Designing Application UI To Assist Executive Function Self-Regulation

Aurora R. Newman
220310897
Computer Science, Newcastle University
CSC8099
Dr. Clara Crivellaro
2023 August 14

[15730 words]

Abstract

Executive functions are a suite of cognitive abilities that allow higher order processes such as organization, planning, decision-making, and more. Executive functions are essential for quality of life, but they may be impaired in individuals with certain disorders. Even neurotypical individuals can experience executive function impairment when their cognitive reserves are strained, such as during times of stress or fatigue.

The aim of this project is to identify interventions for executive function impairment. A user-centered design approach will be used to develop an application interface that can be used to improve executive function skills. The interface will be designed based on findings from the literature and from user research. It will then be evaluated for usability using heuristic evaluations and cooperative evaluations.

The results of this project will contribute to the development of effective interventions for executive function impairment. They will also help to improve the understanding of how executive functions work and how they can be supported using technological interventions.

Declaration

I declare that this dissertation represents my own work except where otherwise stated.

Acknowledgements

I am deeply grateful to my supervisor, Dr. Crivellaro, for her expert guidance and support throughout this project. Her insights and feedback were invaluable in helping me to focus my research and produce a coherent work. I am also indebted to the faculty at Newcastle University, particularly Dr. Nesbitt and Laura Fletcher, for their knowledge, expertise, and encouragement.

I would like to express my sincere gratitude to my parents for their unwavering love and support. Their sacrifices and encouragement have made my education possible. I am also grateful to my friends, Amy, Ben, David, Rachel, Ryan, Shaurya, and Tahir, for their friendship, kindness, and support.

Table of Contents

Introduction 8
Aim 8
Objectives 8
Project Scope 9
Project Deliverables 10
Outline of Material 10
Background Research 10
Disorders Associated with Executive Function Impairment 10
Social Model vs. Medical Model 11
Executive Function and ADHD 12
Executive Function and ASD 13
Executive Function and Substance Use Disorder 14
Executive Function and Suicide 15
Interventions for Executive Function Impairment 15
Diversity for Design Framework 17
Interventions for ADHD-Related Executive Function Regulation 18
Executive Function Regulation Using Technology for Autism 19
Technology and Interventions for Substance Abuse Treatment 20
Technology for Suicide Prevention 20
Commentary on Research 20
Methods, Planning, and Design Preparation 21
User Research Questionnaire 21
Sampling Method and Procedure 21
Participant Consent and Eligibility 21
Participant Demographics 21
Participants Relationship to Executive Functions 22
Respondents with Conditions Affecting Executive Functions 23
Relevant Technology 24
Virtual Hope Box 24
Finch 24
ToDoist 26
Design Notes 26
Desirable Features 27
Heuristics Considered During Design Process 27
Nielsen's Modified by Budd 27
Mobile Interface Evaluation 27
Design Requirements 28
Functional Requirements 28
Nonfunctional Requirements 30
Site Map 34
Results and Evaluation 35
Name 35
Color Considerations 35
Design 36
User Landing 36

My Page....37
Inspiration....38
Training....39
Reminders....40
Connection....41
Evaluation 42
Cooperative Evaluation....42
Evaluating CogniGuide Against Design Notes....42
Evaluating CogniGuide Against Desirable Features....44
Functional Requirements Compliance....45
Nonfunctional Requirements Compliance....47
Nielsen's Modified by Budd....49
Mobile Interface Evaluation....51
Conclusion 54
Summary 54
Retrospective on Objectives 54
Learning Points 57
Future Work 57
References 58
Referenced URLs 65
Appendices 66
Appendix A. User Research Questionnaire 66
Section 1: Consent....66
Section 2. Personal Information....68
Section 3. Executive Functions....70
Section 4. Solution Review....73
Section 5. Conditions....78
Section 6. Thank You....80
Appendix B. Images and Icons Used 80

Table of Figures

Figure 1: Methods Used to Manage Symptoms 22
Figure 2: Relevant Features From Virtual Hope Box 24
Figure 3: Relevant Features From Finch 24
Figure 4: Problematic Features From Finch 25
Figure 5: CogniGuide Site Map 34
Figure 6: Color Palette as Seen by Colorblind Users 35
Figure 7: Initiating CogniGuide 36
Figure 8: Options in My CogniGuide 37
Figure 9: Walking Meditation Using Augmented Reality 39
Figure 10: Reminder Options 40
Figure 11: Connection Opportunities 41

Table of Tables

Table 1: Comparisons between the medical and social models of disability 10
Table 2: Functional Requirements for Application 27
Table 3: Nonfunctional Requirements for Application 29
Table 4: Success in Implementing Design Notes 39
Table 5: Success in Implementing Desirable Features 41
Table 6: Implementation Success of Functional Requirements for Application 42
Table 7: Implementation Success of Nonfunctional Requirements for Application 43
Table 8: Evaluating *CogniGuide* by Heuristics Developed by Budd 45
Table 9: Evaluating *CogniGuide* by Mobile-Specific Heuristics 46
Table 10: Evaluating Original Project Objectives 49
Table 11: Participant Responses in Section 1: Consent 61
Table 12: Participant Responses in Section 2: Personal Information 63
Table 13: Participant Responses in Section 3: Executive Functions 65
Table 14: Participant Responses in Section 4: Solution Review 68
Table 15: Participant Responses in Section 5: Conditions 72

Designing Application UI To Assist Executive Function Self-Regulation

Executive function is a concept that has inspired robust discussion in the literature across multiple fields, including education, psychiatry, and psychology. Executive functions are built on a foundation of cognitive skills and related skills and develop over the course of infancy, childhood, adolescence, and into early adulthood (Hunter et al., 2012), but there is not a firm consensus on exactly which skills comprise executive function. A meta-analysis by Baggetta & Alexander (2016) found that Miyake et al. (2000) was the most commonly cited model of executive function. This model of executive functions is used for the purposes of this project.

Miyake et al. postulated that three executive functions are moderately correlated, distinguishable, and are used in different tasks, but all rely on a common underlying ability or function. Miyake's three functions are shifting, which is the ability to intentionally shift attention between tasks or goals; updating, the ability to add, subtract, and maintain information in working memory; and inhibition, the ability to deliberately inhibit responses and behavior. These basic skills are foundational building blocks for higher level cognitive functions such as reasoning, problem solving, and planning (Diamond, 2012).

Executive functions are positively correlated with overall quality of life, school success prediction, job success, and marital harmony and negatively correlated with obesity, substance abuse, and addiction (Diamond, 2013). Executive functions may be negatively impacted during times of stress, fatigue, loneliness, or lack of exercise, which may make the individual appear to have symptoms of a disorder with executive function impairment, such as Attention-Deficit/Hyperactivity Disorder, or, ADHD (Diamond, 2013). Even neurotypical individuals may experience executive function impairment, but individuals who struggle with executive functions will be more deeply impacted as they have fewer cognitive resources (Sparrow, 2012a).

Aim

As executive dysfunction has been found across a broad spectrum of disorders, this project intends to isolate skills that may be self-managed. Existing frameworks to help regulate executive function skills for relevant disorders will be evaluated against the heuristic evaluations used by Chaparro et al. (2016) to evaluate a neurobehavioral assessment application developed by the National Institute of Health and Northwestern University, specifically Nielsen's as modified by Budd and presented by Sharp et al. (2019, pp.553–554) as well as a 72-item checklist designed for mobile applications (Yáñez Gómez et al., 2014). Individuals who experience executive function impairment will be targeted for the survey because tools that traditionally aid neurotypical individuals frequently fail neurodivergent individuals (Spiel et al., 2022). A novel application user interface will be designed using Figma to address and help users improve executive function. The interface will be evaluated against heuristics and design requirements as well as with user led cooperative evaluation using think aloud protocol

Objectives

The project proposal outlined the objectives of the project to define milestones and overall success.

- Background Review on executive function
    - Find best consensus on skills that comprise executive function.
    - Find ways and disorders in which executive function impairment manifests.
- User Research
    - Survey individuals who struggle with executive function skills to identify technological methods of managing symptoms of executive dysfunction.
    - Identify applications and methods used to ameliorate symptoms of executive function impairment.
    - Identify features to avoid, include, and modify.
- Background review on mental health centered design
    - Find technological solutions aimed at individuals with disorders identified in step one.
    - Identify applications that are designed to assist individuals with disorders identified in step one.
- Evaluate existing systems
    - Identify mental health applications in the literature with relevant features.
- Plan design
    - Develop design requirements based on user research and literature review.
- Design a prototype
    - Based on existing system evaluation, determine gaps and opportunities for new and enhanced system.
    - Design prototype for application that helps users self-regulate symptoms.
- Evaluate Design
    - Evaluate design against original objectives.
    - Evaluate design against design requirements.
    - Evaluate design against guideline reviews, specifically Nielsen's as modified by Budd and presented by Sharp et al. (2019, pp.553–554) as well as a 72-item checklist designed for mobile applications (Yáñez Gómez et al., 2014).

Project Scope

Executive function impairment occurs in a wide variety of disorders. Executive functions may also be impaired in neurotypical individuals during periods of stress. Diagnosing the source of executive function impairment is beyond the scope of the project.

Pursuant to the neurodiversity model (see Social Model vs. Medical Model), some individuals with disorders and conditions that impact executive functions do not identify as being disabled or having a disorder. This application is not intended to treat or cure any condition or disorder. Rather, it is intended to help individuals who struggle with deleterious and adverse symptoms of executive function impairment (stemming from any cause) manage their symptoms.

An application design will be produced. A serviceable application is beyond the scope of this project.

Project Deliverables

This project will deliver an application design that could be used to develop an application.

Outline of Material

- Introduction: Provides an introduction to executive functions. Introduces the project at a birds-eye level.
- Background Research: Literature review on select disorders that are associated with executive function impairment. Discusses relevant technologies intended to help users self-manage symptoms of those disorders.
- Methods, Planning, and Design: Discusses User Research and steps taken to plan and design the application prior to the design.
- Results: Discusses the developed user interface.
- Evaluation: User led cooperative evaluation using think aloud protocol. Evaluating the user interface against design requirements and two relevant guideline reviews.
- Conclusion: Discusses overall project, achieved and failed objectives, and future work.
- References
- Appendices: Results of user research, URLs used for images and icons in application design.

Background Research

The literature was reviewed to determine which disorders were associated with executive function impairment. Executive functions are impaired in a wide variety of neurodevelopmental and acquired disorders (Disorders Associated with Executive Function Impairment). Four disorders and conditions were chosen. Applications and technological interventions have been developed with the purpose of aiding individuals

with those disorders, and relevant literature is discussed in Interventions for Executive Function Impairment.

Disorders Associated with Executive Function Impairment

Executive function impairment is present in many neurodevelopmental and acquired disorders, albeit to varying degrees for the different skills (Sparrow, 2012b). Adults are at risk of being misdiagnosed as their learned coping mechanisms have the potential to mask the source of symptoms (Primich & Iennaco, 2011), and thus executive functions will be broadly considered rather than symptoms of a specific disorder. Executive functions are impaired in mood, anxiety, and other mental disorders, including attention-deficit/hyperactivity disorder (ADHD), addictions, conduct disorder, depression, obsessive compulsive disorder (OCD), and schizophrenia (Diamond, 2013). Different disorders differ in executive dysfunction profile; for example, the ADHD executive function profile shows greater inhibition deficits and lesser cognitive flexibility deficits compared to autism (Hill, 2004). Nonetheless, there is a high degree of comorbidity among some of the disorders, particularly ADHD, oppositional defiant disorder (ODD), and Tourette syndrome, so determining the precise cause of the executive function impairment is not always possible (Sparrow, 2012b). Executive function impairment may also be acquired after brain injury, contracting certain infectious disease (e.g., Lyme disease, enteroviruses, HIV), or exposure to environmental neurotoxins in childhood and adolescence (Hunter & Sparrow, 2012). Furthermore, working memory has been found to improve during development and decline with age (Diamond, 2013).

Social Model vs. Medical Model

Two prominent models divide the neurodivergent community: medical and social. The medical model sees disability as a problem of the individual and tries to bring the disabled person to the standards of the surrounding environment and culture, while the social model suggests that society itself disables the individual and takes a rights-based perspective to the place of the autistic individual in society (Jaarsma & Welin, 2012; Krcek, 2012; Kapp et al., 2013; Bölte et al., 2021). In other words, the medical model sees society as limited by disabled individuals while the social model sees disabled individuals as limited by society (Haegele & Hodge, 2016; Table 1). The medical model has been criticized for gatekeeping services for undiagnosed individuals, failure to consider the desires and needs of disabled individuals, limiting options for disabled individuals, and perpetuating negative perceptions of disabilities (Haegele & Hodge, 2016).

Table 1

Comparisons between the medical and social models of disability

	Medical Model	Social Model
Definition of disability	A phenomenon experienced by the individual that results from impairments to body functions or structures; a deficiency or	A social construct imposed on top of impairments by society; a difference

	abnormality	
Interventions	"Fixing" the disability to "normalize" the individual	Social or political change to decrease barriers and increase understanding
Outcomes of interventions	Normalized function for the individual; individual integrates into existing society	Self-advocacy, changes in environment and understanding, social inclusion
Agent of remedies	Professional	Individual, advocate, or anyone who mediates between the individual and society
Effects on society	Society remains the same	Society becomes more inclusive
Perceptions towards disabled individuals	The individual is faulty	The individual is different
Cognitive authority	Scientists and doctors	Academics and advocates with disabilities
Perception of disability	Negative	Neutral

Note. Adapted from "Disability Discourse: Overview and Critiques of the Medical and Social Models" by Haegele, J. A., & Hodge, S. 2016, *Quest*, *68*(2), p. 194. Copyright 2016 by the National Association for Kinesiology in Higher Education (NAKHE).

The neurodiversity movement grew out of the social model in the 1990s and promotes civil rights for individuals diagnosed with neurological or neurodevelopmental disorders, including ADHD, bipolar disorder, dyslexia, epilepsy, Tourette's syndrome, and autism (Jaarsma & Welin, 2012). Some characteristics associated with these disorders (e.g., high focus, spontaneity, impulsivity) could be considered strengths or difficulties, depending on the circumstance (Benton et al., 2014).

The neurodiversity model has been criticized for being overly positive towards disability and trivializing differences across the spectrum of presentation (Bölte et al., 2021), but for disabled individuals, viewing their disabilities through this lens can be beneficial. For example, some individuals with ADHD regard the disorder as beneficial and find meaning and purpose in their diagnosis (Fleischmann & Miller, 2013). Autism Spectrum Disorder (ASD) in particular has a long history in the neurodiversity movement, which views autism as a positive identity with unique challenges that does not require a cure (Krcek, 2012). The neurodiversity model opposes interventions intended to eliminate atypical but harmless behaviors like avoiding eye contact or self-soothing with repetitive body movements (Kapp et al., 2013). In xyr landmark essay *Don't Mourn for Us*, autistic advocate and founder of Autism Network International Jim Sinclair asked parents to not mourn the "normal" child they lacked and to instead accept the autistic child they had (Sinclair, 1993). Self-identification as autistic as well as neurodiversity awareness were associated with viewing autism positively (Kapp et al., 2013). Autistic

adults who viewed themselves as having a difference in mind as opposed to a disorder, i.e., through a neurodiversity framework instead of medical, were found to have higher self-esteem (Ferenc et al., 2022). For the purposes of this project, the neurodiversity model will be followed.

Executive Function and ADHD

The American Psychiatric Association's fifth edition (text revision) of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5-TR) defines the diagnostic criteria for ADHD as having six or more symptoms of inattention, e.g., careless mistakes, difficulty following through on instructions, easily distracted by unrelated stimuli, and/or six or more symptoms of hyperactivity/impulsivity, e.g., fidgeting, difficulty waiting to speak, difficulty with personal boundaries (American Psychiatric Association [APA], 2022a). These symptoms should be present in two or more spheres (e.g., at home, at work, with friends), reduce quality of life, and are not better explained by another mental disorder (e.g., anxiety disorder, dissociative disorder, substance withdrawal). Depending on symptom distribution, ADHD presentation may be categorized as primarily inattentive (ADHD-I), primarily hyperactive-impulsive (ADHD-HI), or combined (ADHD-C). ADHD is associated with, among others, neurocognitive deficits in a variety of areas, including working memory, set shifting, reaction time variability, response inhibition, vigilance, and planning/organization, i.e., executive functions.

Criticisms have been made of the changes to the DSM-5-TR regarding ADHD, namely that ADHD is a description of behaviors and not an explanation (i.e., if an individual has ADHD it is because he is inattentive, disorganized, and hyperactive-impulsive, and if an individual is inattentive, disorganized, and hyperactive-impulsive it is because he has ADHD) and that an ADHD diagnosis in childhood may not positively improve quality-of-life measures in adolescents (Koutsoklenis & Honkasilta, 2023). However, the DSM-5-TR is the current accepted definition of ADHD diagnostic criteria and will be used for the purposes of this project.

Executive dysfunction has been consistently associated with ADHD over the past 30 years (Kenealy & Paltin, 2012). ADHD symptoms have been shown to be strongly correlated with executive function impairment (Silverstein et al., 2020). Although executive dysfunction is not considered when diagnosing ADHD, Silverstein et al. suggest that the symptoms of executive function impairment are so central to the experience of adult ADHD that the DSM should consider including symptoms of executive function deficits (2020). Symptoms of ADHD align neatly with poor executive function regulation. For example, difficulty waiting to speak and being easily distracted by unrelated stimuli are symptoms of poor inhibitory control, careless mistakes are a symptom of poor working memory, and difficulty organizing activities is a symptom of poor cognitive flexibility.

Silverstein's findings are not limited to adults; Martel et al. (2007) found in a study of 182 adolescents that the control group performed significantly better than the ADHD group in every measure of executive function, even after controlling for comorbid diagnoses of oppositional defiant disorder, conduct disorder, and learning disorders. In a study of 259 children and adolescents with ADHD and 222 without, Biederman et al.

(2004) found that the ADHD group had significantly more executive function deficits than did the control group. Additionally, ADHD with executive function deficits was associated with an increased risk of grade retention and a decrease in academic achievement compared to ADHD alone, even when controlling for socioeconomic status, learning disabilities, and IQ.

