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FAKULTÄT FÜR INFORMATIK

Faculty of Informatics

Computer Aided Training of Executive Functions for Elementary School-Aged Children

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Faculty of Informatics

Computer Aided Training of Executive Functions for Elementary School-Aged Children

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Abstract

Symptoms of the Attention Deficit Hyperactivity Disorder (ADHD), a very common and widespread mental health disease, are often recognizable at early age in childhood. Besides inattention, impulsivity and hyperactivity in many cases, patients diagnosed with ADHD also suffer from deficits in executive functions (EFs). Consequences such as academic performance problems or bad emotional and family functioning are often related to these deficits. Unfortunately, ADHD interventions are often designed for adults and are therefore only restrictedly applicable to children.

Motivated by the insufficient therapy possibilities, the computerized training program JATEF (Java applet based Training of Executive Functions), which was developed within this master thesis, has its goal in helping elementary-school aged children by improving certain EFs. JATEF consists of several different tasks (templates existed in a pen and paper version for adults), which were jointly picked and adapted in cooperation with the Department for Child and Adolescent Psychiatry at the Medical University of Vienna. On the one hand, it is of great importance to maintain the basic idea behind each task throughout the adaption process, but on the other hand, the children's acceptance of the design has to be ensured.

This work has the following two main objectives: Firstly, modifying the tasks for the needs of children and secondly, exploring whether the modifications are sufficient for a use in child therapy. JATEF was developed in accordance to the principles of the software development model known as Evolutionary Prototyping. Thus, prototypes of the tasks enabled the possibility of obtaining user feedback early-on in the design phase. In addition, short development cycles, with conclusive meetings, lead to permanent upgrades and improvements.

After completion of the final prototype, a user study with mental health professionals was conducted. The evaluation of this study revealed that the participants were pleased with the modern design and the universal applicability. Every task of JATEF proved to be easily understandable, simple to operate and, most importantly, suitable for children.

Kurzfassung

Das Aufmerksamkeitsdefizit-/Hyperaktivitätssyndrom (ADHS) gilt als eine sehr weit verbreitete psychische Störung, deren Ausprägungen oft bereits im Kindesalter erkennbar sind. Neben den typischen Symptomen wie Aufmerksamkeitsschwäche, Impulsivität und Hyperaktivität, weisen Patienten mit ADHS in vielen Fällen auch Defizite in ein oder mehreren Exekutivfunktionen auf. Auswirkungen dieser Erkrankung können sich unter anderem im schulischen und familiären Bereich bemerkbar machen. Bedauerlicherweise sind viele ADHS-Therapieansätze für Erwachsene ausgerichtet und deshalb nur eingeschränkt für Kinder anwendbar.

Im Rahmen dieser Diplomarbeit ist das computerunterstützte Trainingsprogramm JATEF (Java Applet based Training of Executive Functions) entstanden, welches speziell zur Defizitskompensation für Kinder im Volksschulalter ausgerichtet ist. Als Grundlage der in JATEF implementieren Übungsaufgaben diente ein Therapiebuch, wobei maßgebende Anpassungen von Nöten waren um die Kindertauglichkeit zu gewährleisten. Die Aufgaben wurden in Zusammenarbeit mit Therapeuten der Universitätsklinik für Kinder- und Jugendpsychiatrie des AKH Wiens ausgewählt und gestaltet. Die herausfordernde Aufgabe neben der Implementiterung selbst, war ein ansprechendes Design für Kinder zu finden wobei gleichzeitig die Grundidee beibehalten werden sollte.

Die beiden Hauptziele dieser Arbeit bestanden aus der Implementierung der angepassten Aufgaben und der Ermittlung, ob die Änderungen ausreichend für einen realen Therapieeinsatz sind. Bei der Implementierung wurde nach dem Softwareentwicklungsmodell *Evolutionäres Prototyping* vorgegangen, um bereits in der frühen Designphase wichtiges Feedback zu erhalten. Durch kurze Entwicklungszyklen mit abschließenden Meetings konnten die einzelnen Aufgaben stetig erweitert und verbessert werden.

Nach Fertigstellung des endgültigen Prototypens, wurde eine Nutzerstudie mit Experten durchgeführt. Diese hat ergeben, dass sowohl das Design der Aufgaben als auch die vielseitige Einsetzbarkeit gut umgesetzt wurden. Die einzelnen Aufgaben betreffend, kann gesagt werden, dass diese leicht verständlich, einfach in der Handhabung und vor allem geeignet für den Einsatz mit Kindern ist.

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CHAPTER

Introduction

1.1 Problem statement

Attention Deficit Hyperactivity Disorder (ADHD) is a widespread illness, beginning in childhood and affecting several areas of life, such as social behavior, education, work life, for example. Symptoms such as inattentiveness, hyperactivity and impulsivity are often related to ADHD. The diagnosis, however, is much more complex than the bare existence of certain symptoms or a deficit of executive functioning [Sergeant et al., 2002]. Exacerbating to different types of ADHD and their combinations, there are also common unspecific problems [National Collaborating Centre for Mental Health, 2009] - which may change in age - linked to this disorder, e.g. sleep disturbances, aggression, mood swings. Assuming that a patient is correctly diagnosed with ADHD, the question of a suitable intervention type is still open to resolve. While some interventions, such as the pharmacological or the psychological treatment, are well established and accepted [Hinshaw, 2006], others such as the EEG-feedback approach or the usage of computer games in therapy are supported by only a few studies (e.g. [Amon and Campbell, 2008, Klingberg et al., 2005, Wilkinson et al., 2008]). However, many studies (e.g. [Döpfner and Lehmkuhl, 2002, Chronis et al., 2006]) have shown that combined interventions, also known as 'multimodal' treatments, often lead to better results than single treatment approaches.

Additionally to the fact that it is hard to find the optimal treatment (combination) for a patient suffering from ADHD because of individual circumstances, many treatment approaches are designed for adults or adolescents only. It is still open to clarify if these approaches have the same impact on children. Existing computer aided training systems (e.g. [Gotsis et al., 2010, Shaffer et al., 2001, Andrade et al., 2006]) for children may be suitable and also effective in ADHD therapy but in their use families are often confronted with high acquisition costs.

1.2 Motivation

Given the problem statement above, it is inevitable to focus the efforts on (1) early diagnosis to contain long-term sequelae and (2) improving therapy approaches to be more effective in child therapy. Here, attention is given to both, with specific focus on the latter.

Motivated by the idea that computers are able to achieve and maintain undivided attention [Griffiths, 2002], JavaTM applets were used in this study to introduce a modern training system for the treatment of ADHD. The effectiveness of computer based therapy using gamelike software has already been presented in [Buschkuehl et al., 2007, Scanlon et al., 2007] but, unfortunately, computer-based therapy is still not very common.

Due to the necessity of early diagnosis and treatment of ADHD to prevent (or reduce the severity of) further consequences (as described in [National Collaborating Centre for Mental Health, 2009]), the chosen target group of the developed program are elementary school-aged children. The primary advantage of starting treatment in childhood is that such an approach has proved to be capable of significantly diminishing the impairments caused by ADHD [National Collaborating Centre for Mental Health, 2009]

It is of great importance to find a proper trade-off between fun, motivation and training for each implemented task. The resulting applets are designed to be available over a website for free, which means that everyone (not only children) will be able to use them anytime, anywhere, with hardly any hardware requirements and with no additional costs.

1.3 Aim of the work

After consultation with mental health professionals, it was mutually decided that a set of JavaTM applets, called **JATEF** (**J**avaTM **A**pplet-based **T**raining of **E**xecutive **F**unctions) in the following, representing different training approaches for specific learning disabilities, should be designed paying particular attention to the specific needs of children. This set of JavaTM applets has been realized within this work, where each applet has its own design and goal to help the user in compensating specific learning disabilities. Based on the books '*Kognitive Therapie bei Störungen der Exekutivfunktionen: ein Therapiemanual*' [Hildebrandt et al., 2004] and '*Handeln lernen*' [Pechtold and Jankowski, 2000] used for treatment of adults with ADHD, a selection of tasks were chosen (as jointly decided with mental health professionals), adapted, redesigned and updated to satisfy the expectations children have of a computer 'game'.

The big advantage of an intervention based on JavaTM applet technology is that a web-based game is more likely to get the attention of children than books would. It was not the aim of this work to create a substitute to psychiatrists, psychologists or any other existing treatment possibilities, but to support the former by increasing the effectiveness of treatment by providing an additional tool. Regarding the goals, JATEF should be:

- 1. easy to adjust for the therapists (in terms of configuring the difficulty level),
- 2. accessible independently of time, space and costs,
- 3. also accessible through mobile devices (e.g. tablets),

- 4. universally applicable (in terms of remodeling elements of the tool to cover different deficits),
- 5. appealing (in terms of design) and
- 6. motivating (to attract children and ensure usage for longer periods).

One of the most important goals was to consitently draw the children's attention to the tasks, so that they were willing to continue the training without resistance or, in the best case scenario, even voluntarily. After several training sessions the test persons will hopefully show significant improvements, which can be assessed by medical professionals. Based on the results of the tests, a study (not part of this work) including an acceptable number of subjects can be carried out to verify the validity of the programs' effectiveness.

1.4 Overview on the structure of the work

This work is divided into seven key chapters, namely:

- Background information
- State of the art
- Research question
- Methodology
- Results
- Evaluation
- Future work

The first chapter's goal is to give the reader an understanding of the basic principles in respect of the technical and medical components of this work. After a brief definition of the term 'applet', the two terms 'executive functions' and 'ADHD' will be discussed in detail to gain insight into what the connection between the two terms is and how they correlate with the research problem.

In the chapter 'state of the art' different therapy approaches will be presented and compared to the computerized intervention. Because of the great multiplicity of therapy possibilities, only the most important and common intervention approaches (e.g. pharmacological, psychological, EEG) will be discussed in this work. Subsequently, a discussion on the role of computers in therapy with corresponding definitions, advantages, disadvantages and their effectiveness will be shown by summarizing important publications on this matter.

After clarification of state of the art treatment possibilities, the chapter 'research question' will contain a concrete definition of the aim of this work. Furthermore, some other existing training programs used in ADHD treatment for children will be presented and differences to JATEF will be emphasized. Another important issue is the trade-off between motivation and design, which will also be a matter of this chapter.

In the methodology chapter, conditions and descriptions of the original tasks will be stated. The main focus of this chapter is (a) to introduce the original tasks and their design and (b) to describe the necessary modification steps. In addition, information on the chosen technology, the target group, the expandability and flexibility of JATEF will be given and justified. At the end of this chapter, the reader will be additionally provided with fundamental information on the development process.

In the results chapter, JATEF will be presented graphically by including several screenshots. After a description of program components, like the *AppletTask* class and the *ClickElement* class, information on the program flow will be given. Furthermore, input files, which demonstrate the diverse field of application of each task, will be analyzed and their usage will be explained.

