated by depression, suggesting that mental health factors may play an important role in exploring these associations (Okello et al., 2013).

Several theoretical models have been suggested to explain increased risk-taking following exposure to trauma. Some propose that engagement in risk behaviours may be a function of maladaptive coping in response to negative emotions and stress as a result of trauma exposure. Cognitive models propose that trauma changes the processing and evaluation of risk, resulting in changes to decision-making. Neuroscientific models propose that heightened amygdala activity and increased sensitivity to threats may impair behavioural regulations and alter responses to risk (Augsburger & Elbert, 2017).

An important factor to consider is the fact that much literature has found that the relationship between trauma exposure and risk-taking changes depending upon the type of trauma experienced. In displaced samples exposed to organised violence, such as war or torture, has

been linked to lower levels of risk-taking on behavioural tasks like the BART. Individuals with higher exposure to violence demonstrated fewer adjusted pumps on the BART, suggesting heightened risk aversion (Tull et al., 2009). These findings contrast with studies reporting increased engagement in real-world risk-taking following childhood adversity. Some studies of refugee samples have produced contrasting results. Some found that adolescents from families with lesser exposure to war and violence reported higher engagement in risk behaviours while those with higher exposure to violence reported lower levels of risk-taking. Conversely, other studies have found that exposure to violence is associated with later increased risk-taking among refugee adolescents (Richter et al., 2015, Catani, 2010). Importantly, PTSD symptoms themselves may have little effect on risk-taking. In displaced samples, severity of PTSD symptoms showed only weak associations with BART performance (Augsburger & Elbert, 2017).

Some studies propose that trauma may alter the threat and reward processing functions rather than directly influencing risk-taking. Individuals exposed to trauma often demonstrate reduced reward sensitivity alongside an elevated sensitivity to threats and losses (Smith et al., 2025). For example, trauma exposed individuals show tendencies to repeat previously rewarded behaviour but continue to avoid previously punished responses even after punishment has been removed (Smith et al., 2025). Adolescents exposed to childhood unpredictability have also been found to favor familiar options over exploration of unfamiliar alternatives, even with the possibility of greater rewards. These results suggest that traumatic experiences may alter underlying cognitive and emotional processes involved in decision making leading to varying patterns of risk-taking dependent upon both the type of trauma and context in which it was experienced.

2.5 Poverty and Risk-Taking

Growing evidence suggests that decision-making processes and risk-taking behaviours are strongly influenced by environmental conditions. Psychological variation may emerge from differences in ecological conditions, environmental uncertainty, market institutions, kinship systems, and broader social environments (Henrich, 2024). Literature has consistently found that what may appear to be irrational decision-making can be the basis of responses to environmental certainty. Therefore, preferences for immediate rewards, risk-taking, or delayed gratification may be influenced by childhood and adult environmental conditions (Griskevicius et al., 2011).

A significant body of developmental research has focused on the potential negative consequences of childhood poverty, particularly on risk-taking behaviours. Childhood poverty could encompass a broad range of experiences, including lack of safety, unpredictability, chronic stress, instability, and reduced control over the environment (Smith et al., 2025). Poverty may expose children to multiple material, social, and physical hardships, and limited access to resources. Such early-life experiences have been associated with poorer cognitive development, educational attainment, and physical health (Ellis et al., 2017; Mani et al., 2013; Vohs, 2013). These findings have contributed to an overwhelmingly deficit-oriented view in which exposure to early-life poverty is understood as disrupting adolescent development.

However, a deficit perspective may provide only a partial account of how individuals respond to challenging environments. Rather than simply impairing development, environments characterised by poverty may shape learning and decision-making in ways that are more adaptive to the problems adolescents may frequently encounter (Ellis et al., 2017). Adolescents in such environments may develop strategies that greatly emphasise immediate rewards, threats, or information that is more relevant to current circumstances. These strategies may appear less

optimal when studied using traditional laboratory environments which differ from the contexts where these behaviours developed (Smith et al., 2025). This could suggest that growing up in poverty may not necessarily disrupt decision-making globally, but may instead influence how adolescents attend to, utilise, and learn from information when making decisions.

This could be illustrated in the way adolescents growing up in poverty process risks and rewards. Negative childhood experiences have been associated with differences in impulsivity, risk-related behaviours, and self-regulation (Birn et al., 2017; Loomis, 2021; Smith et al., 2025). Individuals growing up in environments where threats are frequent or resources are uncertain may place greater emphasis on obtaining immediate rewards or avoiding immediate threats. Indeed, research suggests that children exposed to adversity may prioritise information concerning direct threats over information regarding monetary gains (Bremner et al., 2005; Deslauriers et al., 2018). The relationship between poverty and cognition may also be influenced through cognitive demands associated with resource scarcity. Living in poverty could impose significant mental demands, with concerns about financial resources utilising cognitive capacity that could otherwise be allocated to other tasks (Birn et al., 2017). For example, study on farmers found that cognitive performance improved following harvest periods where financial concerns were reduced (Vohs, 2013). Such findings may suggest that socioeconomic circumstances could influence decision-making not just through learned preferences, but also through immediate cognitive demands associated with resource scarcity.

Such ideas are consistent with current theoretical frameworks. From evolutionary perspectives, organisms must allocate limited resources between competing demands, resulting in variation in strategies concerning investment, reproduction, and future planning (Charnov, 1993; Kaplan & Gangestad, 2005). Life history approaches propose that environments suggest

that environments characterised by socioeconomic hardship may lead individuals to favour strategies that place greater emphasis on immediate rewards, whereas stable environments promote greater investment in future outcomes (Griskevicius et al., 2011). Risk-sensitivity theory proposes that risk-taking should be understood in relation to current resource availability and environmental conditions rather than just stable, individual preferences. When needs are sufficiently met, adolescents may benefit from pursuing safer and more predictable strategies. Under conditions of poverty, however, engaging in risk that could potentially lead to larger payoffs may represent the optimal strategy (Song et al., 2017). Together, these perspectives may suggest that socioeconomic conditions may shape the way adolescents perceive uncertainty, evaluate rewards and losses, and adapt their decisions to their environments.

2.6 Adolescent Mental Health in Sub-Saharan Africa

Adolescence represents a critical developmental period during which many mental health disorders first present. Globally, approximately 10 to 20 percent of children and adolescents experience mental health problems, with depressive disorders, suicide, and anxiety disorders contributing significantly to the overall burden on young people between the ages of 10-19 (Trautmann et al., 2016; Twenge et al., 2019). Recent research has suggested that adolescents in Sub-Saharan Africa (SSA) may be particularly vulnerable to mental health difficulties due to a combination of exposure to significant social and economic adversity and developmental and infrastructural challenges.

Sub-Saharan Africa contains one of the fastest growing adolescent samples in the world, with individuals aged between ten and nineteen making up a significant proportion of samples, and it has been projected to steadily rise over the next decade (UNICEF, Adolescent demographics,

2022). Young people in these regions frequently encounter environmental stressors that increase vulnerability to poor mental health outcomes (Mabrouk et al., 2022; Sequeira et al., 2022).

Recent systematic reviews indicate significant mental health burdens on adolescents in SSA. One review assessing nearly 10,000 youths reported a prevalence of 26.9% for depression, 21.5% for post-traumatic stress disorder (PTSD), and 20.8% for suicidal thoughts (Mabrouk et al., 2022).

Other reviews have estimated prevalence rates of 30% for anxiety disorders, 27% for depressive symptoms, 21% for PTSD, and 12% for suicidal ideation (McKinnon et al., 2016; Yatham et al., 2018; Zarafshan et al., 2015). The high levels of mental health difficulties have been attributed to a range of environmental and psychosocial factors. Adolescents in these regions could often experience abuse, violence, educational exclusion, poverty and food insecurity, unemployment, and exposure to armed conflicts (Hart & Norris, 2024; Mabrouk et al., 2022). Additionally, the region also displays higher prevalence of some chronic health conditions, particularly AIDS/HIV (Mabrouk et al., 2022). Furthermore, the burdens caused by the COVID-19 pandemic further exacerbated the social and economic pressure on adolescents and their families (Hart & Norris, 2024).

The social ecological framework provides a useful model for understanding adolescent mental health within Sub-Saharan Africa (Hart & Norris, 2024). It suggests that mental health outcomes unfold through interactions of multiple levels including individual, interpersonal, community, healthy systems, and social settings. At the individual level, young people undergo rapid developmental changes during adolescence that may increase susceptibility to emotional difficulties. At the interpersonal level, family relationships, peer relationships, and social supports influence wellbeing. Community factors include such things such as food insecurity, poverty, violence, and educational access. Broader societal and policy factors then determine

availability of resources and services for public health concerns. In SSA, these services often receive limited attention (Hart & Norris, 2024). Mental health services remain sparse across the region, with significant shortages of trained professionals, underfunded health departments, and limited access to specialised care (Mabrouk et al., 2022). Further stigma surrounding mental health can limit the extent to which adolescents may seek help and remain untreated.

Untreated mental health difficulties during adolescence are linked to negative consequences for young people. Adolescents experiencing mental health difficulties often encounter poorer physical health outcomes, social difficulties, academic problems, and increased engagement in risk behaviours. The high prevalence of anxiety, depression, trauma exposure and other difficulties in SSA has important implications for understanding risk-taking behaviour in the region. Much of the existing literature has been conducted with mostly WEIRD participants, and they may not experience the same environmental conditions and stressors as adolescents from SSA. Given the elevated rates of poverty, adversity, violence, and mental health difficulties in these contexts, it is possible that the relationships between psychological functioning and risk-taking behaviour may differ from those observed in WEIRD samples.

3. Methods

3.1 Participants and Procedure

Peri-rural adolescents from Uganda (N= 310, 155 girls, mean age=17.01, SD= 1.4, ranging from 15-19) and adolescents from South Africa (N= 195, 132 girls, mean age=16.14, SD= 1.05, ranging from 15-19) participated in the study. The participants from Uganda had an

average of 8.67 years of education (SD= 2.15) and a mean poverty score of 60.3 (SD=10.15).

South African participants had a mean poverty score of 39.98 (SD= 14.57). Table 2 summarises participant demographics for both samples.

In Uganda, fieldworkers trained for the study and visited households across 10 villages. Participants were compensated using small ‘in kind’ goods like soap or wheat. The Balloon Analogue Risk Task was incentivized with the chance to win a small amount of mobile airtime (up to 5,000 UGX / £1.05). Ethics approval was granted 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, Makerere University School of Public Health, and University School of Public Health). In South Africa, participants were recruited based on presentation of mild to moderate symptoms of depression but were excluded if they displayed severe depression or suicidal ideation. Ethics approval was granted by the University of the Witwatersrand Human Research Ethics Committee and the Oxford Tropical Research Ethics Committee. Due to differences in task organisation and participant recruitment, it is not possible to compare results between Ugandan and South African participants.

	<i>N</i>	<i>Age Range</i>	<i>Age Mean (SD)</i>	<i>Education Mean (SD)</i>	<i>Poverty Mean (SD)</i>
Uganda	310	15-19	17.01 (1.4)	8.67 (2.15)	60.03 (10.15)
South Africa	195	15-19	16.14 (1.05)	-	39.98 (14.57)

Table 2. Participant demographics

3.2 Materials and Measurements

3.2.1 The BART

Risk-taking propensity was assessed using the Automatic Balloon Analogue Risk Task. The task consisted of 20 experimental trials followed by a series of practice trials. Risk-taking on the BART was defined as the mean number of pumps on balloons that had not exploded, named adjusted pumps. Higher scores indicated greater risk-taking propensity. During each trial, participants viewed a virtual balloon and indicated the number of times they wished to inflate it, choosing any value between 0 and 128. Greater pumps resulted in larger potential for rewards, but each additional pump also increased the probability that the balloon would explode, resulting in all points accumulated during the trial being lost. Participants were not informed of the balloon explosion point. Across trials, the average explosion point was always 64. The automatic version differs from the original by Lejuez et al. (2002). In the automatic version, the Auto-Bart, participants decide in advance how many pumps they wish to make on each trial, thus reducing potential influences of motor responses and response efforts allowing for a more direct measure of risk preference (Pleskac et al., 2008). Figure 1 pictures the process of the BART and its possible outcomes. The version used in the present study additionally included feedback following each trial. After a balloon burst or was successful, participants were shown the balloon's explosion point as well as the difference between their chosen number of pumps and the explosion threshold. This allowed for participants to observe how close their decisions were to the optimal outcome and thus potentially influence their subsequent decision-making across the following trials.

Importantly, performance on the BART does not necessarily reflect simple preferences for reduced or increased risk levels. Participants must evaluate potential rewards associated with increased pumpings versus increased probability of an explosion, suggesting that successful performance requires some degree of risk-taking while avoiding excessive losses. Previous literature using the BART with adolescents suggests that participants can adapt their behaviour to the probabilistic nature of the task and modify their responses across trials, exemplifying the learning and strategic adaptation needed as important characteristics of BART performance. For example, adolescents have been shown to indicate increasingly consistent response strategies and improved task performance as they learn about the risks associated with different responses (Blair et al., 2018). Similarly, other studies have that adolescents are capable of adapting their behaviour to feedback and uncertainty rather than displaying consistent elevated risk (Éltető et al., 2019). Thus, higher pumping need not always be interpreted as a facet of maladaptive risk-taking, and may instead reflect greater willingness for exploration and adaptation.

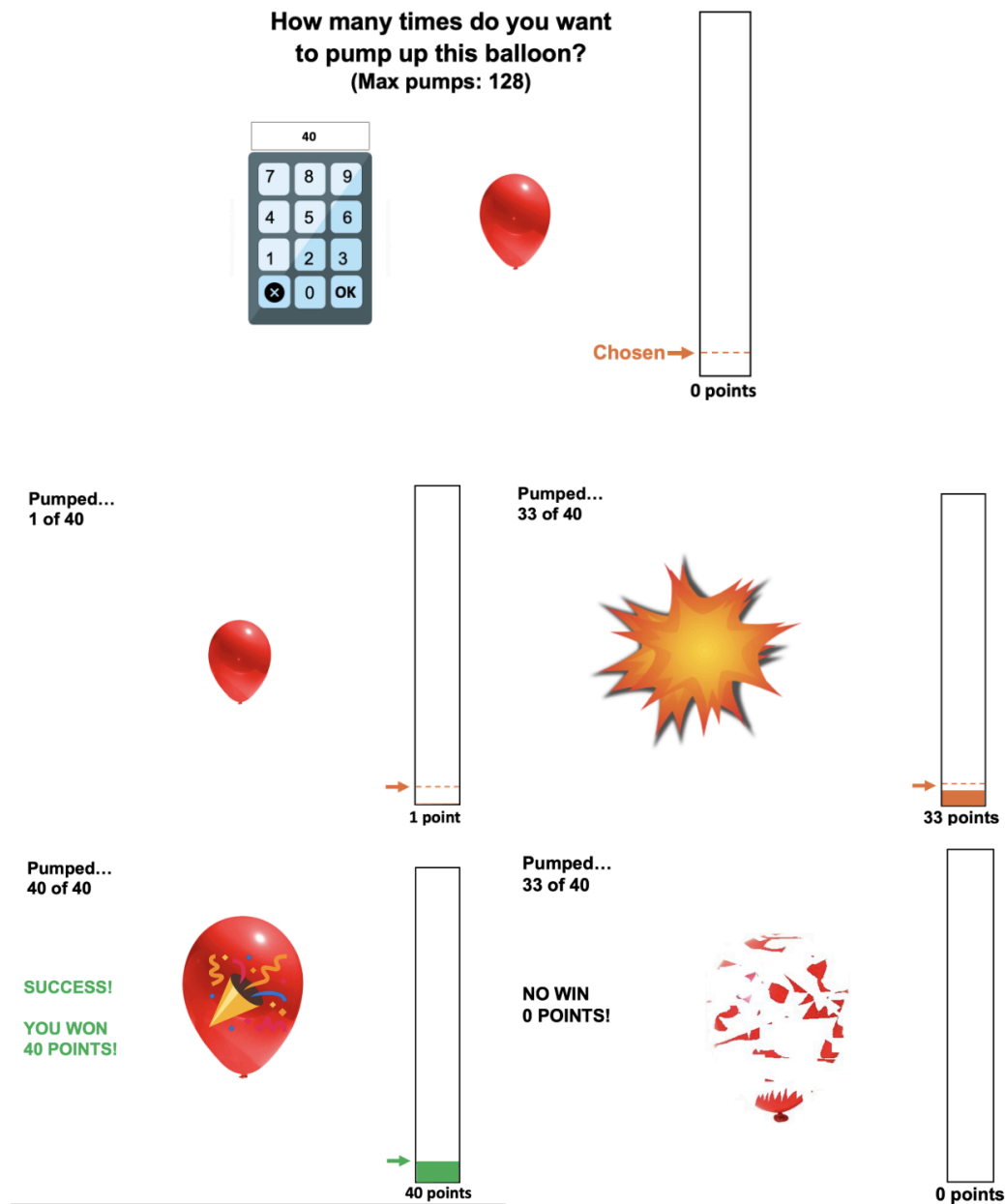


Figure 1. The Balloon Analogue Risk Task.

3.2.2 The Affective Set Shifting Task

Created as an adaptation of the Madrid Card Sorting Task by Barcelo, 2003, itself derived from the Wisconsin Card Sorting Task by David Grant and Esta Berg, the Affective Set Shifting

Task was developed to explore affective set-shifting, which is an essential component of cognitive control, assessing the ability to transition between mental states in response to emotional stimuli (Schweizer et al., 2019).

The task consists of a neutral and affective condition. In the affective condition, the stimuli consisted of pictures of people exhibiting different emotions, such as happy, sad, neutral, or fearful. In the neutral condition, the stimuli were simple geometric shapes. Figure 2 visualises the two conditions. Participants were first shown one card, then asked to match it to one of four possible cards. The cards could be matched based on three potential rules: the colour of the background, the number of stimuli and shapes in the neutral condition, and faces in the affective condition. The sorting rules switched randomly following 6 to 9 trials, with an average of 8 trials per rule. Participants were thus required to adjust to the new rule after receiving error feedback. The trials possessed a thirty-second time limit, and if no response was given within that time, the trial was marked as an error. In order to minimise differences in performance due to variability in detection of emotional expressions, participants in the affective condition were exposed to all face stimuli.

Participants needed at least two trials to learn and adjust to the rule change. The first two trials after the rule change were not considered to ensure that the analysis included only trials that actually signify errors and not attempts at learning the block's new rule. The stimuli in the affective condition (faces) was sourced from a diverse selection of databases, including the Chicago Face Database, Radboud Faces Database, London Face Research Set, Emotional Faces Stimulus Set, and the NIMH Child Emotional Faces Picture Set (Kilford et al., 2026). For the current study, the task was restricted to adult faces between the ages of eighteen to thirty-five of Black African origin. This was to reflect the study's demographic characteristics of the

participants. Half of the stimuli featured female faces. The order of neutral and affective conditions was counterbalanced across participants.

Cognitive control was defined as the overall number of correct trials across both the neutral and affective conditions without differentiating between the two to provide a general index of a participant's ability to complete the task. To examine the relationship between cognitive control risk-taking behaviour, separate simple linear regression models were conducted for Uganda and South Africa. BART mean pumps were considered the dependent variable and cognitive control as the predictor. The overall significance of each regression model was evaluated using the *F*-statistic to assess whether individual differences in cognitive control were associated with individual differences in risk-taking behaviour.

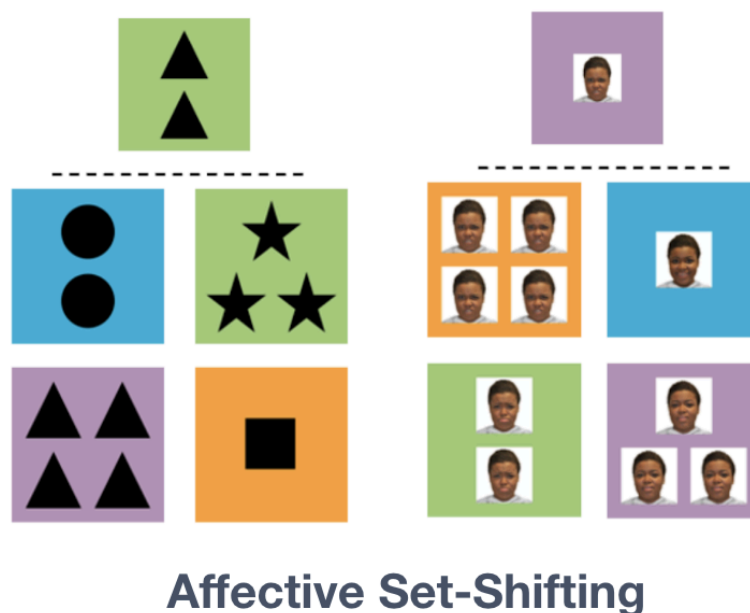


Figure 2. The Affective Set-Shifting Task. This figure illustrates the Affective Set-Shifting task across non-affective (left) and affective (right) stimulus conditions. The non-affective condition used abstract geometric shapes while the affective condition used familial stimuli. The target stimulus is presented above the dashed line with response options below the dashed line.

3.2.3 Internal Consistency and Response Processes

To assess the consistency of BART pumping responses across trials, internal consistency and split-half reliability were examined for both Uganda and South Africa. Internal consistency was assessed using Cronbach's alpha with 95% confidence intervals and was calculated for each sample (Taber, 2018). Split half reliability measures internal consistency as well, by dividing the test into two halves and seeing whether tests consistently measure the same construct (Parsons, 2021). In addition, a permutation-based split-half procedure was conducted using 5000 random permutations to provide an estimate of the reliability of mean pumping scores across randomly divided trial sets. Such analyses are used to assess whether individual differences in BART pumps were sufficiently consistent across trials to support the interpretation of mean pumping as a measure of individual differences in task performance.

Response processes were examined to investigate whether participants adjusted their pumping behaviour according to outcomes and feedback from previous trials. For each trial, the change in pumping behaviour from the previous trial was computed. Previous trial outcomes were categorised as either a successful trial (win) or an exploded balloon (loss). Separate generalised linear mixed-effects models were fitted for both samples with change in pumping acting as the outcome variable, previous trial outcome as the fixed effect, and a random intercept for participants to account for repeated observations. Estimated marginal means were used to compare changes in pumping following wins and losses. A secondary response-process analysis evaluated the extent to which participants approached the explosion point on the previous trial was associated with subsequent changes in pumping. Similarly, generalised linear mixed-effects

models were fitted separately for each sample with change in pumping as the outcome and distance from the explosion point on the previous trial as the fixed effect.