Executive Function and ASD

Diagnostic criteria for ASD include persistent deficits in social communications and interactions in multiple contexts and restricted, repetitive patterns of behavior, interests, or activities (including hyper- or hyporeactivity to sensory input). Individuals must experience difficulties and/or differences outside normal bounds that cause significant impairment and have characteristics starting in early childhood (APA, 2022b). The DSM-5-TR clarifies the DSM-5 diagnostic criteria in that individuals must express symptoms in all arenas to be diagnosed with ASD (Bradley et al., 2022; First et al., 2022). Signs of ASD might include limited speech, limited facial expressions, difficulty making friends, having narrow or intense interests, struggles with changes in schedule, and sensory sensitivity (APA, 2022b).

Executive function impairment is associated with ASD. It can be seen in ASD characteristics like deficits in cognitive flexibility (difficulty forming novel concepts, perseveration) and inhibitory control (lack of judgment, insight, and ability to inhibit inappropriate actions) causing a rigid adherence to their own perspective (Han et al., 2014; Hill, 2004). Executive function impairment has not been shown to cause ASD, but it is related to the symptoms that define ASD (Kenworthy et al., 2012). A meta-analysis of 235 studies with a total of 14,081 participants concluded that individuals diagnosed with ASD exhibited significantly lower executive functions than neurotypical control groups, and anxiety has been strongly correlated with poor executive function performance (Demetriou et al., 2017). Demetriou's further conclusion that this impairment is present throughout neurodevelopment is evidenced in studies by Rosenthal et al. (2013) and Johnston et al. (2019). A study of 185 children with ASD without intellectual disability were assessed using an inventory of executive function and found that older children with ASD showed greater problems with executive function compared with the normative sample than did younger children with ASD (Rosenthal et al., 2013). Compared to age and IQ matched controls, adults with ASD were found to have deficits in executive functions, particularly in cognitive tasks and more behavioral problems, and these executive function impairments are disabling in everyday life (Johnston et al., 2019). Johnston et al. further suggest that executive function deficits are a core feature of ASD.

Executive Function and Substance Use Disorder

Drug overdose deaths are the leading cause of injury death in the United States, and approximately one in ten U.S. adults will develop a nonalcohol drug use disorder in their lifetimes (McCabe et al., 2017). According to the DSM-5-TR, an individual has a substance use disorder if they have a pattern of symptoms caused by using a substance despite negative effects (APA, 2022c). Examples of symptoms include neglecting responsibilities because of substance use, needing more of the substance to achieve the desired effect (tolerance), and experiencing intense cravings or urges to use the

substance. Substance use disorders have three levels of severity, depending on the number of symptoms exhibited. The DSM-5-TR recognizes disorders from ten classes of drugs, including alcohol, caffeine, stimulants, hypnotics, and tobacco. Substance-induced disorders are conditions and problems caused by the effects of a substance such as intoxication, withdrawal, and substance-induced depressive disorder (APA, 2022c, p. 548). The DSM-5, published in 2013, changed the terminology from substance abuse to substance use disorder. Some of the studies cited in this project were published prior to that date and use the term substance abuse.

Poor executive functions are associated with substance use and substance dependence for both illegal (Verdejo-García et al., 2006) and legal substances (Durazzo et al., 2007). A 25 year longitudinal study conducted on 1265 New Zealand-born children found that conduct problems in childhood and adolescence were generally related to substance use, abuse, and dependence, but attentional problems were largely unrelated (Fergusson et al., 2007). Low executive functions are associated with impulsivity (lack of inhibitory control), which is also associated with substance use (Young et al., 2009). It is possible that substance use/abuse impairs executive functions (i.e., executive function impairment is caused by substance use), but one prospective study found that poor inhibitory control predicted later alcohol-related problems, number of illicit drugs used, and comorbid alcohol and drug use, even after controlling for IQ, parental alcoholism and antisocial personality disorder, child attention-deficit/hyperactivity disorder and conduct symptoms, and age (Nigg et al., 2006). Nigg's study implies one of three options: executive functions are a risk factor for substance abuse, substance use and executive functions share genetic influences, or some combination of both. However, Gustavson's twin study concluded that low executive functions are a genetic risk factor for early substance use in adolescence, but not for substance abuse, implicating factors beyond executive function (2007).

Executive Function and Suicide

Death by suicide is the most detrimental outcome in psychiatry and mental health. Diagnosable psychiatric illnesses have been found in 90% of people who die by suicide (Fawcett, 2013). Death by suicide is traditionally considered an outcome and not a diagnosis, but it is a grave enough outcome that the DSM-5 has added suicide subsections for specific mental disorders and conditions that may be considered risk factors for death by suicide (Felthous et al., 2023). These disorders are multitude, ranging from ASD (although only in females), ADHD (possibly because of the prevalence of comorbid conditions), schizophrenia, major depressive disorder (MDD), post-traumatic stress disorder (PTSD), and tobacco use disorder.

In 1998, Shneidman, a clinical psychologist, reviewed decades of suicide notes in L.A. County Coroner's Office. He wrote:

> Suicide is the result of an interior dialogue. The mind scans its options; the topic of suicide comes up, the mind rejects it, scans again; there is suicide, it is rejected again, and then finally the mind accepts suicide as a solution, then plans it, and fixes it as the only answer. The general word for this process is *introspection* (Shneidman, 1998, p. 15, emphasis original).

In the suicidal mind, the field of focus narrows to a pinpoint: escaping unbearable anguish and moving toward cessation of pain. To Shneidman, the implications for suicide prevention are to reduce pain, expand the mind's field of view, and to lighten pressure (p. 139).

The narrow field of focus and lack of cognitive flexibility to consider alternative paths imply executive function deficits, which is confirmed by several studies. After controlling for relevant factors, Ho et al. (2018) and Onat et al. (2018) both found that patients with MDD who had attempted suicide were found to have worse inhibitory control than either the healthy controls or patients with MDD who had not attempted suicide. A similar study conducted by Fernández et al. compared patients with a recent suicide attempt (<30days) diagnosed with MDD, MDD patients with history of attempted suicide, non-attempter MDD patients, and healthy controls (2022). Although all patient groups performed significantly worse than healthy controls on executive function, recent suicide attempters performed more poorly than patients with a history of suicide attempt and depressed non-attempters. A longitudinal study found that inhibitory control and working memory impairments were linked to suicide ideation and attempts, respectively, and that these impairments were maintained over the long term (Riera-Serra et al., 2023). As suicide attempts are linked with executive function deficits and there are many mental disorders and conditions linked to increased risk of suicide, apps related to suicide prevention will be identified and evaluated (see Technology for Suicide Prevention).

Interventions for Executive Function Impairment

Executive functions can be improved (Diamond, 2013). Diamond & Lee (2011) evaluated six approaches for improving executive functions among early school age children, two of which are relevant to this project and do not require technology to implement.

First, certain types of physical activity help improve executive functions. Aerobic exercise was found to improve cognitive flexibility, particularly when exercising bimanual coordination (Diamond & Lee, 2011). These findings were reinforced in a study that examined functional magnetic resonance imagining and executive functions in seventeen children with ADHD before and after an eight week training regimen of rope skipping (Jiang et al., 2022). Jiang et al. found that aerobic exercise can improve the executive function of ADHD children. Becker et al. used a subset of data taken from longitudinal study of 1,100 children when the children were in third grade (UK Year 4) to test the hypothesis that the sport's metabolic intensity and complexity (i.e., if the sport has a fixed focus like swimming or requires shifting of goals like volleyball) can be connected to executive functions and other skills (2018). Results showed a curvilinear relationship between metabolic intensity and executive functions and no direct relationship between type of sport and executive functions. Executive functions peaked at sport with metabolic intensity of 20, so this could be martial arts twice weekly, golf five times weekly, or tennis thrice weekly. The beneficial association between aerobic exercise and executive functions is not limited to children. In a study of adults with mild to moderate Alzheimer's Disease, participants engaging in a six month program of moderate intensity cycling were found to have no difference in executive function between the baseline, three month measurement, and six month measurement; cognitive

decline would be expected during this timeframe due to the degenerative nature of Alzheimer's Disease (Yu et al., 2018). Diamond & Lee (2011) hypothesized sports may benefit executive functions more than simply using aerobic exercise because sports require sustained attention and working memory. Additionally, achievement and social bonding can alleviate the feelings of sadness, stress, and loneliness that contribute to executive function impairments.

Second, martial arts have been shown to improve focus and perseverance (inhibitory control; Diamond & Lee 2011). Children who received traditional taekwondo also improved on mental math, which relies on working memory. In two separate studies, children who received taekwondo were found to have greater benefits than did children assigned to standard physical education or mixed martial arts. This may be because the taekwondo lessons received by the children incorporated elements of mindfulness.

As inhibitory control means managing attention, behavior, emotions, and thoughts to complete a desired task, mindfulness is intuitively linked to inhibitory control (Diamond, 2013; Geronimi et al., 2019). A frequently cited definition of mindfulness is "the awareness that emerges through paying attention on purpose, in the present moment, and nonjudgmentally to the unfolding of experience moment by moment" (Kabat-Zinn, 2006). The mindfulness connection is reinforced by Diamond & Lee with a study of girls aged 10 and 13 years old who were randomly assigned to yoga or physical training; the yoga group showed executive function improvements, and the physical training group did not show executive function improvement (2011). Additionally, children aged 7-9 received mindfulness training and showed greater executive function improvements than did the control group who read silently.

Further studies have shown associations between mindfulness and executive function. A study of 96 Hispanic American children found a direct, significant, and positive association between mindfulness and executive function (Huang et al., 2020). Geronimi et al. found mindfulness to be positively associated with inhibition, working memory, and cognitive flexibility in children (2019). In a pilot study of first-year medical students, self-reported meditation practices were negatively associated with substance use and executive function (Black et al., 2011). However, in a study of adults, MacAulay et al. only found a positive association between mindfulness and inhibitory control, and none at all between mindfulness and cognitive flexibility or working memory (2021).

A third intervention evaluated by Diamond & Lee (2011) was CogMed, a gamified working-memory training computer program. CogMed is used by parents and school systems for underachievement as well as in clinical practices for ADHD and stroke-related brain damage (Shipstead et al., 2012). Users are intended to engage in sessions over a five week period with varying lengths depending on age (25 minutes for preschoolers, 30 for older children, and 45 for adults; Aksayli et al., 2019). Diamond & Lee (2011) reported benefits of the game were found in five studies, two of which returned to the participants six months later and found executive function and math benefits.

However, CogMed's promises may be illusory and less robust than would be desired. A meta-analysis of 50 studies found that there was no significant difference in cognitive abilities (e.g., attention) and academic achievement (e.g., mathematics), and

small to medium effects were observed in memory tasks when comparing groups trained exclusively on CogMed and groups without any working memory training at all (Aksayli et al., 2019). Furthermore, a review of research with CogMed found issues with methodology and replicability, forcing the researchers to conclude that the only promise CogMed can make is that training on CogMed allows users to improve on activities similar to CogMed training; it cannot promise to increase intelligence, improve focus and attention, or provide relief from executive function impairment (Shipstead et al., 2012). Therefore, despite CogMed's popularity and wide use for executive function, it is not used for the purposes of this project.

Diversity for Design Framework

The Diversity for Design (D4D) framework was introduced at CHI '14, a prestigious annual conference for Human Computer Interaction (HCI) researchers and practitioners (Benton et al., 2014). D4D is a participatory design framework, meaning that users are actively involved through the design process. The D4D is a highly tailored methodology that incorporates the child's unique hobbies and interests, ability level, and schedule. It also considers disorder specific considerations, such as a quiet and familiar environment, consistent session structure, and visual schedule for autistic children. Although initially designed for autistic children and dyslexic children, Benton et al. provided explicit instructions on how to adapt the D4D framework for other neurodiverse populations, a challenge taken up by Fekete and Lucero (2019) when they modified the framework for children with ADHD. Fekete and Lucero emphasized that the workshops should not feel like homework or an extra task to be carried out.

Although an application is not easily tailored to individual interests and needs, the D4D framework has relevant lessons. First, the population and culture must be well understood through the literature, taking care to reflect on how these unique strengths, preferences, and differences may impact design needs. Second, children became easily distracted from current activities with resources for previous activities. Just like researchers are advised to remove resources not applicable to the current activity from view, so too should the application take care to only show immediately applicable information. Third, through trial and error, Benton et al. found that the ideal activities should be short, focused, and achievable with tasks having explicit objectives and last no longer than ten minutes. Finally, the application should be customizable so the user feels a heightened sense of ownership. This reinforces findings by Powell et al. (2017; see Interventions for ADHD-Related Executive Function Regulation) and Demo (2017; see Executive Function Regulation Using Technology for Autism).

Interventions for ADHD-Related Executive Function Regulation

As discussed previously, mindfulness may be used to train executive functions. Poor emotional regulation is a hallmark of ADHD, and mindfulness trains the mind to accept thoughts, emotions, and feelings instead of being overwhelmed by them (Zylowska et al., 2009). Zylowska et al. trained participants in Mindful Awareness with weekly 2.5 hour long group sessions and daily at-home practice, using both walking and seated meditation. The meditation program is tailored for individuals with ADHD; relevant features for this project include shorter sessions compared to other similar programs (e.g., 10 minutes instead of 45), visual aids to explain mindful awareness, and a

loving-kindness meditation as people with ADHD are less likely to have healthy self-esteem. Difficulty sustaining attention is emphasized as being common but particularly difficult for people with ADHD.

Ecological momentary assessments (EMA) are used for self-reported moods, behavior, and attitudes in response to a trigger or set to a schedule. These assessments may be used to help emotional regulation in people with ADHD (Cibrian et al., 2021). Additionally, to mitigate ADHD symptoms, children should receive prompt positive feedback for immediate reinforcement (Rodríguez‐Pérez et al., 2019).

A meta-analysis of studies involving ADHD and music found that music similar to that used in video games was generally found to be beneficial for individuals with ADHD as it is designed to improve immersion and flow (Martin-Moratinos et al., 2023). Although people with ADHD have been found to struggle with procrastination, time management, organization, and prioritization (Cibrian et al., 2021), Dipeolu et al. (2015) found that individuals with ADHD can manage provided strict schedules and minimization of distractions.

In a study that evaluated the top ten ADHD apps on Google Play and Apple App Stores, existing apps were not found to fully meet user needs (Powell et al., 2017). Participants included both parents and guardians of children and young adults with ADHD as well as clinicians who work with children and young adults with ADHD. Each participant was presented with the ten apps and led through a guided interview discussion. Participants reported that it was important that the app be relatable (e.g., representative avatar), customizable, targeted to ADHD-related difficulties (e.g., daily routines), educational, culturally relevant, visually appealing, simple to use, and able to help the children with ADHD medication (e.g., monitoring symptoms related to medication, sending reminders to take medication).

A 2019 survey of applications on Google Play, Apple Store, and ADHD-related online magazines found a paucity of scientific support for applications, with only one application having one case study (Somma et al., 2019). Another survey was conducted in 2021 to evaluate technologies using virtual reality (VR), augmented reality (AR), and mixed reality (MR) used to diagnose and treat children with ADHD (Goharinejad et al., 2022). Of the reviewed studies, 93% reported that using VR/AR/MR were effective in meeting at least one study objective. This implies that, while there is an increasing appetite for scientific research in apps used to help manage ADHD, there is still room for additional work.

Relevant applications in the literature include the following:

- *Plan-It Commander*: This game is no longer available due to challenges when the team attempted to commercialize the game (HeartBeat Ventures, n.d.), so all information has been gleaned from the literature. Computer game designed for children with ADHD where the player asks children to solve problems with themes of time management, planning and organizing, and social skills (Cibrian et al., 2021). In a 20-week trial by Bul et al. (2016) with 182 children aged eight to ten years old with ADHD, children were randomly assigned to a game intervention group wherein they played *Plan-It Commander* up to 65 minutes

three times a week (group 1) or a crossover group (group 2). After ten weeks, the groups crossed over, i.e., group 1 stopped playing the game and group 2 started the game intervention . Both groups received their normal ADHD treatments during the course of the game. Parents of participants in both groups reported significantly greater improvements on time management, social skills, and working memory at the end of the respective game intervention.

- *ACTIVATE*: Group of six cognitive games targeting attention, working memory, and speed of information processing marketed for children with ADHD and/or ASD. In a study of 17 female students aged 6-12 at two international schools in Saudi Arabia, students played three 20 minute sessions per week in the classroom with significant improvement found in all three target areas at the end of the four month long course (Sinnari et al., 2018). In a single-blind trial of seventy children with ADHD aged 6-13 years old, Bikic et al. (2018) did not find a significant difference between the intervention group and the control group. However, unlike the study by Sinnari et al. (2018), this study was only eight weeks long. Also, the children were expected to use only the cognitive computer games at home instead of having dedicated time in the classroom.
- *foqus*: smartwatch app for adults with ADHD to develop mindfulness and self-regulation (Dibia, 2016). The app has three features: a Pomodoro timer that allows users to break tasks down into 25 minutes of work and 5 minute breaks, mindful meditation with visual and haptic (vibration) cues that informs users of their average heart rate before and after the meditation, and health tips adapted from a mental health foundation. Ten participants who reported struggling with sustaining attention were asked to use the Pomodoro and meditation features at least once over a seven day period, with 80% (n=8) of users self-reporting lowered stress after meditation sessions.

Executive Function Regulation Using Technology for Autism

The disparity between the social and medical models greatly affects apps designed for autistic individuals. Demo (2017) compares two autism app designs and the discourse around these apps, one that approaches autism through the medical model (Samsung's *Look at Me* launched in 2014 with Autism Speaks Canada) and the other through the neurodiversity model (Toca Boca's autism app bundle launched in April of 2015 for Autism Awareness Month).

Look at Me pairs a user with a parent who directs the user to mimic social norms, particularly regarding facial expressions (hence the name). Each aspect is directed by the app or by the parent who tracks the user through a dashboard. Gameplay is highly controlled and quest-based (i.e., not a sandbox style game). The purpose of the app is to train the autistic user out of unusual but harmless behaviors like avoiding eye contact or subdued facial expressions. Toca Boca apps, on the other hand, are designed for the general public, but have been popular with autistic users and their guardians since the initial release due to the open-ended play philosophy. An example app is the *Toca Boca Hair Salon*, which helps reduce anxiety around hair styles. Unlike *Look at Me* which provides stars for completing missions, Toca Boca relies on the user's curiosity and creativity to self-motivate.

Technology and Interventions for Substance Abuse Treatment

In a survey of licensed addiction counselors practicing in the United States, 74% of respondents reported recommending using a website or app to help patient recovery, despite the fact that most apps and websites have not been tested in changing addiction outcomes (Wray, 2022). Of the participants, 94% would definitely or probably recommend an app that had been tested in scientific studies and found to help users stay sober or reduce their substance abuse.