The evaluation chapter will provide feedback of mental health professionals on the design of JATEF. It remains to be seen whether the design of JATEF is acceptable (suitable for children) and if further modifications have to be performed before starting the training with real patients.

Finally, the future work chapter contains improvement possibilities of JATEF.

CHAPTER 2

Background Information

In this chapter, the reader will gain basic knowledge about several terms that will be used throughout the study. Apart from the technical term *applet*, where clear definitions exist, the medical terms *executive function deficit* and *ADHD* are often used as an umbrella term to describe certain clinical disease patterns and are therefore described differently in literature. To avoid this ambiguity, it is necessary to agree on the definitions and classifications made in this chapter.

Regarding the level of detail of these definitions/classifications, it should be noted that the main goal here is to prepare the reader for the subsequent chapters. In case of unclarity, it is recommended to consult the cited literature to get further information.

2.1 Applets

The technology used for implementing JATEF was the JavaTM applet technology. The main characteristic of this technology is that the programs that are written in the programming language JavaTM run from a web browser. Thus, an advantage of this implementation method is that the training can be run from any web browser and on multiple operating systems. Furthermore, it is also possible to run the training on mobile devices (e.g. tablet pc) that have a built-in web browser, with the necessary JavaTM runtime environment (JRE) installed.

Regarding the runtime performance of JavaTM applets, it can be said that after the first initialization (including the starting process of the JRE), the loading of the applets will be very efficient because most web browsers have integrated caching methods. Associated with this point, it is also of interest that it is not necessary to uninstall JavaTM applets after execution. The applets are only loaded when needed and disappear after leaving the website or closing the web browser automatically. Furthermore, due to the nature of the applet architecture, the user will not have to update the technology as the browser will automatically recognize version differences and take them into account.

JavaTM applets enable the functionality of server-client communication, allowing for training information to be easily obtained from the user (client side) and saved. This information is saved

into a database (on the server side) for further analysis. Furthermore, the user does not have to worry about privacy and safety issues regarding his local system because JavaTM applets are executed in a so called *sandbox* which prevents them from accessing local data.

It should also be mentioned that during the development process special attention and effort was given so that no other libraries or toolkits were used. This means that only components (libraries, classes, methods, etc.) of the original JavaTM Core were used and therefore no dependencies on third party software exist. As a result, the source code is very slim (without optional code that is not used) and is thus runs efficiently.

2.2 Executive functions

Definition

'Executive functions' or 'executive functioning' (EF) are terms used to describe the brain processes that one has to manage in order to achieve a certain goal. These processes are part of the cognitive system and are considered to be responsible for social behavior, self-awareness, abstract reasoning, planning and many other abilities. The close association of EFs with the frontal lobes has caused a synonymous usage of the two terms, which can be problematic in some cases. Research found that the complexity of the connections between the frontal cortex and other brain regions, e.g. the cerebellum, the limbic system or the basal ganglia, makes a simple assignment of the EFs to a single brain region very unlikely. Morgan in [Morgan, 2000] showed that the frontal lobes play an important but not exclusive role in the EF process chain.

Rommelse and Buitelaar described a hierarchical relationship [Rommelse and Buitelaar, 2008] where less complex processes are called lower-order processes, such as encoding, search, decision, etc. and more complex processes are called higher-order processes or EF. These higher-order processes also contain lower-order processes, so that it is very difficult to determine if an executive deficit has its origin in the lower- or higher-order processes. Rommelse and Buitelaar also emphasize this distinction for therapeutic reasons, where it is possible to treat the patient with tasks and exercises either focused from the bottom of the hierarchy (affecting lower-order processes, motor processes) or from the top (affecting EFs).

Because of the wide variety of EFs (Sergeant et al. found 33 definitions published by Eslinger in [Eslinger, 1996]), it is convenient to group them by dimensions regarding tests and/or probable brain localization. Besides the great number of different definitions, most EFs have planning or future directed/oriented behavior as a common component [Wolfe, 2004].

Types

Before starting the examination of several EF types, it is crucial to have evidence that the different types are in fact distinguishable. Miyake et al. focused on this problem and created several models with different correlation factors among the EFs (shifting, updating and inhibition) and came to the result that these three EFs are clearly distinguishable but not fully independent from each other. In other words, one of the main results of this work is the definition of the EF as *separable but related* functions that share some underlying commonality [Miyake et al., 2000]. While Sergeant et al. focused on analyzing five different types of EFs (inhibition, set shifting, working memory, planning and fluency) [Sergeant et al., 2002], other authors, such as Barkley [Barkley, 2000], split them into five diverse (but similar) major groups of EFs (response inhibition, nonverbal working memory, verbal working memory, self-regulation of emotion and motivation & reconstitution) and included associated component processes and social abilities.

In the following, the EF classification proposed by Sergeant et al. will be discussed in more detail and corresponding tests/tasks will be introduced.

• Inhibition

Inhibition plays an important role when discussing EFs because many authors see a clear correlation between the disability to inhibit, also called disinhibition, and the clinical symptoms frequently seen in young children diagnosed with ADHD, which will be discussed in section Definitions and Diagnosis on page 11. Patients diagnosed with disinhibition are often not able to withhold a predominant response and therefore tend to respond to a task before the task is understood or answer the question before sufficient information is available [Wolfe, 2004].

Possibilities to measure response inhibition are the *stop task* and *Stroop*. The former requires the children to inhibit a motor response that is being executed. Concretely, whilst the child is performing a task, whenever a stop signal is presented, the child immediately has to inhibit the response to the primary task. Within this task, it is possible to vary the timing of the stop signal in order to estimate the speed of the inhibitory process (stop signal reaction time: SSRT). In the work of Sergeant et al. the meta-analysis of SSRT showed that in seven of eight studies, children with ADHD were on average 103 ms slower than children in the control group [Sergeant et al., 2002].

The Stroop Test, published by J. R. Stroop in 1935, is a test with its aim at determining and measuring the interference between color naming and word reading. Stroop had the idea of a compound stimulus, which was created by printing the color name in a different ink color (see Figure 2.1). So, this test has two dimensions (the color and the word) and the intention is to measure the effect of one dimension when trying to name the other [MacLeod, 1991].

There are several studies that show that ADHD has an clear impact on Stroop test results and with help of a neural imaging study, it is possible to relate these results to the caudate nucleus region in ADHD subjects. Though there is evidence that the Stroop test is able to distinguish between ADHD and control group, the precise neuropsychological mechanism responsible for this interference effect is still not completely clarified [Sergeant et al., 2002].

• Set Shifting

When talking about set shifting (in the context of ADHD), the ability of shifting *cognitive* sets is meant. More precisely, test subjects have to shift attention from one stimulus attribute to another and therefore display flexibility. This type of EF is also speculated to be localized in the frontal lobes because studies showed that lesions in this area have

BLUE	RED	YELLOW	ORANGE RED
PURPLE	YELLOW	RED	BLUE
ORANGE	BLUE	YELLOW	RED
RED	GREEN	ORANGE	BLUE
PURPLE	YELLOW	BLUE	ORANGE

Figure 2.1: The Stroop Test

significant impact on test results of set shifting tasks. However, the precise anatomical localization is still controversial and other brain regions (responsible for e.g. inhibition or working memory) may also play an important role, as shown using functional magnetic resonance imaging (fMRI) experiments in [Sergeant et al., 2002, Konishi et al., 1998].

The most common testing method for measuring the ability of set shifting is the Wisconsin Card Sorting Test (WCST). This test was developed by D. A. Grant and E. A. Berg in 1948 and consists of five cards, namely the target card and four reference cards. The task of the test subject is to match the target cards with one of the reference cards with respect to various stimulus dimensions, such as color, design or quantity (see Figure 2.2). Because this stimulus can be changed by the experimenter during the test, the subject has to shift his/her cognitive set in order to find the correct match [Grant and Berg, 1948, Konishi et al., 1998].

Sergeant et al. pointed out that the computerized version of the WCST may lead to different results to the traditional version such that autistic children tend to perform better on computational tasks. It is of great importance to keep in mind that the WCST does not only measure the set shifting ability, but also the problem solving ability, the ability to modify incorrect strategies, flexibility and inhibition. Many studies have shown that the WCST is capable of differentiating between ADHD and control groups [Sergeant et al., 2002].

• Working Memory

A good definition of the capacity of working memory is given by Klingberg et al. where they describe it as *the ability to retain and manipulate information* during a short period of time [Klingberg et al., 2002]. Like set shifting, activities using working memory seem to be particularly sensitive to prefrontal damage and therefore the prefrontal cortex has been associated many times with working memory and self ordered pointing [Barkley, 2000].

There are various tasks and tests to measure this capacity but the most famous one is the Self Ordered Pointing Task (SOPT), introduced by Petrides and Milner in 1982 [Petrides



Figure 2.2: The Wisconsin Card Sorting Test

and Milner, 1982]. In the SOPT, the subject is confronted with a page displaying a number of different stimuli, which are spatially arranged. These stimuli can be represented as concrete words, abstract words, concrete designs or abstract designs. The task is to point to each stimuli item only once in a trial. After pointing to an item, the spatial relations change (the items stay the same) and the subject has to remember which items he/she has pointed to in order to avoid pointing at any of them twice. Due to the changing positions of the items, it is necessary to remember the actual items instead of the locations to which they were printed (see Figure 2.3). This task can be varied by increasing the number of stimuli on each page [Sergeant et al., 2002].

• Planning

Planning is often described as a kind of problem solving or as the ability to 'look ahead', to construct a plan, etc. [Sergeant et al., 2002]. A good definition of planning is given by Goel and Grafman, where they state that planning is a distinct cognitive activity, akin design, and deserves careful characterization. Furthermore, they compared planning to charting a course from point A to point B without 'bumping' into the world. All the 'bumping' must be done in some modeling space and eventually some satisfactory path has to be extracted [Goel and Grafman, 1995].

Two tasks measuring the planning ability are the *Tower of Hanoi* (ToH) and *Tower of London* (ToL), which are quite similar. In fact, ToL is a modification of ToH but still with the same goal. Both require the subject to be able to imagine different ways/plans of transferring variously sized disks (ToH) or beads (ToL) on a set of pegs or spindles (in most cases three) before undertaking the actual motor execution of the plan to achieve a certain goal state [Barkley, 1997] (see Figure 2.4).

By doing so, the subject has to adhere to the following three rules (concerning ToH) [Goel



Rowe, Hasher, Turcotte, Neuropsychology, Vol 24(6), Nov 2010, 804-807.

Figure 2.3: The Self Ordered Pointing Task

and Grafman, 1995]:

- 1. Only one disk may be moved at a time.
- 2. Any disk not being currently moved must remain on a peg.
- 3. A larger disk may not be placed on a smaller disk.



Figure 2.4: The Tower of Hanoi

• Fluency

Whilst processing speed and size of vocabulary are two important cognitive processes regarding fluency, again, many other processes are also involved (like inhibition, semantic memory, working memory and also set maintenance) [Sergeant et al., 2002].