3.2.4 Mental Health

3.2.4.1 Depression

Depressive symptoms were measured using the Patient Health Questionnaire - Adolescent (PHQ-A). The PHQ-A is a widely used, reliable self-report tool consisting of 9 items designed to assess depressive symptoms over the past two weeks in adolescents (Kaggwa et al., 2022). The total PHQ-A score ranges from 0 to 27, with scoring ranging from 0 (not at all, 0 days) to 3 (nearly everyday, 12-14 days). Higher scores represent higher depressive symptoms. In Uganda, the PHQ-A is a validated and reliable measure with a Cronbach's alpha of 0.769 in the current samples. In South Africa, the Cronbach's alpha was significantly lower in the current study samples at 0.345, possibly suggesting the the PHQ-A items are only weakly correlated in the South African sample. The Macdonald's omega was 0.787 for Uganda and 0.392 for South Africa. Both the alpha values are reported for comparability with previous work (Morera & Stokes, 2016;), while the omega values are reported in line with recent research (Dunn et al., 2013; McNeish, 2018).

3.2.4.2 Anxiety

Anxiety symptoms were measured using the Generalised Anxiety Disorder-7 questionnaire (GAD-7). It has 7 items used to measure the intensity of anxiety symptoms and possibility of an anxiety disorder (Spitzer et al., 2006). The total GAD-7 score ranged from 0 to 21, with scoring ranging from 0 (not at all, 0 days) to 3 (nearly everyday, 12-14 days). Higher scores represent

higher anxiety symptoms. The GAD-7 showed good internal reliability in both Uganda (Cronbach's score= 0.866, omega score = 0.867) and South Africa (Cronbach's alpha= 0.832, omega score = 0.836).

3.2.4.3 Rumination

Rumination was measured using the Ruminative Response Scale (RRS). It is a ten item questionnaire assessing how people respond to sadness or distress (Parola et al., 2017). In the current study, rumination was by five items on the RRS focusing on factors of brooding. The total score ranges from 0 to 15, with each item being scored from 0 (almost never) to 3 (almost always). Higher scores represent higher levels of rumination. The RRS showed good internal reliability in both Uganda (Cronbach's score= 0.693, omega = 0.700) and South Africa (Cronbach's alpha= 0.717, omega score = 0.700).

3.2.4.4 Emotional Well-Being

The Warwick-Edinburgh Mental Well-Being Scale (WEMWBS) is a fourteen item questionnaire used to assess positive mental health and psychological functioning and how often these positive experiences occur in the last two weeks (Tennant et al., 2007). The total score ranges from 14 to 70, with each item being scored from 1 (none of the time) to 5 (nearly every day). Higher scores represent better positive mental well-being. The WEMWBS showed good internal reliability in both Uganda (Cronbach's score= 0.907, omega score = 0.909) and South Africa (Cronbach's alpha= 0.904, omega score = 0.906).

3.2.4.5 Resilience

Resilience was measured using the Connor-Davidson Resilience Scale (CD-RISC). It is a self-report measure used to assess resilience, or the ability to cope with and adapt to adversity and stress (Connor & Davidson, 2003). The total score ranges from 0 to 40, with each item ranging from 0 (not true at all) and 4 (true nearly all of the time). Higher scores represent higher resilience. The CD-RISC showed good internal reliability in both Uganda (Cronbach's score = 0.830, omega score = 0.836) and South Africa (Cronbach's alpha = 0.792, omega score = 0.796).

3.2.4.6 Behavioural Activation

The Behavioural Activation for Depression is a twenty-five item questionnaire used to assess changes in activation, avoidance, and functional impairment. It has five subscales; Activation, Avoidance/Rumination, Work/School impairment, and Social Impairment (Kanter et al., 2007).. The total score ranges from 0 to 150 ranging from 0 (being very untrue) to 6 (very true) in each subscale. Except for the activation scale, all the other items were reverse coded, so this was fixed to ensure standard scoring for all twenty-five items. Higher scores suggest higher activation. The BADS showed good internal reliability in both Uganda (Cronbach's score = 0.840, omega score = 0.841) and South Africa (Cronbach's alpha = 0.887, omega score = 0.890).

3.2.4.7 Trauma

Trauma was assessed by asking participants if they had ever experienced any trauma, if the trauma was ongoing at the time of the study, and the level of distress caused by the trauma.

Trauma variables included experienced severe illness (health trauma), experienced physical abuse (violence trauma), experienced sexual abuse (sexual trauma), and experienced emotional abuse (emotional trauma).

Questionnaire	Example items	Scale
PHQ-A (Depression)	1. Little interest or pleasure in doing things; 2. Feeling down, depressed, or hopeless; 3. Trouble falling or staying asleep or sleeping too much	0–3 (Not at all – Nearly every day)
GAD-7 (Anxiety)	1. Feeling nervous, anxious, or on edge; 2. Not being able to stop or control worrying; 3. Worrying too much about different things	0–3 (Not at all – Nearly every day)
RRS (Rumination)	1. Think “Why do I always react this way?”; 2. Think “Why can’t I handle things better?”; 3. Think “What am I doing to deserve this?”	0–3 (Not at all – Nearly every day)
WEMWBS (Well-being)	1. Feeling optimistic about the future; 2. Feeling useful; 3. Feeling relaxed	1–5 (None of the time – Nearly every day)
CD-RISC (Resilience)	1. I am able to adapt when changes occur; 2. I can deal with whatever comes my way; 3. see the funny side of things when I am faced with problems	0–4 (Not true at all – Very true all the time)
BADS Executive Dysfunction	1. I stayed in bed for too long even though I had things to do; 2. There were certain things that I needed to do that I didn’t do; 3. I have been content with the amount and types of things I did	0–6 (Very true of me – Very untrue of me)

Table 3. Item examples for mental health measures. See appendix for full list of mental health items.

3.2.5 Real-World Risk Behaviours

Real-world risk measures were taken from scores on ASSIST-Y questionnaires and ad hoc questions on sexual risk, delinquency and gambling, and peer influence. Since few participants reported responses higher than one, the responses were binarized, with a score of 0 indicating that participants did not engage in that risky behaviour and 1 indicating that participants did engage in that risky behaviour. The proportion of participants engaging in each behaviour was calculated, and variables with extremely low prevalence were identified. To improve the ability to interpret the data and ensure standard form of data, non-binary variables were coded into binary indicators reflecting the presence or absence of a behaviour. Final prevalence estimates

were calculated and visualised. Only the indicators with sufficient prevalence, which is over 5% prevalence, were extracted and used for further modelling.

3.2.5.1 Substance Use

Substance use was assessed using the Alcohol, Smoking, and Substance Involvement Screening Test for Youth (ASSIST-Y). It is a brief screening instrument designed to identify substance use among young people (Ibáñez-Martínez et al., 2025). Participants report their use of substances such as alcohol, tobacco, cannabis, opioids, cocaine, amphetamines, inhalants, sedatives, and hallucinogens. Participants were asked if they had ever used these substances, and if so had they used them in the past three months, and whether it resulted in issues, impacts on their daily functioning, or worried other people (Humeniuk et al., 2016). Due to a coding error in Uganda analyses, the ASSIST-Y scoring does not match the original scoring for Ugandan participants.

3.2.5.2 Gambling and Delinquency

Gambling was assessed by asking participants to report the amount of money they had lost or won from gambling and whether they had engaged in gambling in the last 30 days. Gambling was not assessed in South African participants. Delinquency was assessed by asking participants if they had engaged in delinquent behaviour in the past 30 days. It included all types of delinquent behaviour, including hitting, slapping or physically hurting someone, breaking into a house, school, shop or other building without permission, causing serious damage to property that did not belong to you, or stealing something worth more than R 100.

3.2.5.3 Risky Sexual Behaviour

Risky sexual behaviour was assessed by asking participants if they ever had sex before the age of 15, whether they had ever been pregnant or had an unintended pregnancy, whether they have had sex without a condom (unsafe sex), whether they have had sex while under the influence of substances (risky sex), or if they have ever paid for sex (transactional sex).

3.2.5.4 Peer Variables

Peer variables include peer pressure and peer norm variables. Peer norms was calculated by the total of 4 items that asked participants how many of their friends have sexual intercourse, smoke, drink alcohol, or take drugs. Peer pressure was calculated by the total score of 4 items that asked participants how much pressure they receive from their friends to engage in sexual intercourse, smoke, drink alcohol, and take drugs. Each item was scored from 0 (all of my friends for norms or a lot of pressure for peer pressure) to 3 (none of my friends / no pressure at all). Scores were then reverse coded so that higher scores indicated higher peer pressure or higher engagement by peers in risk behaviours.

3.2.6 Poverty and Food Insecurity

Simple Poverty Scorecard Poverty-Assessment Tool is a questionnaire that estimates how likely it is that a household is living in poverty. There are different versions for Uganda and South Africa, but the scoring is the same. It is a low-cost tool consisting of ten questions that assess the number of people in the household, household resources, and education level. The score ranges from 0 to 100, and the total score is used to classify where the household falls in range of the poverty line (Schreiner, 2015, 2017).

Food insecurity was measured using the Item Short Form of the Household Food Insecurity Scale. It comprises 6 items evaluating the last 12 months asking questions regarding access to food resources. Raw scores of 0-1 are considered high/marginal food security, 2-4 as low food security, and 4-6 as very low food security (USDA, 2012) .

3.3 Statistical Analyses

3.3.1 Mental Health

Since the mental health questionnaires assessed overlapping constructs, exploratory factor analyses (EFA) were conducted for both samples to derive wider dimensions of psychological function. Kaiser-Meyer-Olkin factor adequacy (KMO) was 0.64 for Uganda, indicating a mediocre sampling adequacy for each variable. For South Africa, the Kaiser-Meyer-Olkin factor adequacy (KMO) was 0.63, similarly suggesting a mediocre sample adequacy for each variable. Bartlett's test of sphericity was used to determine if the data was suitable for a factor analysis. With significant results of $\chi^2 (15) = 331.587, p < .001$ for Uganda and $\chi^2 (15) = 204.523, p < .001$, it determined that the correlation matrix was likely not an identity matrix and was suitable for factor analysis. Exploratory factor analyses were conducted on standardized variables using principle axis factoring with varimax rotation. An oblique rotation was evaluated to examine factor correlations. The resulting factors were weakly correlated in Uganda ($r = -0.22$) and South Africa ($r = 0.04$), indicating the two dimensions were relatively distinct. Given the limited associations, varimax rotation was subsequently used to obtain a more interpretable factor structure through orthogonal factors. The number of retained factors was examined using multiple criteria, including Kaiser's criterion, parallel analysis, and examination of the resulting factor solutions. Criteria gathered at a two-factor solution in both samples, which was retained

for following analyses. The factor loadings of the individual mental health variables of each factor are presented in Table 4. Based on these loadings, the resulting factor scores were used in analyses examining associations between BART performance and mental health.

The factor solutions were evaluated using model fit indices. In both countries, a two factor solution was retained. The first primary factor reflected symptoms of anxiety, depression, and rumination and was interpreted as a psychological ‘anxiety’ factor. The second factor loaded on wellbeing and resilience and was interpreted as a ‘wellbeing’ factor.

Due to the low internal reliability of the PHQ-A in the South African sample, the linear mixed-effects model was conducted using raw GAD-7 anxiety and WEMWBS well-being scores and BART performance. Each participant provided scores for both mental health factors, so the two observations per participant were not independent. Linear mixed-effect models (LMMs) were subsequently used to account for non-independence of observations. The interaction between BART mean pumps and mental health factors were included as fixed effects, with participants incorporated as a random effect.

Uganda						
	Depression	Anxiety	Behavioral Activation	Rumination	Resilience	Emotional Well-being
Anxiety	0.622	0.913	-.401	0.465	-	-.124
Well-Being	-.0193	-	0.178	0.133	.507	0.7396

South Africa						
	Depression	Anxiety	Behavioural Activation	Rumination	Resilience	Emotional Well-being
Anxiety	0.249	0.708	-.613	0.695	0.222	-.115
Well-Being	-.0262	-	0.117	0.265	0.577	0.841

Table 4. Factor structure of mental health variables.

3.3.2 Real-World Risk Behaviours

Generalised linear mixed models (GLMMs) with binomial distribution and logit functions were estimated for each country to examine the associations between laboratory risk-taking and engagement in real-world risk-taking. Binary indicators of individual risk behaviours were structured into a long format to allow for multiple behavioral observations within participants. Models included risk behaviour categories, mean BART pumps, and interactions as fixed effects.

3.3.3 Poverty and Food Insecurity

Associations between poverty, food insecurity, and BART risk-taking were examined using Pearson and Spearman correlation coefficients. Relationships between poverty and food insecurity were assessed to create an overlap indicator of socioeconomic adversity.

All analyses were conducted in R. Analyses were standardised and performed for both Uganda and South Africa, taking into account contextual and measurement differences between study sites. Statistical significance was evaluated using a two-tailed alpha level of .05. Prior to analysis, data was screened for missing values and descriptive statistics were calculated for all variables. The same set of statistical analyses were conducted across both datasets.

4. Results

4.1 BART Performance

Participants in both countries exhibited an average pumping that fell below the task's optimal level of 64 pumps. In Uganda, the mean number of pumps was 58.71 (95% CI (57.25, 60.17)), which was significantly lower than the optimal value of 64. A one-sample t-test against a reference point of 64 indicated a significant difference at $t = -7.13$, $p < .001$. The reference value of 64 represents the optimal number of pumps assuming risk-neutrality (half of the maximum of 128). Participants pumped fewer than the reference value, meaning participants stopped inflating the balloon earlier than the optimal point and avoided potential losses by also losing out on potential gains. This suggests that on average, participants were more risk averse. In South Africa, participants pumped an average of 50.48 pumps (95% CI (47.67, 53.28)), which was also significantly lower than the optimal value. Figure 3 visualises the mean pumps for both samples. A one-sample t-test against a reference point of 64 indicated a significant difference, $t = -9.51$, $p < .001$, suggesting that participants may have been avoiding potential losses but also giving up potential gains, suggesting they were, on average, risk averse. A Welch two sample t-test comparison between countries showed significantly higher BART risk-taking in Uganda than in South Africa, $t = 5.13$, $p < .001$. The Wilcoxon test produced the same conclusion ($p < .001$).



Figure 3. Mean pumping on the BART. Violin plots showing average pumps in both countries. In Uganda, pumps ranged from 55-65 pumps on average at baseline, with mean pumps being at 58.71. In South Africa, most participants ranged from approximately 40-60 pumps on average with a mean of 51.28 pumps. The reference value of 64, illustrated by the dashed line, represents the optimal number of pumps assuming risk-neutrality (half of the maximum of 128).

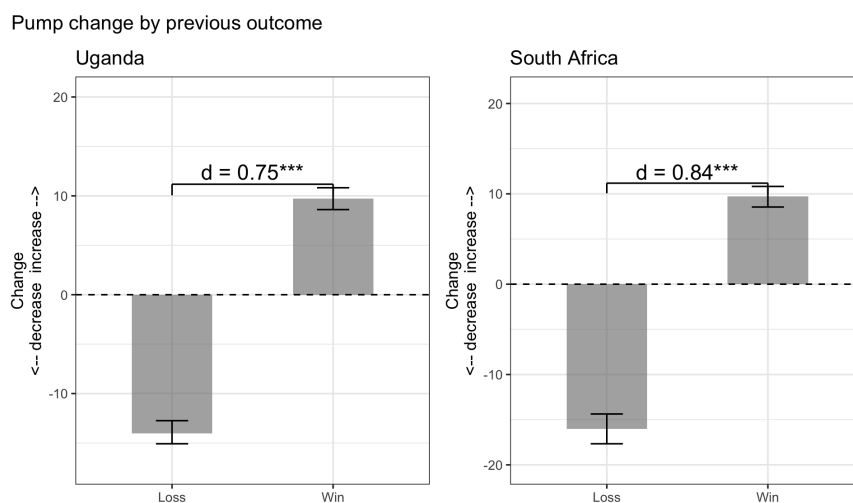
4.2 Internal Consistency and Response Processes

Internal consistency was assessed using Cronbach's alpha with 95% confidence intervals. For Uganda, the α was 0.82 and for South Africa, the α was 0.91. Both values suggest a good internal consistency.

Mixed effect models assessed how participants adjusted their pumping behaviour trial-by-trial. In Uganda, participants significantly decreased their pumps following balloon explosions and increased their pumps following successful trials, $\chi^2(1) = 821.76$, $p < .001$. After losses, participants reduced pumping behaviour by an average of 14.01 pumps, whereas they

increased their pumping by an average of 9.72 pumps after wins. South African participants similarly showed significant sensitivity to previous outcomes, $\chi^2(1) = 633.67$, $p < .001$. Participants decreased pumping by 16.03 pumps following losses and increased pumping by 9.73 pumps following wins.

Mean changes in pumps following wins and losses is presented in figure 4. Furthermore, distance effects were looked at as well. In Uganda, greater distance from the explosion point was associated with larger reactions following pumping behaviour, $\beta = -0.45$, $p < .001$. Similarly, in South Africa, the distance effect was also significant, $\beta = -0.47$, $p < .001$. These findings indicate that participants in both Uganda and South Africa adjusted their behaviour in response to previous pumping outcomes. More specifically, the negative β values suggest that reactions increased as participants moved closer to the explosion point, providing evidence of risk sensitivity and task feedback in both samples.



Change by distance from explosion point

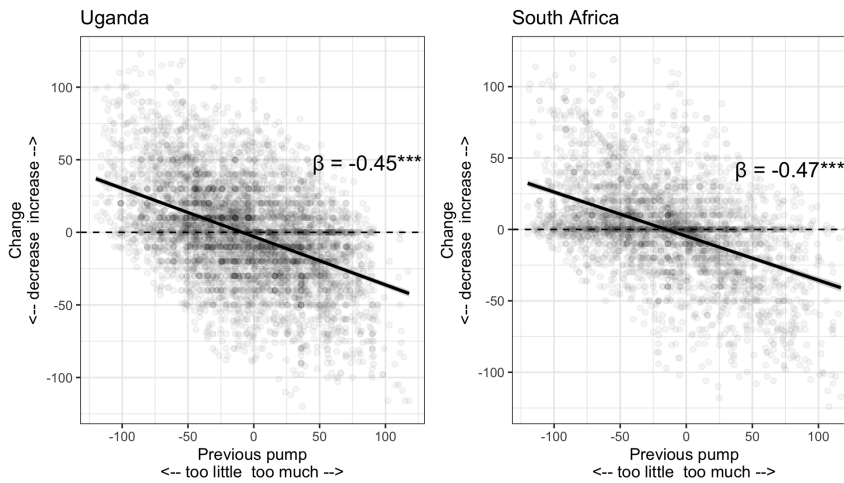


Figure 4. Response Processes on the BART. The upper panel shows mean changes in pump behaviour following wins and losses. Positive values indicate an increase in pumping in the subsequent trial, while negative values indicate a decrease. Effect sizes (Cohen’s *d*) are displayed above comparison. The lower panels show the relationship between previous pumping levels and following changes in pumping behaviour. Negative values indicate previous pumps below the explosion point, and positive values indicate previous pumps above the explosion point.

4.3 Cognitive Control

Simple linear regression analyses were conducted separately for Uganda and South Africa to examine whether cognitive control was associated with risk-taking behaviour on the BART. In Uganda, cognitive control was significantly associated with risk-taking on the BART, more specifically higher cognitive control scores were associated with higher mean pumps on the BART, $B = 0.180$, 95% CI, $p = .010$, $R^2 = .022$. In contrast, the regression model showed no significance in South African participants, $B = 0.016$, 95% CI, $p = .906$, $R^2 < .001$, indicating that there was essentially no association between cognitive control and BART mean pumps in the

South African sample. Associations between cognitive control and mean pumps are pictured in figure 5.

Correlations between shape and face error counts were examined to investigate whether associations between AFS performance and BART risk-taking differed between the neutral and affective conditions. Shape and face errors were positively and moderately correlated in both Uganda ($r = .477, \rho = .462, p < .001$), and South Africa ($r = .531, \rho = .506, p < .001$). This indicated that participants who made more errors in one condition also tended to make more errors in the other condition. The correlation between shape and face errors suggest that the two conditions may capture overlapping individual differences in task performance, and the use of a combined error measure may therefore provide a more reliable estimate of overall cognitive control performance.

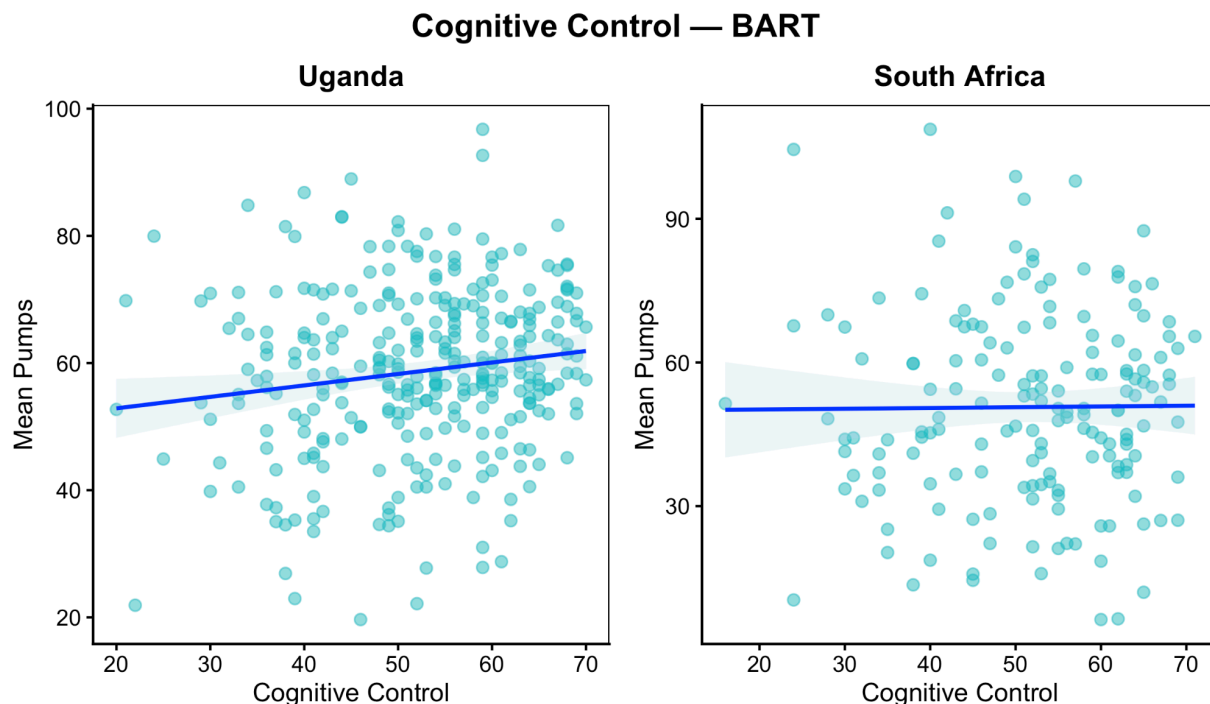


Figure 5. Cognitive Control Associations. Illustrates the association between cognitive control and mean pumps on the BART across two samples. In Uganda, cognitive control was positively associated with mean pumps, seen by the upward sloping line. In South Africa, the line is nearly

flat, highlighting that there was no significant association between cognitive control and mean pumps.

4.4 Mental Health

Exploratory factor analyses were conducted using six mental health measures. The data was suggested to be suitable for a factor analysis with both Kaiser–Meyer–Olkin (KMO) statistics and Bartlett’s test of sphericity (see Methods, section 3.3.1). Parallel analysis and scree plot inspection supported the two-factor solution for both samples.

In Uganda, there was significant interaction between mean pumps and mental health factor type, $\chi^2(1) = 10.10$, $p = .001$. Higher mean pumps tended to be associated with lower anxiety scores, although this effect was not significant, ($\beta = -0.007$, $p = .056$). In contrast, higher mean pumps were significantly associated with higher well-being scores ($\beta = 0.010$, $p = .010$). The difference between these slopes was significant at $t = -3.18$, $p = .002$, suggesting that greater risk-taking was more positively associated with well-being than anxiety symptoms in Uganda. In South Africa, there were no significant associations found between either mental health factor and performance on the BART, $\chi^2(1) = 1.06$, $p = .302$. The interaction between mental health and mean pumps is pictured in figure 6.

Due to the low internal reliability of the PHQ-A in the South African sample, a linear mixed-effects model was conducted using raw GAD-7 anxiety and WEMWBS well-being scores and BART performance. In Uganda, there was a significant interaction between BART performance and mental health measures, $\chi^2(1) = 8.47$, $p = .004$. Higher pumps were significantly associated with higher well-being scores, $b = 0.137$, $SE = 0.043$, $p = .001$. However, anxiety scores were not significantly associated with BART performance, $b = -0.039$, $SE =$

0.043, $p = .360$. In South Africa, there was no significant association between BART performance and mental health measures, both $ps > .42$.

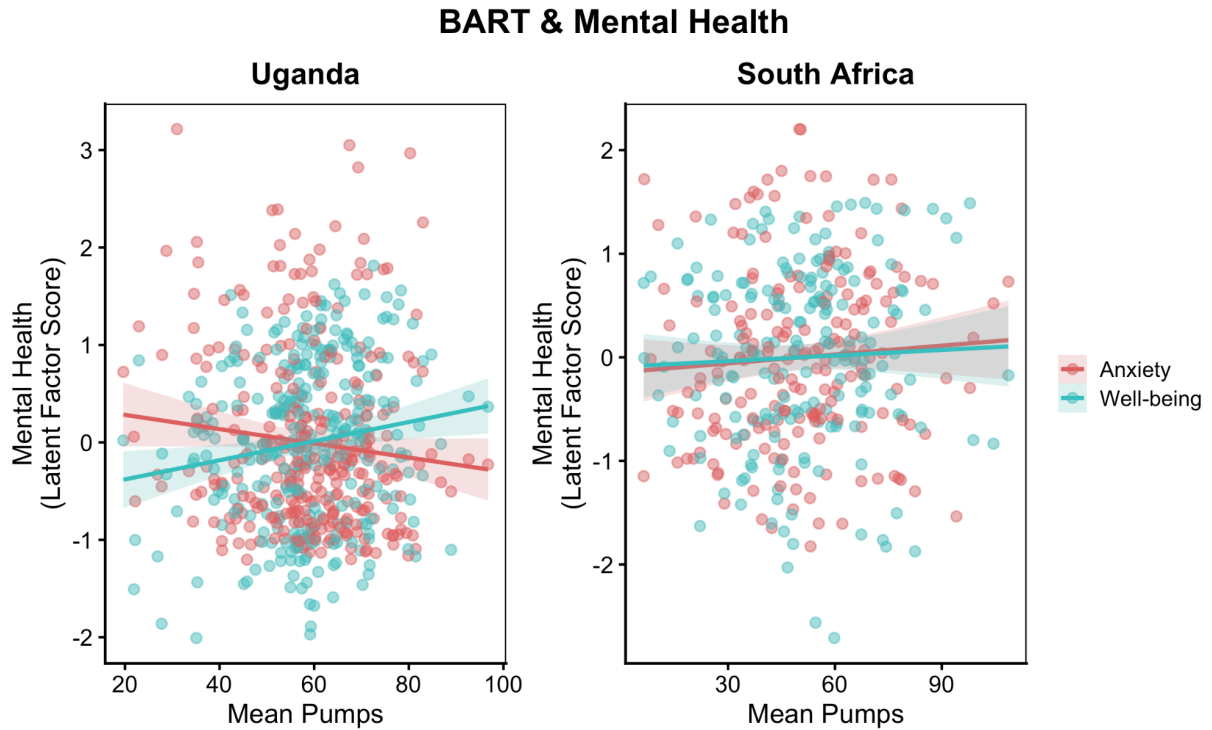


Figure 6. Mental Health Associations. Scatterplots depicting the relationship between participants mean number of pumps and latent factor scores in anxiety and well-being. Regression lines and 95% confidence internals are shown separately for each construct. In the Uganda sample (left panel), mean pumping behaviour was differentially associated with anxiety and well-being, while in the South African sample (right panel).

Among Ugandan boys, a significant interaction was found between BART performance and mental health factor type, $\chi^2(1) = 6.53$, $p = .011$. Higher pumping was significantly associated with higher well-being scores ($\beta = 0.012$, $p = .045$), whereas the negative association with well-being scores was not significant ($\beta = -0.010$, $p = .111$). The difference between slopes was significant, $t = -2.56$, $p = 0.12$. Among girls in Uganda, the interaction between BART pumps and mental health factors was significant at $\chi^2(1) = 3.81$, $p = .051$. Increased pumping showed a

trend with greater well-being, ($\beta = 0.008$, $p = .099$), and lower anxiety ($\beta = -0.005$, $p = .270$), although neither was significant.

In South Africa, there were no significant associations between BART performance and mental health factors for either boys or girls. Interactions were not significant for boys, $\chi^2(1) = 0.04$, $p = .842$, and for girls, $\chi^2(1) = 0.01$, $p = .918$.

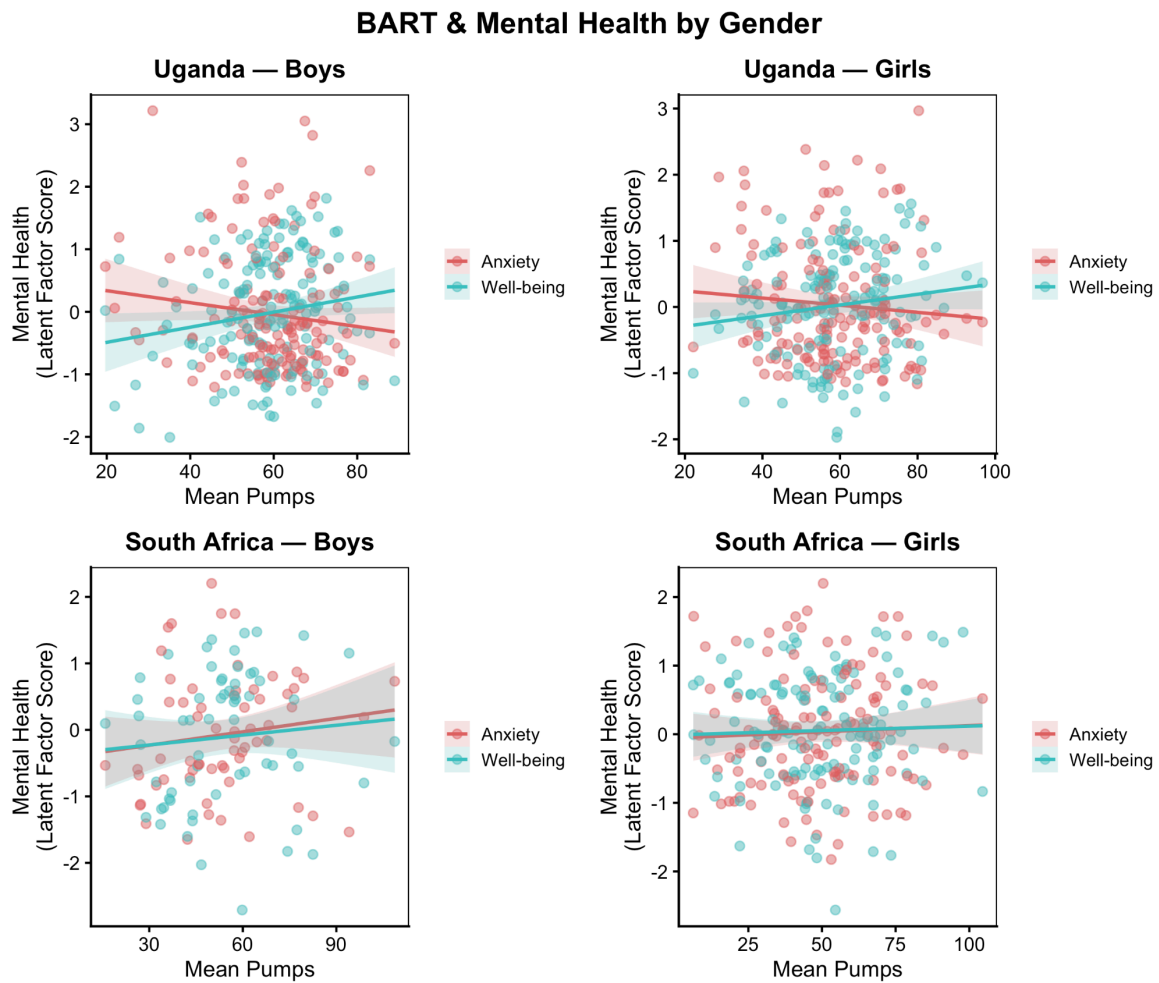


Figure 7. Mental Health Associations By Gender. Mental health and risk-taking by gender. These plots show the relationship between BART risk-taking (mean pumps) and latent mental health factor scores, separately for boys and girls in Uganda and South Africa. Anxiety is shown

in red and well-being in blue. Across both countries, the associations are generally weak, as indicated by the shallow regression slopes and substantial overlap in confidence intervals.

4.5 Real-World Risk Behaviours

Mixed-effects logistic regression models examined whether BART risk-taking predicted engagement in real-world risk behaviours. In Uganda, neither the overall BART performance $\chi^2(1) = 0.49$, $p = .484$, nor the interaction between performance and risk category, $\chi^2(10) = 11.43$, $p = .325$, were significant. Similarly, in South Africa there was no overall association between performance on the BART and risky behaviours $\chi^2(1) = 0.01$, $p = .923$, and the interaction of risk categories was not significant either, $\chi^2(12) = 17.40$, $p = .135$. Similarly, in both sites, there was no association between peer norms or peer pressure on risk taking (all $ps > 0.49$).

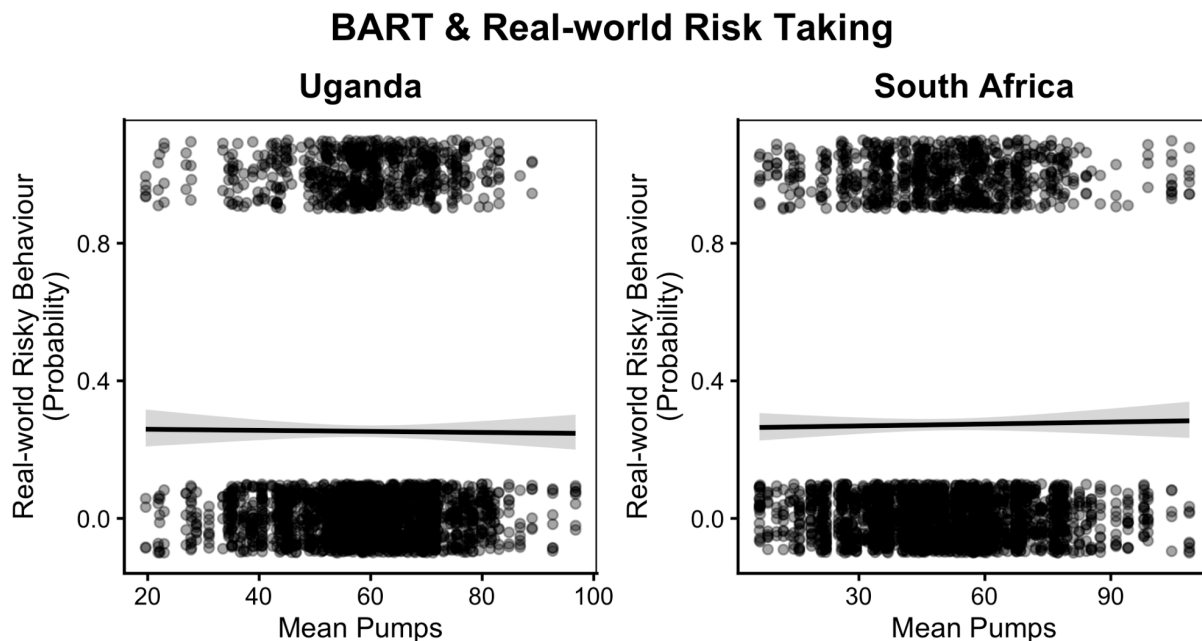


Figure 8. Real-World Risk Associations. Association between BART performance and probability of real-world risk behaviour. Each point represents individual responses with points distributed across two outcomes categories. The black line represents the fitted regression

between BART performance and the probability of real-world risk behaviour, while shaded regions indicate corresponding confidence intervals.

4.6 Poverty and Food Insecurity

Poverty scores were significantly associated with food insecurity in both Uganda, $r = -.26$, $p < .001$, and South Africa, $r = -.19$, $p = .008$, suggesting that greater socioeconomic hardship is associated with greater levels of food insecurity in both countries. In Uganda, BART performance was not associated with poverty, $r = -.04$, $p = .458$, or food insecurity, $r = .001$, $p = .991$. Similarly, no significant association was observed between BART mean pumps and poverty in South Africa, $r = .07$, $p = .315$. However, a small positive association was observed between BART performance and food insecurity in South Africa, $r = .16$, $p = .033$.

5. Discussion

The present study aimed to explore the extent of behavioural risk-taking using the Balloon Analogue Risk Task, and investigated the correlations between BART risk-taking, cognitive control, mental health outcomes, real-world risk behaviours, and socioeconomic characteristics in two samples, one comprised of Ugandan adolescents, and the other of South African adolescents with depressive symptoms. Across both samples, we observed good internal consistency in risk-taking in the BART, suggesting that the BART elicits consistent individual differences in measures of risk-taking. Participants rationally adapted their risk-taking to the features of the task, with significant decreases in their pumping following balloon explosions and increases in their pumping following successful wins, suggesting adequate task comprehension

and engagement in both populations. In revisiting the construct validity of the BART in such new contexts, the patterns observed across both samples were slightly different. In Uganda, higher risk-taking was associated with heightened cognitive control, positive mental health outcomes in relation to anxiety and well-being, and no associations with self-reported impulsive risk-taking in real world risk behaviours. In South Africa, these associations were limited. Taken together, these results suggest that the BART can be used as a measure of risk-taking in Ugandan and South African samples.

5.1 Risk-Taking In The BART

The impulsive risk-taking hypothesis explored whether pumping on the BART could provide a meaningful measure of individual differences in risk-taking in Ugandan adolescents and South African adolescents with depressive symptoms. Overall, the findings offer support for the use of the BART in both samples. BART pumping displayed good internal consistency in both Uganda and South Africa, indicating individual differences in pumping behaviour were satisfactorily consistent across trials to provide an interpretation of differences on task performance. Importantly, a good internal consistency did not imply that participants responded identically across trials. Rather, participants in both samples demonstrated changes in pumping behaviour in response to the structure and feedback of the task, suggesting participants both engaged with the task and adapted their behaviour according to its possibilities, supporting the BART's use as a measure of decision-making in these samples.

One of the most important inferences from the present findings is related to how the BART performance could be interpreted. The BART is frequently intended to be used as a behavioural measure of risk-taking, with higher pumping generally interpreted as a greater willingness to

engage in risk (Sebri et al., 2023). However, the pattern observed in the present study may suggest a different interpretation. Participants do not solely make decisions about risks without consideration of other factors. Rather, they repeatedly make choices, receive feedback and experience consequences of those decisions, and use this feedback to make subsequent decisions. Therefore, performance on the BART could involve exploration, learning, and strategic adaptation, along with a willingness to accept risk. Evidence for both these processes were identified. Despite the adaptive responses, mean pumps in a random half of the trials correlated with mean pumps in the other half, suggesting that participants show consistent individual differences. Similarly, the response processes and learning are another clear example of the adaptation.

The multiple-trial nature of this task can further highlight these adaptive processes. Participants weigh the potential value of continued pumps versus the increasing possibility of the balloon exploding. Early decisions may involve exploration of the extent to which the balloon can be pumped, whereas subsequent decisions may involve integration of information obtained from previous trials (Lejuez et al., 2002). As a result, a participant who pumps more may not necessarily be exhibiting an overall greater preference for risk. Instead, they may be responding to the inherent reward structure of the task, learning the probabilities associated with higher or lower pumping, or adopting strategies that aim to maximise gains. Similarly, lower levels of pumping does not always indicate greater risk aversion, and may instead indicate strategies that prioritise avoidance of losses.

This interpretation may be further exemplified in the positive associations between cognitive control and BART pumping in Uganda. Since higher cognitive control was associated with higher BART pumping, it may seem counterintuitive if increased pumping on the BART

represents poorer behavioural control. However, if BART performance involves adaptive decision-making, then greater cognitive control may allow for participants to integrate feedback and maintain task goals while making more consistent decisions about when to continue or when to stop. Therefore, the positive association between cognitive control and mean pumps in Uganda could reflect more effective engagement in the task rather than willingness to take risks.

Notably, the association was small, and was not replicated in South Africa, so such an interpretation would need further exploration. One possible explanation is that South African participants demonstrated lower levels of pumping than Ugandan participants, although performance was not at floor, indicating that the absence of an association in South African participants is unlikely to be explained solely by a lack of variability in task performance. It could be possible that the relationship between cognitive control and BART performance may differ according to depressive characteristics of the sample. In particular, among adolescents experiencing depressive symptoms, decision-making behaviour may be influenced greatly by motivational factors, such as reduced reward sensitivity or altered motivation to pursue potential gains, rather than by cognitive control alone (Forbes & Dahl, 2011; Hevey et al., 2017; Peeters et al., 2017). Based on such an interpretation, cognitive control may be weakly associated with willingness to increase pumping when the motivational value of potential rewards are reduced. However, such an approach remains speculative as the present study did not examine whether affective and motivational factors moderate the relationship between cognitive control and BART performance.

The learning component of the BART is also important to consider. If participants modify their behaviour according to feedback, then performance on the BART could represent the outcomes of ongoing decision-making processes rather than individual characteristics. This is

more consistent with contemporary approaches. Such an interpretation may also help explain why associations between BART performance and measures of real-world risk behaviours were limited. Real-world risk-taking is often embedded within social and environmental contexts that are more complex than the controlled nature of the BART (Fernie, Cole, Goudie, & Field). Real-world risk behaviours in high adversity settings may be less influenced by individual properties of risk-taking propensity, and more so by contextual factors under which these risk behaviours are exhibited. Environmental factors such as poverty, social norms, family circumstances, peer influences, and environmental constraints (Ellis et al., 2012). Consequently, engagement in real-world risk may represent necessity or opportunity, or environmental exposure rather than a single domain-general risk-taking factor.

An alternative interpretation is that BART risk-taking may be more specifically unrelated to maladaptive real-world risk behaviours, rather than simply being unrelated to risk-taking outside the laboratory altogether. From this perspective, willingness to engage in risk in the BART may represent an aspect of deliberate decision-making that does not necessarily translate into problematic behaviours in everyday life. Such an elucidation would be consistent with lifespan perspectives on risk-taking, which emphasise that risk-taking can be adaptive when the risk levels are related to an individual's goals and circumstances (Romer et al., 2017). However, the present study did not assess adaptive forms of real-world risk behaviours, and therefore cannot determine whether BART performance is associated with adaptive risk-taking outside of a task-based environment.

Relatedly, a lesser considered idea in adolescent research, is that too little risk could be as impulsive as too much risk. If participants are, on average, more risk-averse than strategically optimal, taking greater risks on the BART may not simply reflect poorer behavioural control.

Instead, greater cognitive control may allow participants to overcome an overly cautious response strategy and enable them to examine the potential costs and benefits of continued pumping, resulting in more optimised decisions for the level of risk. In this case, the significant, positive association observed between BART pumping and cognitive control could reflect more effective decision-making over maladaptive risk-taking. Thus, both excessively high and low levels of risk-taking may reflect less than optimal decision-making, dependent upon the demands of the environment. This interpretation highlights the necessity of considering the aptness of risk-taking, rather than assuming that lower levels of risk-taking is inherently more adaptive.

5.2 Deliberate Decision-Making

The deliberate decision-making hypothesis assessed the associations between BART performance and measures of cognitive control, mental health, and real-world maladaptive risk behaviours. In Uganda, greater BART pumping was associated with higher cognitive control and positive mental health outcomes, specifically greater well-being and lower anxiety. BART was not significantly associated with self-reported maladaptive risk behaviours. These findings provide some evidence for the construct validity of BART performance while also suggesting that greater pumping may not simply be an indicator of maladaptive risk-taking. These associations were not observed in the South African sample, offering the idea that these associations may vary according to sample or contextual factors. Table 5 visualises the observed associations for each country, for each hypothesis.

	Risk-Taking in the BART		Observed	
	Impulsive Risk-Taking Hypothesis	Deliberate Decision-Making Hypothesis	Uganda	South Africa
Cognitive Control	-	+	+	NS
Negative Mental Health Outcomes	+	-	-	NS
Positive Mental Health Outcomes	-	+	+	NS
Real World Maladaptive Risk	+	NS	NS	NS

Table 5. Observed associations by hypothesis. For each hypothesis and measured outcome, predicted (left) and observed (right) associations are marked. Negative associations are denoted by the ‘-’ sign and the colour red. Positive associations are denoted with the ‘+’ sign and the colour green. Non-significant associations are denoted by NS.

The positive associations between BART pumping and cognitive control in the Ugandan sample is informative, especially when considering the elaboration of BART performance. If greater pumping were principally an indicator of impulsivity and poor behavioural control, a positive relationship with cognitive control would be counterintuitive. Instead, this finding is consistent with the idea that cognitive control contributes to participants’ ability to make deliberate decisions about when to continue pumping and when to stop. Greater cognitive control could allow participants to evaluate potential benefits and costs and integrate feedback from previous trials. Thus, in some instances, BART pumping may reflect more effective decision-making rather than poorer behavioural control. Such an interpretation is consistent with adaptive risk-taking literature, emphasising that risk-taking need not inherently be maladaptive (Romer et al., 2017).

The associations between BART pumping and mental health in Uganda further exemplify this. Greater pumping was associated with greater well-being and lower anxiety, suggesting that greater willingness to accept risk on the BART was not associated with poorer psychological functioning in this sample. Although some associations between BART performance and mental health have been previously reported, findings have been variable, with sparse research on the influence of psychological difficulties on how individuals respond to losses or adjust their behaviour in lieu of simply increasing or decreasing overall levels of risk-taking (Hevey et al., 2017; Wade et al., 2022). Therefore, the present findings contribute to existing literature by suggesting that, in Ugandan adolescents, greater BART risk-taking may coincide with better psychological functioning.

Indeed, such an interpretation is supported by the absence of significant associations between BART performance and maladaptive real-world risk behaviours in both samples, suggesting that BART pumping does not simply index a general propensity to engage in problematic risk-taking in everyday life. These behaviours occur within social and environmental contexts that are considerably more complex than the controlled conditions of the BART. Opportunities to engage in risk may be shaped by factors such as peer relations, family circumstances, social norms, poverty, and so forth (Ellis et al., 2012). As a result, engagement in real-world risk may reflect the interaction between individual attributes and contextual factors or demands, rather than merely a single domain of general risk-taking tendency.

Combined, these findings propose a more nuanced account of the processes captured by the BART and are consistent with the possibilities that BART performance encapsulates deliberate decision-making under uncertainty. The absence of these findings in the South African sample indicated that this interpretation may not be easily generalised across different samples. Overall,

these outcomes propose that BART risk-taking may be a meaningful measure of decision-making under uncertainty, but its relationship with wider measures of psychological well-being and behavioural characteristics may depend upon population contexts it is assessed in.

5.3 Poverty and Food Insecurity

In line with expectations, poverty and food insecurity were slightly significantly associated in both countries. Adolescents reporting greater economic hardship consequently reported higher levels of food insecurity suggesting these measures captured related dimensions of socioeconomic adversity. However, both measures demonstrated little association with behavioural risk-taking. In Uganda, neither poverty nor food insecurity was associated with BART performance. In South Africa, a small positive correlation was observed between food insecurity and BART performance using Pearson correlations. These findings provide limited support for theories proposing that scarcity and economic hardship directly increase risk-taking behaviour (Haushofer & Fehr, 2014). Models derived from behavioural economics and life history often predict that adversity and scarcity could promote decision-making focus on immediate gains, but the present findings suggest that chronic socioeconomic adversity may not necessarily translate into greater willingness to engage in risk-taking in the BART (Ellis et al., 2009). It could be possible that the BART is insufficiently sensitive to these kinds of adaptive decision-making strategies that emerge under situations of poverty. Real-world decisions that involve food, money, safety, and resource allocation may differ from the rewards on the BART.

5.4 Limitations

This study has several limitations. First, the cross-sectional nature of the study design and reliance on self report data may limit the ability to infer causal relationships between risk-taking, mental health outcomes, real-world risk behaviours, and socioeconomic hardship.

Second, the evaluation of BART performance as either adaptive or maladaptive risk-taking remains limited by the measures included in the present study. Although the findings are consistent with the possibility that BART performance may reflect adaptive decision-making, the study did not include a direct measure of adaptive risk-taking in everyday life. Consequently, the absence of associations between BART performance and maladaptive real-world risk behaviors cannot be taken as evidence that BART performance is closely related to one or both of these constructs.

Third, the two samples differed in important characteristics. The South African sample was selected based on the presence of depressive symptoms, while the Ugandan sample was not. As a result, differences in associations between BART performance and associated measures cannot be attributed to country contexts, and differences between sample outcomes cannot be directly compared.

Lastly, the BART may provide a controlled method for examining decision-making, the task-based, laboratory nature of the task makes the ecological validity limited. The task paradigms of the BART occur in a constrained environment whereas real-world risk behaviors occur in complex social and environmental contexts.

5.5 Future Research

The present findings present several interesting pathways for future research. Longitudinal studies may be useful to clarify relationships between BART risk-taking, real-world risk behaviors, mental health outcomes, and socioeconomic adversity. Longitudinal studies would allow researchers to examine how these relationships develop across adolescence into adulthood. Future research may also investigate developmental differences more explicitly by evaluating narrower age ranges or repeated assessments over time, which may help more clearly identify sensitive periods due to the fact that adolescence encompasses substantial biological, cognitive, and social changes. Future studies would also benefit from more comprehensive, standardised assessments of real-world risk behaviours rather than one item scales. Lastly, examining sex differences in more detail could prove useful, especially due to the inconclusive nature of sex differences in risk-taking in current literature.

5.6 Conclusion

The present study suggests that the BART can be meaningfully used to examine adolescent decision-making in Ugandan and South African samples. Across both sites, participants demonstrated learning and strategic adaptation across trials, suggesting that the adolescents engaged with the task and adjusted their decisions in response to the consequences of their choices and feedback. Higher BART risk-taking was not consistently associated with maladaptive outcomes. In Uganda, greater BART pumping was associated with higher cognitive control and lower anxiety, but was not significantly associated with real world risk behaviours, or socioeconomic adversity. These associations were not seen in the South African sample. Together, these findings indicate that BART performance need not be interpreted as a direct

measure of maladaptive risk-taking. Rather, performance appears to signify aspects of decision-making under uncertainty, including learning from feedback and balancing potential rewards and losses. Overall, these findings contribute to research on adolescent risk-taking by extending examinations of the BART in samples that remain underrepresented in literature and support the use of the BART as a measure of adolescent risk-taking in these samples, while emphasising the importance of interpreting BART performance in relation to specific cognitive, psychological, social, and environmental characteristics of the sample being studied.

6. Appendices

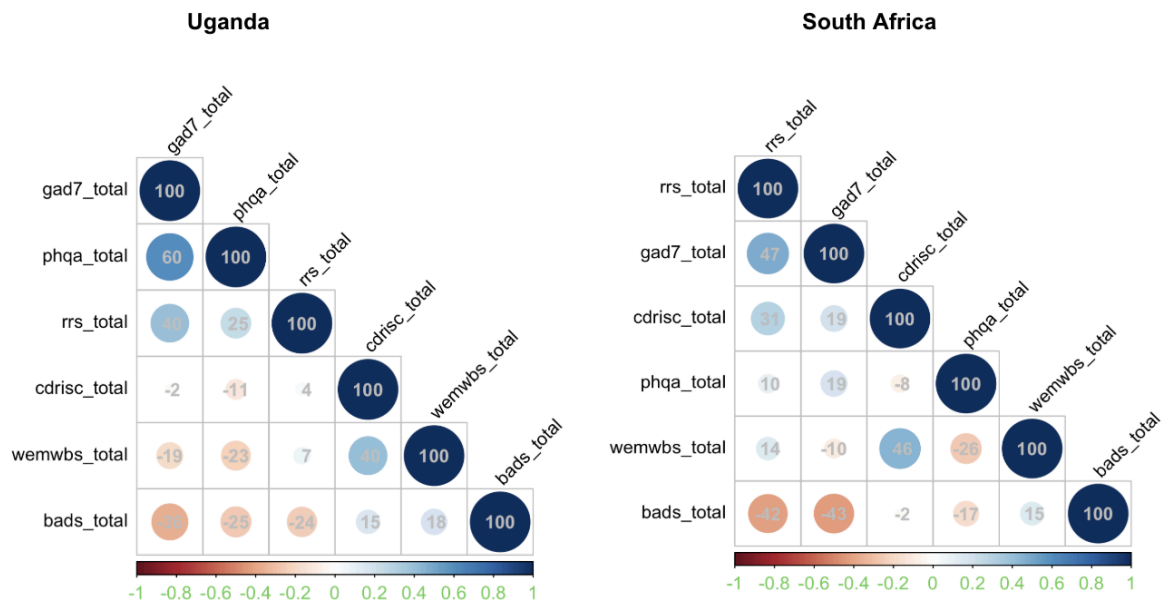


Figure 9. Mental Health Correlation Matrices. Correlation matrices showing the relationships among psychological behavioural measures. Each matrix indicates pairwise correlation coefficients between total scores for six mental health outcomes. Size and colour represent the strength and direction of the correlation with blue indicating positive correlations and red indicating negative correlations. The numerical values within the circles indicate the corresponding correlation coefficients.

Questionnaire	Items	Scale
PHQ-A (depression in adolescents)	1. Little interest or pleasure in doing things; 2. Feeling down, depressed, or hopeless; 3. Trouble falling or staying asleep or sleeping too much; 4. Feeling tired or having little energy; 5. Poor appetite or overeating; 6. Feeling bad about yourself; 7. Trouble concentrating on things; 8. Moving or speaking slowly; 9. Suicidal thoughts/self-harm	0–3 (Not at all – Nearly every day)
GAD-7 (generalised anxiety disorder)	1. Feeling nervous, anxious, or on edge; 2. Not being able to stop or control worrying; 3. Worrying too much about different things; 4. Trouble relaxing; 5. Being restless; 6. Easily annoyed or irritated; 7. Feeling afraid as if something awful might happen	0–3 (Not at all – Nearly every day)
RRS (rumination)	1. Think “Why do I always react this way?”; 2. Think “Why can’t I handle things better?”; 3. Think “What am I doing to deserve this?”; 4. Think “Why do I have problems others don’t?”; 5. Think about a recent situation, wishing it had gone better	0–3 (Not at all – Nearly every day)
WEMWBS (mental well being)	1. Feeling optimistic about the future; 2. Feeling useful; 3. Feeling relaxed; 4. Feeling interested in other people; 5. I've had energy to spare; 6. I've been dealing with problems well; 7. Thinking clearly; 8. Feeling good about yourself; 9. Feeling close to others; 10. Feeling confident; 11. Able to make up your mind about things; 12. Feeling loved; 13. Interested in new things; 14. Feeling cheerful	1–5 (None of the time – Nearly every day)
CD-RISC (resilience)	1. I am able to adapt when changes occur; 2. I can deal with whatever comes my way; 3. see the funny side of things when I am faced with problems ; 4. Having to cope with stress can make me stronger; 5. I tend to bounce back after illness, injury or other hardships; 6. I believe I can achieve my goals, even if there are obstacles; 7. Under pressure, I stay focused and think clearly; 8. I am not easily discouraged by failure; 9. I think of myself as a strong person when dealing with life's challenges and difficulties; 10. I am able to handle unpleasant or painful feelings like sadness, fear and anger.	0–4 (Not true at all – Very true all the time)
BADS (executive dysfunction)	1. I stayed in bed for too long even though I had things to do; 2. There were certain things that I needed to do that I didn't do; 3. I have been content with the amount and types of things I did; 4. Engaged in diverse activities; 5. I made good decisions about what type of activities and/or situations I put myself in; 6. Active but unproductive; 7. Active and achieved goals; 8. Avoided important things; 9. Avoided emotions; 10. Avoided thinking about things; 11. Did hard things that aligned with goals; 12. Did something hard but worthwhile; 13. Ruminated on problems; 14. Thought about solutions but didn't act; 15. Dwelling on past negative events; 16. Didn't see friends; 17. Withdrawn and quiet socially; 18. Avoided social interaction; 19. I pushed people away with my negativity; 20. Cut off from others; 21. Avoided responsibilities, school or work; 22. Responsibilities suffered; 23. Structured daily activities; 24. Only did distracting activities; 25. Affected by others' negativity	0–6 (Very true of me – Very untrue of me)

Table 6. Mental health measures. Full item list for mental health measures.

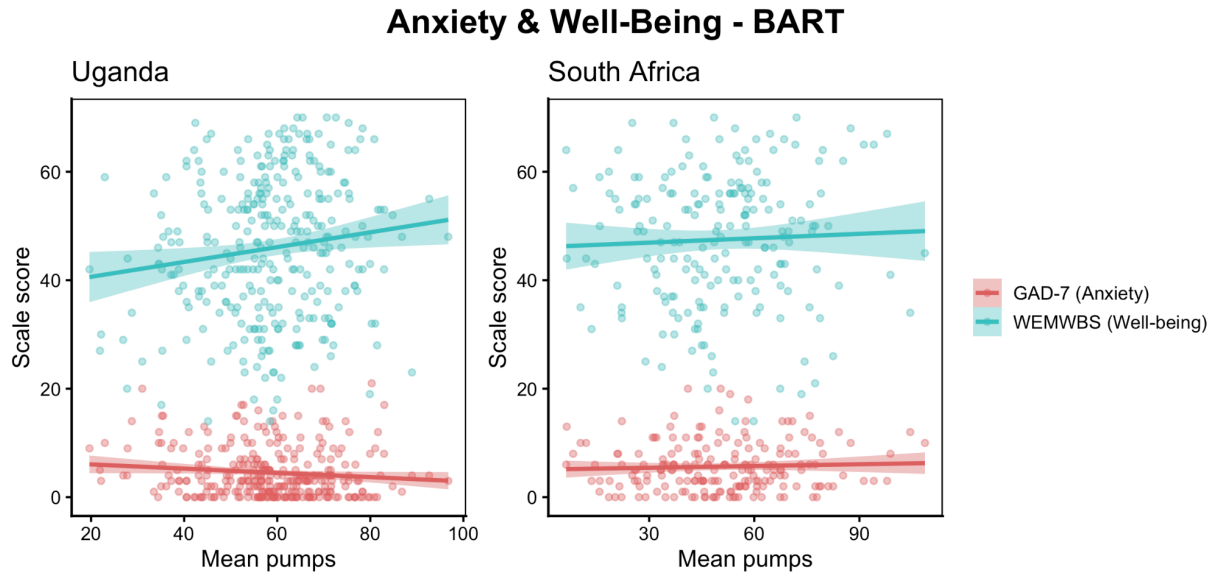


Figure 10. Anxiety and Well-Being Construct Associations. Associations between mean number of pumps and GAD-7 anxiety and WEMWBS well-being scores. Each point represents individual observations. The red line and points represent anxiety scores and the blue line and points represent well-being scores. Shaded areas around the regression line indicate confidence intervals. The figure illustrates the relationship between performance on the BART as mean pumps and psychological outcomes across Uganda and South Africa.

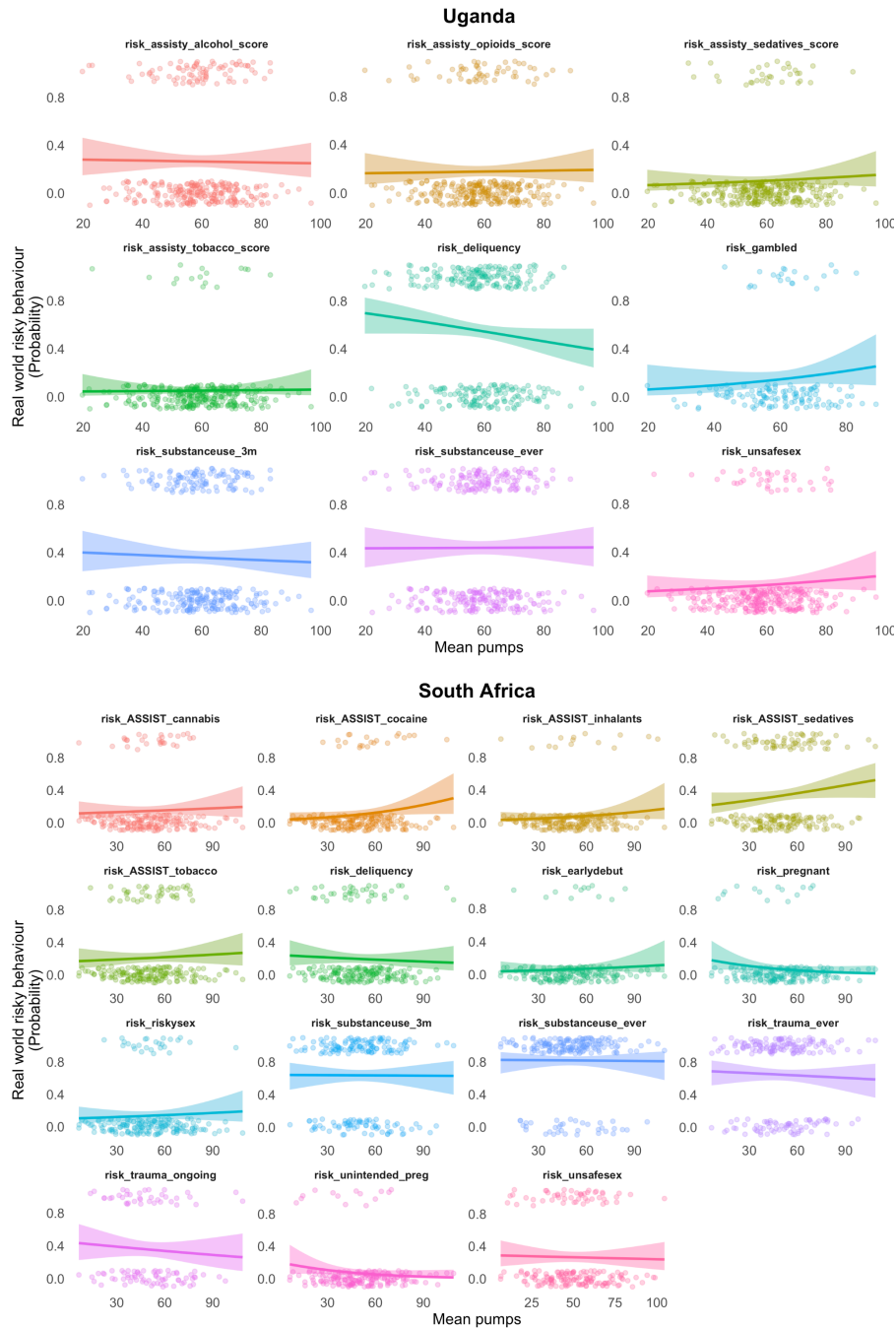


Figure 11. Real-World Risk And Mean Pumps. Associations between participants' mean number of pumps and engagement in real world risk behavior, separately for individual risk domains. Solid lines represent fitted regression estimates, and shaded regions indicate confidence intervals. For both countries, associations between mean pumping behavior and self-report risk behavior were generally small, with considerable variability across risk domains.

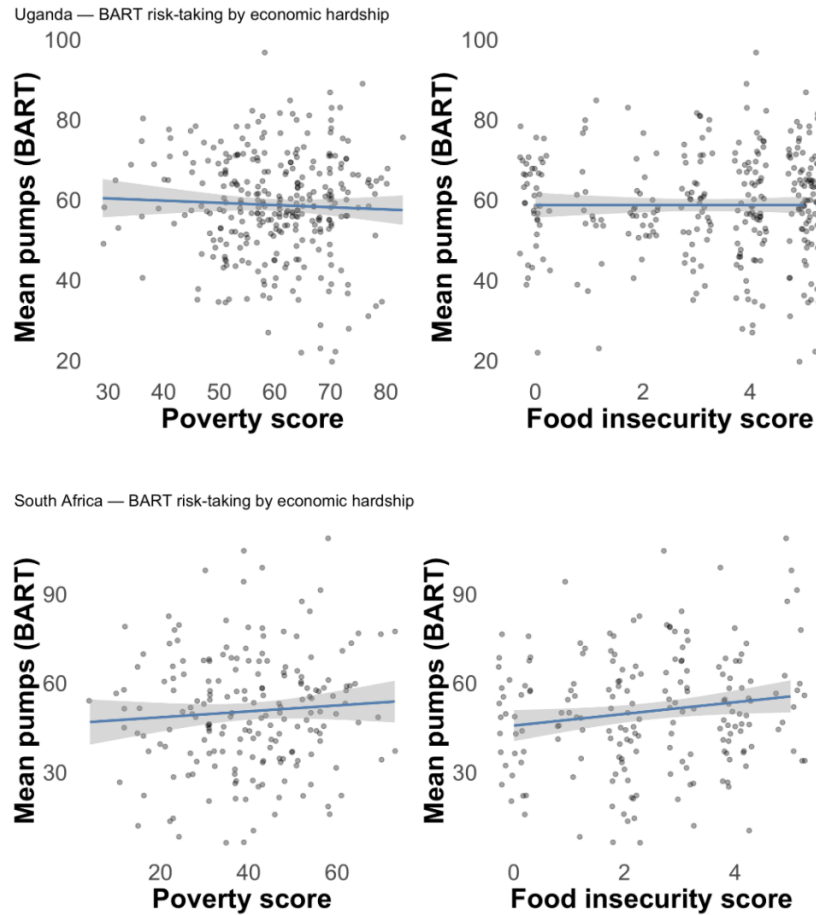


Figure 12. Socioeconomic Characteristics Associations. Scatterplots indicating the relationship between mean BART pumps and indicators of economic hardship. Regression lines represent linear associations with 95% confidence intervals. In Uganda, economic hardship showed little association with BART performance. There was a slight positive association between economic hardship and mean pumping behavior in South African participants, especially for food insecurity scores.

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