Neale and Bowen surveyed 20 users of the SURE recovery app and found users' first impressions, including trust and personal recommendations, strongly affected users' decision to select and install the app (2022). Engagement increased if the app made users feel positive.

Mindfulness therapy was used to improve executive functions in adolescents with substance use disorders (Alizadehgoradel et al., 2019). Although only one substance has been tested in this way (methamphetamine), the data are promising, and meditation can be easily incorporated into an app design. As cravings are associated with inhibitory control and working memory impairment, the findings may be extrapolated to other sources of executive function impairment.

Technology for Suicide Prevention

Suicide ideation and attempts are correlated with executive function impairment, so it stands to reason that apps designed to help users shift away from the goal of cessation and resist impulses to enact plans will also have implications to help users with cognitive flexibility and inhibitory control. In a 2017 review of mobile apps for suicide prevention, de la Torre et al. reviewed twenty apps in Google Play and Apple App Stores as well as six relevant papers, concluding that mobile health apps can help prevent suicide. Castillo-Sánchez et al. followed up two years later (2019). As in 2017, they looked for suicide prevention apps on Google Play and Apple App Stores, but four were no longer available and many of the apps were not updated after 2018. Castillo-Sánchez et al. found that, of the 16 apps reviewed, the US Department of Defense developed app *Virtual Hope Box* had the highest number of downloads and reviews, no in-app advertisements or purchase options, frequent updates, and avoids the word "suicide" which may be triggering to some users. (Note: this app is reviewed in Relevant Technology in Literature.)

A paper by Shand et al. (2013) identified by de la Torre et al. (2017) designed an evaluation for the effectiveness of a suicide prevention app for young Indigenous Australians. This app helps participants identify thoughts and feelings; regulate their emotions through several strategies such as mindfulness, acceptance, and self-soothing activities, e.g., going for a walk, spending time in nature, calling a friend; and identify values important to them and set small, achievable goals related to their values (e.g., kindness, compassion, courage). The author was unable to find this application for testing.

Commentary on Research

Owing to the plethora of disorders linked to executive function impairment, the author chose four disorders. ADHD and ASD were selected due to the connection to the author, who was recently screened for both. The university library website was used to find books and peer reviewed articles on the disorders, executive functions, and interventions used to treat those disorders. One difficulty encountered was that most of the research for ADHD and ASD is performed with children. Another difficulty was the lack of agreement with regards to the exact definition of executive functions. The author attempted to match each study's framework to the Miyake framework as best as possible. A third difficulty encountered was that many of the applications recommended in the literature were no longer available, so some applications that looked promising could not be used. Based on this research, there is a gap for programs that assist individuals who struggle with executive function regulation.

Methods, Planning, and Design Preparation

While planning the app, considerations were taken as to the state of the art, taking specific notice of features to avoid, features to include, and opportunities to improve current systems. Participants were recruited and surveyed using an online questionnaire, an application mentioned in the literature was reviewed, and an application used by the author was reviewed. Criteria were developed for an interface based on the user research, background research, and author's use.

User Research Questionnaire

A questionnaire was used to gain insight on current methods of executive function self-regulation. An online survey was used due to the time constraints of this project and as it allowed more participants from a wider variety of sources. The complete survey questions and results may be reviewed in Appendix A.

Sampling Method and Procedure

Convenience sampling was used to recruit participants for a questionnaire. Participants were recruited through social media, specifically, the neurodiversity subreddit (r/neurodiversity), autism subreddit (r/autism), Facebook, and a WhatsApp channel for computer science postgraduate students. Participant responses were collected for 17 days. Participants were eligible if they were older than 18.

Participant Consent and Eligibility

Ethical approval was obtained from the University Ethics Committee from Newcastle University prior to recruitment of participants. An online survey was posted using Google forms. No compensation was provided for participation. Before beginning the survey, participants read a brief summary of the survey and learned how their responses would be used. Participants were required to consent before starting the survey.

Participant Demographics

Participants (n=32) were fairly diverse in terms of age and nation of origin. Rather than providing an exact age, participants were asked to select an age range, 25% of whom were 19-25, 31% aged 26-34, 13% aged 35-44, and 19% aged 65-74. The other four

respondents were aged 55-64 (n=3) and 45-54 (n=1). Slightly more participants were female than male (n=17 and 15, respectively). No participants reported being gender fluid or nonbinary. Most of the respondents were from the USA or the UK (n=15 and 8, respectively). One participant declined to answer. The remaining nine respondents were from Asia. In terms of education, nearly all had some form of higher education as 47% of respondents had a bachelor's degree, and 41% reported having a master's degree. Two respondents had some secondary school, one had a high school diploma or equivalent, and one had a doctorate degree.

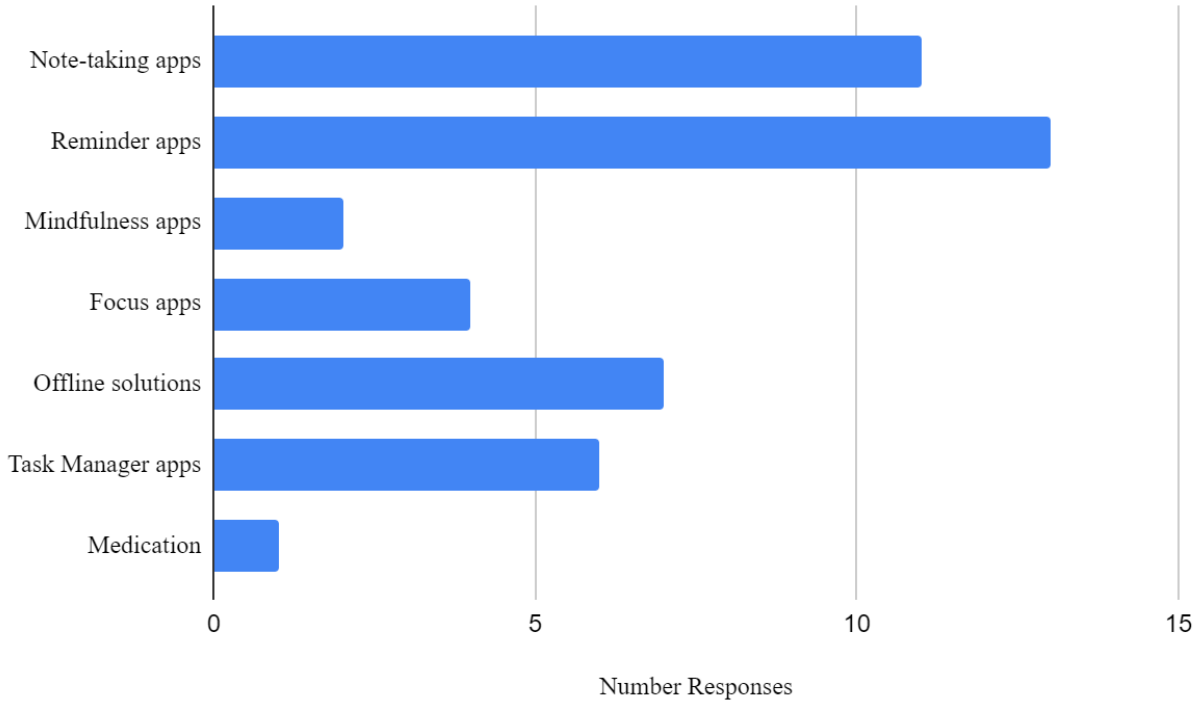
The five respondents who reported having a condition that affected executive functions had, on average, less education than the other respondents (average 14 years for condition group and 16 years for non-condition group). Both respondents who reported having some secondary school were in the condition group.

Participants Relationship to Executive Functions

The participants were next asked about their relation to executive functions. A brief summary on executive functions and executive dysfunction was given at the start of this section. Participants then read a short description of each executive function, and they were asked if they struggled with that function. Of the 32 respondents, 13 reported struggling with inhibitory control, 13 with working memory, and eight with cognitive flexibility. When asked if participants used any applications or habits to manage executive functions, 16 said yes, but 25 respondents answered the following question, "How do you manage your symptoms?" Note-taking apps and reminder apps were most reported to be used (n=17 and 15, respectively; Figure 1). Eight participants reported using offline solutions with a further two participants using paper lists and notes and one participant using medication.

As the purpose of the survey is to learn more about applications used to regulate executive function, the sixteen respondents who answered "No" to the question "Do you use any applications or habits to manage executive functions?" were quitted from the survey. The remaining sixteen respondents who answered "Yes" were instructed to identify one of the methods they use to regulate executive function, report which executive function is aided, frequency of use, efficacy, two features they like, and one feature they dislike. Three respondents used to-do lists, two used exercise, two used Google calendar reminders, one used background music, one used the focus mode on their phone and laptop, and one used meditation. Most of the methods aided inhibitory control and working memory (n=12 and ten, respectively), but three reported assistance with cognitive flexibility. Nine participants reported using their method multiple times per day, two said once per day, three said every few days, and one said a few times a month. On a scale of one to ten where one means the method is totally ineffective and ten is absolutely essential, both the average and most commonly reported efficacy reports were seven. Five respondents liked having features that gave them customized reminders and notifications, one of whom used the focus option to turn off all notifications. When asked about possible improvements, three said they wished the method had integrated reminders, and three reported a desire for their various methods (e.g., note-taking, reminders) to be integrated in one application.

Figure 1
Methods Used to Manage Symptoms



Note. This figure denotes the number of positive responses for each category of method.
[a]Answers are presented in the same order as the options given on the survey.
[b]Participants were allowed to write in their own answer, and this is the source for the answer "Medication".

Respondents with Conditions Affecting Executive Functions

Of particular interest for this project are features helpful for respondents with conditions that affect executive function. Five respondents reported relevant conditions, with four of those respondents having received a diagnosis (self-diagnoses are allowed for this survey). All five respondents reported using their method multiple times a day, four of whom used the method for inhibitory control, four for working memory, and two for cognitive flexibility. The most common responses were automated reminders and calendars. Participants felt a sense of relief when writing down tasks so they can focus on other things. They also like reminder features and color coding reminders. One participant recommended GoblinTools, which helps to deconstruct to-do lists into more fundamental steps. (For example, "Make a salad" becomes "gather ingredients, wash and chop vegetables, combine vegetables in a bowl, add dressing, toss salad to mix ingredients, and serve salad").

Relevant Technology

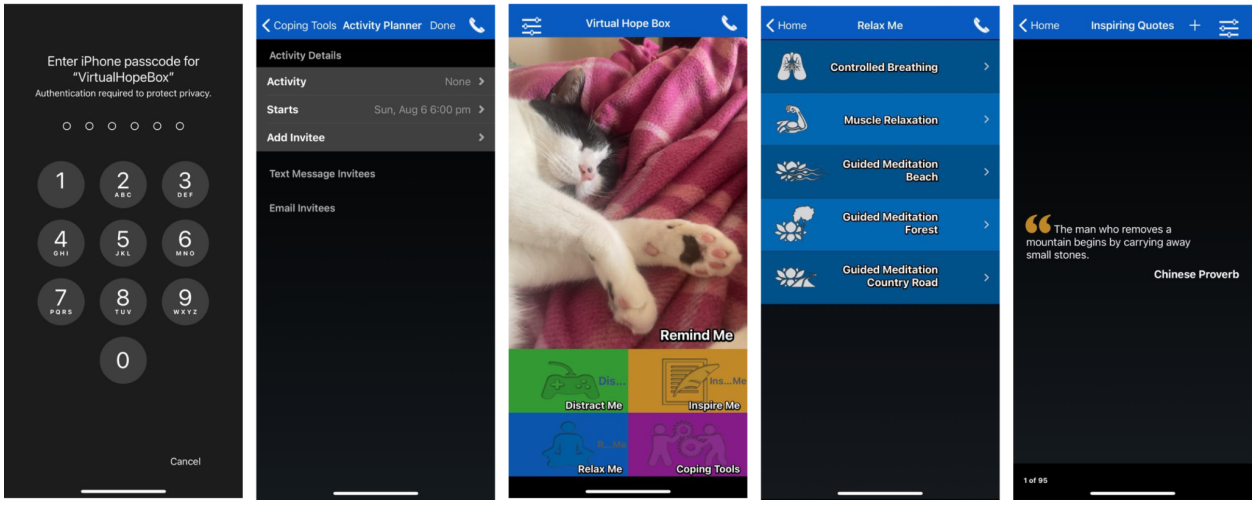
Relevant interventions are discussed in depth in Interventions for Executive Function Impairment. Relevant applications and programs specific to the disorders are discussed below.

Virtual Hope Box

The *Virtual Hope Box* as identified by Castillo-Sánchez et al. (2019) has many useful features for this project, including a lock screen to prevent unauthorized access, activity planner, user customization in the form of uploading meaningful images and videos, guided meditation, and inspirational quotes (Figure 2). It has a simple interface with relatively few features, so it is easy and intuitive to use. As it is primarily related to suicide prevention, however, it is not immediately applicable to many users struggling with executive function impairment.

Figure 2

Relevant Features From Virtual Hope Box



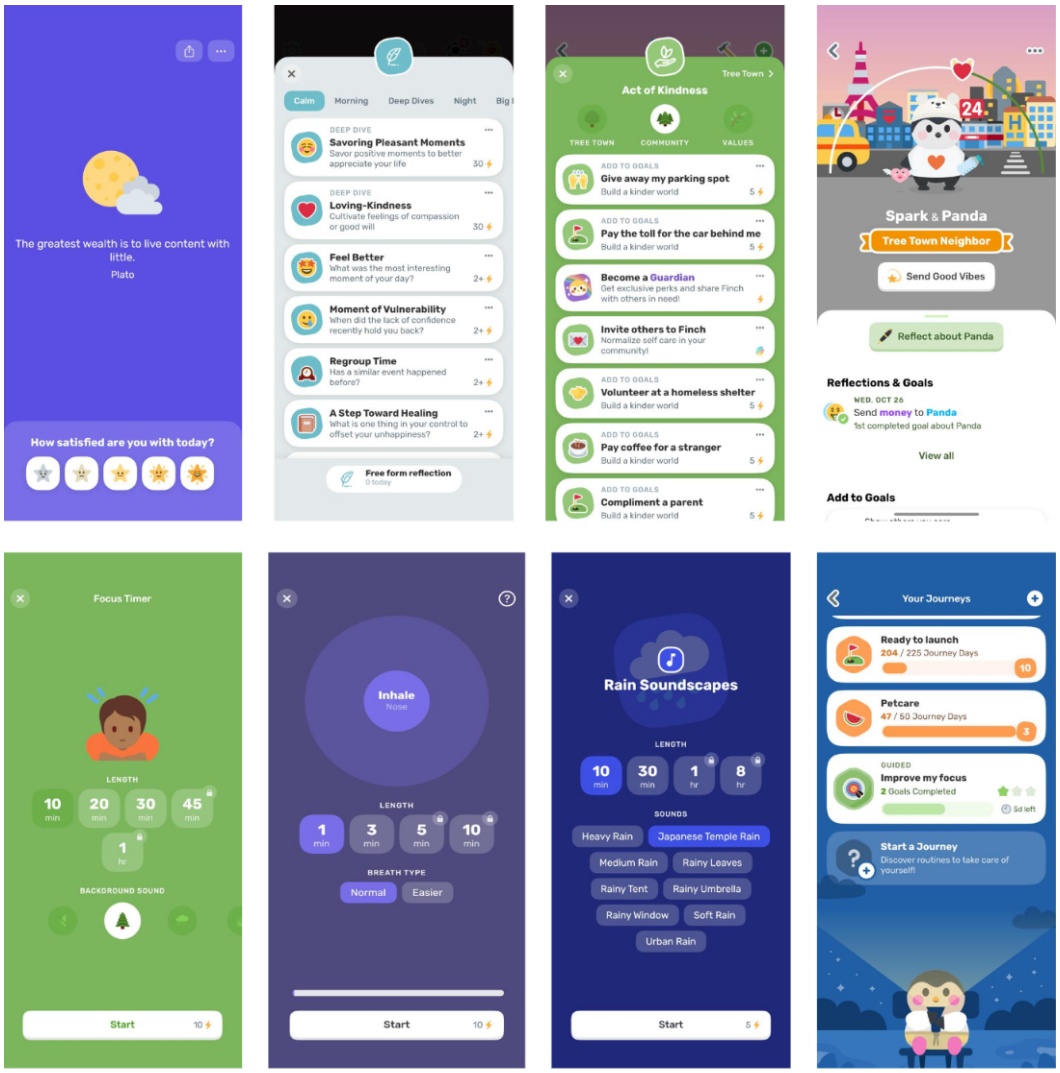
Note. This figure shows five valuable features from *Virtual Hope Box*: security feature, activity planner, user personalization with an uploaded photo, guided meditation, and inspirational quote.

Finch

Finch is a self care app to help people who struggle with stress, mental health, or lack of motivation. By completing quick self care exercises, the pet grows. Users are encouraged to set "journeys" which are suites of goals tailored towards improvement (e.g., mindfulness, gratitude, relationships, work-life balance, confidence, active lifestyle). *Finch* is intended for potential users struggling with anxiety and/or depression. Neurodivergent users can also benefit with easy and clear goal-setting for tidiness, nutrition, hygiene, and overall wellness. The author frequently uses *Finch* to ameliorate and mitigate symptoms of executive function impairment related to ASD. It has many useful features such as journaling, mood check-ins, focus timer, meditation timers, suites of goals called "journeys", soundscapes, and friend features (Figure 3).

Figure 3

Relevant Features From Finch

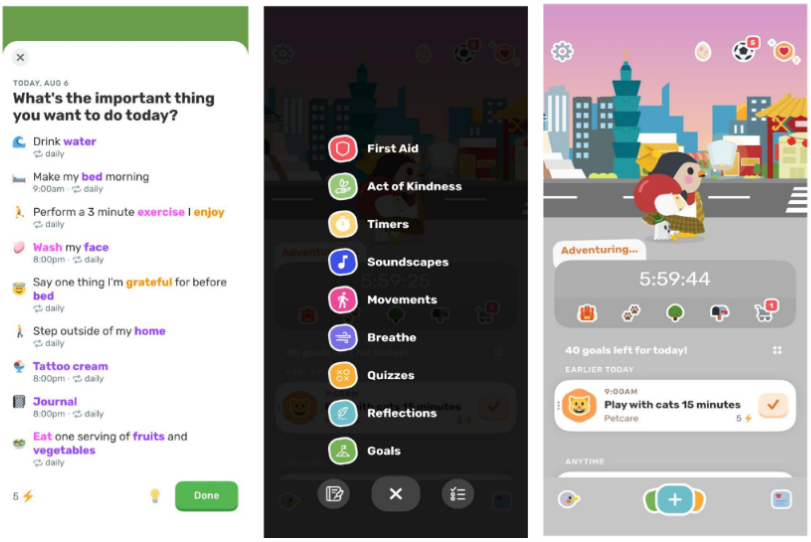


Note. This figure shows eight valuable features from *Finch*: mood check-in, journal prompts, suggestions of acts of kindness for the community, friend features, focus timer, timed breathing exercises, soundscapes, and goal journeys.