Fluency tasks require the subject to generate a set of adequate responses to a given stimulus, within a certain time period. There are two common types of fluency tasks, where the subject is asked to use two different ways of set generation.

In short, there are firstly the semantic tasks, where the subject has to find words matching a given semantic category (e.g. sports, animal types) and secondly, the phonemic tasks,

where the subject has to retrieve words beginning with a given letter. Some authors have argued that the phonemic task is more difficult to complete because the subjects do not only need to generate the set of adequate words but also suppress the usual tendency to search for words by meaning [Phillips et al., 2002].

2.3 Attention Deficit Hyperactivity Disorder

Definitions and Diagnosis

Attention deficit hyperactivity disorder (ADHD) is a chronic, mental disorder, where the behavior of concerning subjects is often characterized by the terms of *inattention*, *impulsivity* and *hyperactivity*. Regarding to [National Collaborating Centre for Mental Health, 2009], the mentioned terms are defined as follows:

- Impulsivity = Premature and thoughtless actions.
- Hyperactivity = A restless and shifting excess of movement.
- Inattention = A disorganized style, preventing sustained effort.

Because each of the symptoms can be present in an individual to a different extent, which again can be influenced by context as well as by the constitution of the person, a correct diagnosis is not a simple procedure. Hence, there are attempts to define and classify ADHD in children by measurable values in order to (a) avoid incorrect diagnosis and (b) improve early recognition.

The two most important official definitions and classifications of ADHD in childhood are given by the *Diagnostic and Statistical Manual of Mental Disorders* (DSM, see Table 2.3) and the *International Classification of Diseases* (ICD, see Table 2.2).

Table 2.1: Excerpt taken from DSM-IV-TR [America Psychiatric Association, 1994]

A. Either (1) or (2): (1) Inattention: six (or more) of the following symptoms of inattention have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level: (a) often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities (b) often has difficulty sustaining attention in tasks or play activities (c) often does not seem to listen when spoken to directly (d) often does not follow through on instructions and fails to finish school work, chores, or duties in the workplace (not due to oppositional behavior or failure to understand instructions) (e) often has difficulty organizing tasks and activities (f) often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework) (g) often loses things necessary for tasks or activities (e.g., toys, school assignments, pencils, books, or tools) (h) is often easily distracted by extraneous stimuli (i) is often forgetful in daily activities (2) Hyperactivity-Impulsivity: six (or more) of the following symptoms of hyperactivityimpulsivity have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level: Continued on next page

Table 2.1 – continued from previous page

Hyperactivity

- (a) often fidgets with hands or feet or squirms in seat
- (b) often leaves seat in classroom or in other situations in which remaining seated is expected
- (c) often runs about or climbs excessively in situations in which it is inappropriate (in adolescents or adults, may be limited to subjective feelings of restlessness)
- (d) often has difficulty playing or engaging in leisure activities quietly
- (e) is often 'on the go' or often acts as if 'driven by a motor'
- (f) often talks excessively

Impulsivity

- (a) often blurts out answers before questions have been completed
- (b) often has difficulty awaiting turn
- (c) often interrupts or intrudes on others (e.g., butts into conversations or games)

B. Some hyperactive-impulsive or inattentive symptoms that caused impairment were present before age 7 years.

C. Some impairment from the symptoms is present in two or more settings (e.g., at school [or work] and at home).

D. There must be clear evidence of clinically significant impairment in social, academic, or occupational functioning.

E. The symptoms do not occur exclusively during the course of a Pervasive Developmental Disorder, Schizophrenia, or other Psychotic Disorder and are not better accounted for by another mental disorder (e.g., Mood Disorder, Anxiety Disorder, Dissociative Disorders, or a Personality Disorder).

As one can see, the diagnosis criteria defined by DSM-IV-TR are quite different to the ones defined by ICD-10, which can be misleading in the diagnosis process. In ICD-10, the defined impairment *Hyperkinetic disorder* is, generally speaking, only a subtype of ADHD (also see Chapter Subtypes). Exacerbating these definition inconsistencies is the fact that symptoms related to ADHD may also vary with the age of the subject, as stated in [National Collaborating Centre for Mental Health, 2009]. There, common problems associated with ADHD in children (e.g. non-compliant behavior, motor tics, sleep disturbances, aggression, mood swings) were observed to appear in different manifestations at different ages. To give a specific example, hyperactivity may involve demanding extremes of activity in pre-school age while increased

Table 2.2: Excerpt taken from ICD-10 [World Health Organization, 2007]: Behavioural and emotional disorders with onset usually occurring in childhood and adolescence. In the current version of the ICD, ADHD can be found in chapter 5, where mental and behavioural disorders are listed. This chapter again, is split into several sections, where the section F90-F98 will be of interest to the reader.

F90	Hyperkinetic disorders					
	A group of disorders characterized by an early onset (usually in the first five years					
of life), lack of persistence in activities that require cognitive involvement,						
	dency to move from one activity to another without completing any one, toget					
	with disorganized, ill-regulated, and excessive activity. Several other abnormalities					
	may be associated. Hyperkinetic children are often reckless and impulsive, prone to					
	accidents, and find themselves in disciplinary trouble because of unthinking breaches					
	of rules rather than deliberate defiance. Their relationships with adults are often so-					
	cially disinhibited, with a lack of normal caution and reserve. They are unpopular					
	with other children and may become isolated. Impairment of cognitive functions					
	is common, and specific delays in motor and language development are dispropor-					
tionately frequent. Secondary complications include dissocial behavi						
	self-esteem.					
F90.0	Disturbance of activity and attention					
	Attention deficit:					
	- disorder with hyperactivity					
	- hyperactivity disorder					
	- syndrome with hyperactivity					
	Excludes: hyperkinetic disorder associated with conduct disorder					

movements, where calm is expected, appear in school-age and an inner sense of restlessness is present in adult life.

For the sake of completeness, it should be mentioned that there are also other ways for classifying ADHD such as standardized rating scales, for example see WHO's 'Self-report Scale' (the online test for adults can be found here: http://psymed.info/default. aspx?m=Test&id=64&l=3) or assessment interviews with parents and teachers, which will not be discussed further in this work.

Comorbidity

Additionally to the difficult diagnosis procedure, there are also several comorbid disorders accompanying ADHD. The main goal here should not be the finding of a differential diagnosis due to mismatching of symptoms with respect to the criteria system, but the correct recognition of existing comorbidities. To give an example, Harpin stated that around 60 % of children with Tourette's Syndrome fulfill criteria for ADHD [Harpin, 2005]. Furthermore he showed by a study of Swedish school aged children, that at least 65 % of the children with ADHD have one or more comorbid conditions (e.g. autistic spectrum disorder).

In [Hinshaw, 2006], the authors wrote that in over half of all examined ADHD cases, comorbid aggressive-spectrum was detected, which qualifies for diagnoses of oppositional defiant disorder (ODD) or conduct disorder (CD). More importantly for this work, Hinshaw determined that approximately one quarter of all children and adolescents with ADHD also display learning disorders.

Recognition of comorbidities is vital because it plays an important role in the treatment selection process. As there is no standard treatment for ADHD, the treatment interventions have to be individually customized for each patient. To give an example, Döpfner and Lehmkuhl could prove that behavioral intervention induced significantly better results in children with comorbid anxiety disorder (but without aggressive-spectrum disorder) than the common intervention and that children with or without comorbid aggressive-spectrum disorder (but without anxiety disorder) had better results with medical intervention [Döpfner and Lehmkuhl, 2002].

Academical Impact

After clarifying the disease pattern of ADHD, this section will briefly deal with the possible academical impact and the necessity of training interventions. The biggest problem here is that children with ADHD are typically more inattentive than children without ADHD which leads to the result that they exhibit academic performance problems in up to 80 % of cases [Rabiner et al., 2010]. Shaw and Lewis stated in their work [Shaw and Lewis, 2005] that children with ADHD consistently underachieve academically and over 50 % of these children failed annual school exams with a 90 % likelihood of school failure and a 50 % likelihood of under-achievement in employment.

Besides exclusive academical aftermaths, Harpin wrote that many children also experience bad emotional- and family-functioning as they tend to develop antisocial behaviour. While the former entails lower self esteem, worse mental health, reduced parent time and family activities, the latter causes increased behaviour patterns such as stealing, lying, arson and truancy [Harpin, 2005].

Subtypes

As already mentioned, there are certain subtypes, also called subgroups, of ADHD. These subgroups were introduced because the three main symptoms (inattention, impulsivity and hyperactivity) can be expressed differentially and therefore influence behavioural patterns in each individual. As a consequence, the corresponding treatment is also heavily dependent on the diagnosed subgroup.

Mainly, there are three subgroups to be distinguished:

• **Inattentive type**: The inattentive type, also called *predominantly inattentive type* [Hinshaw, 2006], is characterized by an extreme level of inattention with very low levels of hyperactivity or impulsivity. Regarding the DSM-IV-TR classification, six (or more) symptoms have to be present in the inattention section A(1) and less than six in the hyperactivity-impulsivity section A(2). Children with this type of ADHD are typically very quiet and do not get into trouble often, making diagnosis more difficult. Hinshaw also pointed out that only minimal research efforts have been directed towards the treatment of this type despite the fact that this type is the most prevalent.

Additional indicators of inattention (exemplary taken from [Grohol, 2010]) are:

- Not paying attention to details.
- Becoming easily distracted by irrelevant sights and sounds.
- Not appearing to listen when spoken to directly.
- Hyperactive-Impulsive type: Secondly, there is the hyperactive-impulsive type, also called *predominantly hyperactive/impulsive type*, of ADHD, where individuals display six or more symptoms from the section A(2) and less than six from the section A(1). In [Grohol, 2010], Grohol distinguished the hyperactive type from the impulsive type where hyperactivity is described by the term 'always seems to be on the go' with be-vaviour patterns such as feet wiggling, noisily pencil tapping or trying to stay busy/doing multiple things at once. The impulsive type is characterized by the inability to control immediate reactions. Impulsive children also tend to blurt out inappropriate comments or show their emotions without restraint.

Additional indicators of hyperactivity-impulsivity (exemplary taken from [Grohol, 2010]) are:

- Feeling restless, squirming while seated.
- Interrupting or intruding on others.
- Having difficulty waiting in line.
- **Combined type**: The combined type is specified as the case of having six (or more) symptoms of the inattention section A(1) and six (or more) symptoms of the hyperactivity-impulsivity section A(2), at the same time. Though this type is not the most prevalent one (the inattentive is), the combined type is the most likely to be referred for clinical service [Hinshaw, 2006]. Typical symptoms for this subgroup are all the aforementioned symptoms in the other subgroups.

2.4 Relation between executive functions and ADHD

Many scientists believe that one of the main reasons for behaviour/symptoms typical for ADHD arises from a primary deficit in EF. EF theory is supported by many studies, where subjects with ADHD score worse than the subjects in the control groups. A possible explanation for these results may be given by observations showing that prefrontal lesions often lead to ADHD typical behaviour (inattention, hyperactivity and impulsivity) as well as deficits on EF tasks [Willcutt et al., 2005].

Sergeant et al. showed in their paper [Sergeant et al., 2002] that significant differences in EF tasks between children with disorders like ADHD, ODD, CD or higher functioning autism (HFA) and control groups exist. In their work, they presented and summarized more than 60 studies concerning various EF tasks, target groups (disorder types) and age range. Table 2.3 shows some extracted results of studies that were perceived as relevant (age range: elementary school age; disorder: ADHD) to this work.

Table 2.3: Short excerpt of relevant study results taken from [Sergeant et al., 2002].	This table
consists of studies where the age range fitted that of elementary school age and the	examined
disorder was ADHD.	

Study by	Subjects	Age	EF tasks	Results
		range		
Schachar, Mota, Logan,	72 ADHD	7-12	Stop Task	SSRT: ADHD > Controls
Tannock & Klim (2000)	33 Controls			
Nigg (1999)	25 ADHD	6-12	Stop Task	SSRT: ADHD > Controls
	25 Controls			
Pineda, Ardila & Rosselli	62 ADHD	6-12	WCST	Errors: ADHD > Controls
(1999)	62 Controls		Fluency	ADHD < Controls
Rubia, Oosterlaan,	11 ADHD	6-12	Stop Task	SSRT: ADHD > Controls
Sergeant, Brandeis & Van Leeuwen (1999)	11 Controls			
Wiers, Gunning &	28 ADHD	7-11	SOP	Errors: ADHD > Controls
Sergeant (1998)	34 Controls			
Carter, Krener, Charder-	20 ADHD	9-12	WCST	Errors: ADHD > Controls
jian, Northcutt & Wolfe (1995)	20 Controls			
Weyandt & Willis (1994)	36 ADHD	6-12	ТоН	Score: ADHD < Controls
	45 Controls			
Pennington, Groisser &	16 ADHD	7-10	ТоН	Score: ADHD < Controls
Welsh (1993)	23 Controls			
Grodzinsky & Diamond	66 ADHD	6-11	Stroop	Errors: ADHD > Controls
(1992)	64 Controls		Fluency	ADHD < Controls
Koziol & Stout (1992)	19 ADHD	7-14	Fluency	ADHD < Controls
	7 Controls			

Willcutt et al. conducted a meta-analysis of 83 studies where groups with ADHD and groups without ADHD were formed and tested on EF tasks [Willcutt et al., 2005]. Their conclusion was that results of tasks like response inhibition, vigilance, working memory and planning were significantly weak in children with ADHD and could not be explained by group differences in intelligence, academic achievement or symptoms of other disorders.

As one can see in Table 2.3, there seems to be a close relation between EFs and ADHD but the implication of these two (in both directions) is not yet completely proven. Willcutt et. al. wrote that EF weaknesses are neither necessary nor sufficient to cause all cases of ADHD and difficulties with EF (tasks) appear to be one important component of the complex neuropsychol-

ogy of ADHD. Furthermore, the association of EFs and ADHD shown by many studies in the past do not take into account that other disorders and comorbidities (e.g. ODD, CD, HFA) may bias the results. Sergeant demanded multiple group comparisons in order to show that the EF differences are specific to ADHD and not to other clinical groups.

Rommelse and Buitelaar also pointed out that though EFs are closely associated to ADHD, non-EFs such as motor functions must not be disregarded only because they are underexposed in the majority of the existing theories [Rommelse and Buitelaar, 2008]. As already mentioned in Section 2.2 on page 6, EFs and non-EFs are strongly inter-related and a precise responsibility assignment is not always possible. Thus, ADHD and its deficits could either be explained by the direct impairment of EFs or by the impairment of non-EFs, in which case EF deficits are only secondary.

Given the evidence to suggest that EFs are a key factor in the diagnosis of ADHD and that 'brain games', such as the Stroop and the Wisconsin tests, are an effective tool in measuring EFs, and therefore the severity of ADHD, in children, it seems intuitive to determine how such tools can be developed. Further, given the ever increasing presence of computers in our lives, it is inevitable that the use of computer-based tests to further enhance current diagnosis and treatment measures for ADHD is likely to become more common. Development of such computational tools is thus the focus of this study.

CHAPTER 3

State of the art

In the following sections, brief descriptions and characteristics of existing intervention possibilities for ADHD are given. The intervention types discussed here are

- pharmacological intervention,
- behavioural intervention,
- combined intervention approaches,
- EEG-feedback intervention and
- online therapeutic interventions.

Rather than going into deep detail of each intervention (except for the online interventions as they are the major part of this work), the methodology, the advantages and disadvantages of each approach are presented instead. For completeness, it is acknowledged that other intervention types also exist, which will not be discussed in this work (e.g. dietary intervention). For clarity, intervention types are firstly distinguished in terms of computer usage in ADHD treatment.

After giving a basic understanding regarding the above mentioned intervention types, this chapter will subsequently deal with two subordinated questions:

- 1. What are the advantages of computerized training?
- 2. How effective are computer programs in training children with ADHD?

3.1 Interventions without the usage of computers

Pharmacological intervention

The pharmacological intervention is by far the most commonly used (approximately 85 % of children diagnosed with ADHD) approach in ADHD therapy and one reason is the strong evidence for the efficacy of stimulant medication (e.g. methylphenidate), which increases the level of dopamine in the brain. The benefit of stimulant medication is the large effect it has on the core symptomatology where early outcome can be recognized on the behaviour at home or in school (e.g. reduced disruption in classroom, increased compliance) [Chronis et al., 2006]. Alternatively, non-stimulants like atomoxetine can also be used as medication [National Collaborating Centre for Mental Health, 2009] but here, the effects will not appear as quickly as with stimulant medication.

Despite the clear positive impact of medication, there are also some drawbacks associated with the pharmacological intervention approach. Firstly and most importantly, the pharmacological benefits last only as long as the medication is in the child's system [Hinshaw, 2006]. That means that the positive long-term effects of taking medication could not be proven sufficiently, while negative side-effects such as insomnia or appetite suppression appear in many cases [Chronis et al., 2006, Leins et al., 2007]. Secondly, this intervention approach is declined by many parents, especially if the child is in a very young age (even manufacturers of stimulant medication do not recommend their use for the treatment of children under 6 years [National Collaborating Centre for Mental Health, 2009]). Döpfner and Lehmkuhl wrote that the *per se* predominance of the pharmacological intervention against other intervention types has to be questioned if results other than short-term effects are of interest [Döpfner and Lehmkuhl, 2002].

Finally, as ADHD is suggested to have its cause in multiple reasons (e.g. not only mental but also familial), it is unlikely that medication is a sufficient way to treat this disorder without the simultaneous use of other intervention approaches [Chronis et al., 2006].

Behavioural intervention

This intervention method basically consists of two different approaches, where each approach is linked to a different environment though the borders between the environments are rather blurry.

The first approach is based on the parent-child relationship and/or the teacher-student relationship. In both cases, the concerning people (parents or teachers) receive consultation from a behavioural expert in such tactics as measuring behaviour, targeting problems for intervention, token reward program, utilizing consistent (and nonphysical) punishments and many more [Hinshaw, 2006]. While teachers receive additional instructions on classroom behaviour management where techniques such as giving praises or planning ignorance are included [Ravichandran and Jacklyn, 2009], parents learn to avoid the use of developed maladaptive and counterproductive parenting strategies [Chronis et al., 2006]. Simplified, the main objective in both approaches is to structure the everyday environment of the child and reduce/avoid possible stress situations through a better understanding of the child's behaviour.

In the second approach, the cognitive-behavioural approach, the intervention is conducted directly with the child, either individually or in small groups [Hinshaw, 2006]. Here, the child

will be trained in self-instruction/self-control, problem solving and self-reinforcement strategies in order to improve the error-coping ability. Ravichandran and Jacklyn presented a five-step process to problem-solving for children consisting of (1) defining the problem, (2) setting a goal, (3) generating problem-solving strategies, (4) choosing a solution and (5) evaluating the outcome with self-reinforcement. Under this process, they observed a significant decrease in child activity compared to the control group [Ravichandran and Jacklyn, 2009].

Combined Interventions

Combined interventions were introduced due to their versatility and only a few will be discussed here. First of all, it should be clarified that the term combined intervention typically stands for the simultaneous use of a pharmacological and a non-pharmacological, usually psychological treatment [National Collaborating Centre for Mental Health, 2009].

Studies have shown that the combination of treatments yielded greater levels of improvement than single-modality interventions [Hinshaw, 2006]. To give an example, the psychological treatment typically takes more time to work, so the pharmacological intervention is often used in the first instance in order to achieve a more rapid improvement, where time plays an important role (e.g. imminent exclusion from school).

Furthermore, the NICE Guideline on diagnosis and management of ADHD in children [National Collaborating Centre for Mental Health, 2009] suggests that stimulants may enhance conditionability, which presents an important factor in behavioural learning. As a result, psychological interventions that utilizes learning principles can be improved by stimulant medication.

Other combinations, such as pharmacological intervention plus parent training, are also very common and suggest better results than the standard (pharmacological) intervention alone [Döpfner and Lehmkuhl, 2002].

To sum up, combined intervention should be preferred if available, as Table 3.1 demonstrates with a few results of the Multimodal Treatment Study of Children with ADHD (MTA) [MTA Cooperative Group, 1999].

3.2 Interventions based on the use of computers

As computers are nowadays well established in nearly every part of life, it is not surprising that they even made it to the sensible area of psychiatry. Still, as Das has pointed out, compared to other medical specialists, psychiatrists use computers in routine care less often [Das, 2002]. In his work, Das stated that there are several factors causing this difference but security and confidentiality of patient information may be the most important issues concerning the use of computers.

Furthermore, Das reviewed 57 articles on computer programs in psychiatry published from 1966 and 2002, grouped them by the type of computer program and published as in Table 3.2.

With reference to Table 3.2 and the discussion of Das, the largest area of research has been on *decision and diagnostic support* programs, but for various reasons the interest in such programs has declined rapidly in the last few years. In contrast to that, programs used for *patient screening and therapy* constantly increased over the examined time period. Since JATEF has

Table 3.1: MTA Study: Excerpts of the results representing the effects after a period of 14 months (adapted from [Döpfner and Lehmkuhl, 2002]). PHARM = Pharmacological intervention including advice; BI = Behavioural intervention; COMB = Combined intervention of MED and BI; CC = Community care

Parameter	COMB vs.	Intervention vs.	
- Judge	Intervention	Standard (CC)	
Inattention			
- Teacher	COMB = PHARM	COMB > CC	
	COMB > BI	PHARM > CC	
		VT = CC	
- Parents	COMB = PHARM	COMB > CC	
	COMB > BI	PHARM > CC	
		VT = CC	
Hyperactivity/			
Impulsivity			
- Teacher	COMB = PHARM	COMB > CC	
	COMB = BI	MED > CC	
		VT = CC	
- Parents	COMB = PHARM	COMB > CC	
	COMB > BI	MED > CC	
		VT = CC	
Aggression			
- Teacher	COMB = PHARM	COMB > CC	
	COMB = BI	PHARM > CC	
		VT = CC	
- Parents	COMB = PHARM	COMB > CC	
	COMB = BI	PHARM = CC	
		VT = CC	

clearly to be classified as an online program (see Section 2.1 on page 5), this study will focus on online program types.

Offline therapeutic intervention programs

Two important computer-based interventions that do not utilise the internet are offline games and computer programs based on biofeedback. A recognizable trend of computer programs in the medical domain is that many recent implementations are customized for children. These computer programs are often designed like games or quizzes, so that children get attracted by them and do not have the feeling of being tested or trained while exercising. The interesting part of this trend is not only analyzing how effective such games are and what role they play in

	Decision and	Patient		
	diagnostic	screening	Data collection	Data
Time Period	support	and therapy	and management	modeling
1967 to 1977	60.0 %	10.0 %	25.0%	5.0 %
1980 to 1990	55.6 %	22.2 %	22.2%	0.0~%
1992 to 2001	28.0 %	40.0 %	16.0%	16.0 %

Table 3.2: Percentage distribution of articles published during three time periods grouped by type of computer program (taken from [Das, 2002]).

treatment, but also how such programs have to be designed in order to satisfy both the mental health professionals and the children.

Apart from online programs, which will be discussed later, a rarely used method among parents for treating ADHD is the approach that uses the help of an electroencephalogram (EEG). The gained EEG-feedback, also called neurofeedback, is explained as a training technique to teach individuals to consciously use physiological signals from their body to recognize and change internal states. In doing so, scientists try to teach how to control these signals in order to improve the children's health and performance [Amon and Campbell, 2008].

Regarding the methodology of EEG-feedback usage in ADHD intervention, the child is attached to electrodes on the scalp so that the brain activity can be observed. The child's goal is to manipulate the input of the video game (a direct response of the EEG-feedback is displayed on the screen) by altering the brain waves in order to fulfill a certain game task. Griffiths described this methodology as the attempt to teach patients to control normally involuntary body functions by providing real-time monitors of these responses [Griffiths, 2002].

More specifically, the EEG-feedback can be split up into brain waves of different frequency ranges where, in the case of ADHD, a decrease of low frequency ranges (theta range) and an increase of high frequency ranges (beta range) is desired [von Brisinski, 2001, Leins et al., 2007, Allhambra et al., 1995].

Online therapeutic intervention programs

Because of the wide variety of programs used in treatment, it is not always easy to find a clear distinction in order to build a proper classification. To begin, let us make a first distinction between *online* and *offline* computer programs. While the former are described by characteristics like 'internet-supported' or 'web-based', the latter are the traditional stand-alone programs, thus work without any communication with a server.

According to [Barak et al., 2009], four types of internet-supported interventions exist:

- 1. Web-based interventions
- 2. Online counseling and therapy
- 3. Internet-operated therapeutic software

4. Other online activities

In addition, every web-based intervention contains four key components, which build an indispensable basis.

Firstly, the *program content*. This is the most basic and necessary component, which has its intent either in education or the creation of therapeutic change.

Secondly, the *use of multimedia* plays an important role in every web-based intervention. Besides using text to present the program content, it is also recommended to include graphics, animations or clips to make the program more dynamic and interesting. Dependent on the aim of the program, it should be stated that the use of many different media will not always produce better performances [Shaw and Lewis, 2005]. This aspect will be discussed in more detail below (see Section 3.2 on page 28).

Thirdly, the *level of interactive online activities*. Patient engagement and interest seem to increase with increased interaction.

Fourthly, *guidance and supportive feedback*. This component specifies how much feedback (from none to highly customized patient feedback) a web-based intervention program provides, where feedback can either be generated programmatically or provided by a human.

Barak et al. defined three subtypes (differing from the four components listed above) of web-based interventions, see Table 3.3. Internet-supported intervention types and subtypes are summarized briefly (further information about each type can be found in [Barak et al., 2009]).

Web-based education interventions

Web-based education interventions have the aim of providing information about certain (mental) health issues to the patient in order to improve and enhance their awareness and knowledge. The treatment of such a therapeutic intervention can be classified as either inactive or active, though some of them are able to provide feedback [Barak et al., 2009].

Self-guided web-based therapeutic interventions

These types of programs are used to actively change a patients behavior positively, thus these programs can be defined as active. A self-guided web-based therapeutic intervention often uses several multimedia formats or multiple activities and provides automated feedback. Depending on the program, the feedback level can vary from no tailored feedback to highly tailored (e.g. corrective, explanatory) feedback responses [Barak et al., 2009].

Human-supported web-based therapeutic interventions

Similar to self-guided web-based therapeutic interventions, the human-supported web-based therapeutic interventions also provide behavior change content to influence the patient positively. The difference between these two types is that here, a human professional is part of the system and is responsible for feedback. As a result, the response delay depends on the employed communication modality (e.g. emails, forum postings, Skype conferences, telephone calls). Another difference is that this type of intervention is often controlled and requires registration in

Table 3.3: Overview of internet-supported intervention program types. (Modified version of the table taken from [Barak et al., 2009].)

Program types	Subtypes	Characteristics	
1.) Web-based interven-	(a) Web-based education	- provide information	
tions	interventions	- inactive	
		- poor feedback mechanism	
	(b) Self-guided web-	- active behavioral changes	
	based therapeutic	- multimedia usage	
	interventions	- complex feedback mechanism	
	(c) Human-supported	- similar to 1.b)	
	web-based therapeutic	- human feedback	
	interventions	- controlled	
2.) Online counseling and		- communication through inter-	
therapy		net	
		- no distance dependency	
		- poor expression possibility	
		- no emergency assistance	
3.) Internet-operated ther- apeutic software	(a) Robotic simulation	- chat-bots	
	(b) Rule-based expert sys-	- assessment	
	tems	- planning	
		- monitoring	
	(c) Gaming/virtual reality	- fun-factor	
		- for exposure therapy	
4.) Other online activities	(a) Blogs	- possibility to publish own	
		thoughts	
		- receive response	
		- easy to use	
	(b) Support groups	- gain support/empathy	
		- preserve privacy	

order to gain access to it, while self-guided web-based therapeutic interventions are designed to have a broad reach and therefore have a public health function [Barak et al., 2009].

Online counseling and therapy

Online counseling and therapy is a type of intervention where the communication between patient and health professional takes place exclusively over the internet. The possible communication modalities are *individual* or *group conversation* and *synchronous* (e.g. instant messaging) or *asynchronous* (e.g. email) response.

On the one hand, there is the great advantage of a therapy alternative independent from the distance between patient and therapist, but on the other hand, there are also disadvantages such

as less powerful expression possibilities (in comparison to face-to-face therapy), concealing true identity on both sides, digital divide and the lack of emergency assistance if needed [Barak et al., 2009].

Internet-operated therapeutic software

This type of intervention is split into three other subtypes, namely *robotic simulation* (based on dialog), *rule-based expert systems* and *gaming/virtual environments*.

The first subtype is characterized by chat-bots (e.g. ELIZA), which are able to have a conversation with the patient, recently even through spoken response instead of text only.

The second subtype is used for background activities such as assessment, treatment planning/selection and monitoring, rather than for active patient interaction.

Thirdly, games and virtual environments provide the opportunity of sharing common interests, simulating situations and gaining information without the therapy aspect. Although virtual reality programs are already successfully used for exposure therapy in some hospitals, the overall efficiency and reliability question is still to be answered [Barak et al., 2009].

Other online activities

According to Barak et al., personal blogs and support groups are the main types in this section. Blogs can be used to publish one's thoughts, experiences and feelings and receive response from others with the advantage that minimal technical skills are required. The benefit of blogging is that the blogger is encouraged to engage in reflection, knowledge sharing and debate. With support groups users are able to get emotional support and empathy through chat rooms, discussion forums, etc. while preserving a certain level of privacy (especially important if it is a stigmatizing condition) [Barak et al., 2009].

Now, where the internet-supported program types are well defined, a classification of JATEF should be made. Considering the main characteristics of each subtype it can be said that the training program presented by this work, which will be used to train executive functions through certain tasks and quizzes, can be classified as a 'self-guided web-based therapeutic intervention' (1b).

Firstly, the aim of JATEF is primarily to improve executive functioning and therefore a 'behavioral change' is clearly intended. Secondly, the use of pictures, animation and motivating feedback correspond to the above mentioned definition. Finally, the distinction between (1b) and (1c), namely the accessibility, makes it clear that the implemented training program regards to (1b), because of its free and open access.

Advantages and negative prejudices of computerized training

Compared to common intervention types, computerized training implies several advantages but, of course, there are also some negative aspects associated with this topic. Subsequently, to keep this section succinct, only a few examples will be given though many others exist.

Firstly, in most cases computers are associated with positive feelings by children because of their close relation to video games, which are experienced as fast moving, colourful, interactive and challenging [Shaw and Lewis, 2005]. In addition, computers are able to attract their attention easily, which simplifies the relationship building process between therapist and patient and therefore may increase motivation [von Brisinski, 2001].

Secondly, there are studies that show that children with ADHD playing computer or video games do not get more distracted than children from the control group, when a distractor is added (e.g. TV playing a popular cartoon) [Locke and Kharrazi, 2010]. Thus an improvement in their ability to focus can be assumed. (This assumption is based on observations that showed that children with ADHD often tend to make more motor movements while playing video games.) Griffiths formulated this as a benefit to achieve and maintain a person's undivided attention for long periods of time [Griffiths, 2002].

Thirdly, regarding web-based intervention, there is the big advantage of the possibility to receive treatment/therapy whenever and wherever it is needed. The space independent factor is especially crucial for areas where medical infrastructure is lacking. In addition, the training may not be biased by the fact that some patients behave and perform differently depending on the environmental setting (e.g. home, hospital, school).

Fourthly, video games provide children with goal setting situations that include feedback, so that it is possible for them to rehearse a task over and over again until the goal is reached. This interactivity may again stimulate learning. Furthermore, video games, or the use of computers in general may help to overcome technophobia or eliminate gender imbalance [Griffiths, 2002].

Finally, training based on a computer program may provide more functionality to the child than the classic pen and paper training, such as spell checks, grammar checks or copy and paste [Shaw and Lewis, 2005]. Also, hand writing does not become an issue and mistakes can often be corrected easily without leaving any traces behind, so that children may feel more comfortable and less monitored or controlled.

On the other hand, the great fear of psychiatrists is that computer programs are developed as a substitution to them. This might also be one of the reasons why computer programs had and still have a bad reputation in psychiatry. They are often not interested in using computer programs in therapy as they believe that those are a threat to their autonomy or their professional identity [Das, 2002].

Another reason why computer games were initially rejected (in the 1980s) might be the opinion that computer games feature aggressive elements [Griffiths, 1999]. Parents were afraid that the child would show increased aggressive behaviour after playing computer games. However, the association between computer games and increased aggressiveness was then made without the backup of empirical evidence.

The study of Chan and Rabinowitz [Chan and Rabinowitz, 2006] is one of many examples where no association between playing video games and aggressive behaviour was found. On the contrary, the carthasis theory suggests that children might be able to release physiological stress and therefore behave less aggressive after playing computer games.

Besides fears and myths, there are actual disadvantages of video games, such as addiction: Video games are heavily associated with increased addiction scores as measured by YIAS-VG [Chan and Rabinowitz, 2006]. This increased score implies negative impact on relationships and daily activity.

Another disadvantage (not directly concerning the patient) is that the technology on which the video games are based, changes rapidly. As a result, comparisons and evaluations across studies are hard to make [Griffiths, 2002].

Effectiveness of computerized training

Regarding the effectiveness of computerized training, three examples will be discussed here. Depending on the test settings and the aim of the training, nearly every executive function or core symptom of ADHD can be improved by specific training methods.

- [Klingberg et al., 2002]: The first considered work here showing the effectiveness of a training program for working memory (WM) was published by Klingberg et al. in 2002. There, fourteen children diagnosed with ADHD between the ages of 7 and 15 years were randomly assigned either to the treatment group or to the control group and pretested on five cognitive tasks:
 - Trained version of the visuo-spatial WM task
 - Span board task
 - Stroop task
 - Raven's Colored Progressive Matrices
 - Choice reaction time task.

The actual computerized training program which was used within the treatment sessions consisted of 4 different tasks ((1) visuo-spatial WM task, (2) backwards digit-span task, (3) letter-span task, (4) choice reaction time task) and in addition the number of head movements during a 15-minute period was recorded.

After five weeks of training the post-training evaluation was carried out. To sum up the results, it can be stated that all children in the treatment group improved. Significant improvements were recognizable on the Stroop task. The number of head movements also dropped significantly from 1001 to 315 in the treatment group (control group: 1496 -> 1881).

• [Shaw and Lewis, 2005]: The second work discussed here was published by Shaw and Lewis in 2005 and compared the impact of different training formats ((a) pen and paper, (b) pen and paper with animation, (c) computerized, (d) computerized with animation). Twenty children with ADHD and twenty typically developing children aged between 7 and 12 years were tested within this study.

The overall statement of this experiment is that among children with ADHD the greatest performance improvement was reached with basic computerized tasks. Additional animation did not enhance the performance to a greater degree. The reason therefore is that the
amount of activity in animated computer format posed a distraction from paying attention to the actual information, as reported by the children.

However, the greatest value of on-task activity (calculated by the percentage of time spent on a task in relation to the total time needed to complete the task) was measured on animated computerized tasks.

• [Klingberg et al., 2005]: In 2005, Klingberg et al. stated in their work that a significant treatment effect could be recognized for all executive tasks (e.g. span-board, Stroop accuracy, Stroop time). In their study, 53 children with ADHD, aged between 7 and 12 years, were tested, where children in the treatment group improved significantly more than children of the control group.

Furthermore, the parent ratings showed a significant reduction with respect to the child's ADHD symptoms, such as inattentiveness and hyperactivity/impulsivity. This work of Klingberg et al. also indicates that WM and executive functions could actually be improved by training (the training effects remained stable for several months) and that this improvement may lead to children participating in more WM demanding activities in daily tasks.

For more examples and publications proving the effectiveness of computerized training see for e.g. [Leins et al., 2007, Amon and Campbell, 2008, Allhambra et al., 1995, Rabiner et al., 2010, Scanlon et al., 2007, Shaffer et al., 2001].

3.3 Analysis of existing computer programs

In the following, some existing computer programs developed for ADHD therapy are listed and described briefly. It is important to stress the drawbacks of existing computer programs in order to clarify the necessity of the implemented program.

• **Captain's Log**(**R**): Captain's Log(**R**), part of the *Computerized Mental Gym* package, is a wide-spread software (within the USA and distributed in 23 foreign countries). It was originally used to help patients with brain injuries, but the developer, Joseph Sandford, soon realized that it was also applicable on patients with ADHD. Technically, Captain's Log consists of 9 different modules (e.g. attention skills, memory skills, numeric concepts, logic skills) where each module contains several exercises. Although the system requirements for this software are straight forward (OS: Windows, sound card driver etc.), up to date hardware components are required to ensure a proper execution of this program. To give a short summary on the exercises, it can be stated that with this wide range of functionality Captain's Log seems to cover the whole ADHD deficit spectrum. The only drawback that can be found on the first sight is the high fee with 495 USD a year for the license. (For further information, see [Sandford, 1985].)

- Play Attention® Sheer GeniusTM [Unique Logic and Technology (UL&T), 2011]: This computer learning system was inspired by technology developed by NASA and uses brain signals to navigate through the games. Apart from the software, a BodyWave®armband (for the brain signal recognition), an interface box and a Bluetooth dongle are necessary components of this training. The aim of the game is to improve focus, concentration, memory skills and finish tasks which again will hopefully improve performances in school or work. During the games, Sheer GeniusTM (an avatar representing a virtual coach) will give feedback, comment and reward the performed work in order to motivate the user and adapt the difficulty according to task results, to ensure the program remains challenging; a factor which is a very positive aspect. Unfortunately, no details on the tasks could be found, except for the fact that every task has to be controlled by focusing and being attentive. Regarding the costs, Play Attention®is rather expensive, with prices beginning from 100 USD a month or about 5 USD a day. (For further information, please check [Unique Logic and Technology (UL&T), 2011].)
- Interactive Metronome© [Shaffer et al., 2001]: This training method is based on the traditional use of non interactive metronomes as temporal teaching tools, invented by Étienne Loulié in 1696. Studies have shown that the required abilities such as planning, timing and rhythmicity of motor regulation are correlated with certain learning or attentional problems. To oversimplify, the user has to selectively execute a certain task (e.g. clapping both hands together or tapping the toes on the floor), which will be recognized through contact-sensing triggers whenever a metronome beat is given. These exercises are designed to improve ADHD patients concentration by helping them to discriminate between the sounds produced by the metronome and internal thoughts or external distractions. Though the Interactive Metronome training may have a positive impact on children's behaviour, it should be questioned if this sort of game is able to afford this \$599 investment. (For further information, please check [IM HOME, 2011].)
- **Supermarket Game** [Andrade et al., 2006]: This program simulates a shopping tour in a virtual supermarket and consists of only one task implemented in two different modes. While the user is provided with a shopping list and has to acquire the items with the restraint that paths must not be crossed a second time in both modes, the second mode has the additional constraint that the items in the shopping list have to be picked in a given order. As stated in the work by Andrade et al., the Supermarket Game is a tool that was especially developed to help neuropsychologists in the ADHD diagnosis process. Here, the biggest difference to a classical training software may be the fact that the main focus of the Supermarket Game is to diagnose patients.
- **BrainTwister** [Buschkuehl et al., 2007]: This computerized offline training system is very similar to the one presented in this work. The main goal of BrainTwister is to train and improve various brain functions by repeating different cognitive tasks. In addition, it is possible with BrainTwister to choose between single and group modes. BrainTwister consists of seven different task types, where only one of them is designed specifically for

children. There, the user firstly has to decide if the animal pictures are rotated upside down and secondly keep the sequence of animal pictures in mind and reproduce this sequence afterwards. Though this program is nicely designed and can be executed on different operating systems, there are some disadvantages. Firstly, the program is mainly designed for adults (which is also recognizable by the small number of tasks for children) and secondly, it is not for free (price for a private license: 40 Euros; price for a site license: 215 Euros).

• SMART-Games [Gotsis et al., 2010]: According to the published paper, children with Autism Spectrum Disorders (ASDs) shall improve in sensory and motor skills, imitation and turn-taking, joint attention and theory of mind by playing the Social Motivation Adaptive Reality Treatment Games (SMART-Games). This intervention consists of two major components, namely a game running on a computer and a plush toy with embedded textile-based sensors, which is also called PID (Plush Interface Device) and three game modes. The main goal is to manipulate (e.g. hugging, touching) the PID in a way that the character on the computer screen (it has the same appearance as the PID) keeps a happy mood. Although ASD is different to ADHD, many similarities, especially in the therapy process, exist and in both cases patients exhibit impairments in social, communicative and behavioural functioning [Goldberg et al., 2005]. The disadvantage of SMART-Games is that there are only three very similar game modes, so that the child may get bored very quickly. In addition, no further information about the price could be found, but it can be assumed that the package (PID and computer program) is not for free.

As presented in Table 3.4, it can be said that there are several computer programs that aim to improve certain executive functions (also designed for children) but all of them have drawbacks.

First of all, there is the cost aspect. As one can see, many of the presented computer programs are quite expensive, so that affected families with a low income may not have access to them. Furthermore, all of the programs are developed as offline games, which means that the computer programs have to be installed on one computer and subsequent training is possible on the same computer only.

Finally, it should be mentioned that the implemented set of tasks is designed in a way that adaptations (regarding difficulty, media, length of each task, etc.) of tasks can easily be carried out by physicians or other medical staff without the presence of a programmer. Thus, mental health professionals do not have the opportunity of configuring each task instantly without the dependency of technically trained personnel.

The program presented here is designed to improve in all three of the aforementioned drawbacks.

Name	Year	# of	Remarks	Price
		Tasks		
Captain's	1985	36	- Many different exercises	495 USD
Log®			- Requires an up-to-date PC	(p.a.)
			- Suitable for children	
Play	1994	n/a	Additionally requires	>100 USD
Attention®			(a) a BodyWave®armband	(monthly)
			(b) an interface box	
			(c) a Bluetooth dongle	
			- Interesting control approach	
			- Good feedback/adaption included	
			- Suitable for children	
Interactive	2001	1	Additionally requires	599 USD
Metronome©			(a) the Metronome apparatus	(home
			(b) a glove with contact sensor	license)
			(c) the Tap Mat	
			- Monotonous	
			- Suitable for children	
Supermarket	2006	2	- Used in diagnosis	n/a
Game			- Based on Fuzzy Logic, C++	
			- Suitable for children	
BrainTwister	2007	7	- Supports a group mode	40 EUR
			- Cross-platform	
			- Partially suitable for children	
SMART-Games	2010	3	Additionally requires the PID	n/a
			- Monotonous	
			- Suitable for children	

 Table 3.4: Comparison of existing computer programs used in ADHD treatment.

CHAPTER 4

Research question

The primary goal of this work is to discuss and answer the following question:

• How can JavaTM applets support the training of children with EF deficit?

In more detail, it is of interest to determine how such training has to be designed and adapted in order to be suitable for the target group: namely children between 6 and 12 years of age. As already stated in [Shaw and Lewis, 2005], a certain trade-off between motivation and distraction has to be found when implementing a training program for children. With the support of mental health professionals, the design of each task will be optimized with the aim of achieving a high level of acceptance in the target group.

In order to fulfil the above goals, the work presented here will subsequently

- introduce existing computerized treatment interventions for patients diagnosed with ADHD,
- compare traditional treatment opportunities to a computerized treatment intervention and, finally
- present the implemented JavaTM applet based training program, JATEF, by analyzing each task separately in more detail.

When implementing and designing a program for children, there are several things one has to consider. Apart from the content which clearly has to be adapted, there are also different requirements regarding the design (colour and media selection), the training procedure and the motivation.

As Griffiths has presented in his work on educational benefits of video games [Griffiths, 2002], the question of the design of a game is rather complex and diversified. Table 4.1 shows some examples taken from this listing, identified as being of importance when designing a game for children.

Regarding the deployed media (e.g. fonts, colours, images, animations), a good trade-off between encouragement and media-overflow is aspired. Discreet clip-art images for children (e.g. animals, holiday themes, sports) during the task and motivating animations at the end of each task were chosen in order to avoid unnecessary distractions, as reported in [Shaw and Lewis, 2005]. Shaw and Lewis have also shown that additional usage of cartoon characters or animations do not enhance performance to a greater degree than the basic computerization of a pen and paper task.

Another requirement of computer games is the motivation aspect. An increase in interest might stimulate greater performance but it has been shown that effort and arousal also increase with the level of interest [Shaw and Lewis, 2005]. Additionally, feedback may also play an important role in the motivation process. If no feedback opportunity/tool is provided to the user, there is little chance for them to learn from errors and improve their performance, which could lead to frustration or disinterest in continuing with the training.

In the next chapter, state of the art ADHD interventions are presented in order to provide a comparison with compute-based training.

Design Element	Planned Implementation
Educational or therapeu-	Due to the implementation of several different tasks, a wide range
tic objective	of executive function deficit coverage is aspired. Basically, the
	objective of each task was given by the existing ADHD training
	book [Pechtold and Jankowski, 2000] where the tasks were taken
	and adapted from. After the adaptation process, physicians eval-
	uate the tasks to ensure the suitability for children and that the
	implementation did not have any impact on the main objective.
Type of game	Though there are many puzzle tasks, some tasks also require
	physical skill or reasoning.
Difficulty	The difficulty level of every task is completely adjustable by pa-
	rameters. Depending on the desired difficulty level and the train-
	ing subjects, the implemented program can be configured for the
	training of young children as well as for advanced users.
Duration	Again, this element is completely adjustable in every task, so that
	individually adaptations are possible.
Participant age and char-	The main target group are elementary school-aged children, but
acteristics	through the possibility to adjust the difficulty level and the dura-
	tion of each task without any bounds, even adolescents and adults
	can be challenged by the tasks.

Table 4.1: Important design elements of a game (taken from [Griffiths, 2002]) and their planned implementation

CHAPTER 5

Methodology

5.1 Basic conditions

During the design phase of JATEF, there were several conditions and restrictions to consider, which will be discussed in this section. While the main goal was defined as the adaption of the existing tasks for the new target group, namely children aged between 6 and 10 years, there were also other issues to take into consideration such as hardware and software requirements. The graphical user interface of the modified tasks was designed to optimize the trade-off between motivation and challenge. On the one hand, each task should preserve its positive impact on certain EFs but, on the other hand, each task also had to be designed in a child-orientated way. It was important to avoid attributes that children may associate with negative feelings, such as additional homework, for example.

The following conditions were jointly decided with a child-psychiatrist (Christian Popow) and a neuropyschologist (Susanne Ohmann).

Target group

The primary target group of JATEF are children aged between 6 and 10 years, thus elementary school-aged children, diagnosed with ADHD. Great care was taken to ensure that every task is solvable by children in this age group, without any additional help. Although JATEF was implemented primarily for children with ADHD, children with other disorders or impairments where a deficit of executive functioning is noticeable (oppositional defiant disorder (ODD), conduct disorder (CD) or higher functioning autism (HFA) [Sergeant et al., 2002], for example) may be trained successfully with JATEF. To ensure a proper training procedure, patients should be capable of either managing a computer mouse or a touch screen and have internet access on their electronic device (e.g. computer, laptop, tablet PC).

Besides children, other patient groups, such as adolescents or adults, who want to practice and improve their executive functioning performance, may also benefit from training with JATEF. Due to the high flexibility of JATEF, it is possible to adjust the tasks for children (with images, simple words or numbers) as well as for adults (with more difficult and complex questions) without great effort.

Hardware and Software

Concerning hardware, there were only few requirements which had to be considered during the implementation process. It was jointly decided that JATEF should be executable from personal computers, laptops and tablet PCs. As tablet PCs do not feature a keyboard, every training task should be practicable by clicking on screen elements only (through a computer mouse, a touch-pad or a touchscreen) rendering any kind of keyboard input unnecessary.

Closely associated to the previous requirement and to allow for use on tablet PCs with smaller display, or lower screen resolution, there were constraints regarding the screen resolution of the training tasks. In order to ensure a high-quality display of each training task, and its graphical components on every device, the dimensions (width, height) of JATEF were limited to 480 pixels and 320 pixels. The primary goal here was to guarantee optimal fitting of the tasks into the limited area without the necessity of resizing or using any scroll bars.

JATEF was implemented as a set of JavaTM applets so that the only software requirements for a proper execution of the training tasks are:

- A web browser
- An installed JavaTM runtime environment (JRE).

Both of which are free of charge and, generally speaking, are pre-installed on computers and other devices (where internet access is possible) so that installing of software is highly unlikely. Further characteristics and advantages of the usage of JavaTM technology were given in Section 2.1 on page 5.

Expandability and Flexibility

A key objective during the development process of JATEF was to preserve a certain level of expandability and flexibility. Thus, besides providing a training tool, consisting of many different tasks, JATEF should also present easy adjustment possibilities for each task. In particular, it should be said that each task can be adapted in two dimensions:

- 1. **Length**: The number of questions per task is freely adjustable via the input file. With the number of questions, the required time for a certain task can directly be modified and controlled. There is no upper bound regarding the number of questions per task but for attention reasons it is recommended not to exceed 5 questions per task.
- 2. **Difficulty**: Each task of JATEF consists of display elements that can also be specified by the input file. Generally speaking, the task difficulty is represented by the selection and setting of the displayed elements, which act as placeholder for the content (text, number, image) of each question.

Considering these aspects, JATEF can be seen as a task environment where mental health professionals have the freedom to perform adjustments on a very high level and without the help of software engineers. These adjustments can be carried out directly by changing the input files through an arbitrary text editor.

Task selection

The selection process of the tasks was performed in cooperation with the above-mentioned mental-health professionals. The selection aimed to cover a broad range of executive function deficits.

Needless to say, it is neither realistic nor promising to cover the whole variety of selective achievement deficits with one training program. Thus, JATEF only focuses on several EF domains while leaving other domains (e.g. anticipation, inhibition) untouched for further research and development. Table 5.1 demonstrates which abilities can be trained with JATEF as well as those that are beyond the scope of the training.

Ability	Covered by JATEF?
Anticipation	Not covered
Critical faculties	Not covered
Decision making	Vergleichen-task
Decision-making	<i>Bewerten</i> -task
Determining differences in value, size or quantity	Bewerten-task
Determining equality	<i>Vergleichen</i> -task
Determining the matching element	Umstellfähigkeit-task
Determining the non-metabing element	Schlussfolgerung-task
Determining the non matching element	<i>Fehlersuche</i> -task
Determining the whole thing by deduction	<i>Detail</i> -task
Fluency	Umstellfähigkeit-task
Following paths	<i>Linien</i> -task
Inhibition	Not covered
Interference	Not covered
Dianning	Planungsschritte-task
Flaming	<i>Fehlersuche</i> -task
Replicating patterns	Puzzle-task
Sorting of objects	Planungsschritte-task
Soluting of objects	Suchen-task
Working memory & concentration	Suchen-task

Table 5.1: Overview of the abilities covered/not covered by JATEF.

5.2 Design and adaption of considered tasks

In this section, the design and the navigation possibilities of JATEF are introduced, before the implemented tasks are listed (in alphabetic order) and discussed in more detail. The focus here is to describe how the original tasks (taken from the exercise book for adults [Pechtold and Jankowski, 2000] and referred to under task name by page number) have been adapted in order to fulfill the requirements of JATEF (the final design of the tasks can be found in Section 6.1 on page 46).

General design considerations

As mentioned previously, the screen dimensions of each task are set by a width of 480 pixels and a height of 320 pixels, requiring a compact and user friendly navigation layout. In order to overcome the space limitation and for the sake of uniformity and consistency, the navigation frame of each task is kept constant and consists of three panels placed in the north, the center, the west and the east of the task (an illustration of this 'frame' is presented in Figure 6.1).

Under this design, the actual area for the displayed task-specific elements is defined by the rectangular shaped panel in the center of the training screen, which is 420 pixels wide and 300 pixels high.

Summarized, each task consists of the following components:

• North-panel:

- a label where the name of the task is displayed,
- a progress bar where the recent question and the total number of questions are displayed and,
- a link which triggers the display of the description/instruction of the task.
- West-/East-panel: The panels in the west and in the east are used to navigate through the questions of a task, in particular to jump to the previous or the next question.
- **Center-panel**: The panel in the center represents the area where the actual question will be displayed and the interaction with the user will take place. In addition, the description/instruction text will also be displayed on this area.

Task I: Bewerten¹

The *Bewerten*-task (page 129 et seq.) requires the user to determine whether or not the value in the first column is equal to the one in the second column. If not, the user is additionally asked to write down a plus symbol if the value in the second column is greater and a minus symbol if the value in the first column is greater. The original task design consisted of a simple table with 3 columns as illustrated in Table 5.2. Additionally, the user is asked to write down how often a greater value could be noticed in the first/second column at the end of the task.

¹engl. evaluation

Rechnungsbetrag	Überwiesener Betrag	zu viel überwiesen (+)? zu wenig überwiesen (-)?
1455,-	1455,-	
4812,-	4810,-	
2344,-	2400,-	

Table 5.2: Bewerten: original task design

As the referenced scenario and design (in which the user compares bills) are not appropriate for children, the following modifications were made:

- The introduction text describing the scenario and the table design were omitted, because they do not influence the main goal of the task.
- For simplification, the request to write the number of greater values in the first/second column down, was omitted.
- One comparison is displayed at a time only.
- Besides the comparison of numbers, the possibility of comparing letters and text or images was added.
- It is possible in JATEF to compare multiple elements in both columns (sides) at once (e.g. compare three elements on the left hand side with three elements on the right hand side).
- The user must give an answer if the elements on both sides are equal (in the original task no answer would be correct).

Task II: Detail

This task was not contained in the exercise book but is considered by mental-health professionals to be important and therefore necessary to include. The aim of the task is to guess the animal (other objects are also possible) shown by a picture of which small details are revealed step by step. Beginning with only one part/piece of the whole image, the user has to guess the object (select one of the provided possible answers). If the user does not know what object is shown, they can make use of hints which will unlock further parts of the image, until the whole object is visible.

A precondition of the task was to divide an image with an object on it (e.g. animal, tool, person, toy) into smaller pieces and then present the pieces to the user. The images have to be created in advance where special attention should be paid to the separation/splitting process of the object in the image. Depending on the desired difficulty level, significant parts of the object can be provided in the beginning (easy) or at the end (difficult).

Task III: Fehlersuche²

The original task (named *Wesentliches erkennen*³, page 134 et seq.) required the user to read a short text that describes a scenario (e.g. hiking trip) and several key words (e.g. map, compass, umbrella). Within these key words, there are also words which do not match with the given scenario (e.g. tie, bathing shoes). The goal is to distinguish between these sets of words and to mark the matching ones. The design of the task was similar to the one provided by Table 5.3.

Table 5.3: Wesentliches erkennen: original task desig

Für eine Tageswanderung in einem Ihnen wenig bekannten Waldgebiet stellen Sie				
eine Liste der Dinge auf, die Sie mitnehmen wollen. Welche von den unten aufge-				
führten Dingen sind dafür nützlich? Kreu	zen Sie die nützlichen Dinge an!			
(a) Wanderkarte	(b) dicke Socken			
(c) Badeschuhe	(d) Rucksack			
(e) Regenschirm	(f) Krawatte			

The implemented *Fehlersuche*-task differs from the original task *Wesentliches erkennen* in the following ways:

- For the purpose of simplification, the scenario is described by only a key word (e.g. hiking trip) instead of the whole text (text is still possible if required).
- It is also possible to display an image representing a scenario instead of a key word or a text (e.g. image of a mountain).
- The provided words can be exchanged by, or mixed with, other images.

Task IV: Linien⁴

This task was also not contained in the exercise book but inspired by existing labyrinth games where the user has to follow a path from the beginning to the end. In the current version, five starting points (marked with a symbol that can be represented as a letter, a number or an image) on the left hand side are connected by entangled lines to five ending points on the right hand side (also marked with a symbol).

A symbol, which matches one of the starting point symbols, is displayed at the top of the task. Starting from this point, the user has to follow this specific path and mark the corresponding ending point.

The difficulty level of this task depends only on the input file where the image of the labyrinth with the five paths is specified. By choosing a different labyrinth image (which must be created with a graphics program in advance), the difficulty level can be adjusted.

²engl. error search ³engl. detection of the essential ⁴engl. lines

Task V: Planungsschritte⁵

This task can be found on page 100 et seq. of the exercise book and deals with the chronological positioning of given activities. At first, a short introduction text describing a situation is provided. A series of activities are then listed, in a random order, as presented in Table 5.4. The user's assignment is to arrange the activities into chronological order by enumerating them starting with 1 for the first. Regarding the design of this task, it can be said that it was kept simple and sufficient, so that the implementation of this task could be done analogically.

Sie stehen in einer Telefonzelle mit Münzfernsprecher und wollen eine
Firma anrufen, deren Telefonnummer Sie nicht kennen. Bringen Sie die
folgenden Schritte in die richtige Reihenfolge, beginnend mit 1.
Sie melden sich mit Ihrem Namen (a)
Wenn Sie eine Verbindung haben, werfen Sie Münzen nach (b)
Sie wählen die betreffende Telefonnummer (c)
Sie suchen passende Münzen (d)

Sie suchen im Telefonbuch die richtige Nummer (e)

Sie werfen einige kleinere Münzen ein (f)

Sie betreten die Telefonzelle (g)

	Table 5.4:	Planung:	original	task	design
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The big difference between the original design and the implemented task in JATEF is that, in order to avoid use of a keyboard, the user has to choose a number from a given selection list. Furthermore, for reasons of comprehensibility, the introduction text was omitted (as it does not play an important role in this task) and the described activities were exchanged by single words.

While the usage of numbers instead of words will require mathematical skills, the enumeration of images (e.g. baby; child; adolescent; adult) could be used for users with reading disabilities.

Task VI: Puzzle

In order to practice the ability of replicating a certain graphical template, the *Puzzle*-task was introduced and implemented as a part of JATEF. Here, the user's objective is to rebuild a given graphical pattern (consisting of 4x5 grid), which is provided on the left hand side of the task area, on the empty grid on the right hand side.

For this purpose, six different basic patterns (tiles) are provided on the bottom panel. Such tiles can be picked up, dragged and dropped onto the grid. In order to simplify this task, no tiles have to be rotated and a correction can be made by dropping the tile without a pattern (empty tile) onto the wrong grid cell.

⁵engl. planning

Task VII: Schlussfolgerung⁶

The aim of this task (page 93 et seq.) is to request the user to find and cross out the only *non-matching* element (word or number) out of a set of elements. To give an example, in the set containing the words *blue, red, soft* and *green*, the word *soft* does not fit into this set because it is not a colour. A set of numbers could contain only even numbers except for one odd number.

Generally speaking, the design of this task was not changed very much except for the placement of the set elements and the additional possibility to display images as set elements. The number of the elements within a set can be adjusted through the input file, without any upper limitations.

Task VIII: Suchen⁷

Regarding the *Suchen*-task, which can be found in the exercise book on page 114 et seq., the user has the assignment to connect a varying number of letters or numbers in a specific (in most cases ascending) order. These letters or numbers are randomly placed on the task area as illustrated in Table 5.5, so that the difficulty of this task is not only to keep the recent element in mind while connecting but also to actually find the following (e.g. next highest) element at each step.



		A 1		. 1	1 .
		Suchant	original	toolz	doolan
таше.	77.	SUCHER.	OLIVINAL	LANK	UESIVI
			011, 111001		www.man
			<u> </u>		<u> </u>

The difficulty of this task is compounded by the following circumstances:

⁶engl. deduction ⁷engl. search

- The elements are not completive, which means that gaps between the elements may occur (e.g. connecting 10 randomly chosen letters, connecting 20 randomly chosen numbers in a range between 1 and 100).
- The missing letters or numbers and the total amount of missing elements have to be written down after the connecting procedure.

Regarding the JATEF implementation of this task, the first thing to substitute was the connection procedure, which was originally realized by drawing a line between two elements. This procedure had to be replaced by the following steps: (a) pressing the left mouse button over the start element, (b) holding the mouse button pressed and dragging the pointer to the end element, (c) releasing the mouse button over the end element. During the holding process, an imaginary line between the start element and the recent mouse position will be visible. The additional subtasks (writing down of missing elements and the total amount of missing elements) were left out intentionally for two reasons: (1) no keyboard should be required in any task; (2) the counting exercise of the subtask is already covered by other tasks (e.g. 5.2).

Task IX: Umstellfähigkeit⁸

This task (page 179 et seq.) consists of two parts, namely a short instruction part where rules are defined and a part containing a table specified with 4 columns (command column, profession column, first name column, last name column). Depending on the symbol in the first column (command column) and the given rules, the user has to read the word standing in one of the other columns out loud. For a better understanding, an example on the design of this task is presented in Table 5.6.

Lesen Sie folgende Liste laut vor. Ist ein Stern zu Beginn der Zeile, lesen Sie					
nur den Vornamen. Befinden sich zwei Sterne vor der Zeile, lesen Sie nur den					
Nachnamen; fehlt der Stern, so lesen Sie nur die Berufsbezeichnung.					
* Biologe Thorsten Müller					
	Sekretär	Martin	Ruprecht		
**	Varmassar	liirgon	Major		

Table 5.6:	Umstellfähigkeit:	original	task design
------------	-------------------	----------	-------------

As JATEF was not designed to recognize voice or other audio signals, the command to read out loud was replaced by the clicking on the desired element in the table. Furthermore, a universally employable solution was achieved by the implementation of following points:

Jürgen

Vermesser

Meier

• Instead of having a rule and a command, the command itself specifies which element to click. Thus, the command was formulated more precisely (e.g. command = profession, last name) so that no rules are necessary.

⁸engl. adaptation

- Only one row is displayed at the same time instead of displaying the whole table at once.
- The elements can now be chosen from adjusted topics, such as animals or tools for example, which are more interesting for children.
- Table elements can also be represented by images.

Task X: Vergleichen⁹

In the original task (*Arbeitsgenauigkeit*¹⁰, page 124 et seq.), the user has the assignment to compare two values (target state and actual state) of an inventory and note down if these values are either different or equal. (This task can be seen as a simplified version of the *Bewerten*-task). The design of this task was a simple table with 4 columns as illustrated in Table 5.7.

Gegenstand	Ist-Anzahl	Soll-Anzahl	Korrektur
Bleistifte	5232	5323	
A4-Ordner	56	65	

Table 5.7: Vergleichen: original task design

Clearly, the scenario (in that case: inventory) and the design are not appropriate for children, so this task was modified and implemented in the following ways:

- The inventory scenario was omitted (unnecessary for the task).
- The table was omitted by splitting the task into several questions that contained one row only.
- Additionally to the comparison of numbers, it is now possible to compare text or images as well.
- It is also possible to compare multiple elements at once (two or more elements on the left hand side with two or more elements on the right hand side).

5.3 Development process

The chosen software development methodology was *Prototyping*. Regarding the specification made in [Davis et al., 1998], the more precise term for the applied development model is *Evolutionary Prototyping*. This model is characterized by the following properties/advantages (only exemplary):

• Early prototypes can ensure the satisfaction of the users' need.

⁹engl. comparison ¹⁰engl. accuracy

- The requirements are not fully understood initially (user feedback is needed which leads to user involvement throughout the development process).
- Supplied feedback can be used to reveal strengths and weaknesses of the system.
- The prototyping process starts at those system aspects that are best understood.
- Short development cycles ensure rapid progress.

Provided with task templates taken from the exercise book [Pechtold and Jankowski, 2000], first sketches of the user interface were created and presented to mental health professionals during a kick-off meeting. Besides discussions on improvement possibilities regarding the appearance of the tasks, basic conditions (as stated in chapter 5.1 on page 35) were also specified.

After careful research of existing training programs that are related to this topic, implemented task prototypes were presented. From this day on, regular meetings with the following agenda were held.

- 1. At the beginning of each meeting, the implemented prototypes/modifications were presented.
- 2. Improvement suggestions on the tasks were given, discussed and noted down.
- 3. A To-Do list (containing bugs, modifications, additional tasks) for the next meeting was created.

In the interval between the meetings, effort was put into processing the current To-Do list, improving the usability and testing of the system.

The program was developed and tested under the Eclipse (http://www.eclipse.org/) development platform. