FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

CAPE-TEENS: Assessing Executive Functions and Lifestyle Factors to Predict Risk in Adolescence

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Resumo

A adolescência é um período de desenvolvimento caracterizado por alterações significativas a nível físico, cognitivo e emocional, contribuindo para uma maior tendência a participar em comportamentos de risco. A investigação tem demonstrado que as funções executivas, a sensibilidade a recompensa e fatores contextuais como a qualidade do sono, o stress e a atividade física, desempenham um papel importante em moldar a tomada de decisão na adolescência. No entanto, as abordagens de avaliação existentes recorrem frequentemente a implementações heterogéneas de tarefas e a ferramentas de avaliação independentes, o que limita a reprodutibilidade dos estudos e a integração de informação cognitiva e contextual.

Esta dissertação apresenta o **CAPE-TEENS**, uma plataforma web que estende a framework CAPE-KIDS existente para apoiar a avaliação cognitiva de adolescentes entre os 10 e os 15 anos. A plataforma proposta introduz novas funcionalidades para a avaliação da sensibilidade a recompensa através de fluxos de tarefas condicionais, uma framework configurável de questionários para a recolha de informação contextual e de estilo de vida, e funcionalidades melhoradas para gestão de participantes. Foi realizada uma revisão sistemática da literatura, seguindo as diretrizes PRISMA 2020, com o objetivo de identificar as tarefas de funções executivas, os paradigmas de sensibilidade a recompensa e os fatores externos mais frequentemente associados ao comportamento de risco na adolescência, sendo os resultados utilizados para orientar a especificação e implementação da plataforma.

As funcionalidades propostas foram implementadas no âmbito da arquitetura modular já existente do CAPE-KIDS, usando React no frontend, NestJS no backend, e PostgreSQL como base de dados. Foi realizado um estudo-piloto envolvendo adolescentes dentro da faixa etária definida, com o objetivo de avaliar a validade e a usabilidade das funcionalidades implementadas. Os resultados demonstraram a execução bem-sucedida das tarefas de sensibilidade a recompensa, da administração de questionários e do armazenamento e exportação dos dados de avaliação, sem falhas técnicas ao longo do estudo.

A plataforma desenvolvida expande as capacidades do CAPE-KIDS, fornecendo um ambiente integrado que combina a avaliação das funções executivas, a avaliação da sensibilidade a recompensa e a recolha de fatores contextuais numa única framework configurável. O CAPE-TEENS estabelece uma base para investigação futura sobre a avaliação cognitiva na adolescência e a previsibilidade do comportamento de risco, contribuindo para protocolos de avaliação mais estandartizados e abrangentes.

Palavras-chave: Adolescência, Comportamentos de Risco, Funções Executivas, Sensibilidade a Recompensa, Engenharia de Software, Questionários, Fatores Externos.

Abstract

Adolescence is a developmental period characterized by significant physical, cognitive and emotional changes that contribute to an increased propensity for risk-taking behaviour. Research has shown that executive functions, reward sensitivity, and contextual factors such as sleep quality, stress, and physical activity play an important role in shaping adolescent decision-making. However, existing assessment approaches frequently rely on heterogeneous task implementations and independent assessment tools, limiting the reproducibility of studies and the integration of cognitive and contextual information.

This dissertation presents **CAPE-TEENS**, a web-based platform that extends the existing CAPE-KIDS framework to support cognitive assessment for adolescents aged 10–15 years. The proposed platform introduces new functionalities for reward sensitivity assessment through conditional task flows, a configurable questionnaire framework for collecting contextual and lifestyle information, and improved participant management features. A systematic literature review following the PRISMA 2020 guidelines was conducted to identify the executive function tasks, reward sensitivity paradigms, and external factors most frequently associated with adolescent risk-taking, with the findings guiding the platform's specification and implementation.

The proposed functionalities were implemented within the existing modular architecture of CAPE-KIDS using React on the frontend, NestJS on the backend, and using PostgreSQL for the database. A pilot study involving adolescents within the target age group was conducted to evaluate the validity and usability of the implemented features. The results demonstrated the successful execution of reward sensitivity tasks, questionnaire administration and reliable storage and export of assessment data, without technical failures during the study.

The developed platform expands the capabilities of CAPE-KIDS by providing an integrated environment that combines executive function assessment, reward sensitivity evaluation, and contextual factor collection within a single configurable framework. CAPE-TEENS establishes a foundation for future research on adolescent cognitive assessment and risk-taking predictability while supporting more standardized and comprehensive assessment protocols.

Keywords: Adolescence, Risk-Taking, Executive Functions, Reward Sensitivity, Software Engineering, Questionnaires, External Factors.

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List of Acronyms

EF	Executive Function
WCST	Wisconsin Card Sort Task
TMT	Trail Making Task
BART	Balloon Analog Risk Task
BRIEF	Behavior Rating Inventory of Executive Function
API	Application Programming Interface
ORM	Object-Relational Mapper
DTO	Data Transfer Object
JWT	JSON Web Token

Chapter 1

Introduction

1.1 Context and Problem

Adolescence is a developmental period characterized by profound cognitive, psychological, and neurobiological changes [2]. During this stage, individuals undergo substantial maturation of brain structures associated with decision-making, self-regulation, and goal-directed behaviour [10]. At the same time, adolescents exhibit increased sensitivity to rewards and novelty-seeking experiences, resulting from an imbalance between rapidly developing reward-processing systems and executive control mechanisms that are still maturing. This asymmetry contributes to an increased propensity for risk-taking. Although risk-taking plays an important role in exploration, autonomy development, and identity formation, excessive engagement in risky activities may lead to adverse outcomes, including substance use [40], problematic internet use [23], unsafe driving practices [13], and other health-compromising actions, causing an increase in mortality rates [21]. Furthermore, the effects of this transient phenomenon may persist into adulthood, producing long-term consequences for physical, psychological, and social well-being.

Executive functions (EFs) comprise a set of higher-order cognitive processes that enable individuals to regulate behaviour, adapt to changing environmental demands, and pursue a goal-oriented attitude [8]. The three core components of executive functioning are inhibitory control, working memory, and cognitive flexibility. These functions continue to develop throughout adolescence and are strongly associated with the maturation of the prefrontal cortex. A growing body of research has demonstrated associations between executive functioning and engagement in risky behaviours [30]. In particular, deficits in inhibitory control and working memory have been linked to increased impulsivity, greater reward sensitivity, and a higher likelihood of particpating in activities with potentially harmful outcomes [34]. Consequently, the assessment of executive functions during early adolescence may contribute to the identification of individuals at greater risk of developing maladaptive behavioural patterns, enabling the implementation of preventive interventions and cognitive training strategies at an earlier stage.

Despite the increasing interest in the relationship between executive functioning and adolescent risk-taking, several methodological limitations remain. A systematic review conducted as part of this research revealed substantial heterogeneity in the tasks used to assess executive functions across studies. Even widely adopted paradigms frequently differed in terms of task parameters, stimuli, scoring procedures, and outcome measures, limiting comparability and reducing the reproducibility of findings. Furthermore, although executive functioning is influenced by a wide range of contextual and environmental factors, these variables are rarely integrated simultaneously into assessment protocols. Factors such as sleep quality, stress levels, dietary habits, physical activity, socioeconomic status, and family environment have been shown to influence both executive functioning and risk-taking propensity. Nevertheless, these factors are typically examined independently from executive function assessment, resulting in a fragmented understanding of adolescent cognitive and behavioural development. These limitations highlight the need for a standardized and integrated framework capable of supporting executive function assessment while simultaneously incorporating relevant contextual information. Such an approach would facilitate more reliable comparisons across studies, promote methodological consistency, and provide a more comprehensive understanding of the factors associated with risk-taking during adolescence.

1.2 Presented Solution

To address the limitations identified in the literature, this dissertation proposes CAPE-TEENS (Cognitive Assessment and Personalized Experimentation for Teenagers), a web-based platform designed to support the assessment, monitoring, and training of executive functions in adolescents aged 10 to 15 years. CAPE-TEENS extends the previously developed CAPE-KIDS platform, which provides a centralized and configurable framework for executive function assessment and training in children. Building upon its existing architecture and functionalities, CAPE-TEENS adapts the platform to the specific cognitive, and developmental characteristics of adolescence, while expanding its capabilities to support research on executive functioning and risk-taking during this critical developmental period. In addition to providing standardized implementations of executive function tasks, the platform incorporates mechanisms, such as questionnaire-based assessments, for collecting contextual information known to influence cognitive performance and behavioural outcomes. Through this integrated framework, CAPE-TEENS seeks to improve the standardization, accessibility, and reproducibility of executive function research while supporting the investigation of cognitive and contextual factors associated with adolescent risk-taking.

1.3 Research Question and Objectives

Following the challenges identified in the previous sections, the research and work presented in this dissertation are guided by the following research question:

> *How can the CAPE-KIDS framework be extended to support executive function, reward sensitivity and contextual factor assessment for adolescents aged 10–15 years?*

To address this research question, the following objectives were defined:

1. Analyse the current state of the art regarding executive function assessment, risk-taking behaviour, and contextual factors during adolescence.
2. Analyse the architecture, functionalities, and limitations of the existing CAPE-KIDS platform.
3. Define the requirements for extending CAPE-KIDS to the adolescent population.
4. Design new platform components that support new task types and contextual factor assessment through questionnaires.
5. Implement the proposed extensions within the CAPE-TEENS platform.
6. Validate the developed platform through a pilot study involving adolescent participants.

1.4 Dissertation Structure

This dissertation is composed of 7 chapters. Chapter 2 describes and analyses the state of the art, while chapter 3 contains an overview of the existing CAPE-KIDS platform. Chapter 4 contains the specification and design details of the CAPE-TEENS functionalities, and chapter 5 presents its implementation procedure. Chapter 6 includes the pilot study with the aim of validating the platform's usability and feasibility. Finally, chapter 7 summarizes the dissertation's findings, highlights its limitations and presents recommendations for future enhancements of the CAPE-TEENS platform.

Chapter 2

State of the Art

2.1 Executive Functions and Risk-Taking in adolescence

Executive functions and **reward sensitivity** are two key cognitive constructs involved in self-regulation and decision-making during adolescence, both of which have been associated with risk-taking behaviour. Executive functions comprise three core processes:

- **Cognitive Flexibility** or **Set-Shifting** refers to the ability to strategically adapt behaviour in response to changing environmental demands. It enables individuals to shift attention between different tasks, perspectives, or rules and to adjust their responses in varying circumstances [17][6].

- **Inhibitory Control** is the ability to suppress automatic responses, impulses, or irrelevant stimuli in favour of actions that align with current goals. This function enables individuals to regulate their behaviour and resist distractions that may interfere with task performance [17] [6].

- **Working Memory** is the ability to temporarily maintain, update, and manipulate information that is no longer present in the immediate environment. This function allows individuals to keep track of previous stimuli while responding to new information and dealing with continuously changing demands.

In addition to executive functions, **reward sensitivity** plays a central role in adolescent decision-making and risk-taking behaviour. Reward sensitivity refers to the degree to which individuals are motivated by, respond to, and seek potential rewards [7]. During adolescence, reward-processing systems undergo significant development, often resulting in heightened responsiveness to rewarding stimuli and an increased preference for immediate rewards over delayed but potentially greater outcomes. The relationship between executive functions and reward sensitivity is particularly relevant during adolescence. While executive functions support self-regulation and impulse control, reward sensitivity manages the pursuit of novel, stimulating, and potentially rewarding experiences. An imbalance between these systems, characterized by heightened reward sensitivity and still-maturing executive control processes, has been associated with increased impulsivity, sensation seeking, and engagement in risky behaviours [39][29]. Consequently, both executive functions and reward sensitivity are important constructs for understanding and assessing risk-taking propensity during adolescence.