Despite *Finch*'s many beneficial features, in a cooperative evaluation using think aloud protocol, three tested users were frustrated that "Add My Own Goal" was suggested after one and a half pages of automatically generated goal suggestions. Also, although the interface is aesthetically pleasing, it was too complex for some users who found the layout unintuitive. Additionally, journal entries may not be viewed after submission.

Figure 4

Problematic Features From Finch



Note. This figure shows three problematic features from Finch. The first shows the list of goals, the second shows the extensive options available, and the third shows the layout.
[a]The first image shows the first of four pages of goals to scroll through before being able to add one's own goal.
[b]The third shows the intuitive layout. Users complained that the middle row below the timer did not look like usable icons.

ToDoist

ToDoist is a popular application for managing to-do lists. Of particular use was the prioritization feature wherein users may set the priority for a particular task.

Design Notes

This section is a brief summary of insights gleaned from the background research (Interventions for Executive Function Impairment) and from user research (User Research Questionnaire). Applications should:

- be relatable.
- be customizable.
- target specific problems experienced by the community in question.
- allow room for user creativity.
- promote mindfulness, self-acceptance, and user values.
- avoid triggering words like "suicide".
- only show immediately relevant information.
- provide short, focused, and achievable tasks.

- explicitly state task objectives and methodology.

Desirable Features

The following features were found to be advantageous per questionnaire participant feedback, studies, and author use.

- The application should incorporate moderate aerobic exercise with integrated mindfulness as Diamond & Lee (2011) found that taekwondo and yoga helped with EFs.
- Meditation for inhibitory control; Sessions should have options for 5, 10, and 15 minutes following Zylowska et al. (2009).
- Opportunities for connection as cognitive reserves may be strained during times of loneliness, leading to reduced executive functions (Diamond, 2013).
- Focus session with optional music similar to video games
- Make to-do lists with color coding options and capacity to automatically add appointments into Google Calendar and other similar applications; this was noted to be advantageous by questionnaire respondents.
- Schedules and distraction minimization can help people with ADHD in the workplace (Dipeolu et al., 2015).
- EMA: mood check-ins (Cibrian et al., 2021).
- For greater usability for dyslexic users, a search bar with auto-complete, tolerance of spelling errors, and case insensitivity should be used (Kennecke et al., 2022).
- According to user research, applications should integrate with other applications, have customizable levels of notifications, allow phone notifications to be turned off, and have note-taking and reminder capabilities.

Heuristics Considered During Design Process

Chaparro et al. (2016) used two heuristic evaluations to evaluate a neurobehavioral assessment application. Due to the similarity in applications, those same evaluations will be used to guide the design process.

Nielsen's Modified by Budd

Nielsen's heuristics are a cornerstone in HCI, but are not fully updated for the modern web, so Budd modified and updated the heuristics (Sharp et al., 2019, pp.553–554). Key points are clarity of language and iconography, simplicity in design and flow processes, context for information presented and feedback messages, and an attractive design. As the application is intended for users who may be experiencing executive function impairment, clarity and simplicity were of greater priority. These will be explored in more depth in Evaluation.

Mobile Interface Evaluation

Just as Budd modified the heuristics for the developing web, so too did Yáñez Gómez et al. innovate an evaluation for mobile applications as they have different design requirements (2014). The evaluation is a best-practices checklist to ensure usability. The checklist will be used in Evaluation, but key design features highlighted by the checklist used in the design process include using user recognition rather than recall, reduced number of items in menus to avoid memory overload, clear language, ability to move forward and backwards, and some personalization.

Design Requirements

Pursuant to the user research and findings from the literature, functional and nonfunctional requirements were outlined for the purposes of the application interface. The requirements outline what the interface is expected to do, and the priorities of those expectations.

Functional Requirements

The following functional requirements were developed to guide the design process.

Table 2
Functional Requirements for Application

No.	Description	Justification	Priority
FR-1	Unauthorized users may not access user information.	Journal entries should be entered without fear of someone else reading the personal information.	H
FR-2	Users can track their mood on logging in.	EMAs may be used to help emotional regulation (Cibrian et al., 2021).	M
FR-3	Users can track their mood over time.	When experiencing a low mood point, it can be difficult to recognize that moods are cyclical and that the low point will end.	M
FR-4	Users may upload media such as photos and videos.	Customizing the application will help the users feel a greater sense of ownership (Demo, 2017; Powell et al., 2017)	M
FR-5	Users may maintain a journal to record their thoughts, feelings, hopes, and fears.	Journaling may help manage mental illness (Sohal et al., 2022).	H

FR-6	Users may add friends.	Executive functions may be impaired during times of loneliness (Diamond, 2013).	L
FR-7	Users may send messages to app friends with predetermined messages.	Executive functions may be impaired during times of loneliness (Diamond, 2013).	L
FR-8	Users may customize notifications.	Schedules and distraction minimization can help people with ADHD in the workplace (Dipeolu et al., 2015).	M
FR-9	Users may write letters to themselves to be opened during difficult times.	When users are undergoing a mental health crisis, they need personalized encouragement.	H
FR-10	Users may meditate while listening to soundscapes, music, or silence.	Mindfulness has been shown to positively impact people across multiple demographics (Diamond & Lee, 2011; Huang et al., 2020; Geronimi et al., 2019; Black et al., 2011; Zylowska et al., 2009; Alizadehgoradel et al., 2019; Shand et al., 2013).	H
FR-11	Users may add goals.	Goals can help users focus on long-term planning and improve overall quality of life.	H
FR-12	Users may create suites of goals (journeys) to focus on particular long-term goals.	Goals can help users focus on long-term planning and improve overall quality of life.	M
FR-13	Application will assist users invite friends to an activity.	Executive functions may be impaired during times of loneliness (Diamond, 2013).	M
FR-14	Users may set priority levels for goals and for reminders.	The ability to filter goals and reminders will help users streamline their search and focus their energies on the highest priority tasks. This is particularly important when users are in a mental health struggle.	M
FR-15	Users may use a search function to find pages instead of navigating the	For greater usability for dyslexic users, a search bar with	M

	menu.	auto-complete, tolerance of spelling errors, and case insensitivity should be used (Kennecke et al., 2022).	
FR-16	Users may exercise with a mindfulness guidance audio track.	Lack of exercise has been shown to negatively impact executive functions (Diamond, 2013). Aerobic exercise has been shown to improve executive functions in children with ADHD (Jiang et al., 2022; Becker et al., 2018) and adults with mild to moderate Alzheimer's Disease (Yu et al., 2018). Exercise with mindfulness has been shown to help children (Diamond & Lee, 2011).	M
FR-17	Users may customize the application.	Customizing the application will help the users feel a greater sense of ownership (Demo, 2017; Powell et al., 2017)	M

Note. This table demonstrates the functional requirements of the application interface. Generally speaking, the functional requirements say what the application is meant to do.
[a]There are three levels of priority: High (H), Medium (M), and Low (L).

Nonfunctional Requirements

The following functional requirements were developed to guide the design process.

Table 3
Nonfunctional Requirements for Application

No.	Description	Justification	Priority
NFR-1	The application should be accessible to users with disabilities, including vision impairment, color blindness, and dyslexia.	Mental health should be accessible to everyone.	H
NFR-2	The user interface should allow users to move forward and backwards.	Yáñez Gómez et al., 2014 Heuristic #17	H
NFR-3	Users may block other users.	Even if only positive messages are allowed, the potential for abusers to harass their victims should not be overlooked.	H

NFR-4	Users may choose to record voice notes or write journal entries	Users who are visually impaired may benefit from the ability to quickly and easily record audio. Other users, particularly those who are hard of hearing, would benefit from being able to write.	M
NFR-5	When mood >3 on check-in, users are allowed to write a letter or record a voice note to their future selves.	When users are undergoing a mental health crisis, they need personalized encouragement.	H
NFR-6	When mood=1 on check-in, users are allowed to read/listen to encouraging notes from themselves.	When users are undergoing a mental health crisis, they need personalized encouragement.	H
NFR-7	Users may listen to soundscapes.	Soundscapes are pleasing to the ear and nonintrusive, allowing for greater focus.	H
NFR-8	Users may add sounds for use in meditation and focus	Customizing the application will help the users feel a greater sense of ownership (Demo, 2017; Powell et al., 2017)	M
NFR-9	Where possible, user submitted photos will be displayed.	Customizing the application will help the users feel a greater sense of ownership (Demo, 2017; Powell et al., 2017)	L
NFR-10	Menus for navigation are limited to four items.	Too many options will overwhelm the user.	H
NFR-11	If options may be expanded, menu labels will clearly indicate so.	Users must be able to recognize touchable targets.	M
NFR-12	Target size for icons and options are at least 1 cm x 1 cm to prevent fat-finger syndrome.	Yáñez Gómez et al., 2014 Heuristic #23	M
NFR-13	When options are presented in a column of rows, users may select anywhere in a given row to move to the next screen.	Yáñez Gómez et al., 2014 Heuristic #26	M
NFR-14	Images must not be larger than the viewable area.	Yáñez Gómez et al., 2014 Heuristic #42	M

NFR-15	Icons must be easily distinguishable and recognizable.	Nielsen's/Budd's Clarity: Use meaningful icons	H
NFR-16	All information on the screen should be immediately usable.	Yáñez Gómez et al., 2014 Heuristic #30	H
NFR-17	Each page should be labeled.	Nielsen's/Budd's Provide Users with Context: Highlight the current section in the navigation.	M
NFR-18	Navigation options will be presented consistently (e.g., x's always in the upper left, confirm in the lower right).	Inconsistent navigation confuses the users.	H
NFR-19	Users are prompted to confirm commands with destructive consequences (e.g., deleting files).	Prevent accidental activation.	H
NFR-20	In a menu, exit always appears at the bottom.	Inconsistent navigation confuses the users.	M
NFR-21	In a menu, titles are either centered or left-justified.	Inconsistent display confuses the users.	M
NFR-22	User actions are named consistently across prompts.	Inconsistent navigation confuses the users.	H
NFR-23	Each individual icon is in a similar style to the rest of the icons.	Inconsistent display confuses the users.	H
NFR-24	All explanations are to be written clearly and concisely to be understood by the lay person.	Nielsen's/Budd's Clarity: Write clear, concise copy.	H
NFR-25	The search function should allow auto-complete.	For greater usability for dyslexic users, a search bar with auto-complete, tolerance of spelling errors, and case insensitivity should be used (Kennecke et al., 2022).	M
NFR-26	The search function should be tolerant of spelling errors.	For greater usability for dyslexic users, a search bar with auto-complete, tolerance of spelling errors, and case insensitivity should be used (Kennecke et al., 2022).	M

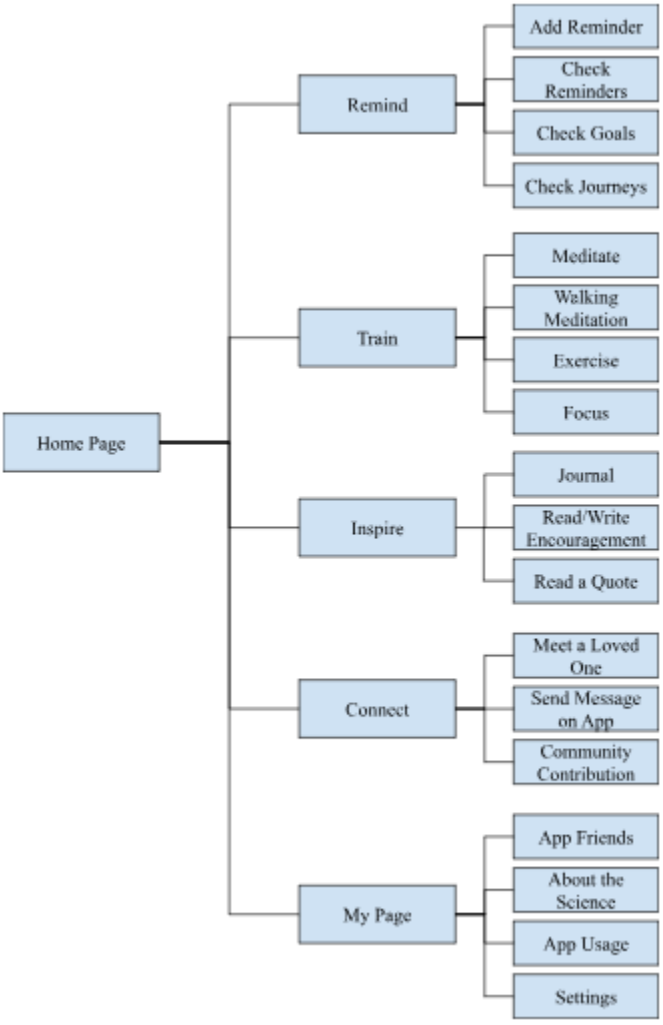
NFR-27	The search function should not be case sensitive.	For greater usability for dyslexic users, a search bar with auto-complete, tolerance of spelling errors, and case insensitivity should be used (Kennecke et al., 2022).	M
NFR-28	Colors should be distinguishable to colorblind users.	Mental health should be accessible to everyone.	H
NFR-29	All icons should be accompanied with text for screen readers.	Mental health should be accessible to everyone. Screen readers are used by some visually impaired individuals.	H

Note. This table demonstrates the nonfunctional requirements of the application interface. Generally speaking, the nonfunctional requirements dictate how the application executes the requirements.
[a]There are three levels of priority: High (H), Medium (M), and Low (L).

Site Map

A site map was generated to map out the application features (Figure 5).

Figure 5
CogniGuide *Site Map*



Results and Evaluation

Name

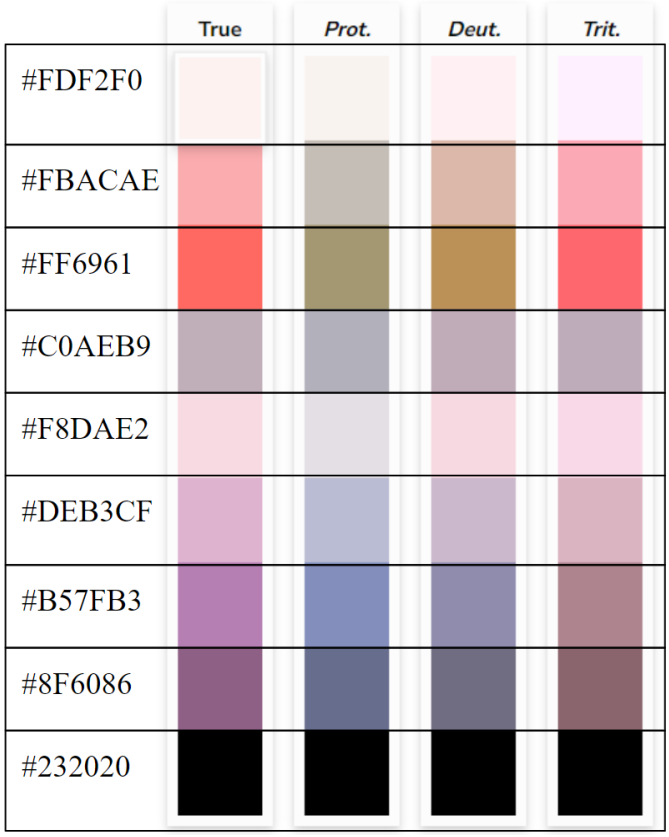
The application was named *CogniGuide* to evoke cognition (Cogni-) and a feeling of friendliness (guide). The portmanteau makes clear the app is intended to gently guide the user's cognition.

Color Considerations

A pink color palette was chosen for its aesthetic value with care being taken that all colors used are distinguishable by colorblind users (Figure 6). The colors used in the alternative color schemes offered were chosen from the 2014 Material Design color palettes developed by Google (Google, 2018).

Figure 6

Color Palette as Seen by Colorblind Users



Note. The true column shows the true colors used by the application design, Prot.shows as users with protanopia would see the colors, Deut. as users with Deuteranopia, and Trit. as users with tritanopia would see the colors. Created using "Coloring for Colorblindness" by D. Nichols (n.d.).

Design

On many pages of the application, a photo of pink hydrangeas is visible. In the pink view of *CogniGuide*, this is the default image. However, once users upload their own images, those images will be used instead of the default. An example of this may be seen in the home screen, which uses a photo of kittens.

User Landing

Upon opening the app, the user is instructed to enter the password for their phone to prevent unauthorized access; this is similar to *Virtual Hope Box* (Figure 2). After entering the password, the user is greeted with a motivational quote and a mood check-in, similar to *Finch* (Figure 3; Cibrian et al., 2021). The user then enters the home page, from where they may access any part of the application (Figure 7). Each of the pages may be accessed by the text label, image, or through the icon bar at the bottom. The user-submitted photo (in this case, kittens) may also be used to access the My CogniGuide. The user may also use the search bar to go directly to the desired destination.

Figure 7

Initiating CogniGuide

Note. Users must enter their phone password and do a mood check-in before accessing the application. The home screen contains links to five other pages (reminders, training, inspiration, connection, and my page) as well as a search bar.

My Page

Once entering "My CogniGuide", users have four choices (Figure 8). First, they may read a brief summary of their usage of the application. They can also view their uploaded media (e.g., soundscapes, photos) and a mood trend graph. Second, the user may view their friends on the app, send a friend a message, or write a reflection about the friend. Third, users may change their options for themes and notifications. Users may choose between a pink, green, orange, or blue theme. Alternatively, they can choose a simple mode, which is either white text on a black screen or black text on a white screen. Simple mode is a text-only version with large print for users who are visually impaired. Additionally, users may choose to receive reminders in the morning, evening, and/or at a custom time. They may also choose to receive notifications if a friend request is received and/or accepted. Finally, users may choose to learn more about the science of *CogniGuide*. Brief overviews of executive functions, executive function impairments, and executive function improvement methods have been written using friendly levels of English.

Figure 8
Options in My CogniGuide

Note. My CogniGuide allows the user to personalize their experience with their friendships, notifications, display, and by learning more about executive functions.

Inspiration

Users may see one of three pages upon entering the inspiration landing page, depending on their mood at check-in. If their mood is high (4 or 5 out of 5), users may write a letter or record an audio message to read at a later date. These letters may only be viewed if their mood is low (1 out of 5). At this point, users may elect to either read or listen to one of these supportive messages.

At any mood level, users may elect to write in or visit past entries in their journal. If they so desire, they may respond to a randomly selected prompt, or they can write without a prompt. For both, they may elect to write or to record a voice message. The journal entries could be of personal significance (e.g., reflecting on moments of triumph, vulnerability, hope) or they could be a note (e.g., shopping list). Users may write a title for their entry but are not required to do so. Finally, users may read an inspirational quote. They may also choose to add a quote with personal significance, if they so desire.

Notes are one of the two most commonly used features to aid executive functions among the adults surveyed for the questionnaire (User Research Questionnaire).

Training

The bulk of evidence-based interventions for executive function regulation are located in the training page. Users may choose between traditional guided meditation, walking meditation, exercise with mindfulness, and a focus timer (Figure 9). While exploring meditation, users may opt to lock their phone to prevent them from becoming distracted by other apps (Nadeau, 2015), enable a timer, and/or listen to guidance. Similar to Zylowska et al. (2009), the guidance is tailored for individuals who struggle with executive function by using shorter durations and a kindness-focused presentation. The fact that sustaining attention is difficult will be highlighted during the guidance. Listeners may also choose between a soundscape, focus music similar to video game music (Martin-Moratinos et al., 2023), or one of the sounds they had previously uploaded. Once beginning meditation, users are encouraged to match their breathing to a waxing and waning circle.

The walking meditation has the same options as traditional (i.e., phone lock, timer, guidance, soundscape, focus music, my sounds), but uses augmented reality to help the user focus (Goharinejad et al., 2022). The user must find an open space clear of obstacles. *CogniGuide* displays a line down the center of the screen. The user must keep a circle centered on the line for the duration of the walking meditation (Figure 9).

Figure 9
Walking Meditation Using Augmented Reality

Note. The user is instructed to find an open area in which to practice walking meditation, and they must focus on keeping the circle centered on the line.

Exercise has been shown to improve executive functions (Diamond & Lee, 2011; Jiang et al., 2022; Becker et al., 2018; Yu et al., 2018). Martial arts and yoga have some evidence of improving executive functions, likely because they combine exercise with mindfulness (Diamond & Lee 2011). Thus, *CogniGuide* provides options to exercise with reminders of mindfulness. Users may choose between a guided walk, jog, or bike ride; apartment friendly aerobics; beginner friendly aerobics; or seated aerobics (for users with limited mobility). Users may also choose to play focus music.

Finally, users may elect to use a focus timer for either 5, 10, 25, or a custom number of minutes. Adults with ADHD often struggle with time management (Cibrian et al., 2021). The popular Pomodoro focus method recommends 25 minutes of focus with a five minute break (Dibia, 2016). While using the focus timer, users may choose to listen to a soundscape, focus music, an uploaded sound, or silence.

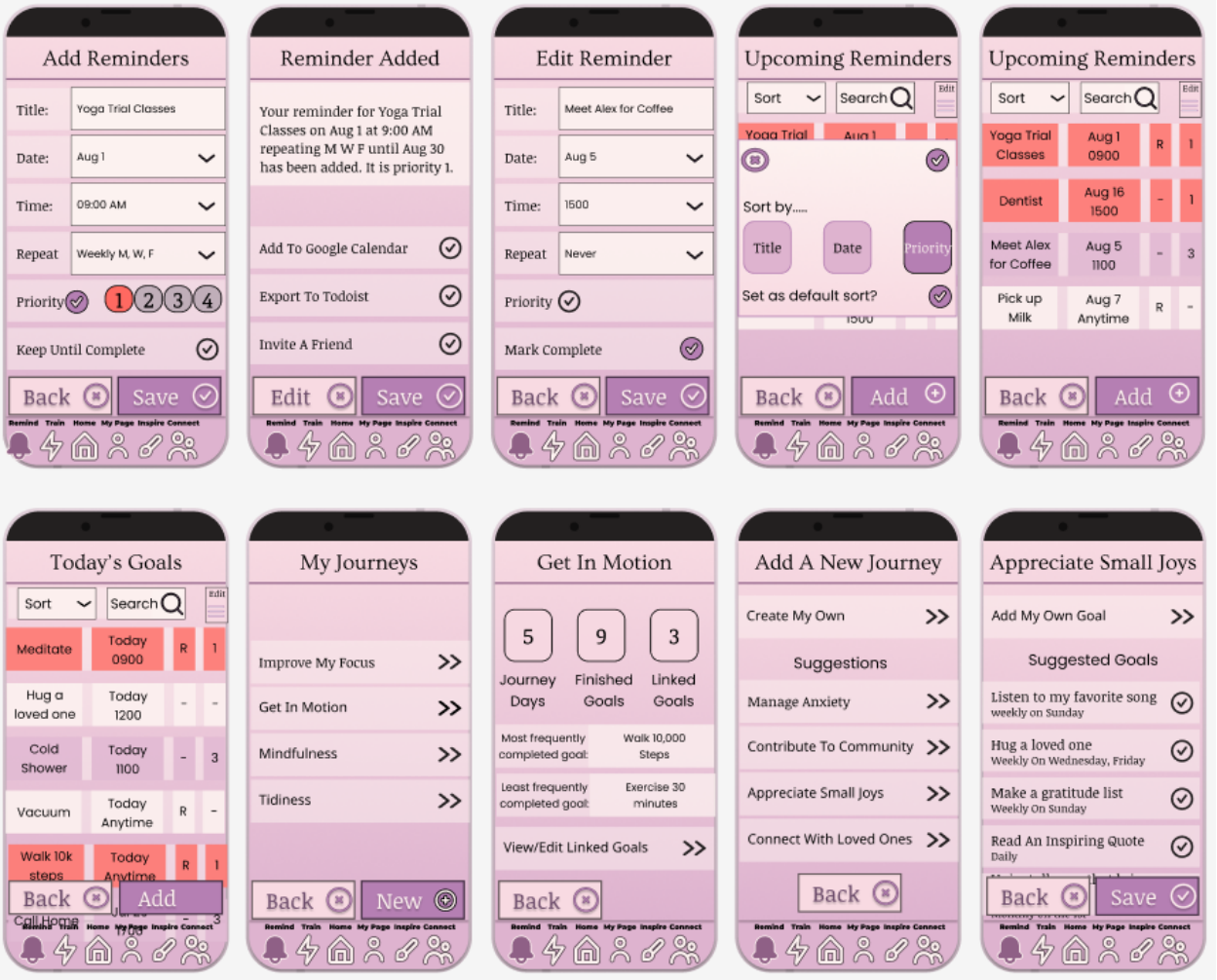
Reminders

Reminders are one of the two most commonly used features to aid executive functions among the adults surveyed for the questionnaire (User Research Questionnaire). Users may add reminders, goals, and goal journeys from the Reminder page (Figure 10). Reminders must have a title and date, and users may opt to include a time, repeat on a daily, weekly, monthly, or yearly basis, priority level (1-4), and to keep the reminder until it is complete or let it expire at the end of the day. Users may choose to see upcoming, past due, completed, or all reminders. If a priority level has been set, the reminders are color coded so users may see at a glance how many high priority tasks are left for the day. Users may sort the reminders by title, date, or priority. Users may also edit the reminder to mark it complete.

Users may also check goals and choose to add them to a journey (suite of goals). When adding goals, users must enter a title and a date. Users may choose to associate it with a journey, repeat the goal on a daily, weekly, monthly, or yearly basis, set a priority level (1-4) and to keep the reminder until it is complete or let it expire at the end of the day. Users may set long term goals with journeys and link goals to the journey. Users may select a suggested journey, or they may create their own. Users may elect to add suggested goals to their journey, or they may create their own goals.

Figure 10

Reminder Options



Note. Options available under the remind menu: add, edit, and sort reminders; goals; and viewing and adding journeys.

Connection

Users may use this page to connect with loved ones. Executive functions may be impaired during times of stress and loneliness (Diamond, 2013). *CogniGuide* provides a template for users to invite their loved ones to an activity (Figure 11), similar to *Virtual Hope Box* (Figure 2). Users may also send a message of kindness to a friend on

CogniGuide, similar to *Finch* (Figure 3). Unlike *Finch*, users may choose to send a message to a stranger who is having a difficult day (difficult day defined as having mood level 1 or 2 at check in; Figure 11). Finally, users are given ideas to give back to their community, and they are prompted to add their own ideas (Figure 11).

Figure 11

Connection Opportunities

Note. Select options under the Connect menu: assistance in planning an activity, sending a message of kindness, and ideas for community contributions.

Evaluation

In this section, *CogniGuide*'s design will be evaluated against the design notes from the literature and user research (Design Notes), desirable features (Desirable Features), the functional and nonfunctional requirements (Design Requirements), Nielsen's heuristics as modified by Budd and presented by Sharp et al. (2019, pp. 553-554), and heuristics developed for a mobile interface that prioritizes usability (Yáñez Gómez et al., 2014).

Cooperative Evaluation

Four users were asked to complete four tasks using *CogniGuide*'s Figma prototype. They were asked to change the display theme to one of their choice, to add a reminder, read a motivational quote, and to try a meditation exercise. One user was a male American software engineer (65 years of age) and the other three were MSC Computer Science students at Newcastle University. One student was a British man in his mid 30s, one student was a young Indian man in his mid 20s, and the final student was a woman from Hong Kong (late 20s). All reported that the structure of the application was easy to follow, but some of the design was a bit confusing. For example, the older user struggled with the popups and suggested making the background a bit translucent to highlight the attention appropriately. The youngest test participant said the process was

"straightforward", but that having multiple options to get to the same place on the home screen was "redundant".

Evaluating CogniGuide *Against Design Notes*

According to the findings from the background research and from user research, *CogniGuide* should follow some design notes identified previously. Of the nine design notes, six were fully implemented, two were partially implemented, and one was implemented (Table 4).

Table 4
Success in Implementing Design Notes

Design Note	Success	Explanation
CogniGuide should be relatable.	1	*CogniGuide* does not use avatars, so a representative avatar was not implemented
CogniGuide should be customizable.	3	Users may upload photos to personalize the application, and they may choose between six display versions. Users may also upload their own music and sounds.
CogniGuide should target specific problems experienced by the community in question.	2	*CogniGuide* seeks to help all adults who experience executive function impairment, so this is nearly every adult alive. *CogniGuide* does attempt to cater to individuals with lower cognitive reserves, but it is impossible to target specific problems to such a vast community.
CogniGuide should allow room for user creativity	2	*CogniGuide* allows users to write journals and express themselves verbally. However, there are not at present features that allow expression through drawing. This is a consideration for further work (Conclusion).
CogniGuide should promote mindfulness, self-acceptance, and user values.	3	*CogniGuide* has guided mindfulness. *CogniGuide*'s journal prompts are geared towards promoting self-acceptance. Through the Community feature, *CogniGuide* users are invited to contribute to causes important to them.

CogniGuide should avoid triggering words like “suicide”.	3	*CogniGuide* does not use terminology relating to self-harm.
CogniGuide should only show immediately relevant information.	3	All displayed information is immediately relevant to the task on the page.
CogniGuide should provide short, focused, and achievable tasks.	3	By default, *CogniGuide* recommends short timed tasks for meditation and exercise.
CogniGuide should explicitly state task objectives and methodology.	3	*CogniGuide* uses clear and succinct copy to guide users through tasks.

Note. The table shows the design notes from the methods section and how well each note was utilized in *CogniGuide*. The success is rated on a scale of 1-3 where 1 is totally absent, 2 is mixed success, and 3 is implementation.

Evaluating* CogniGuide *Against Desirable Features

According to the findings from the background research and from user research, *CogniGuide* should include some desirable features identified previously. All features were, at the very least, partially implemented (Table 5). Of the 12 features, seven were fully implemented and five were partially implemented.

Table 5

Success in Implementing Desirable Features

Desirable feature	Success	Explanation
Moderate aerobic exercise with integrated mindfulness	3	This feature was wholly incorporated with variations of aerobics offered.
Meditation	3	This feature was wholly incorporated with variations of meditation offered.
Opportunities for connection	2	Only predetermined messages may be set, limiting the opportunities for both abuse and connection.
Focus session with optional music similar to video games	3	This feature was wholly incorporated with multiple sound options.

To-Do lists with color coding and integration with other applications	3	This was wholly incorporated.
Schedules and distraction minimization	2	Although *CogniGuide* cannot provide personalized schedules, users may set focus timers with other applications locked, minimizing distractions and allowing concentration
EMA: mood check-ins	3	Users are asked to check their mood levels upon opening the application
Search bar	2	A search bar was incorporated into only the home page.
According to user research, applications should integrate with other applications.	2	Users may export reminders from *CogniGuide* to Google Calendar and to ToDoist, but there are no options to import reminders or goals. Applications outside Calendar and ToDoist are not supported at this time.
According to user research, applications should have customizable levels of notifications.	2	Users may opt to receive check-in reminders and friend-related reminders, or to turn off notifications entirely. There are no options to set multiple notifications for one reminder or goal.
According to user research, applications should allow phone notifications to be turned off.	3	This feature is allowed.
According to user research, applications should have note-taking and reminder capabilities.	3	This feature was incorporated.

Note. The table shows the desirable features from the methods section and how well each feature was utilized in *CogniGuide*.
[a]The success is rated on a scale of 1-3 where 1 is totally absent, 2 is mixed success, and 3 is implementation.

Functional Requirements Compliance

CogniGuide is evaluated against the functional requirements developed in methods. All 17 functional requirements were at least partially achieved, with 15 fully achieved (Table 6). The two partially achieved requirements were of medium

prioritization: FR-8 and FR-15. FR-8 (users may customize notifications) was partially accomplished as users may opt to receive check-in reminders and friend-related reminders, or to turn off notifications entirely. However, there are no options to set multiple notifications for one reminder or goal. FR-15 (Users may use a search function to find pages instead of navigating the menu) was partially achieved as a search bar was only incorporated into the home page. FR-16 (Users may customize the application) was achieved as users may upload photos to personalize the application, and they may choose between six display versions. Users may also upload their own music and sounds.

Table 6

Implementation Success of Functional Requirements for Application

No.	Description	Priority	Success
FR-1	Unauthorized users may not access user information.	H	3
FR-2	Users can track their mood on logging in.	M	3
FR-3	Users can track their mood over time.	M	3
FR-4	Users may upload media such as photos and videos.	M	3
FR-5	Users may maintain a journal to record their thoughts, feelings, hopes, and fears.	H	3
FR-6	Users may add friends.	L	3
FR-7	Users may send messages to app friends with predetermined messages.	L	3
FR-8	Users may customize notifications.	M	2
FR-9	Users may write letters to themselves to be opened during difficult times.	H	3
FR-10	Users may meditate while listening to soundscapes, music, or silence.	H	3
FR-11	Users may add goals.	H	3
FR-12	Users may create suites of goals (journeys) to focus on particular long-term goals.	M	3
FR-13	Application will assist users invite friends to an activity.	M	3
FR-14	Users may set priority levels for goals and for reminders.	M	3
FR-15	Users may use a search function to find pages instead of navigating the menu.	M	2

FR-16	Users may exercise with a mindfulness guidance audio track.	M	3
FR-17	Users may customize the application.	M	3

Note. This table demonstrates the functional requirements of the application interface. Generally speaking, the functional requirements say what the application is meant to do.
[a]There are three levels of priority: High (H), Medium (M), and Low (L).

Nonfunctional Requirements Compliance

All 29 nonfunctional requirements were fully implemented successfully (Table 7).

Table 7
Implementation Success of Nonfunctional Requirements for Application

No.	Description	Priority	Success
NFR-1	The application should be accessible to users with disabilities, including vision impairment, color blindness, and dyslexia.	H	3
NFR-2	The user interface should allow users to move forward and backwards.	H	3
NFR-3	Users may block other users.	H	
NFR-4	Users may choose to record voice notes or write journal entries	M	3
NFR-5	When mood >3 on check-in, users are allowed to write a letter or record a voice note to their future selves.	H	3
NFR-6	When mood=1 on check-in, users are allowed to read/listen to encouraging notes from themselves.	H	3
NFR-7	Users may listen to soundscapes.	H	3
NFR-8	Users may add sounds for use in meditation and focus	M	3
NFR-9	Where possible, user submitted photos will be displayed.	L	3
NFR-10	Menus for navigation are limited to four items.	H	3
NFR-11	If options may be expanded, menu labels will clearly indicate so.	M	3
NFR-12	Target size for icons and options are at least 1 cm x 1 cm to prevent fat-finger syndrome.	M	3
NFR-13	When options are presented in a column of rows, users may select anywhere in a given row to move to the next screen.	M	3

NFR-14	Images must not be larger than the viewable area.	M	3
NFR-15	Icons must be easily distinguishable and recognizable.	H	3
NFR-16	All information on the screen should be immediately usable.	H	3
NFR-17	Each page should be labeled.	M	3
NFR-18	Navigation options will be presented consistently (e.g., x's always in the upper left, confirm in the lower right).	H	3
NFR-19	Users are prompted to confirm commands with destructive consequences (e.g., deleting files).	H	3
NFR-20	In a menu, exit always appears at the bottom.	M	3
NFR-21	In a menu, titles are either centered or left-justified.	M	3
NFR-22	User actions are named consistently across prompts.	H	3
NFR-23	Each individual icon is in a similar style to the rest of the icons.	H	3
NFR-24	All explanations are to be written clearly and concisely to be understood by the lay person.	H	3
NFR-25	The search function should allow auto-complete.	M	3
NFR-26	The search function should be tolerant of spelling errors.	M	3
NFR-27	The search function should not be case sensitive.	M	3
NFR-28	Colors should be distinguishable to colorblind users.	H	3
NFR-29	All icons should be accompanied with text for screen readers.	H	3

Note. This table demonstrates the nonfunctional requirements of the application interface. Generally speaking, the nonfunctional requirements dictate how the application executes the requirements.
[a]There are three levels of priority: High (H), Medium (M), and Low (L).

Nielsen's Modified by Budd

Nielsen's Heuristics modified by Budd and presented by Sharp et al. (2019, pp. 553-554) were used to evaluate *CogniGuide* (Table 8). Thirteen of the heuristics were fully implemented. Three of the heuristics related to providing users with context were not fully implemented. Users are not provided with a breadcrumb trail, shown the number of steps in a process, or shown a progress indicator while pages are loading. Most tasks only require one or two pages, so a breadcrumb trail and progress bar were not deemed necessary. Furthermore, the pages should not take much time to load, so a progress indicator was not created. One heuristic related to positive user experience was not

followed: Provide rewards for usage and progression. Following Demo (2017), the innate creativity of users is relied upon to motivate them.

Table 8
Evaluating CogniGuide *by Heuristics Developed by Budd*

Heuristic	Subheuristic	Success
Clarity	Write clear, concise copy.	3
	Only use technical language for a technical audience.	3
	Write clear and meaningful labels.	3
	Use meaningful icons.	3
Minimize Unnecessary Complexity and Cognitive Load	Remove unnecessary functionality, process steps, and visual clutter.	3
	Use progressive disclosure to hide advanced features.	3
	Break down complicated processes into multiple steps.	3
	Prioritize using size, shape, color, alignment, and proximity.	3
Provide Users with Context	Provide a clear site name and purpose.	3
	Highlight the current section in the navigation.	3
	Provide a breadcrumb trail (that is, show where the user has been in a website).	1
	Use appropriate feedback messages.	3
	Show the number of steps in a process.	1
	Reduce perception of latency by providing visual cues (for instance, a progress indicator) or by allowing users to complete other tasks while waiting.	1
Promote a Pleasurable and Positive User Experience	Create a pleasurable and attractive design.	3
	Provide easily attainable goals.	3
	Provide rewards for usage and progression.	1

Note. The table shows Budd's heuristics and how well *CogniGuide* measures against each heuristic. The success is rated on a scale of 1-3 where 1 is totally absent, 2 is mixed success, and 3 is implementation.

Mobile Interface Evaluation

CogniGuide was evaluated against a list of heuristics and subheuristics with 72 mobile-specific subheuristics developed by Yáñez Gómez et al. (2014; Table 9).

Table 9
Evaluating CogniGuide *by Mobile-Specific Heuristics*

Heuristic	Subheuristic	Success
1. Visibility Of System Status: System Status Feedback:	1. All the items on a list should go on the same page.	3
	2. if a list of items can be sorted according to different criteria, provide the option to sort that list according to all those criteria.	3
	3. if a list contains items that belong to different categories, provide filters for users to narrow down the number of elements that they need to inspect.	3
	4. if the list contains only one item, take the user directly to that item.	3
1. Visibility Of System Status: Selection/Input Of Data	10. discoverability: users should recognize touchable areas.	3
	12. expandable menus should be used sparingly.	3
3. User Control And Freedom	17. accidental activation (lack of back button).	3
4. Consistency And Standards: Orientation	20. navigation (horizontal and vertical) must be consistent across orientations.	1
	21. inconsistent content across orientations.	3
5. Error Prevention	22. accidental activation (lack of back button).	3
	23. touchable areas should be minimum of 1 cm × 1 cm.	3
	24. Provide space between touch targets.	3
	26. When several items are listed in columns, one on top of another, users expect to be able to hit anywhere in the row to select the target corresponding to that row.	3
	27. do not make users download software that is inappropriate for their phone.	3
	28. Do not use JavaScript or Flash.	3

6. Recognition Rather Than Recall: Memory Load Reduction	29. Users should be able to start the task as soon as possible.	3
	30. the controls that are related to a task should be grouped together and reflect the sequence of actions in the task.	3
7. Flexibility And Efficiency Of Use: Search	33. the length of the search box should be at least the size of the average search string.	3
	34. Use autocompletion and suggestions.	2
	35. do not use several search boxes with different functionalities on the same page.	3
	36. if the search returns zero results, offer some alternative searches or a link to the search results on the full page.	3
8. Aesthetic And Minimalist Design: Multimedia Content	40. getting rid of Flash content.	3
	41. avoid using animated carousels.	3
	42. do not use image sizes that are bigger than the screen. The entire image should be viewable with no scrolling.	3
	46. do not use moving animation.	3
8. Aesthetic And Minimalist Design: Orientation	52. desktop websites have a strong guideline to avoid horizontal scrolling. But for touch screens, horizontal swipes are often fine.	3
8. Aesthetic And Minimalist Design: Navigation	53. do not replicate a large number of persistent navigation options across all pages of a mobile site.	3
10. Help And Documentation	55. focus on one single feature at a time. Present only those instructions that are necessary for the user to get started.	3
12. Pleasurable And Respectful Interaction: Input Data	57. be tolerant of typos and offer corrections.	3
	58. save history and allow users to select previously typed information.	3
13. Privacy	71. for multiuser devices, avoid being permanently signed in on an application.	N/A

Note. Adapted from "Heuristic Evaluation on Mobile Interfaces: A New Checklist" by R. Yáñez Gómez et al., 2014, The Scientific World Journal, 2014, page(10-14). Copyright 2014 by Rosa Yáñez Gómez et al. Irrelevant subheuristics (e.g., subheuristics related to shopping) were not included.
[a]*CogniGuide* was measured against relevant subheuristics. Some heuristics were excluded on the basis of relevancy (i.e., all missing numbered subheuristics).
[b]The success is rated on a scale of 1-3 where 1 is totally absent, 2 is mixed success, and 3 is implementation.

Conclusion

Summary

Executive functions are vital for a happy, healthy life. They are positively correlated with many quality of life signifiers (Diamond, 2013). However, at precisely the time when one must rely on them the most (e.g., stress, loneliness, fatigue), they are most likely to be depleted (Sparrow, 2012a). For both neuroatypical and neurotypical individuals, executive functions can be improved with time and effort (Diamond, 2013). Mindfulness has been shown to positively impact children (Diamond & Lee, 2011; Huang et al., 2020; Geronimi et al., 2019), young adults (Black et al., 2011), individuals with ADHD, adolescents with substance use disorders, and young Indigenous Australians. Aerobic exercise has been shown to improve executive functions in children with ADHD (Jiang et al., 2022; Becker et al., 2018) and adults with mild to moderate Alzheimer's Disease (Yu et al., 2018). User research shows that integration across applications and the ability to store reminders in a centralized location is important to users, particularly those with conditions that impact executive functions. Using these insights, an application interface was developed and evaluated for accessibility and usability. Through a cooperative evaluation, users reported that the simple interface was "intuitive" and "straightforward".

Retrospective on Objectives

The original project aim was, broadly speaking, to identify skills that comprise executive functions, identify disorders that are associated with executive function impairment, find interventions in the literature for associated disorders and for executive function impairment more generally, and query questionnaire participants on self-management of executive function regulation. This information was used to identify features to avoid, include, and modify. A prototype was designed and evaluated using cooperative walk-throughs and two heuristic evaluations. In a general sense, each objective was achieved fully through the course of the project.

Specifically speaking, however, not every objective was fully completed (Table 10). For example, one partially completed objective was to "find ways and disorders in which executive function impairment manifests." This was only partially completed as there are many disorders associated with executive dysfunction, including ADHD, Oppositional Defiant Disorder, Tourette Syndrome, some intellectual disabilities, seizure disorders, pediatric cancers, and more (Sparrow, 2012b). It would be impossible to cover

every disorder and condition associated with executive functions given the time and page constraints.

Table 10
Evaluating Original Project Objectives

Superobjective	Objective	Success	Section
Background Review on executive function	Find best consensus on skills that comprise executive function.	3	Introduction
	Find ways and disorders in which executive function impairment manifests.	2	Disorders
User Research	Survey individuals who struggle with executive function skills to identify technological methods of managing symptoms of executive dysfunction.	2	User Research
	Identify applications and methods used to ameliorate symptoms of executive function impairment.	2	Methods
	Identify features to avoid, include, and modify.	3	Desirable Features
Background review on mental health centered design	Find technological solutions aimed at individuals with disorders identified in step one.	2	Interventions
	Identify applications that are designed to assist individuals with disorders identified in step one.	2	Interventions
Evaluate existing systems	Evaluate mental health applications in the literature with relevant features.	2	Relevant Technology
Plan design	Develop design requirements based on user research and literature review.	3	Design Requirements
Design a prototype	Based on existing system evaluation, determine gaps and opportunities for new and enhanced system.	3	Design Notes and Features
	Design prototype for application that helps users self-regulate symptoms.	3	Design
Evaluate Design	Evaluate design against original objectives.	3	Table 10
	Evaluate design against design requirements.	3	Compliance

Evaluate design against guideline reviews, specifically Nielsen's as modified by Budd and presented by Sharp et al. (2019, pp.553–554) as well as a 72-item checklist designed for mobile applications (Yáñez Gómez et al., 2014).	3	Heuristic Evaluation

Note. The table shows the original project objectives (Objectives), evaluates success, and provides links to sections in which each specific objective is discussed in more detail. [a]The success is rated on a scale of 1-3 where 1 is totally absent, 2 is mixed success, and 3 is implementation.

User Research goals were also only partially covered. For ethical reasons, participants with executive function impairments could not be directly targeted for research, so the pool of participants was broader than would have been optimal. Only five respondents reported having conditions affecting executive functions (Respondents with Conditions Affecting Executive Functions). Because of this small pool, the author cannot confidently say that she has thoroughly identified applications and methods used to mitigate the impact of executive function impairment.

Attempts were made to evaluate existing systems designed to assist users with executive function impairment based on studies, but there were some roadblocks. First, some applications found in the literature are no longer available in stores (e.g., *Plan-It Commander*). Second, the evidence was not always as compelling as it should be. For example, CogMed is a computer program widely used by professionals (Shipstead et al., 2012). However, multiple meta-analyses found that CogMed's promises were illusory, and training on CogMed only makes the users better at using CogMed (Shipstead et al., 2012; Aksayli et al., 2019). There were also mixed findings for ACTIVATE. Third, the D4D Framework that helps children with ADHD, Dyslexia, and ASD must be highly tailored and is not easily adapted to a more standardized application (Benton et al., 2014; Fekete & Lucero; 2019).

Learning Points

The learning curve has been steep, and it was difficult to find direction at the start of the project due to the vast number of disorders associated with executive functions. It was also difficult to recognize when enough background research had been conducted as there are, as of August 10, more than 14,000 articles on the Newcastle University Library Collections related to executive functions and either ADHD, ASD, suicide, or substance use disorder. Therefore, the author continued to review the literature until July 28, leaving just enough time to design the application. Having a finer focus from the start would have allowed for a deeper look at these disorders, rather than a wider breadth.

The author also learned that one resource is not sufficient to prove efficacy for a method. She had planned on relying on CogMed as an inspiration based on a review by Diamond & Lee (2013), but decided to verify this with other studies. Two meta-analyses confirmed that CogMed is not a proven training program for individuals with executive function impairment. This instigated a more thorough review of the other features suggested by the literature (e.g., mindfulness, exercise).

The author also learned how to take broad concepts from other fields (e.g., mindfulness, executive functions) and translate those into the field of HCI. She learned how to find evidence-based interventions and develop them into application features. Furthermore, she considered maintaining and balancing stakeholder interests while developing the application. For example, visually impaired, dyslexic, and colorblind users were considered while designing the application interface through choices like the simple mode, typeface, color scheme, and more. However, there is still room for improvement with accessibility.

Future Work

There is much room for future work. The most important would be to bring the application fully up to accessibility guidelines by WCAG 2.2 (World Wide Consortium, 2023). For example, at present, the application is only designed to be used in portrait mode, which violates Success Criterion 1.3.4.

There are also some potential additional features to be considered. First, a participant recommended Goblin Tools, which uses a language learning model to break down lists into smaller tasks (Respondents with Conditions Affecting Executive Functions). Second, the friends feature could be expanded to leaderboards for completing tasks like meditation and logging exercise. Users could also cooperate together on meta-tasks, such as meditating for a combined total of two hours in a one week period. The message feature could also be expanded to allow users to send messages with contents checked using a language learning model and a robust moderation team. Third, the goals and reminders could have a mood setting to unlock. When users check in with a low mood, they could feel overwhelmed by a lot of tasks. By setting mood locking features, some goals could be hidden from users when they need to focus on the essential tasks of life and unlocked when they check in with a high mood. Finally, some individuals struggle to communicate verbally, so an option to draw in response to journal prompts could be added.

References

Aksayli, N. D., Sala, G., & Gobet, F. (2019). The cognitive and academic benefits of Cogmed: A meta-analysis. *Educational Research Review*, *27*, 229–243. https://doi.org/10.1016/j.edurev.2019.04.003

Alizadehgoradel, J., Imani, S., Nejati, V., & Fathabadi, J. (2019). Mindfulness-based substance abuse treatment (MBSAT) improves executive functions in adolescents with substance use disorders. *Neurology, Psychiatry and Brain Research*, *34*, 13–21. https://doi.org/10.1016/j.npbr.2019.08.002

American Psychiatric Association. (2022a). Attention-deficit/hyperactivity disorder. In *Diagnostic and statistical manual of mental disorders* (5th ed., text rev.). https://doi.org/10.1176/appi.books.9780890425787.x03_Bipolar_and_Related_Disorders

American Psychiatric Association. (2022b). Autism spectrum disorder. In *Diagnostic and statistical manual of mental disorders* (5th ed., text rev.). https://doi.org/10.1176/appi.books.9780890425787.x03_Bipolar_and_Related_Disorders

American Psychiatric Association. (2022c). Substance-related and addictive disorders. In *Diagnostic and statistical manual of mental disorders* (5th ed., text rev.). https://doi.org/10.1176/appi.books.9780890425787.x03_Bipolar_and_Related_Disorders

Baggetta, P., & Alexander, P. A. (2016). Conceptualization and operationalization of executive function. *Mind, Brain, and Education*, *10*(1), 10–33. https://doi.org/10.1111/mbe.12100

Becker, D. R., McClelland, M. M., Geldhof, G. J., Gunter, K. B., & MacDonald, M. (2018). Open-Skilled Sport, Sport Intensity, Executive Function, and Academic Achievement in Grade School Children. *Early Education and Development*, *29*(7), 939–955. https://doi.org/10.1080/10409289.2018.1479079

Benton, L., Vasalou, A., Khaled, R., Johnson, H., & Gooch, D. (2014). Diversity for design: A framework for involving neurodiverse children in the technology design process. In: Jones, M., Palanque, P., Schmidt, A., and Grossman, T, (Eds) *CHI '14: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, vol 11746*. ACM New York. https://doi.org/10.1145/2556288.2557244

Biederman, J. , Monuteaux, M. C. , Doyle, A. E. , Seidman, L. J. , Wilens, T. E. , Ferrero, F. , Morgan, C. L. & Faraone, S. V. (2004). Impact of executive function deficits and attention-deficit/hyperactivity disorder (ADHD) on academic outcomes in children. *Journal of Consulting and Clinical Psychology, 72*(5), 757-766.

Bikic, A., Leckman, J. F., Christensen, T. Ø., Bilenberg, N., & Dalsgaard, S. (2018). Attention and executive functions computer training for attention-deficit/hyperactivity disorder (ADHD): results from a randomized, controlled trial. *European Child & Adolescent Psychiatry*, *27*(12), 1563–1574. https://doi.org/10.1007/s00787-018-1151-y

Black, D. S., Semple, R. J., Pokhrel, P., & Grenard, J. L. (2011). Component processes of executive function—mindfulness, self-control, and working memory—and their relationships with mental and behavioral health. *Mindfulness*, *2*(3), 179–185. https://doi.org/10.1007/s12671-011-0057-2

Bölte, S., Lawson, W. B., Marschik, P. B., & Girdler, S. (2021). Reconciling the seemingly irreconcilable: The WHO's ICF system integrates biological and psychosocial environmental determinants of autism and ADHD. *BioEssays*, *43*(9), 2000254. https://doi.org/10.1002/bies.202000254

Bradley, L., Noble, N., & Hendricks, B. (2022). DSM-5-TR: Salient changes. *The Family Journal*, *31*(1), 106648072211235. https://doi.org/10.1177/10664807221123558

Bul, K. C., Kato, P. M., Van der Oord, S., Danckaerts, M., Vreeke, L. J., Willems, A., van Oers, H. J., Van Den Heuvel, R., Birnie, D., Van Amelsvoort, T. A., Franken, I. H., & Maras, A. (2016). Behavioral Outcome Effects of Serious Gaming as an Adjunct to Treatment for Children With Attention-Deficit/Hyperactivity Disorder: A Randomized Controlled Trial. *Journal of Medical Internet Research*, *18*(2), e26. https://doi.org/10.2196/jmir.5173

Castillo-Sánchez, G., Camargo-Henríquez, I., Muñoz-Sánchez, J. L., Franco-Martín, M., & de la Torre-Díez, I. (2019). Suicide prevention mobile apps: Descriptive analysis of apps from the most popular virtual stores. *JMIR mHealth and uHealth, 7*(8)https://doi.org/10.2196/13885

Chaparro, M., Carroll, M., & Hook, J. (2020). Improving the usability of a digital neurobehavioral assessment. In T. Ahram & C. Falcão (Eds.), *Advances in Usability, User Experience, Wearable and Assistive Technology* (Vol. 1217, pp. 69–76). Springer International Publishing AG. https://doi.org/10.1007/978-3-030-51828-8_10

Cibrian, F. L., Hayes, G. R., & Lakes, K. D. (2021). *Research advances in ADHD and technology*. Morgan & Claypool Publishers.

de la Torre, I., Castillo, G., Arambarri, J., López-Coronado, M., & Franco, M. A. (2017). Mobile apps for suicide prevention: Review of virtual stores and literature. *JMIR MHealth and UHealth*, *5*(10), e130. https://doi.org/10.2196/mhealth.8036

Demetriou, E. A., Lampit, A., Quintana, D. S., Naismith, S. L., Song, Y. J. C., Pye, J. E., Hickie, I., & Guastella, A. J. (2017). Autism spectrum disorders: A meta-analysis of executive function. *Molecular Psychiatry*, *23*(5), 1198–1204. https://doi.org/10.1038/mp.2017.75

Demo, A. T. (2017). Hacking agency: Apps, autism, and neurodiversity. *Quarterly Journal of Speech*, *103*(3), 277–300. https://doi.org/10.1080/00335630.2017.1321135

Diamond. A. (2012). Activities and programs that improve children's executive functions. *Current Directions in Psychological Science : a Journal of the American Psychological Society, 21*(5), 335–341. https://doi.org/10.1177/0963721412453722

Diamond. A. (2013). Executive functions. *Annual Review of Psychology, 64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science (New York, N.Y.), 333*(6045), 959–964. https://doi.org/10.1126/science.1204529

Dibia, V. (2016). FOQUS: A smartwatch application for individuals with ADHD and mental health challenges. *ASSETS '16: Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility*, 311–312. https://doi.org/10.1145/2982142.2982207

Dipeolu, A., Hargrave, S., & Storlie, C. A. (2014). Enhancing ADHD and LD diagnostic accuracy using career instruments. *Journal of Career Development*, *42*(1), 19–32. https://doi.org/10.1177/0894845314521691

Durazzo, T. C., Gazdzinski, S., & Meyerhoff, D. J. (2007). The neurobiological and neurocognitive consequences of chronic cigarette smoking in alcohol use disorders. *Alcohol and Alcoholism*, *42*(3), 174–185. https://doi.org/10.1093/alcalc/agm020

Fawcett, J. (2013). Suicide and anxiety in DSM-5. *Depression and Anxiety*, *30*(10), 898–901. https://doi.org/10.1002/da.22058

Fekete, G., Lucero, A. (2019). P(L)AY ATTENTION! Co-designing for and with children with attention deficit hyperactivity disorder (ADHD). In: Lamas, D., Loizides, F., Nacke, L., Petrie, H., Winckler, M., Zaphiris, P. (Eds) *Human-Computer Interaction – INTERACT 2019. INTERACT 2019. Lecture Notes in Computer Science(), vol 11746*. Springer, Cham. https://doi.org/10.1007/978-3-030-29381-9_23

Felthous, A. R., Kulkarni, N., & Belean, C. (2023). DSM-5-TR diagnosis as a guide to suicide risk assessment. *Behavioral Sciences & the Law*. https://doi.org/10.1002/bsl.2617

Ferenc, K., Płatos, M., Byrka, K., & Król, M. E. (2022). Looking through rainbow-rimmed glasses: Taking neurodiversity perspective is related to subjective well-being of autistic adults. *Autism*, 136236132211358. https://doi.org/10.1177/13623613221135818

Fergusson, D. M., Horwood, L. J., & Ridder, E. M. (2007). Conduct and attentional problems in childhood and adolescence and later substance use, abuse and dependence: Results of a 25-year longitudinal study. *Drug and Alcohol Dependence*, *88*, S14–S26. https://doi.org/10.1016/j.drugalcdep.2006.12.011

Fernández, J., Alberich, S., Zorrilla, I., González-Ortega, I., López, M., Pérez-Solà, V., Vieta, E., González-Pinto, A.M., & Saiz, P.A. (2022). Altered executive function in suicide attempts. *European Psychiatry, 65*(S1), S124-S124. doi:10.1192/j.eurpsy.2022.343

First, M. B., Yousif, L. H., Clarke, D. E., Wang, P. S., Gogtay, N., & Appelbaum, P. S. (2022). DSM‐5‐TR: Overview of what's new and what's changed. *World Psychiatry*, *21*(2), 218–219. https://doi.org/10.1002/wps.20989

Fleischmann, A., & Miller, E. C. (2012). Online narratives by adults with ADHD who were diagnosed in adulthood. *Learning Disability Quarterly*, *36*(1), 47–60. https://doi.org/10.1177/0731948712461448

Geronimi, E. M. C., Arellano, B., & Woodruff-Borden, J. (2019). Relating mindfulness and executive function in children. *Clinical Child Psychology and Psychiatry*, *25*(2), 435–445. https://doi.org/10.1177/1359104519833737

Goharinejad, S., Goharinejad, S., Hajesmaeel-Gohari, S., & Bahaadinbeigy, K. (2022). The usefulness of virtual, augmented, and mixed reality technologies in the diagnosis and treatment of attention deficit hyperactivity disorder in children: an overview of relevant studies. *BMC Psychiatry*, *22*(1). https://doi.org/10.1186/s12888-021-03632-1

Gustavson, D. E., Stallings, M. C., Corley, R. P., Miyake, A., Hewitt, J. K., & Friedman, N. P. (2017). Executive functions and substance use: Relations in late adolescence and early adulthood. *Journal of Abnormal Psychology*, *126*(2), 257–270. https://doi.org/10.1037/abn0000250

Haegele, J. A., & Hodge, S. (2016). Disability Discourse: Overview and Critiques of the Medical and Social Models. *Quest*, *68*(2), 193–206. https://doi.org/10.1080/00336297.2016.1143849

Han, Y.M.Y., Cheung, Mc., Sze, S.L., Chan, A.S.Y. (2014). Altered immune function associated with neurophysiological abnormalities and executive function deficits in children with autism. In: Patel, V., Preedy, V., Martin, C. (Eds.) *Comprehensive Guide to Autism*. Springer, New York, NY. https://doi.org/10.1007/978-1-4614-4788-7_90

Hill, E. L. (2004). Executive dysfunction in autism. *Trends in Cognitive Sciences*, *8*(1), 26–32. https://doi.org/10.1016/j.tics.2003.11.003

Ho, M.-C., Hsu, Y.-C., Lu, M.-L., Gossop, M., & Chen, V. C.-H. (2018). "Cool" and "hot" executive functions in suicide attempters with major depressive disorder. *Journal of Affective Disorders*, *235*, 332–340. https://doi.org/10.1016/j.jad.2018.04.057

Huang, C. C., Lu, S., Rios, J., Chen, Y., Stringham, M., & Cheung, S. (2020). Associations between mindfulness, executive function, social-emotional skills, and quality of life among Hispanic children. *International Journal of Environmental Research and Public Health, 17*(21), 7796. https://doi.org/10.3390/ijerph17217796

Hunter, S., & Sparrow, E. P. (2012). *Executive function and dysfunction: Identification, assessment, and treatment*. Cambridge University Press.

Hunter, S., Edidin, J., & D. Hinkle, C. (2012). The developmental neuropsychology of executive functions. In S. Hunter & E. Sparrow (Eds.), *Executive function and*

dysfunction: Identification, assessment and treatment (pp. 17-36). Cambridge: Cambridge University Press. doi:10.1017/CBO9780511977954.004

Jaarsma, P., & Welin, S. (2011). Autism as a natural human variation: Reflections on the claims of the neurodiversity movement. *Health Care Analysis*, *20*(1), 20–30. https://doi.org/10.1007/s10728-011-0169-9

Jiang, K., Xu, Y., Li, Y., Li, L., Yang, M., & Xue, P. (2022). How aerobic exercise improves executive function in ADHD children: a resting‐state fMRI study. *International Journal of Developmental Neuroscience*, *82*(4). https://doi.org/10.1002/jdn.10177

Johnston, K., Murray, K., Spain, D., Walker, I., & Russell, A. (2019). Executive function: Cognition and behaviour in adults with autism spectrum disorders (ASD). *Journal of Autism and Developmental Disorders*, *49*(10), 4181–4192. https://doi.org/10.1007/s10803-019-04133-7

Kabat-Zinn, J. (2003). Mindfulness-Based Interventions in Context: Past, Present, and Future. *Clinical Psychology: Science and Practice*, *10*(2), 144–156. https://doi.org/10.1093/clipsy.bpg016

Kapp, S. K., Gillespie-Lynch, K., Sherman, L. E., & Hutman, T. (2013). Deficit, difference, or both? Autism and neurodiversity. *Developmental Psychology*, *49*(1), 59–71. https://doi.org/10.1037/a0028353

Kenealy, L., & Paltin, I. (2012). Executive functions in disruptive behavior disorders. In S. Hunter & E. Sparrow (Eds.), *Executive function and dysfunction: Identification, assessment and treatment* (pp. 93-100). Cambridge: Cambridge University Press. doi:10.1017/CBO9780511977954.008

Kennecke, A., Wessel, D. & Heine, M. (2022). Dyslexia and Accessibility Guidelines – How to Avoid Barriers to Access in Public Services. *i-com*, *21*(1), 139-155. https://doi.org/10.1515/icom-2021-0040

Kenworthy, L., Anthony, L., & Yerys, B. (2012). Executive functions in autism spectrum disorders. In S. Hunter & E. Sparrow (Eds.), *Executive function and dysfunction: Identification, assessment and treatment* (pp. 101-108). Cambridge: Cambridge University Press. doi:10.1017/CBO9780511977954.009

Koutsoklenis, A., & Honkasilta, J. (2023). ADHD in the DSM-5-TR: What has changed and what has not. *Frontiers in Psychiatry*, *13*. https://doi.org/10.3389/fpsyt.2022.1064141

Krcek, T. E. (2013). Deconstructing disability and neurodiversity: Controversial issues for autism and implications for social work. *Journal of Progressive Human Services*, *24*(1), 4–22. https://doi.org/10.1080/10428232.2013.740406

MacAulay, R. K., Halpin, A., Andrews, H. E., & Boeve, A. (2021). Trait mindfulness associations with executive function and well-being in older adults. *Aging & Mental Health*, *26*(12), 1–8. https://doi.org/10.1080/13607863.2021.1998352

Martel, M., Nikolas, M., & Nigg, J. T. (2007). Executive function in adolescents with ADHD. *Journal of the American Academy of Child & Adolescent Psychiatry*, *46*(11), 1437–1444. https://doi.org/10.1097/chi.0b013e31814cf953

Martin-Moratinos, M., Bella-Fernandez, M., & Blasco-Fontecilla, H. (2023). Effects of music on ADHD symptomatology and potential application of music in video games: A systematic review (Preprint). *Journal of Medical Internet Research*, *25*. https://doi.org/10.2196/37742

McCabe, S. E., West, B. T., Jutkiewicz, E. M., & Boyd, C. J. (2017). Multiple DSM-5 substance use disorders: A national study of US adults. *Human Psychopharmacology: Clinical and Experimental*, *32*(5), e2625. https://doi.org/10.1002/hup.2625

Miyake, A., Friedman, N.P., Emerson, M.J., Witzki, A.H., Howerter, A. and Wager, T.D. (2000). The unity and diversity of executive functions and their contributions to complex 'frontal lobe' tasks: A latent variable analysis. *Cognitive Psychology*, 41(1), pp.49–100. doi:https://doi.org/10.1006/cogp.1999.0734.

Nadeau, K. G. (2015). The ADHD Guide to Career Success: Harness Your Strengths, Manage Your Challenges (2nd ed.). New York: Taylor and Francis. DOI: 10.4324/9781315723334. 85

Neale, J., & Bowen, A. M. (2022). Lessons for uptake and engagement of a smartphone app (SURE Recovery) for people in recovery from alcohol and other drug problems: Interview study of app users. *JMIR Human Factors*, *9*(1), e33038. https://doi.org/10.2196/33038

Nigg, J. T., Wong, M. M., Martel, M. M., Jester, J. M., Puttler, L. I., Glass, J. M., Adams, K. M., Fitzgerald, H. E., & Zucker, R. A. (2006). Poor response inhibition as a predictor of problem drinking and illicit drug use in adolescents at risk for alcoholism and other substance use disorders. *Journal of the American Academy of Child and Adolescent Psychiatry, 45*(4), 468–475. https://doi.org/10.1097/01.chi.0000199028.76452.a9

Onat, M., İnal Emiroğlu, N., Baykara, B., Özerdem, A., Özyurt, G., Öztürk, Y., Şahin, Ü., Ildız, A., Kaptancık Bilgiç, B., Hıdıroğlu Ongun, C., & Pekcanlar Akay, A. (2018). Executive functions and impulsivity in suicide attempter adolescents with major depressive disorder. *Psychiatry and Clinical Psychopharmacology*, *29*(3), 332–339. https://doi.org/10.1080/24750573.2018.1541647

Powell, L., Parker, J., & Harpin, V. (2017). ADHD: Is there an app for that? A suitability assessment of apps for the parents of children and young people with ADHD. *JMIR MHealth and UHealth*, *5*(10). https://doi.org/10.2196/mhealth.7941

Primich, C., & Iennaco, J. (2011). Diagnosing adult attention-deficit hyperactivity disorder: The importance of establishing daily life contexts for symptoms and impairments. *Journal of Psychiatric and Mental Health Nursing*, *19*(4), 362–373. https://doi.org/10.1111/j.1365-2850.2011.01845.x

Riera-Serra, P., Gili, M., Navarra-Ventura, G., Riera-López, A., José, J., Coronado-Simsic, V., Castro, A., & Roca, M. (2023). Longitudinal associations

between executive function impairments and suicide risk in patients with major depressive disorder: A 1-year follow-up study. *Psychiatry Research*, *325*, 115235–115235. https://doi.org/10.1016/j.psychres.2023.115235

Rodríguez‐Pérez, N., Caballero‐Gil, P., Rivero‐García, A., & Toledo‐Castro, J. (2020). A secure mHealth application for attention deficit and hyperactivity disorder. *Expert Systems*, *37*(1). https://doi.org/10.1111/exsy.12431

Rosenthal, M. , Wallace, G. L. , Lawson, R. , Wills, M. C. , Dixon, E. , Yerys, B. E. & Kenworthy, L. (2013). Impairments in real-world executive function increase from childhood to adolescence in autism spectrum disorders. *Neuropsychology, 27*(1), 13-18. doi: 10.1037/a0031299.

Shand, F. L., Ridani, R., Tighe, J., & Christensen, H. (2013). The effectiveness of a suicide prevention app for Indigenous Australian youths: Study protocol for a randomized controlled trial. *Trials*, *14*(1), 396. https://doi.org/10.1186/1745-6215-14-396

Sharp, H., Rogers, Y., & Preece, J. (2019). *Interaction design: Beyond human-computer interaction* (5th ed.). Wiley.

Shipstead, Z., Hicks, K. L., & Engle, R. W. (2012). Cogmed working memory training. *Journal of Applied Research in Memory and Cognition, 1*(3), 185-193. doi: 10.1016/j.jarmac.2012.06.003.

Shneidman, E. S. (1998). *The suicidal mind.* Oxford University Press.

Silverstein, M. J., Faraone, S. V., Leon, T. L., Biederman, J., Spencer, T. J., & Adler, L. A. (2020). The relationship between executive function deficits and DSM-5-defined ADHD symptoms. *Journal of Attention Disorders, 24*(1), 41–51. https://doi.org/10.1177/1087054718804347

Sinclair, J. (1993). Don't mourn for us. *Our Voice, 1*(3). Retrieved from http://www.autreat.com/dont_mourn.html

Sinnari, D., Krause, P., Abulkhair, M. (2018). Effects of e-games on the development of Saudi children with attention deficit hyperactivity disorder cognitively, behaviourally and socially: An experimental study. In: Antona, M., Stephanidis, C. (Eds) *Universal Access in Human-Computer Interaction. Methods, Technologies, and Users. UAHCI 2018. Lecture Notes in Computer Science(), vol 10907*. Springer, Cham. https://doi.org/10.1007/978-3-319-92049-8_44

Sohal, M., Singh, P., Singh Dhillon, B., & Singh Gill, H. (2022). Efficacy of journaling in the management of mental illness: A systematic review and meta-analysis. *ProQuest*, *10*(1). https://doi.org/10.1136/fmch-2021-001154

Somma, F., Rega, A., & Mennitto, A. (2019). Software-assisted learning in children with attention deficit hyperactivity disorder: A review. *EDULEARN19 Proceedings*, 3004–3009. https://doi.org/10.21125/edulearn.2019.0803

Sparrow, E. (2012a). Assessment and identification of executive dysfunction. In S. Hunter & E. Sparrow (Eds.), *Executive function and dysfunction: Identification,*

assessment and treatment (pp. 65-90). Cambridge: Cambridge University Press. doi:10.1017/CBO9780511977954.006

Sparrow, E. (2012b). Executive dysfunction in the neurodevelopmental and acquired disorders. (2012). In S. Hunter & E. Sparrow (Eds.), *Executive function and dysfunction: Identification, assessment and treatment*. Cambridge: Cambridge University Press.

Spiel, K., Hornecker, E., Williams, R. M., & Good, J. (2022). ADHD and technology research – Investigated by neurodivergent readers. *CHI Conference on Human Factors in Computing Systems*. https://doi.org/10.1145/3491102.3517592

Verdejo-García, A., Bechara, A., Recknor, E., & Pérez-García, M. (2006). Executive dysfunction in substance dependent individuals during drug use and abstinence: An examination of the behavioral, cognitive and emotional correlates of addiction. *Journal of the International Neuropsychological Society, 12*(3), 405-415. doi:10.1017/S1355617706060486

Wray, T. B. (2022). Exploring whether addictions counselors recommend that their patients use websites, smartphone apps, or other digital health tools to help them in their recovery: Web-based survey. *JMIR Formative Research*, *6*(6), e37008. https://doi.org/10.2196/37008

Yáñez Gómez, R., Cascado Caballero, D. and Sevillano, J.-L. (2014). Heuristic evaluation on mobile interfaces: A new checklist. *The Scientific World Journal*, [online] 2014, pp.1–19. doi:https://doi.org/10.1155/2014/434326.

Young S. E., Friedman N. P., Miyake A., Willcutt E. G., Corley R. P., Haberstick B. C., Hewitt J. K. (2009). Behavioral disinhibition: Liability for externalizing spectrum disorders and its genetic and environmental relation to response inhibition across adolescence. *Journal of Abnormal Psychology*, 118, 117–130.

Yu, F., Vock, D. M., & Barclay, T. R. (2018). Executive function: Responses to aerobic exercise in Alzheimer's disease. *Geriatric Nursing*, *39*(2), 219–224. https://doi.org/10.1016/j.gerinurse.2017.09.005

Zylowska, L., Smalley, S. L., and Schwartz, J. M. (2009). Mindful awareness and ADHD. In F. Didonna (Ed.), *Clinical Handbook of Mindfulness* (pp. 319-338). New York: Springer. DOI: 10.1007/978-0-387-09593-6_18. 93

Referenced URLs

Google. (2018). *The color system*. Material Design. Retrieved 2023 August 4 from https://m2.material.io/design/color/the-color-system.html#color-usage-and-palettes

Heartbeat Ventures. (n.d.). *Plan-It Commander*. Heartbeat Ventures. Retrieved July 20, 2023, from https://www.heartbeat.ventures/plan-itcommander

Nichols, D. (n.d.). *Coloring for Colorblindness*. DavidMathLogic. Retrieved 2023 August 1 from https://davidmathlogic.com/colorblind/#

World Wide Consortium. (2023, July 20). *Web Content Accessibility Guidelines (WCAG) 2.2* (C. Adams, C. Alastair, R. Montgomery, M. Cooper, & A. Kirkpatrick, Eds.). W3C. https://www.w3.org/TR/WCAG22/

Appendices

Appendix A. User Research Questionnaire

This appendix presents the original text of the form. All emphases are original. After each section of questions, responses are given. Required questions and exit points are indicated.