2.2 External Factors

Executive function and risk-taking are influenced not only by cognitive processes, but also by a range of contextual and environmental factors. During adolescence, these factors can affect cognitive wellbeing, decision-making and self-regulation, contributing to individual differences in executive function performance and risk-taking propensity [36][12]. Among the most relevant external factors identified in the literature are sleep quality, stress, physical activity, dietary habits, socioeconomic status, and interpersonal relationships. These factors interact with cognitive development in different ways and may either support or hinder the maturation of executive functions and behavioural regulation [12]. Furthermore, several of these factors are particularly relevant during adolescence, which is marked by biological changes and increased vulnerability to emotionally arousing and peer-influenced situations.

Given their impact on both cognitive functioning and behaviour, external factors should be considered alongside executive function and reward sensitivity assessments. A comprehensive understanding of adolescent risk-taking therefore requires not only the evaluation of cognitive processes, but also the consideration of the environmental and contextual conditions that may shape their expression.

2.3 Systematic Review Methodology

To support the development of this dissertation, a systematic review was conducted in accordance with the PRISMA 2020 guidelines. The review aimed to identify executive function assessment methods, relevant external factors, and their relationship with risk-taking during adolescence.

Articles were retrieved from four sources: PubMed, ScienceDirect, SCOPUS, and Elicit. The databases were last accessed in November 2025. While PubMed, ScienceDirect, and SCOPUS were searched using predefined search queries, Elicit was used to identify relevant studies through a research-question-based prompt.

The search query used in each platform was: *((teen OR teenager OR teenagers OR adolescent OR adolescents OR adolescence) AND "executive function task") OR ((teen OR teenager OR teenagers OR adolescent OR adolescents OR adolescence) AND "executive function" AND "FMRI")* in PubMed; *"adolescent" AND ("risk taking" OR "decision making") AND "executive function task" OR ("adolescent" AND "lifestyle factors" AND "executive function task")* in ScienceDirect; and *((teen OR teenager OR teenagers OR adolescent OR adolescents OR adolescence) AND "executive function task") OR ((teen OR teenager OR teenagers OR adolescent OR*

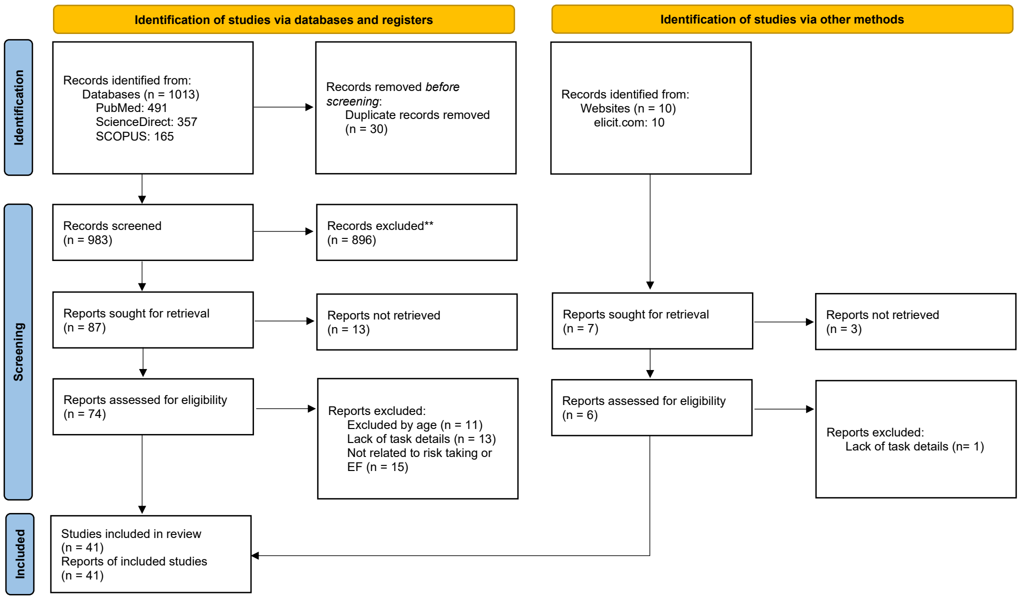

Figure 2.1: PRISMA Flow Diagram describing the article retrieval process

adolescents OR adolescence) AND "lifestyle factors" AND "executive function") in SCOPUS. Additionally, the following prompt was used in Elicit: *"How can external factors affecting executive function, as well as executive function tasks, be used to predict risk-taking in adolescence?".*

Studies were screened according to a predefined set of inclusion and exclusion criteria. Eligibility was primarily determined based on the participants' age range, the use of executive function assessment methods in adolescent populations and the investigation of external factors influencing executive function or risk-taking. The study selection process is summarized in figure 2.1, which illustrates the different stages of the review.

2.4 Review Findings

2.4.1 Executive Function and Reward Sensitivity Tasks

The studies included in the review employed a wide variety of tasks to assess executive functions and reward sensitivity. Table A.1 displays each task employed by article. Despite this diversity, several paradigms emerged as the most frequently used methods for evaluating specific cognitive processes.

For working memory assessment, the most commonly employed tasks were the **Digit Span Task** and the **N-back Task**. Both tasks require participants to temporarily maintain and manipulate information while responding to continuously changing demands. Working memory performance was frequently associated with decision-making, as individuals with reduced working memory capacity may have greater difficulty considering multiple sources of information simultaneously, favouring immediate rewards over long-term outcomes [30].

Assessment of inhibitory control was predominantly conducted using the **Go/No-Go Task** and the **Stroop Task**. While the Go/No-Go Task primarily measures response inhibition by requiring participants to withhold responses to specific stimuli, the Stroop Task evaluates interference inhibition through the suppression of irrelevant information. Across the reviewed studies, poorer inhibitory control was consistently associated with increased impulsivity and a greater tendency to engage in risky, addictive, or otherwise maladaptive behaviours [39].

The **Wisconsin Card Sorting Test (WCST)** and the **Trail Making Task (TMT)** were the most frequently identified measures of cognitive flexibility. These tasks require participants to adapt their responses to changing rules or task requirements, thereby evaluating their ability to shift attention and strategies. Although cognitive flexibility was assessed in several studies, its association with reward sensitivity and risk-taking appeared less consistent than that observed for working memory and inhibitory control [27].

Regarding reward sensitivity, the **Balloon Analog Risk Task (BART)** was the most commonly employed assessment method. Together with other gambling-based paradigms, such tasks evaluate how individuals balance potential rewards against the possibility of negative outcomes. Higher reward sensitivity was generally associated with a greater willingness to accept increasing levels of risk in pursuit of larger reward, a behavioural pattern frequently linked to elevated risk-taking propensity.

Several studies incorporated emotionally salient stimuli into cognitive assessment protocols. Given the heightened sensitivity of adolescents to social and emotional cues, stimuli such as facial expressions were often combined with more neutral elements to investigate the interaction between emotional processing, executive functioning, and decision-making.

2.4.2 External Factors

In addition to executive function and reward sensitivity assessment, many studies examined contextual and environmental factors that may influence cognitive performance and behavioural outcomes during adolescence.

Among the identified factors, sleep was the most frequently investigated and consistently emerged as one of the strongest predictors of executive function performance. Several studies reported associations between insufficient sleep and impairments in executive functioning, particularly in working memory and inhibitory control [6]. Given that many adolescents fail to achieve the recommended duration and quality of sleep, sleep-related variables appear to represent a particularly relevant factor when assessing risk-taking propensity during this developmental period.

Other lifestyle-related factors were also associated with executive function performance. Dietary habits, particularly diets characterized by high fat and sugar consumption, were linked to poorer inhibitory control and reduced cognitive flexibility [3]. Similarly, elevated stress levels were associated with diminished working memory performance [28].

Beyond individual lifestyle factors, broader environmental influences were also identified. Socioeconomic status and exposure to poverty-related adversity were associated with an earlier onset of risky behaviour and increased vulnerability to adverse outcomes [39]. These findings highlight the importance of considering not only cognitive processes, but also the social and environmental contexts in which adolescent development occurs. Physical activity was another frequently discussed factor. Although its direct relationship with executive function was less consistently reported, regular physical activity was generally associated with improved cognitive performance and has been explored as a potential protective factor capable of supporting cognitive recovery and regulation [20].

The reviewed studies relied predominantly on self-report questionnaires to assess contextual factors. Questionnaires were also employed in some cases for executive function assessment, most notably through the use of the **Behavior Rating Inventory of Executive Function (BRIEF)** [27].

2.5 Research Gaps

The systematic review identified several limitations within the current state of the art on cognitive assessment for risk taking prediction in adolescence.

- **Lack of standardization across assessment methods:** Although a number of executive function and reward sensitivity tasks were repeatedly employed throughout the reviewed studies, considerable variability was observed in their implementation. Differences in task parameters, such as stimuli, timing configurations and scoring procedures were common, even among studies using the same assessment paradigm. This methodological heterogeneity hinders direct comparison between studies, limits reproducibility, and complicates the establishment of consistent benchmarks for executive function performance.

- **Limited integration of contextual factors into assessment protocols:** Variables such as sleep quality, stress, and socioeconomic status were often identified as relevant predictors of cognitive performance and risk-taking propensity. However, they were rarely incorporated as part of a comprehensive assessment framework. As a result, cognitive performance is frequently evaluated without sufficient consideration of the conditions that may influence its expression.

- **Fragmented Assessment Approaches:** While executive functions, reward sensitivity, and contextual factors have all been associated with adolescent risk-taking, these constructs are frequently analysed independently. Consequently, many studies fail to capture the complex interactions between cognitive processes and environmental influences that collectively contribute to behavioural outcomes during adolescence. Furthermore, many studies relied heavily on self-report measures and questionnaire-based instruments to assess behavioural and contextual variables. While these tools offer practical advantages, such as requiring less resources, their subjective nature may introduce reporting biases and limit the accuracy of the collected data.

2.6 Limitations

Some limitations of the systematic review should be considered when interpreting its findings.

First, although the primary focus of this dissertation is early adolescence, particularly spanning ages 10 to 15 years, the review included studies involving participants between the ages of 10 and 18 years. This broader age range was adopted to capture the full developmental spectrum of adolescence and to identify trends and patterns that may emerge throughout this period. However, adolescence is characterized by change, meaning that findings observed in older adolescents may not be directly applicable to younger age groups. Consequently, some reported associations between executive functions, reward sensitivity, external factors, and risk-taking behaviour may vary according to the specific stage of adolescent development under consideration.

A second limitation relates to the temporal scope of the literature search. To obtain a comprehensive overview of the topic, no lower publication date limit was applied, allowing the inclusion of studies published up to 2025. While this approach facilitated the identification of foundational contributions and long-term research trends, it also increased the possibility of including studies whose methodologies, assessment tools, or theoretical frameworks may no longer reflect current research practices. Nevertheless, the inclusion of older studies was considered important for understanding the evolution of executive function and risk-taking research within adolescent populations.

2.7 Implications for CAPE-TEENS

The findings of the systematic review reveal the need for integrated assessment frameworks capable of combining executive function tasks, reward sensitivity measures, and contextual information within a unified environment. While existing approaches frequently assess these dimensions independently, a comprehensive understanding of adolescent risk-taking requires consideration of both cognitive and environmental factors.

A major finding of the review was the lack of standardization across executive function and reward sensitivity assessment methods. Although several tasks emerged as commonly used paradigms, considerable variation was observed in their implementation. These findings confirm the need for configurable task implementations capable of promoting methodological consistency while maintaining the flexibility required for different research contexts.

The review also demonstrated the relevance of reward sensitivity as a complementary resource for executive function assessment. Given its association with adolescent decision-making and risk-taking, support for reward sensitivity tasks was identified as an indispensable requirement for any platform intended to study cognitive and behavioural outcomes during adolescence. Furthermore, external factors were consistently associated with executive function performance. However, these variables were rarely integrated into cognitive assessment protocols. Consequently, the ability to collect and analyse contextual information alongside cognitive performance data emerged as a key requirement for future assessment frameworks. The review further displayed the use of questionnaire-based approaches for evaluating contextual factors as well as executive function. This supports the incorporation of questionnaire mechanisms, enabling a more comprehensive assessment of adolescent cognitive functioning.

The CAPE-KIDS platform already provides a platform for executive function assessment in children. However, the findings of the review reveal additional requirements specific to adolescent populations, including support for reward sensitivity assessment and lifestyle factor monitoring. These requirements directly informed the specification and development of CAPE-TEENS, which is presented in the following chapters.

2.8 Summary

This chapter presented the current state of the art in executive function assessment during adolescence, providing the theoretical foundation for the development of the CAPE-TEENS platform. The core executive functions, reward sensitivity, and relevant contextual factors were discussed, highlighting their relationship with adolescent risk-taking. A systematic review was subsequently conducted to investigate current assessment methods and predictors of risk-taking during adolescence. The review identified commonly used executive function and reward sensitivity tasks, as well as external lifestyle factors associated with cognitive performance. Furthermore, several methodological limitations were identified, including the lack of standardized assessment protocols and the limited integration of contextual information. These findings informed the requirements and design considerations underlying the development of CAPE-TEENS.

Chapter 3

CAPE-KIDS Overview

The main objective of CAPE-TEENS is to extend and adapt the CAPE-KIDS platform to account for adolescence risk taking prediction through assessment of executive function and other relevant factors. CAPE-KIDS provides the foundation for this work by offering a web-based framework for the creation, configuration, and deployment of executive function assessment tasks. The platform supports the evaluation of the three core executive functions, cognitive flexibility, inhibitory control, and working memory, through configurable experimental paradigms and centralized data management.

Given that CAPE-TEENS builds upon the architecture and functionalities already established by CAPE-KIDS, an understanding of the existing platform and its limitations is necessary before presenting the requirements, design decisions, and extensions introduced in this dissertation.

3.1 Existing Architecture

The CAPE-KIDS platform follows a server-client architecture, dividing different responsibilities into three components:

- The **backend** is composed of a monolithic RESTful API server responsible for the system's business logic, data processing and communication between the frontend and the database.
- The **frontend** is a Single-Page Application (SPA), responsible for the entire user interface and sending data objects and requests to the server. It provides interfaces for task execution, experiment configuration, participant management, and result visualization. Additionally, it is responsible for running the experiment and task engine.
- The **database** serves as the system's Single Source of Truth, storing all the entities that define its state and providing centralized data management for the platform.

The CAPE-KIDS platform is designed around two primary user roles: **Researchers** and **Participants**. Both user roles are able to create an account and log in to gain access to the platform. Access permissions are determined by the user's assigned role, ensuring that researchers

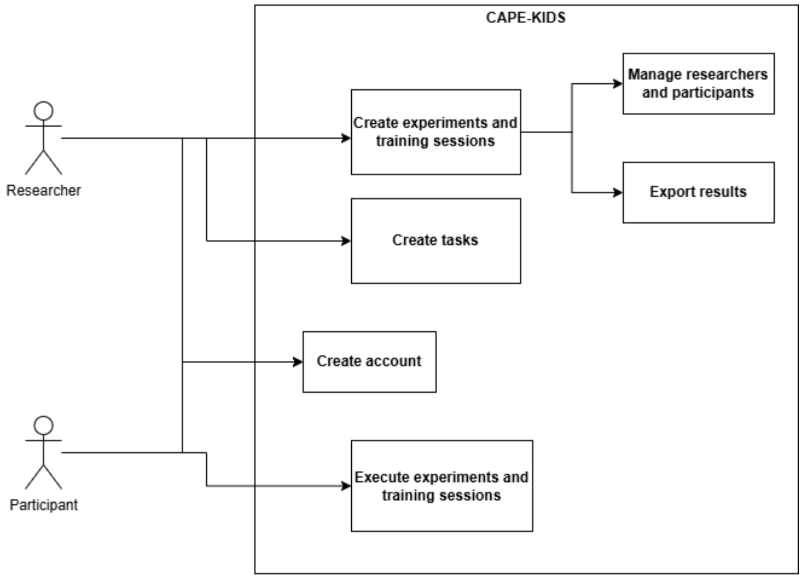

Figure 3.1: Use case diagram presenting the main interactions between different types of user and the CAPE-KIDS platform

and participants are provided with the appropriate level of access to platform resources. Figure 3.1 presents the interactions between each actor and the platform's functionalities.

Researchers are responsible for the creation, configuration, and management of cognitive assessment activities within the platform. Their responsibilities include designing experiments, executive function tasks, and training sessions, as well as managing participant access and collaborating with other researchers. Additionally, researchers are able to monitor, access, and export assessment results for subsequent analysis.

Participants constitute the target population of the experiments and training sessions deployed through the platform. Their primary role is to complete the assessments and training activities for which they have been granted access by authorized researchers.

3.2 Existing Features

The analysis of CAPE-KIDS focused on identifying the functionalities that could serve as a foundation for the development of CAPE-TEENS. The platform provides three primary assessment-related entities: **Experiments**, **Training Sessions**, and **Tasks**.

Experiments constitute the main assessment mechanism of the platform. They are designed to be completed once by each participant, allowing researchers to collect performance data for subsequent analysis.

On the other hand, training sessions are intended to support the repeated execution of cognitive activities, enabling participants to practice and improve specific executive function skills over time.

Tasks represent reusable and modular assessment components that can be incorporated into both experiments and training sessions. This modular approach promotes flexibility and reduces

Figure 3.2: CAPE-KIDS 16:9 screen editor including media and trigger options

the effort required to create new assessment activities by allowing researchers to reuse previously defined task configurations across multiple contexts.

3.2.1 Timeline Editor

The creation and configuration of experiments, training sessions, and tasks are supported through the **Timeline Editor**, which constitutes the core framework of the platform. The editor enables researchers to create executive function tasks by arranging and configuring a sequence of steps that define the participant experience and task logic.

In order to accommodate different assessment scenarios from the three main core executive functions, editor contains four different step types. **Custom Blocks** are primarily used to present instructions, feedback, or informational content to participants. Interactions occurring within these blocks are not recorded as assessment results. The **Sequential Stimuli** step presents a sequence of stimuli and requires one single input response for each stimulus. Similarly, the **Multi Trigger Stimuli** step also presents a sequence of stimuli but requires a combined response at the end of the sequence, allowing for the implementation of more complex tasks such as the Digit Span working memory task. Both step types include configurable parameters such as the number of trials, stimulus presentation duration and inter-stimulus intervals. These steps also support stimulus randomization, reducing response predictability and contributing to the validity of the assessment process. Additionally, the platform provides a **Task** step type, which allows previously defined tasks to be incorporated as reusable components within larger experiments or training sessions.

Timeline steps are configured through the **Screen Editor**, a visual 16:9 canvas that enables researchers to define stimuli and participant interactions. As shown in figure 3.2, the editor supports the inclusion of textual and image-based stimuli, as well as the configuration of event triggers responsible for controlling experiment progression and flow.

3.2.2 Participant and Researcher Management

In the timeline editor page, experiment owners can invite participants and assign access permissions to other researchers. Access to experiments and training sessions is controlled through a permission-based system. Participants may access only the activities for which they have been explicitly authorized, either through the user interface or an access link generated by a researcher. Furthermore, the platform also supports collaboration between researchers by allowing experiment and training ownership to be shared with authorized users. As a result, multiple researchers can contribute to the management, execution, and analysis of assessment activities within the same study. Upon completion of an experiment or training session, participant responses and performance metrics are automatically stored in the platform database. Researchers with the appropriate permissions can subsequently access and export the collected results for further processing and interpretation.

3.3 Existing Data Model

The core structure of experiments, training sessions, and tasks within CAPE-KIDS is defined through the **Timeline** entity. A timeline represents a sequence of activities and stores information regarding the type of assessment activity to which it belongs, as well as the collection of associated timeline steps. Each individual step is represented by a **TimelineStep** entity, while **StepConnection** defines the relationships between steps and controls the progression flow throughout the activity. Together, these entities form the foundation of the platform's workflow model, enabling researchers to create structured cognitive assessment activities through configurable sequences of events. Figure 3.3 contains the database model of the aforementioned tables.

Activity-specific information, including title, description, enrolled participants and researchers and assessment results is maintained separately from the timeline structure. This separation promotes modularity and allows the same workflow framework to be reused across different parent entity types. Furthermore, the polymorphic design of the timeline model also enables the creation of new activity types without requiring significant structural modifications to the underlying workflow. This characteristic is particularly relevant for the development of CAPE-TEENS, as it facilitates the integration of new components while preserving compatibility with the existing platform structure.

3.4 Summary

This chapter presented an overview of the CAPE-KIDS platform, focusing on its architecture, data model, and core functionalities. The analysis was conducted to establish the foundation upon which CAPE-TEENS was developed and to identify the requirements arising from the extension of the platform to an adolescent population. The existing framework supports the creation and deployment of executive function assessment activities through a timeline-based editor composed

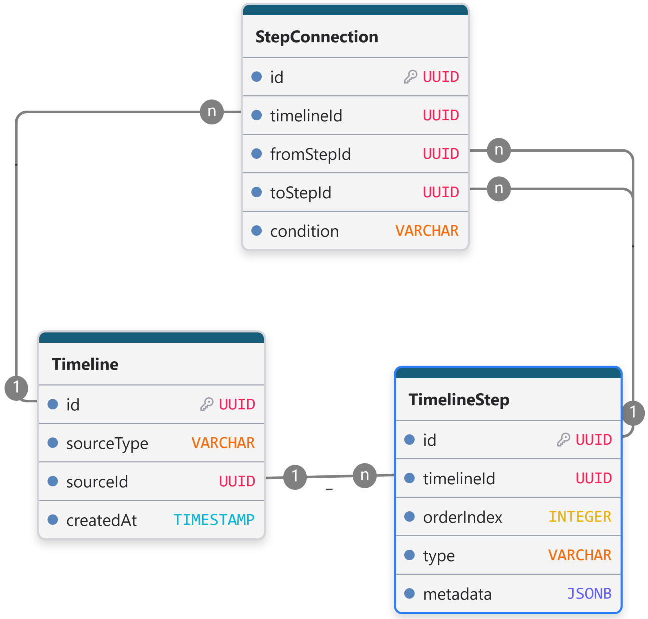

Figure 3.3: Data model of the Timeline, TimelineStep and StepConnection tables

of configurable step types. This modular approach promotes task standardization while providing the flexibility required to implement different assessment paradigms. In addition, the platform includes the functionality of participant and researcher management, enabling the administration of access for experiments, training sessions and tasks. The conclusions obtained from the analysis of CAPE-KIDS informed the requirements and design decisions presented in the following chapter, supporting the specification of the new functionalities introduced in CAPE-TEENS.

Chapter 4

System Specification and Design

4.1 CAPE-TEENS Requirements

The following requirements were derived from several meetings with domain experts and findings obtained from the literature review conducted in the previous chapter. Together, these inputs guided the specification and development of the CAPE-TEENS platform.

To better organize requirements based on priority, the MoSCoW method was employed. This approach classifies requirements based on three different categories: **must-have**, **should-have** and **could-have**. These categories rank each requirement in descending order of priority. Must-have requirements represent functionalities essential to the platform, while should-have requirements provide significant value but are not mandatory for release, and could-have requirements encompass lower priority functionalities that can be incorporated in future iterations.

4.1.1 Requirement List

R1. [MUST] The system should provide a step template that allows for a conditional response to a trigger.

R4. [MUST] The system must allow researchers to create and configure questionnaires.

R5. [MUST] The system must allow researchers to add and edit multiple choice answers to the questionnaire's questions, with a minimum of two answers per question.

R7. [MUST] The system must allow a questionnaire owner to invite and manage other researchers.

R8. [MUST] The system must allow a questionnaire's researchers to invite participants to be able to complete it.

R9. [MUST] The system must allow researchers with due authorization manage a given questionnaire.

R10. [MUST] The system must allow participants with due authorization to respond to a given questionnaire only once.

R12. [MUST] The system must allow researchers with the due authorization to export a given participant's questionnaire response.

R2. [SHOULD] The system should allow researchers to access a list containing every registered participant.

R3. [SHOULD] The system should allow researchers to access a selected participant's information, including the enrolled experiments and questionnaires.

R11. [SHOULD] The system should allow researchers with due authorization as well as the concerned participant to access the participant's response to a questionnaire.

R6. [COULD] The system can allow researchers to use a different type of answer other than multiple choice in a questionnaire question.

R13. [COULD] The system could provide a detailed overview of a participant's experiment and training results, including various calculated metrics.

R14. [COULD] The system could allow for the implementation of questionnaires in an experiment.

R15. [COULD] The system could support integration of wearable devices to collect and analyse external factors.

4.2 CAPE-TEENS Design

The requirements defined in the previous section reveal the necessary extensions to the existing CAPE-KIDS platform, particularly regarding reward sensitivity tasks and the integration of additional assessment mechanisms, illustrated by the use case diagram shown in figure X.

The specification and design of the implemented features preserve the architectural and design principles of CAPE-KIDS, including modularity and configurability, allowing for further expansion and future enhancements of the platform. To support the design process, a set of mockups were produced using Figma. These mockups served as a visual representation of the proposed functionalities, providing a reference for their implementation. The following sections present the design considerations of the core developments.

4.2.1 Timeline Editor: Conditional Step

One of the core requirements identified for CAPE-TEENS was support for the creation of reward sensitivity tasks. Unlike the executive function tasks already available in CAPE-KIDS, these assessments frequently involve uncertain outcomes, where a participant's action may lead to different results according to predefined probabilities. Supporting this type of behaviour required the introduction of a new step type capable of directing task progression based on probabilistic conditions.

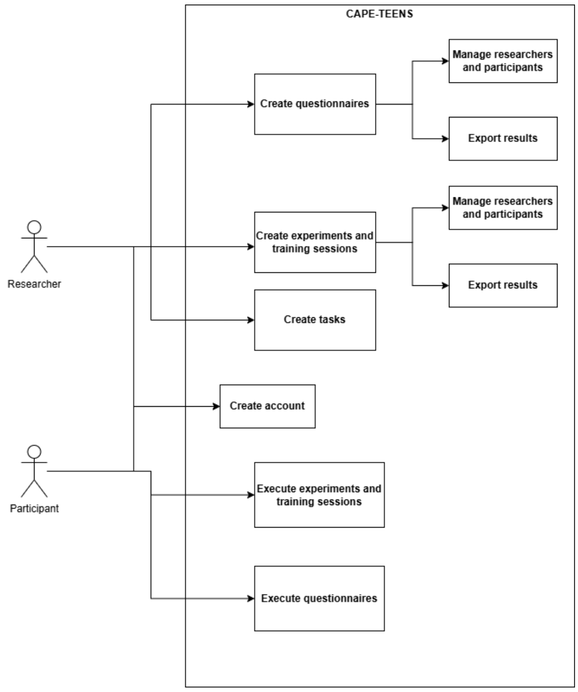

Figure 4.1: Updated use case diagram of the CAPE-TEENS platform including new proposed user interactions

To address this requirement, a **Conditional Step** was designed. This step introduces a new trigger action that allows a participant to be directed to one of two different steps, each associated with a configurable probability. Due to the nature of its workflow, the conditional step does not require global configuration options related to response feedback or stimulus ordering. Consequently, its design follows the structure of the **custom block** step type rather than the sequential stimuli and multi trigger stimuli steps. Figure 4.2 presents the proposed configuration interface for the conditional step, including the newly introduced **Conditional Go To Step action**, which determines the subsequent step according to a defined probability.

4.2.2 Questionnaires

The introduction of questionnaire support emerged as one of the most valuable requirements for CAPE-TEENS, addressing the need to assess external factors that cannot be adequately captured through cognitive tasks alone.

Unlike the conditional step, which extended the existing timeline framework through the addition of a new step type, the questionnaire functionality required the design of a dedicated interface for the creation and management of questionnaires, questions, and response options. To ensure consistency with the existing platform, the proposed design follows the same timeline-based design principles that underpin the CAPE-KIDS architecture. Figure 4.3 illustrates the proposed questionnaire editor interface, together with the modal used to create and configure individual questions.

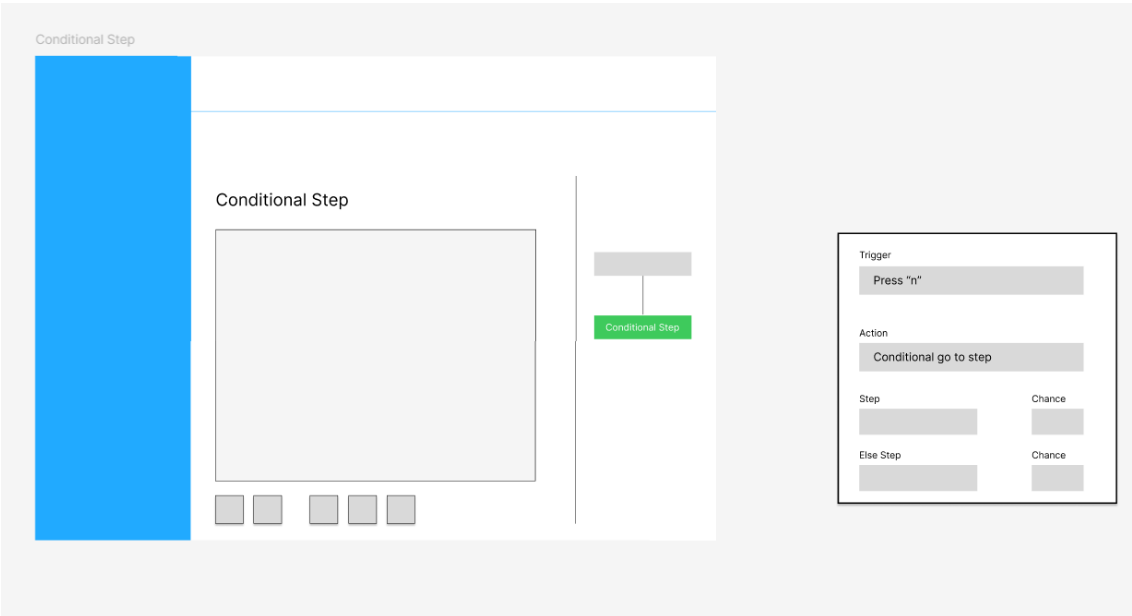

Figure 4.2: Mockup of the conditional step including trigger action modal

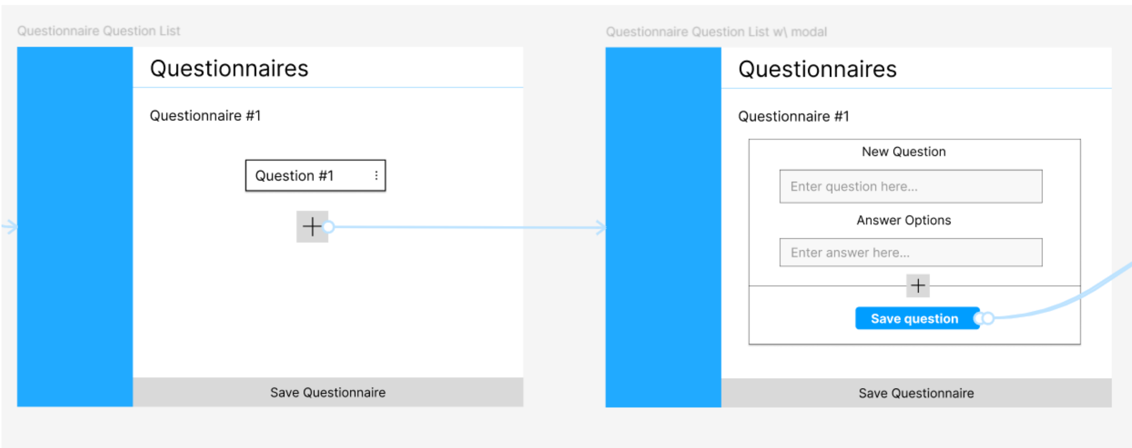

Figure 4.3: Mockup of the questionnaire editor interface and question modal

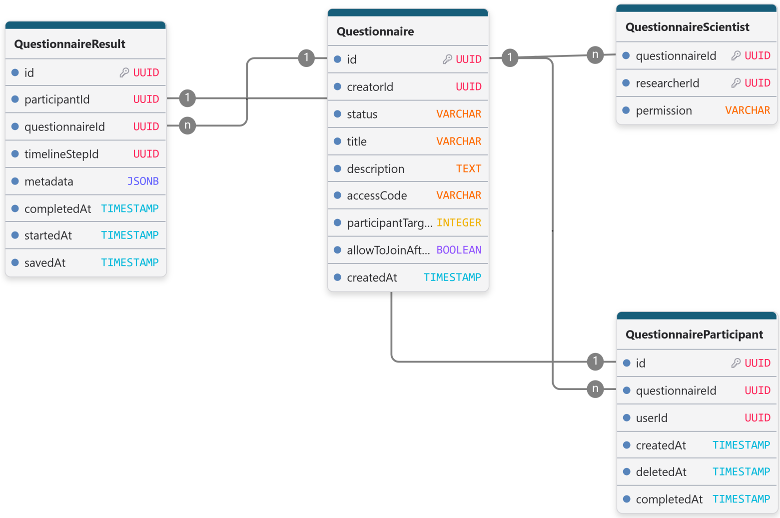

Figure 4.4: Data model of the Questionnaire table and related entities

4.3 Database Specification

The database extensions introduced in CAPE-TEENS were designed considering the existing CAPE-KIDS data model. The modular architecture of the platform enabled the incorporation of new functionalities through minimal additions and modifications, allowing for the expansion of the existing system while preserving compatibility with previously implemented features.

To support the questionnaire framework, several new entities were introduced. The **Questionnaire** table serves as the central entity of the module, storing both descriptive information, such as the questionnaire name and description, and configuration data related to participant access, including access codes and target participants. The relationship between questionnaires and users is handled through the **QuestionnaireScientist** and **QuestionnaireParticipant** tables, which store the researchers responsible for managing a questionnaire and the participants assigned to complete it, respectively. Participant responses are recorded in the **QuestionnaireResult** table, ensuring the persistence of collected data and enforcing a single response per assigned participant.

To integrate questionnaires into the existing workflow infrastructure, the **Timeline** entity was extended to introduce questionnaires as an additional source type. This modification enables questionnaires to leverage the same timeline-based architecture already employed in experiments, training sessions and tasks, that promote consistency and reusability across the platform. Figure 4.4 contains the new database elements introduced for questionnaire support.

In contrast, the implementation of the conditional step did not require the introduction of new database entities. Since the functionality is fully supported by the existing timeline model, only the *type* field present in the **TimelineStep** table was extended to accommodate the new step category.

Figure 4.5 presents the updated database model.

Figure 4.5: Updated CAPE-TEENS database model

4.4 Summary

This chapter presented the specification and design choices of the CAPE-TEENS platform, building upon the existing CAPE-KIDS architecture. The requirements were gathered and organized by priority, establishing the main objectives for the platform's development. Based on these requirements, the new functionalities were designed visualized in mockups using Figma, supporting the design and implementation process. Particular emphasis was placed on the introduction of reward sensitivity assessment through the conditional step and on the development of a questionnaire framework for the collection of contextual and lifestyle data. Finally, the database model was extended to support the new questionnaire functionality while maintaining compatibility with the existing CAPE-KIDS architecture.

Chapter 5

Implementation

This chapter presents the implementation details of the CAPE-TEENS platform, starting with an overview of the system's main components and technologies, and subsequently delving into the newly added features and extensions, according to the requirements attained by the specification process executed in the previous chapter.

5.1 System Overview

The implementation of CAPE-TEENS was carried out on top of the existing CAPE-KIDS architecture. As described in the overview chapter, CAPE-TEENS maintains a server-client architecture, being composed of three main components: a backend RESTful API server, a frontend application and relational database.

The frontend is responsible for providing researchers and participants with access to the platform functionalities through a web-based user interface. User actions are communicated to the backend through the backend's API endpoints, which handle business logic, data validation, and authorization. The backend, in turn, interacts with the database to persist and retrieve application data. Additionally, to ensure consistency between the frontend and backend, both components rely on a shared library containing common validation objects. This separation of responsibilities promotes maintainability and facilitates the incorporation of new functionalities.

The application components are deployed using **Docker containers**, providing isolated execution environments and simplifying dependency management and deployment. This approach improves portability and allows the platform to be consistently executed across different environments without requiring changes to the application itself.

Figure 5.1 presents the overall architecture of the CAPE-TEENS application.

Backend

The backend was developed using the **NestJS** framework from Node.js. The **TypeORM** library was used as the server's **Object-Relational Mapper (ORM)** to map database entities to application objects, simplifying data access and persistence operations. Additionally, **Zod** was used

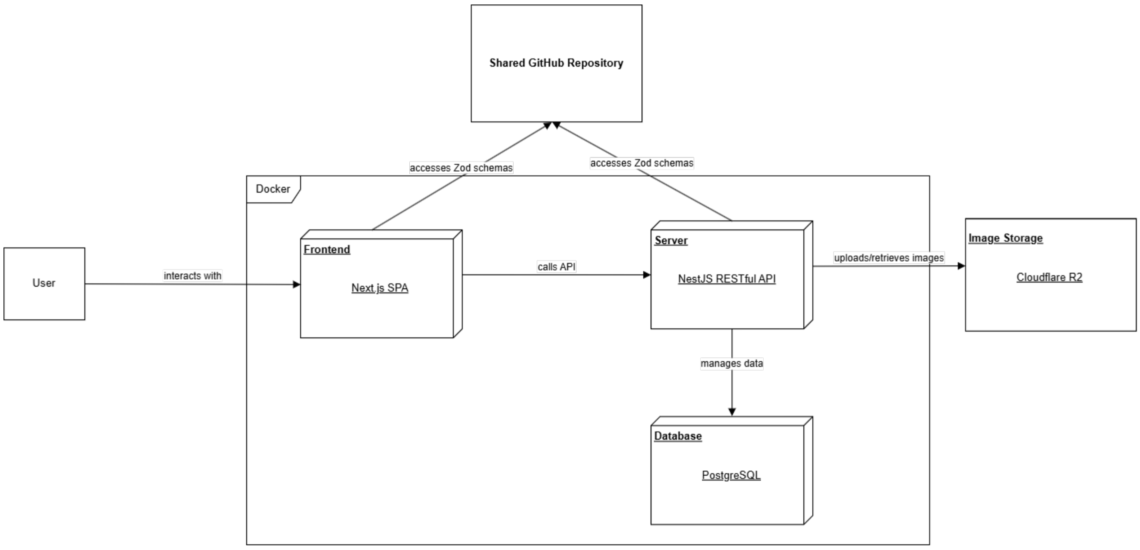

Figure 5.1: Architecture diagram displaying the high-level components of the CAPE-TEENS application.

to define validation schemas from which **Data Transfer Objects (DTOs)** were derived, ensuring consistent validation of data exchanged between system components. In turn, these schemas are stored in a **shared private library** to be accessed by both the frontend and backend, reducing inconsistencies between operations. The backend is also responsible for user authentication and session management, which are handled through stateless **JSON Web Tokens (JWTs)**. Additionally, a NestJS guard was implemented to validate the token on every API route.

Testing

Unit tests were developed to improve the reliability of the newly implemented backend features. Due to time constraints, the tests focused on the most critical operations of the questionnaire service, tasked with questionnaire creation and management, ensuring the validity of the service logic independently from the remaining system components. The tests were implemented using the testing framework provided by NestJS, together with **Jest** for the creation of mocks and the use of assertions. External dependencies, including repositories and services, were mocked to isolate the behaviour of the tested services and evaluate only their internal logic.

Frontend

The frontend was developed using **React** and **TypeScript**, with the **Material UI** component library providing a consistent design system across the platform. Form creation and validation rely on **React Hook Form** in conjunction with the shared Zod schemas, allowing client-side validation to remain consistent with the rules enforced by the backend. State management is handled through **Zustand**, with the application's state organised into several dedicated stores to promote modularity.

A central component of the frontend is the timeline editor. The experiment engine is executed entirely within the frontend, and is responsible for compiling and interpreting the timeline configuration, as well as dynamically rendering the corresponding stimuli, instructions, and interaction elements according to the defined sequence and parameters. During experiment execution, stimulus presentation and response times are measured using the browser's **performance.now()** API. Unlike conventional system clocks, this interface provides a high-resolution monotonic timer, allowing timestamps to be recorded with sub-millisecond precision. This approach minimizes timing inaccuracies introduced by clock adjustments and provides the precision required for cognitive assessments, where response latency constitutes an important outcome measure. Additionally, the platform calculates the difference between configured timeout stimulus duration and the actual elapsed time before the next step is triggered. This value provides an estimate of timing deviation introduced during task execution.

Database

CAPE-TEENS uses **PostgreSQL** as its relational database. The platform makes use of its **jsonb** data type for storing timeline metadata. This approach allows step-specific configurations to be represented as flexible JSON structures while retaining efficient querying and indexing capabilities. Database interaction is handled through the backend's ORM, which maps application entities to the relational tables.

5.2 Added features and changes

5.2.1 Conditional Step

Reward sensitivity tasks frequently rely on uncertainty, where the same participant action may lead to different outcomes according to predefined probabilities. To support this type of behaviour within the CAPE-TEENS platform, a new **Conditional Step** was introduced into the timeline editor. This step enables the creation of branching task flows in which a participant may be directed to different subsequent steps following the same interaction. Figure 5.2 illustrates two possible execution paths associated with the same conditional action in a task. In this task, the participant can choose to inflate a balloon, with a 70% chance for the balloon to inflate, increasing the reward and a 30% chance of popping, representing loss of points.

Unlike sequential stimuli and multi trigger stimuli steps, the conditional step does not require configuration parameters such as response feedback or stimulus randomization. Consequently, its implementation follows a structure similar to that of the custom block step type, consisting primarily of a configurable screen editor and associated trigger actions.

The functionality is supported through the introduction of a new trigger action, **Conditional Go To Step**, which allows researchers to specify two possible target steps and their respective probabilities of occurrence. To ensure a valid execution flow, the system enforces that the sum

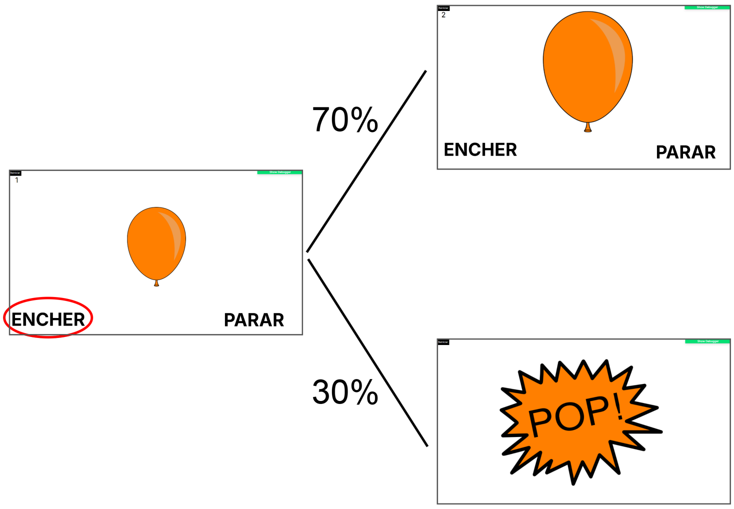

Figure 5.2: Possible outcomes of conditional step in a task

of both probabilities equals 100%, guaranteeing that a subsequent action is always selected. During task execution, the experiment engine evaluates the probabilities defined by the researcher and determines the subsequent step according to a randomly generated outcome. This mechanism enables the implementation of reward-based decision-making paradigms while preserving the modularity of the timeline model. Figure 5.3 presents the configuration interface used to define a conditional transition and its associated probabilities.

5.2.2 Questionnaire Framework Implementation

The questionnaire framework represents one of the main extensions introduced in CAPE-TEENS, enabling the collection of external information alongside cognitive assessment data. To facilitate its integration with the existing platform architecture, questionnaires were implemented as a new timeline source type, allowing them to reuse the mechanisms already present in CAPE-KIDS.

The implementation of the questionnaire framework required the introduction of new API endpoints to support questionnaire creation, participant management, response submission, and result retrieval. These endpoints were documented through the platform's **Swagger** interface to facilitate development and testing. To maintain consistency between frontend and backend validation, new Zod schemas were introduced in the shared repository. These schemas define the structure of questionnaires and questionnaire participants, ensuring that validation rules remain identical across all system components. Furthermore, the existing **Timeline** and **TimelineStep** schemas were extended to support questionnaires and questions as additional source and step types, respectively. State management for questionnaire-related operations was implemented through dedicated Zustand stores, enabling efficient synchronization between user interactions and application state while preserving consistency with the existing frontend architecture.

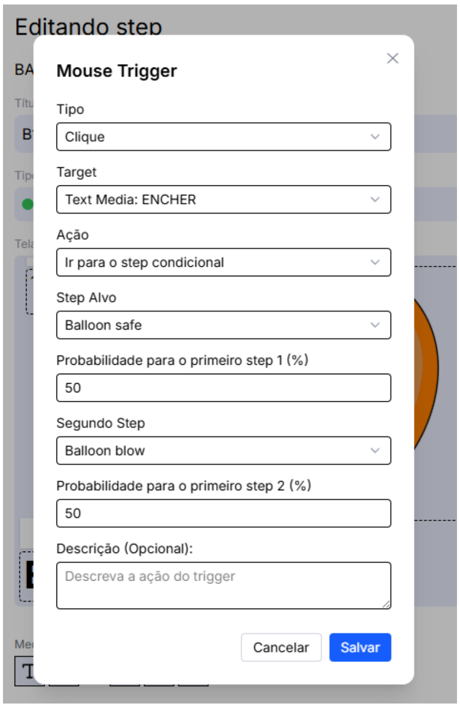

Figure 5.3: Conditional step keyboard trigger modal including the new "Go to Step Conditional" action

Questionnaire Editor

Although questionnaires share the same underlying timeline infrastructure as experiments, training sessions, and tasks, their workflow differs significantly from cognitive assessment activities. Consequently, a dedicated editor was developed to support the creation and management of questionnaires. Researchers can construct questionnaires by adding multiple-choice questions through a dedicated configuration modal. Each question contains a title, and a variable number of answer options. To ensure the validity of participant responses, the system enforces a minimum of two answer options per question. Figure 5.4 illustrates the modal used to create and configure individual questions.

Once created, all questions are displayed within the editor, allowing researchers to review, edit and remove questionnaire content. Figure 5.5 presents the questionnaire editor interface, including a list of added questions.

Participant and Researcher Management

Questionnaires implement the same access management model used by the existing platform activities. Researchers may assign participants and collaborate with other researchers through dedicated management interfaces. Assigned participants gain permission to access and complete the questionnaire, while assigned researchers obtain privileges to edit, preview, and manage questionnaire content. To preserve data integrity and prevent duplicate submissions, participants are restricted to a single response per questionnaire.

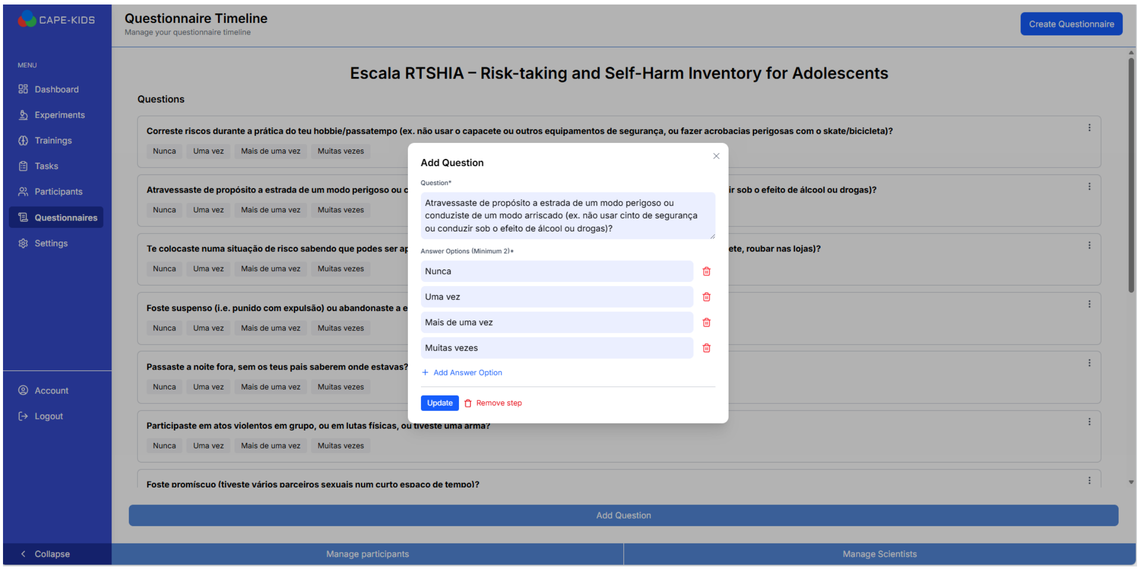

Figure 5.4: Question configuration modal

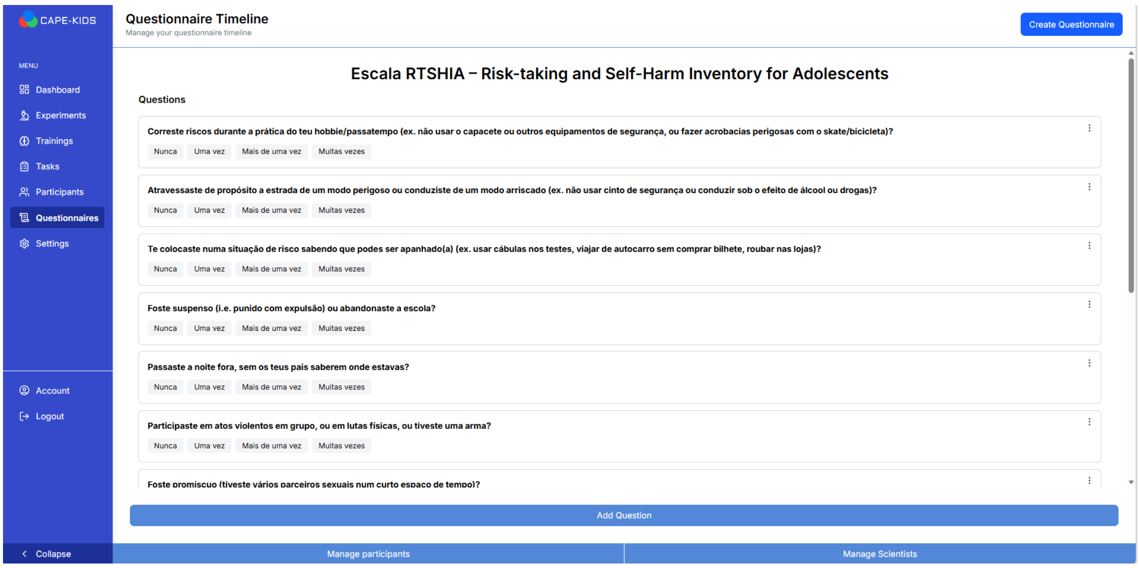

Figure 5.5: Questionnaire editor of the RTSHIA Scale for risk taking and self-harm assessment

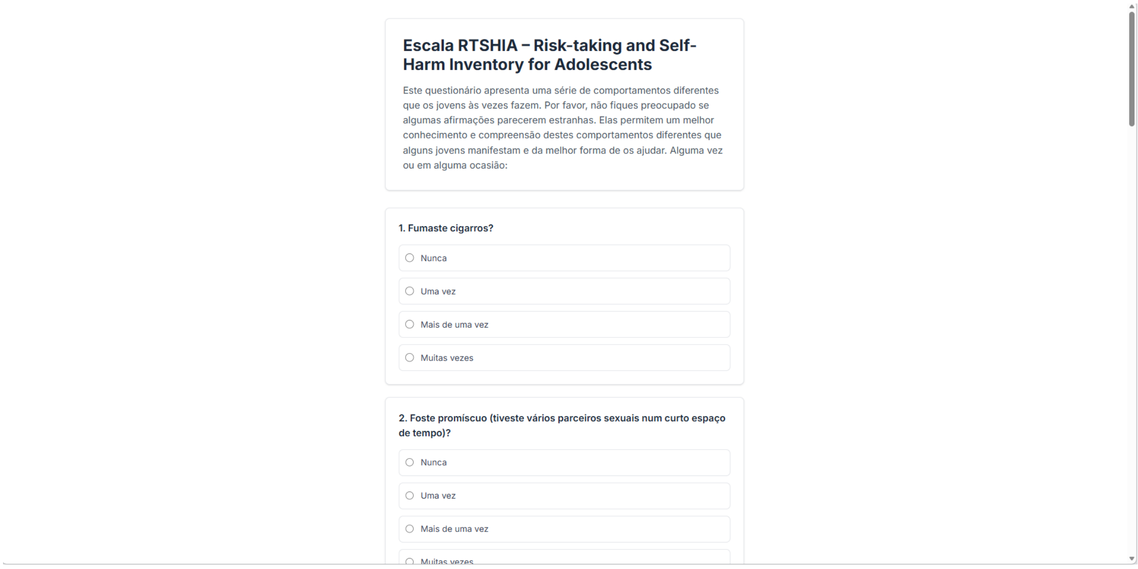

Figure 5.6: Response screen of the RTSHIA Scale Questionnaire

Questionnaire Response and Results

During execution, participants are presented with the questionnaire questions sequentially through a dedicated interface, as shown in figure 5.6. Upon submission, responses are validated and stored in the platform database through the **QuestionnaireResult** entity. Researchers can subsequently access and export collected responses, allowing questionnaire data to be analysed alongside executive function and reward sensitivity assessment results.

5.2.3 Participant Management

To improve participant administration and provide researchers with a centralized view of participant information, a dedicated participants page was developed. Prior to this addition, participant-related information was distributed across individual experiments, making it more difficult to obtain an overview of participant involvement within the platform.

The new page displays a list of all participants registered in the system and provides researchers with access to detailed participant information. Researchers can view the participant's enrolment history, including the experiments to which they have been assigned to. This functionality facilitates participant tracking and simplifies the management of assessment activities across multiple studies.

The page can be accessed through the Participants option available in the platform's sidebar navigation menu. Figure 5.7 presents the implemented participant management interface.

5.3 Summary

This chapter presented the implementation of the CAPE-TEENS platform, describing the technical solutions adopted to extend the existing CAPE-KIDS architecture. The implementation was car-

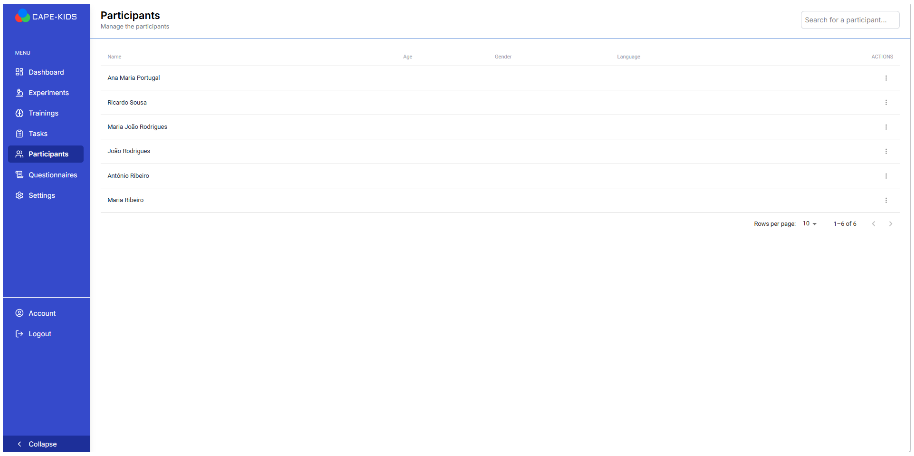

Figure 5.7: Participants page displaying the list of all registered participants

ried out across the platform's three main components—the backend, frontend, and database—which collectively support data management, business logic, experiment execution, and user interaction. Particular attention was given to ensuring data consistency and maintainability through shared validation mechanisms and reusable architectural components.

The chapter also detailed the implementation of the platform's main contributions. These include the introduction of the **Conditional Step**, enabling the creation of reward sensitivity tasks through probabilistic task flows, and the development of a **Questionnaire Framework** to support the collection of contextual and lifestyle information. In addition, a participant management interface was implemented to provide researchers with a centralized view of participant information and experiment enrolment.

Together, these extensions broaden the assessment capabilities of the original platform, enabling the integration of executive function, reward sensitivity, and external factors assessment within a single environment. The next chapter presents the validation of the implemented features and evaluates their suitability for adolescent risk-taking assessment.

Chapter 6

Validation: The CAPE-TEENS Study

Following the specification and implementation of the proposed features present in the previous chapter, it is necessary to evaluate suitability and usability of the CAPE-TEENS platform in a real-life context. To this end, a pilot study was conducted involving adolescent participants and a set of assessment activities implemented through the platform. The study aimed to evaluate the functionality of the newly introduced features, while also assessing the platform's ability to support the execution of cognitive assessment tasks and the collection of external information with the goal of predicting risk taking behaviour.

This chapter describes the methodology adopted for the pilot study, including participant characterization, study materials, and experimental procedures. The results obtained from the assessment activities are then presented and analysed, followed by a discussion of the platform's performance, limitations, and implications for adolescent risk-taking assessment.

6.1 Study Setup

6.1.1 Participants

The validation study involved a group of four participants aged between 10 and 12 years, corresponding to the target population for which CAPE-TEENS was designed. Participation in the study was voluntary, and informed consent was obtained from the participants' legal guardians prior to their involvement. An individual account was created for each participant, enabling enrolment in the study activities and allowing the storage of assessment results within the platform.

6.1.2 Study Materials

The study was designed to evaluate the functionality of the CAPE-TEENS platform through the administration of executive function tasks, reward sensitivity tasks, and a risk-taking questionnaire. To this end, participants completed two experiments and one questionnaire:

- **CAPE-TEENS: Executive Functions**

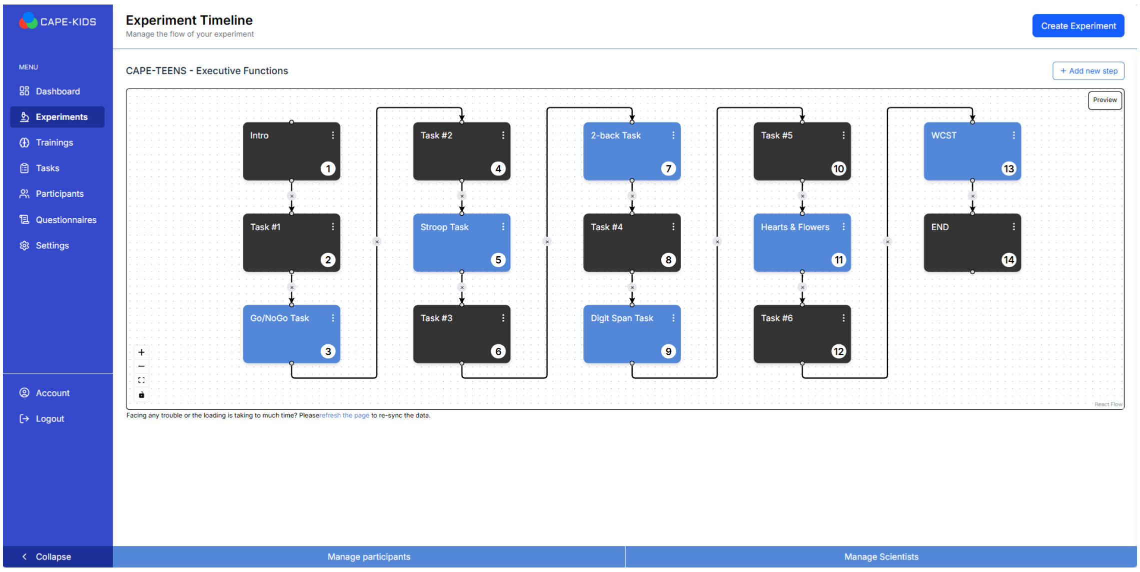

Figure 6.1: "CAPE-TEENS: Executive Functions" Timeline Editor

- **CAPE-TEENS: Reward Sensitivity**
- **RTSHIA Scale – Risk-Taking and Self-Harm Inventory for Adolescents**

The **RTSHIA Scale questionnaire** consists of 12 items designed to assess engagement in risk-taking behaviours during adolescence. The questionnaire was included to provide a behavioural measure that could later be compared with cognitive and reward sensitivity performance.

6.1.3 CAPE-TEENS: Executive Functions

The **CAPE-TEENS: Executive Functions** experiment was designed to assess the three core executive function domains: inhibitory control, working memory, and cognitive flexibility. The experiment begins with an introductory screen, followed by six assessment tasks comprising two tasks for each executive function core.

To ensure participant understanding and reduce the likelihood of procedural errors, each task follows a common structure consisting of an instruction screen, a practice phase, and the main assessment phase. After the completion of the practice trials, a three-second transition period is presented before the beginning of the main task. Figure 6.1 illustrates the timeline structure employed throughout the experiment. The six tasks included in the experiment were the following:

- **Go/No-Go Task** and **Stroop Task**, assessing inhibitory control;
- **2-Back Task** and **Digit Span Task**, assessing working memory;
- **Hearts and Flowers Task** and **Wisconsin Card Sorting Task**, assessing cognitive flexibility.

6.1.4 CAPE-TEENS: Reward Sensitivity

The **CAPE-TEENS: Reward Sensitivity** experiment was designed to assess participants' responses to uncertain outcomes and reward-based decision making. The experiment consists of an introductory screen followed by two reward sensitivity tasks.

Each task includes an instruction phase and a main assessment phase. Unlike the executive function tasks, no practice rounds were included due to the non-linear and probabilistic nature of the tasks employed in the experiment.

The experiment includes the following tasks:

- **Balloon Analog Risk Task (BART)**, a widely used measure of risk-taking behaviour involving progressively increasing reward and risk;
- **Pencil Task**, a reward-based decision-making task designed to evaluate participants' sensitivity to gains and losses under uncertainty.

6.1.5 Task Configuration

The configuration parameters of each task were defined based on the findings of the literature review and recommendations provided by domain experts. Parameters such as the number of trials, stimulus duration, inter-stimulus intervals, and task difficulty were selected to ensure suitability for the target age group while maintaining consistency with established assessment protocols. Table 6.1 summarizes all tasks employed in the study and their respective configuration parameters.

6.2 Study Procedure

Each participant completed the study individually using a desktop or laptop computer equipped with a keyboard and mouse. Prior to the beginning of the study, participants received a brief explanation regarding the purpose of the assessment and the operation of the platform. Throughout the session, a researcher was present to provide assistance in case of technical difficulties and questions. However, no guidance regarding task execution or participant responses was provided during the assessment. Participants completed the executive function experiment, the reward sensitivity experiment and the RTSHIA questionnaire, respectively, through the CAPE-TEENS platform. The average duration of each session was approximately 30 minutes.

All participant interactions were automatically recorded by the platform and exported for subsequent analysis. For cognitive assessment tasks, the collected data included participant interactions, response times, answer status, and other task-specific metrics. Questionnaire responses were similarly stored and associated with the corresponding participant account.

Task	Executive Function	Nº of Practice Trials	Nº of Trials	Stimuli Duration	Inter Stimuli Duration
Go/No-Go Task	Inhibitory Control	8 trials	40 trials (3:1 Go/No-Go Rate)	3000 ms	500 ms
Stroop Task	Inhibitory Control	6 trials	45 trials	2000 ms	500 ms
2-back Task	Working Memory	5 numbers	40 numbers	1000 ms	500 ms
Digit Span Task	Working Memory	1 trial (2 digits)	4 different lengths (2-5 digits) 3 trials each	1000 ms	1000 ms
Hearts and Flowers Task	Cognitive Flexibility	6 trials only hearts 6 trials only flowers	32 hearts and flowers	2000 ms	1000 ms
Wisconsin Card Sort Task	Cognitive Flexibility	5 trials (colour criteria)	30 trials (shape criteria) 30 trials (amount criteria) 30 trials (colour criteria)	No duration	1000 ms feedback 1000 ms inter stimuli
Balloon Analog Risk Task	Reward Sensitivity	No practice trials	1 trial - 10 balloon states	No duration	2000 ms
Pencil Task	Reward Sensitivity	No practice trials	1 trial - 10 pencils	No duration	1000 ms

Table 6.1: Table of tasks and task details included in the CAPE-TEENS study

6.3 Results

All participants successfully completed the tasks without experiencing any technical failures or interruptions during the execution of the study materials. Prior to the beginning of each assessment task, participants demonstrated an adequate understanding of the task instructions. Although some tasks required additional clarification from the accompanying researcher, this was limited to procedural aspects and did not prevent participants from completing the assessment.

The newly implemented functionalities also operated as intended throughout the study. The conditional timeline step correctly executed probabilistic task flows during the reward sensitivity assessment, while the questionnaire framework enabled participants to complete and submit their responses without errors. Furthermore, all experiment and questionnaire data were successfully captured and stored in the platform database and subsequently exported, providing researchers with access to performance metrics such as participant responses, response times captured by the performance.now() method, and task outcomes. The quantitative results obtained for each participant are presented in Tables B.1, B.2, B.3, and B.4. The participants were anonymised, ensuring that they could not be identified from the reported results. Although the primary objective of the study was not to analyse participants' cognitive performance, the collected results demonstrate that the platform successfully recorded the expected metrics for each assessment activity.

Overall, the validation study demonstrated that the CAPE-TEENS platform reliably supports the execution of executive function, reward sensitivity, and questionnaire-based assessments within the intended age group, providing a stable and accessible environment for adolescent cognitive assessment.

6.4 Discussion and Implications

The conducted study addresses the main research question of this dissertation: *How can the CAPE-KIDS framework be extended to support executive function assessment, monitoring, and contextual factor integration for adolescents aged 10 to 15 years?* The implementation of the conditional step expanded the timeline editor to support probabilistic task flows required by reward sensitivity tasks, while the questionnaire framework introduced a complementary assessment method for collecting additional external information. Together with the participant management improvements, these features extend the original CAPE-KIDS platform to better support the assessment requirements of adolescent populations.

This validation study also provides evidence that the CAPE-TEENS platform successfully meets the objectives established for this dissertation. The platform operated reliably throughout the study, allowing participants to complete cognitive assessment tasks and questionnaires without technical failures. Additionally, unit tests performed on the platform's backend further support the technical validity of the new features.

Beyond validating the implemented functionalities, the developed platform has broader implications for adolescent cognitive assessment. The literature review highlighted the absence of standardized approaches capable of combining executive function assessment with reward sensitivity measures and contextual factors within a single environment. CAPE-TEENS addresses this limitation by providing researchers with an integrated and configurable platform that supports the design, administration, and management of multiple assessment modalities. By centralizing these components within a single unified framework, the platform has the potential to improve the consistency, reproducibility, and efficiency of future studies investigating adolescent risk-taking behaviour. Although some participants required additional clarification regarding specific task interactions, particularly in the Stroop Task, these observations primarily relate to interface usability rather than implementation correctness. They provide valuable feedback for future refinements of the user interface while demonstrating that the platform is suitable for use with adolescents ranging from ages 10 to 15.

6.5 Limitations

The findings of the validation study should be interpreted with consideration of several limitations. First, the study involved a relatively small population, comprised of only four participants, limiting the validity of the observed results. Future evaluations involving larger and more diverse participant groups would provide stronger evidence regarding the platform's usability and applicability.

Additionally, although study materials were created and configured considering the current literature and expert review, the validation focused primarily on the technical cogency and usability of the developed features, as well as the applicability of the resulting platform, rather than on establishing the predictive relationship between executive function, reward sensitivity, contextual factors, and adolescent risk-taking behaviour. Demonstrating this relationship will require longitudinal studies involving larger datasets and more comprehensive statistical analyses.

Finally, although the platform supports the assessment of contextual factors through questionnaires, these measures rely on self-reported information and therefore remain subject to the limitations commonly associated with questionnaire-based data collection.

6.6 Summary

This chapter presented the validation of the CAPE-TEENS platform through a pilot study involving four participants aged 9–12 years. The study included two different experiments and a questionnaire, evaluating the execution of executive function tasks, reward sensitivity tasks and the retrieval of contextual information within a realistic assessment setting. The results demonstrated the correct operation of the implemented functionalities, successful data collection and export, and the overall suitability of the platform for adolescent cognitive assessment. Finally, the implications and limitations of the validation were discussed.

Chapter 7

Conclusion

This dissertation explored the assessment of risk-taking behaviour during adolescence through the extension of a centralized platform for designing and deploying cognitive and behavioural assessment tasks. It examined the current state of the art in adolescent risk-taking assessment and detailed the design and implementation of the new functionalities that constitute the CAPE-TEENS platform. This chapter presents the main contributions of this work, discusses its limitations, and outlines directions for future development of the CAPE platform.

7.1 Key findings and Main Contributions

One of the main objectives of this dissertation was to understand the main factors associated with risk-taking behaviour during adolescence and to explore how these factors could be assessed within a unified digital platform. To that end, a systematic literature review was conducted, during which several gaps in the current state of the art were identified. Firstly, the assessment activities and tasks employed across studies lacked consistent and standardized configurations, limiting the reproducibility and comparability of results. Furthermore, contextual factors were often analysed separately from executive function and reward sensitivity despite their recognised influence on adolescent risk-taking behaviour. These findings motivated the development of CAPE-TEENS as an integrated platform capable of supporting the assessment of cognitive, behavioural, and contextual factors within a single environment.

This dissertation contains the following as its main contributions:

- **A mapped landscape of adolescent risk-taking assessment -** a scoping review following PRISMA guidelines surveyed the executive function and reward sensitivity tasks most used with adolescents, alongside the lifestyle and contextual variables most consistently linked to risk-taking and used the findings to motivate a concrete set of platform requirements based on gaps in the state of the art.

- **Support for reward sensitivity tasks –** a new step type was created to support probabilistic task flows, where task outcomes are decided by a conditional action. This allows for the creation of gambling tasks and other reward sensitivity methods.
- **Questionnaire framework –** a new tool allowing the creation of questionnaires. This new assessment method supports the analysis of external factors not accessible through the use of tasks, such as contextual and lifestyle factors.
- **Participant management interface –** a new interface allowing for researchers to view and access every participant registered to the platform, as well as their details, improving the organization, monitoring, and administration of participants across assessment activities.
- **Platform validation study -** a pilot study involving participants from the target age group was conducted to evaluate the implemented features in a realistic assessment setting. The results provided evidence regarding the usability of the platform and its suitability for supporting adolescent risk taking assessment activities.

Overall, the developed solution demonstrates that the CAPE-KIDS framework can be successfully extended to support reward sensitivity evaluation and contextual factor integration for adolescents aged 10 to 15 years. Through the introduction of new assessment tools and platform functionalities, CAPE-TEENS broadens the scope of the original framework and provides a unified environment for the study of factors associated with adolescent risk-taking behaviour.

7.2 Limitations

Despite the achieved objectives, several limitations should be acknowledged. First, the questionnaire framework currently solely supports multiple-choice questions, limiting the variety of information that can be collected through the platform. Additional question formats may be required to accommodate more complex assessment protocols. Due to the modular architecture of the platform, support for additional question types could be incorporated with limited modifications to the existing framework.

Furthermore, contextual factor assessment currently relies primarily on self-reported questionnaire data. Although questionnaires constitute a practical and widely adopted assessment method, they may not fully capture the dynamic nature of factors such as sleep quality, physical activity, or stress levels.

Lastly, the validation study was conducted with a limited number of participants, restricting the extent to which conclusions regarding the platform's applicability can be generalized.

7.3 Future Work

Several opportunities exist for the continued development of CAPE-TEENS. One of the most relevant directions is the integration of wearable devices capable of automatically collecting contextual and lifestyle information. Such integration would reduce reliance on self-reported data and provide richer contextual information for risk-taking assessment.

Future work may also expand the platform's support for multimedia stimuli, including audio and video content, allowing the implementation of a wider range of cognitive and behavioural assessment paradigms. In addition, results visualization and export could be enhanced through the inclusion of more detailed performance metrics, such as average response time and percentage of correct answers, and a clearer division of tasks within the experiment, providing researchers with improved tools for data analysis.

Finally, the experiment framework itself could be extended to support more complex and dynamic task structures, including variable stimuli and advanced task logic. These improvements would further increase the platform's flexibility and enable the implementation of a broader range of cognitive assessment protocols.

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Appendix A

Reviewed Executive Function Tasks by Article

Authors	Year	Task	Target EF
Choy O. [8]	2025	Digit Backward Span	Working Memory
		Trail Making Task	Cognitive Flexibility
		Balloon Analog Risk Task	Reward Sensitivity
Cao et al. [6]	2025	N-back Task	Working Memory
Palmer et al. [25]	2025	Stroop Task	Inhibitory Control
		Go/No-go Task	Inhibitory Control
Turan et al. [38]	2025	Flanker Task	Inhibitory Control
Lievore et al. [19]	2025	Go/No-go Task	Inhibitory Control
		Visuospatial Span	Working Memory
		Wisconsin Card Sorting Test	Cognitive Flexibility
Paige et al. [24]	2024	Go/No-go Task	Inhibitory Control
Stinson et al. [35]	2024	Stop-Signal Task	Inhibitory Control
Ma et al. [20]	2024	Flanker Task	Inhibitory Control
		N-back Task	Working Memory
		Wisconsin Card Sorting Test	Cognitive Flexibility
Atak et al. [3]	2023	Trail Making Task	Cognitive Flexibility
		Stroop Task	Inhibitory Control
Zhang et al. [41]	2022	Trail Making Task	Cognitive Flexibility
		Digit Symbol Span	Working Memory
		Wisconsin Card Sort Test	Cognitive Flexibility
		Semantic Verbal Fluency	Working Memory
Kryza-Lacombe et al. [17]	2021	Dimensional Change Card Sort Task	Cognitive Flexibility
		Flanker Task	Inhibitory Control
		Piñata Task	Reward Sensitivity
Andreoni et al. [1]	2020	Pencil Task	Reward Sensitivity
		Dimensional Change Card Sort Task	Cognitive Flexibility
		Flanker Task	Inhibitory Control
		List Sorting Memory Test	Working Memory
		Picture Sequence Memory Test	Working Memory
Ross et al. [31]	2019	Stop-Signal Task	Inhibitory Control
		Visuospatial Span	Working Memory
		Digit Backward Span	Workinh Memory
		Letter Span	Working Memory
Skippen et al. [34]	2019	Stop-Signal Task	Inhibitory Control
		Cambridge Gambling Task	Reward Sensitivity
		Information Sampling Task	Reward Sensitivity
Banich et al. [4]	2019	Localizer Task	Working Memory
		Stroop Task	Inhibitory Control
Gardiner et al. [11]	2018	Delay Discounting Paradigm	Reward Sensitivity
Breiner et al. [5]	2018	Cognitive Control Under Emotion Task	Inhibitory Control
Op de Macks et al. [21]	2018	Yellow Light Game	Reward Sensitivity
McCormick et al. [22]	2017	Balloon Analog Risk Task	Reward Sensitivity
Simmonds et al. [33]	2017	Memory Guided Saccade Task	Working Memory
Pope et al. [27]	2016	Trail Making Task	Cognitive Flexibility
		Digit Backward Span	Working Memory

Table A.1: Executive Function Tasks by article

Authors	Year	Task	Target EF
Ursache et al. [39]	2015	Iowa Gambling Task Hearts and Flowers Task	Reward Sensitivity Inhibitory Control
Peeters et al. [26]	2015	Self-Ordered Pointing Task Stroop Task	Working Memory Inhibitory Control
Hwang et al. [14]	2014	Stroop Task	Inhibitory Control
Krishnan-Sarin [16] et al.	2013	Stroop Task	Inhibitory Control
Telzer et al. [36]	2013	Balloon Analog Risk Task Go/No-go Task	Reward Sensitivity Inhibitory Control
Satterthwaite et al. [32]	2013	N-back Task	Working Memory
Keulers et al. [15]	2012	Go/No-go Task Gambling Task	Inhibitory Control Reward Sensitivity
Romer et al. [29]	2011	Digit Backward Span Visuospatial Span Corsi Block Tapping N-back Task	Working Memory Working Memory Working Memory Working Memory
Van Leijenhorst et al. [18]	2010	Gambling Task	Reward Sensitivity
Figner et al. [9]	2009	Columbia Card Sort Test Digit Symbol Span	Reward Sensitivity Working Memory
Romer et al. [30]	2009	Corsi Block Tapping N-back Task Digit Symbol Span Task Spacial Working Memory Stroop Task Flanker Task Reversal Learning Balloon Analog Risk Task	Working Memory Working Memory Working Memory Working Memory inhibitory Control Inhibitory Control Reward Sensitivity Reward Sensitivity
Qin et al. [28]	2009	N-back Task	Working Memory
Thush et al. [37]	2008	Self-Ordered Pointing Task Implicit Association Test	Working Memory Working Memory

Appendix B

Pilot Study Quantitative Results

Participant	Task	Average Response Time	Result
Participant 1	Go/No-Go	435.3	40/40
	Stroop	988.8	44/45
	2-back	745.2	31/40
	Digit Span	2126.0	9/9
	Hearts & Flowers	754.6	31/32
	WCST	2214.2	60/90
	BART	2842.1	6 trials
	Pencil Task	4833.3	7 pencils

Table B.1: Participant 1 Task Results

Participant	Task	Average Response Time	Result
Participant 2	Go/No-Go	1042.4	39/40
	Stroop	1005.1	39/45
	2-back	956.7	35/40
	Digit Span	2734.6	Failed on 3 digits
	Hearts & Flowers	946.1	30/32
	WCST	2871.2	42/90
	BART	2333.3	4 trials
	Pencil Task	4250.0	3 pencils

Table B.2: Participant 2 Task Results

Participant	Task	Average Response Time	Result
Participant 3	Go/No-Go	971.8	40/40
	Stroop	1232.8	41/45
	2-back	1064.6	33/40
	Digit Span	3129.0	Failed on 2 digits
	Hearts & Flowers	1266.4	30/32
	WCST	2309.2	49/90
	BART	2375.0	3 trials
	Pencil Task	3666.7	1 pencil

Table B.3: Participant 3 Task Results

Participant	Task	Average Response Time	Result
Participant 4	Go/No-Go	819.0	40/40
	Stroop	809.4	45/45
	2-back	1008.4	36/40
	Digit Span	2949.0	Failed on 2 digits
	Hearts & Flowers	881.7	31/32
	WCST	2460.5	61/90
	BART	2666.7	5 trials
	Pencil Task	4500.0	6 pencils

Table B.4: Participant 4 Task Results