Section 1: Consent

You are invited to participate in a study about self-regulation of executive function. This survey will ask about how you use applications and programs to stay on task, exercise self-control, and hone working memory.

The survey should take about **10 minutes**. There are no risks or benefits involved in participating. Participation is **voluntary**. However, some of the questions are related to regulation of mental health. If you feel uncomfortable, **please feel free to withdraw at any point**. Names, email, and other identifying information will not be collected. All responses are anonymous.

You must be **18 or older** to participate in this study. Data collected are used to develop an application design for a dissertation at Newcastle University.

Question: Would you like to continue? (required)

Table 11

Participant Responses in Section 1: Consent

Participant	Timestamp	Would you like to continue?
1	7/7/2023 14:47:35	Yes
2	7/7/2023 14:48:07	Yes
3	7/7/2023 14:50:05	Yes
4	7/7/2023 14:53:20	Yes
5	7/7/2023 14:53:58	Yes
6	7/7/2023 15:03:21	Yes
7	7/7/2023 15:18:43	Yes
8	7/7/2023 15:29:20	Yes
9	7/7/2023 15:48:38	Yes
10	7/7/2023 15:49:45	Yes
11	7/7/2023 17:34:27	Yes
12	7/7/2023 17:48:01	Yes
13	7/7/2023 17:49:51	Yes
14	7/7/2023 19:29:51	Yes
15	7/8/2023 4:17:38	Yes
16	7/8/2023 10:53:21	Yes
17	7/8/2023 12:29:15	Yes

18	7/8/2023 23:31:48	Yes
19	7/9/2023 1:58:11	Yes
20	7/9/2023 18:01:11	Yes
21	7/9/2023 22:09:04	Yes
22	7/9/2023 23:56:06	Yes
23	7/10/2023 9:38:06	Yes
24	7/10/2023 12:14:44	Yes
25	7/10/2023 23:01:20	Yes
26	7/14/2023 12:24:17	Yes
27	7/15/2023 1:59:53	Yes
28	7/15/2023 2:07:05	Yes
29	7/16/2023 21:44:24	Yes
30	7/20/2023 22:23:29	Yes
31	7/21/2023 5:15:49	Yes
32	7/21/2023 5:16:03	Yes

Note. Responses given in the first page of the form with time and date stamps and consent to continue.

Section 2. Personal Information

Question: Please select your age range.

Possible answers are 0-18, 19-25, 26-34, 35-44, 45-54, 55-64, 65-74, 75+, and Prefer not to say. Participants may select only one option. Participants who select 0-18 are moved to the form submission page.

Question: Please select your gender. (required)

Possible answers are Non-binary / gender fluid, Male, Female, and Prefer not to say. Participants must select one and only one option.

Question: Where are you from? (required)

Possible answers are Australia, Canada, China, Hong Kong, Ireland, Macau, Korea (South), New Zealand, South Africa, Taiwan, UK, USA, and Prefer not to say. Participants may also enter their own answer using the Other…. option. Participants must select one and only one option.

Question: What is your highest level of education?

Possible answers are some secondary school, high school diploma or equivalent, bachelor's degree, master's degree, doctorate degree, professional degree (e.g., law, medicine, dentistry), and Prefer not to say. Participants may select only one option.

Table 12

Participant Responses in Section 2: Personal Information

Participant	Age range.	Gender	Nation	Education
1	26-34	Male	UK	Master's degree
2	19-25	Male	UK	Master's degree
3	19-25	Male	Singapore	Bachelor's degree
4	26-34	Male	India	Master's degree
5	26-34	Female	China	Master's degree
6	26-34	Female	Hong Kong	Master's degree
7	35-44	Male	UK	Bachelor's degree
8	35-44	Female	UK	Bachelor's degree
9	26-34	Male	UK	Master's degree
10	65-74	Female	USA	Bachelor's degree
11	19-25	Female	China	Master's degree
12	26-34	Female	Taiwan	Master's degree
13	19-25	Female	Prefer not to say	Master's degree
14	19-25	Male	UK	Bachelor's degree
15	35-44	Male	USA	Some secondary school
16	19-25	Female	India	Master's degree
17	19-25	Male	UK	Bachelor's degree
18	45-54	Female	USA	Bachelor's degree
19	35-44	Female	USA	Doctorate degree
20	19-25	Male	Indonesia	Master's degree
21	55-64	Female	USA	High school diploma or equivalent
22	55-64	Female	USA	Bachelor's degree

23	26-34	Male	UK	Bachelor's degree
24	26-34	Female	USA	Master's degree
25	55-64	Female	USA	Some secondary school
26	65-74	Male	USA	Bachelor's degree
27	65-74	Female	USA	Bachelor's degree
28	65-74	Male	USA	Bachelor's degree
29	65-74	Female	USA	Bachelor's degree
30	65-74	Male	USA	Bachelor's degree
31	26-34	Female	USA	Bachelor's degree
32	26-34	Male	USA	Master's degree

Note. Responses given in the second page of the form regarding age, gender, nation of origin, and education.
[a]Participant numbers are the same as in Table 11.

Section 3. Executive Functions

Executive Functions are cognitive processes to work with ideas, think before acting, overcome new challenges, resist temptation, and stay focused.

The three core executive functions are **inhibitory control, working memory, and cognitive flexibility**.

Executive dysfunction can occur in times of stress, fatigue, hunger, pain, loneliness, overstimulation, or sudden change in structure (e.g., starting a new job).

Executive function impairment is also present in many neurodevelopmental and acquired disorders (e.g., addictions, ADHD, conduct disorder, depression, OCD, schizophrenia).

Executive functions deteriorate with age.

Question: Do you struggle with inhibitory control? (required)

Inhibitory control is controlling attention, behavior, thoughts, and emotions to do what's needed instead of what's desired.

We use inhibitory control to:

stay on a difficult task despite the temptation to give in, tune out background noise in a café to listen to a friend, delay gratification, allow others to finish their questions and sentences

Possible answers are Yes and No.

Question: Do you struggle with working memory? (required)

Working memory: holding, manipulating, adding, and subtracting information in your mind.

We use working memory to:

diverge from a normal route to do an errand instead of defaulting to autopilot and going home, perform mental arithmetic, mentally reorder a to-do list, consider alternatives to a plan

Possible answers are Yes and No.

Question: Do you struggle with cognitive flexibility? (required)

Cognitive flexibility: being able to change perspectives spatially or interpersonally, to step outside our own viewpoint and consider another perspective

We use cognitive flexibility to:

try a new strategy, change plans quickly in response to new information and opportunities, shift between tasks or goals, imagine ourselves from someone else's perspective

Possible answers are Yes and No.

Question: Do you use any applications or habits to manage executive functions? (required)

Possible answers are Yes and No. Participants who select no are moved to the form submission page.

Question: How do you manage your symptoms?

Possible answers are Focus app (e.g., Finch, Forest, Study Bunny), Meditation and mindfulness apps (e.g., Headspace, Calm, Gratitude Journal), Note-taking apps (e.g., Notes, Google Drive, OneNote), Reminder apps (e.g., Google Calendar, Structured, Reminders), Task Manager app (e.g., Flora, Google Tasks, Habitica), Offline solutions (e.g., meditation, martial arts, aerobic exercise), and Other, wherein a participant may enter their own response. Participants may select multiple options.

Table 13

Participant Responses in Section 3: Executive Functions

P	IC	WM	CF	EF methods used?	How do you manage your symptoms?
1	No	No	No	No	
2	No	No	No	No	Note-taking apps
3	No	Yes	No	No	
4	No	No	No	No	Note-taking apps, Reminder apps
5	No	No	No	Yes	Note-taking apps, Reminder apps

6	Yes	Yes	No	Yes	Meditation and mindfulness apps, Note-taking apps, Reminder apps
7	Yes	No	No	Yes	Offline solutions
8	Yes	Yes	Yes	Yes	Note-taking apps, Reminder apps
9	No	No	No	No	
10	Yes	No	Yes	No	Paper lists, notes
11	Yes	No	No	Yes	Focus app, Reminder apps, Task Manager app
12	No	Yes	No	Yes	Focus app, Note-taking apps, Reminder apps
13	Yes	Yes	No	No	Note-taking apps
14	No	Yes	No	Yes	Offline solutions
15	Yes	No	No	Yes	Meditation and mindfulness apps, Note-taking apps, Reminder apps, Task Manager app, Offline solutions
16	Yes	No	No	Yes	Focus app, Note-taking apps, Reminder apps, Task Manager app
17	Yes	No	No	Yes	Focus app, Note-taking apps, Reminder apps
18	No	No	No	Yes	Note-taking apps, Reminder apps, Task Manager app, Offline solutions
19	No	No	Yes	No	Reminder apps
20	No	Yes	No	No	
21	Yes	Yes	No	No	
22	No	No	No	No	Offline solutions
23	No	Yes	No	No	Note-taking apps, Note-taking on paper
24	No	No	No	Yes	Note-taking apps, Reminder apps, Offline solutions
25	No	Yes	Yes	Yes	Reminder apps
26	No	Yes	Yes	No	
27	No	No	No	No	Note-taking apps
28	No	No	Yes	Yes	Offline solutions
29	Yes	No	No	No	
30	No	No	No	No	Note-taking apps, Excel spreadsheets and Word lists
31	Yes	Yes	Yes	Yes	Note-taking apps, Reminder apps, Task Manager app, Offline solutions, Medication

32	Yes	Yes	Yes	Yes	Note-taking apps, Reminder apps, Task Manager app

Note. Responses given in the third page of the form.
[a]Participants are given an overview of executive functions and a short description of each executive function before being asked about their relationship with executive functions.
[b]Some headings are abbreviated to save space: "Participant" is abbreviated to "P", "Working Memory" to "WM", "Inhibitory Control" to "IC", "Cognitive Flexibility" to "CF", and "Executive Functions" to "EF".

Section 4. Solution Review

Please choose one of the methods that you use to manage your symptoms.

As a reminder, executive Functions are cognitive processes to work with ideas, think before acting, overcome new challenges, resist temptation, and stay focused.

The three core executive functions are:

- Inhibitory control: controlling attention, behavior, thoughts, and emotions to do what's needed instead of what's desired.
- Working memory: holding, manipulating, adding, and subtracting information in your mind.
- Cognitive flexibility: being able to change perspectives spatially or interpersonally, to step outside our own viewpoint and consider another perspective

Question: What is the method that you use to regulate executive function? (required)

Participants enter their own answer in the form of a short answer.

Question: Which executive function is aided? (required)

Participants may choose one or more of the following: Inhibitory control, Working memory, Cognitive flexibility, and None.

Question: How often do you use the application or habit, on average?

Participants may choose only one of the following: Multiple times daily, Once per day, Every few days, A few times a month, Once a month, Rarely, or Other…, wherein a participant may add their own answer.

Question: How effective do you find it in managing your executive functions?

Participants choose an answer between one and ten where one is totally ineffective and ten is can't function without it.

Question: What is another feature you like about this method?

Participants enter their own answer in the form of a short answer.

Question: What is one improvement you would suggest? (required)

Participants enter their own answer in the form of a short answer.

Table 14
Participant Responses in Section 4: Solution Review

P	Method	EF Aided	Usage Rate	Efficacy	Positive Feature	Positive Feature	Improvement
5	When I complete my task, I encourage myself.	Working Memory	Every few days	8	I like alert of the app.	It's easy to arrange task.	More functuons for the app.
6	Structured	Working Memory	Multiple times daily	6	Time blocking	Inbox - jot down things to do quickly in one place	Iphone and Desktop versions sometimes don't sync
7	Jogging or walking, and sometimes talking to myself out loud	Inhibitory Control, Working Memory	Every few days	7	When I start to jog my thoughts are all scrambled, and if I've been having a tough emotional time I can't really regulate my thoughts well, but after a while it seems to straighten out my thoughts a bit and allows me to see the root cause or solution to a problem. The same is true of walking and talking to myself, but to a slightly lesser extent.	It gets me away from all the clutter and data flowing into my head. And away from the activities I use to procrastin ate.	I'd like to learn how to do this without getting sweaty, like meditation or something

8	Background music to help drown out environmental distractions.	Inhibitory Control	When I need to focus on something like studying. I don't have regular study habits. Sporadically multiple times daily.	8	I can choose the music I listen to.	Noise cancelling in my earphones really helps, too. Equally to the music, I would say.	I can't imagine how it could be improved.
11	To turn on the focus mode on phone and laptop.	Inhibitory Control	A few times a month	1	I love it could avoid all messages when I focus on working and studying.	It can remind me should be focused during a time.	No. Apple makes it perfect
12	Inhibitory control	Inhibitory Control, Working Memory	Multiple times daily	7	Notion: people can choose different way of note-taking	N/A	No notification on calendar
14	Exercise	Inhibitory Control	Every few days	7	Has other physical and mental benefits	Clears your mind and allows you to thi k clearly afterwards	Might take a few hours
15	Meditation	Inhibitory Control, Working Memory, Cognitive Flexibility	Multiple times daily	10	Focus	Clarity	Comprehension

16	Try to stay focused.	Inhibitory Control, Working Memory	Multiple times daily	7	Customize the number of reminders for a task or an event.	Looking how free or packed your day is and allocate time accordingly.	Wish it all exist in 1 single app than 5 different ones.
17	Cognitive flexibility	Inhibitory Control	Once per day	6	Seamless integration across all devices on mac makes using note and calendar usage convenient	Simple UI but you can do alot with it, such as make tables, bullet points, highlight, bolden font etc.	Easy Integration with windows devices
18	ToDoist - list app	Working Memory	Multiple times daily	8	Ability to have multiple To Do lists for different topics	Ability to share lists with my husband and assign tasks to him	Integrated reminders with alarms
24	Pen and paper; daily to-do list made with morning coffee	Inhibitory Control	Once per day	7	Sticky Note App on the laptop displays my reminders as soon as I open my laptop/ harder to lose than my paper to-do list	None	None
25	Google calender or timer on my phone	Working Memory	Multiple times daily	6	I receive notifications	I can keep track of many things this way	Dont have one

28	Experience inhinity controls	Inhibitory Control, Working Memory, Cognitive Flexibility	Multiple times daily	10	Experience	Hands on	Rely on interaction
31	Reminders on phone via Google calendar and tasks. Ritalin/psychiatric medication. Notes from counseling. Mood and activity tracking via Daylio app. Goblintools App.	Inhibitory Control, Cognitive Flexibility	Multiple times daily	8	I like reminders and I like organized systems to manage my different symptoms and life stresses. If I don't write things down in these systems I will forget information quickly.	I like these apps and systems because they are simple and easy to use. There wasn't a big learning curve.	I wish that there were a better color coding system for Google calendar and a way to organize events on the calendar by category/ order of importance. Green for most flexible parts of day and red for urgent matters that are non negotiable. I could do so manually but thats just another thing to remember to do.
32	Making detailed lists including intermediate steps	Inhibitory Control, Working Memory	Multiple times daily	7	Being able to add, subtract, and check off risks quickly as I go about Mt day.	It gets the task out of my head so I can focus on the actual task rather than rememberi ng all the tasks I still	It doesn't have a reminder feature so I have been considering using Microsoft Planner instead which I can

		have to do.	set automatic reminders for.

Note. Responses given in the fourth page of the form regarding age, gender, nation of origin, and education.
[a]Some participants were ejected from the survey after responding that they do not use methods to manage executive functions. These participants were not included on this table as they did not reach this page. Therefore, some participant numbers are missing.

Section 5. Conditions

Question: Do you have any conditions that affect your executive functions? (required)

This could be diagnosed or self-diagnosed.

Participants may choose Yes, No, or Prefer not to say. If participants choose No, they continue to the form submission.

Question: Do you have any conditions that affect your executive functions?

Participants may choose Yes, No, or Prefer not to say.

Question: Please describe the condition(s).

As with all questions on this survey, your answer is anonymous and voluntary.

Participants enter their own answer in the form of a short answer.

Table 15
Participant Responses in Section 5: Conditions

P	Presence of Conditions	Presence of Diagnosis	Please describe the condition(s).
5	No	Yes	
6	No	No	
7	No	No	
8	No	No	
11	Invalid	Invalid	Invalid
12	No	No	
14	No	No	
15	Yes	Yes	Cptsd, ocd, adhd, anxiety
16	Yes	No	
17	No	No	
18	No	No	
24	No	No	
25	Yes	Yes	ME/ CFS
28	No	Prefer not to say	

31	Yes	Yes	ADHD, Autism, Major Depressive disorder, generalized anxiety disorder, pstd symotons but not full diagnois. Ocd symptoms but also overlaps with autism and trauma so no offical diagnosis.
32	Yes	Yes	ADHD that i take focalin to help with this condition.

Note. Responses given in the fifth page of the form regarding conditions impacting executive functions.
[a]Some participants were ejected from the survey after responding that they do not use methods to manage executive functions. These participants were not included on this table as they did not reach this page. Therefore, some participant numbers are missing.
[b]The heading "Participant" is abbreviated to "P" to save space.

Section 6. Thank You

Thank you very much for your time in completing this questionnaire.

If you have any questions, please feel free to contact me at c2031089@newcastle.ac.uk.

I really appreciate your time and effort.

Appendix B. Images and Icons Used

CogniGuide was created using photos and icons. As of the time of writing, they are all free to use for personal and commercial projects.

photo urls:

Unless otherwise indicated, all icons were created by IconDuck and are available under the MIT License.
https://www.figma.com/community/plugin/1146185971371499441/Eva-Icons-by-Iconduck

The default image of the pink hydrangea was found on flickr; the creator gave permission to use: https://www.flickr.com/photos/14666009@N06/4494381601

The blue alarm clock used in the home page:
https://pixabay.com/vectors/clock-square-time-instrument-alarm-34597/

The paintbrush used in the home page:
https://pixabay.com/vectors/paint-brush-paint-brush-color-1266212/

The connection image used in the home page:
https://pixabay.com/vectors/communication-connection-global-1297544/

The friend icon on My CogniGuide Friends page:
https://pixabay.com/vectors/buddy-chat-person-messaging-37197/

Two of the photos used in the alternate themes came from PixaBay.

The stars photo:
https://pixabay.com/photos/astronomy-bright-constellation-dark-1867616/

The sunrise photo was taken by the author.

The forest photo came from here: https://pixabay.com/photos/forest-trees-fog-conifers-pine-3622519/

The brightness icon from here: https://pixabay.com/vectors/sun-sunny-bright-daylight-attitude-378365/

The smiley faces for mood check in: https://pixabay.com/photos/smileys-customer-satisfaction-review-5617876/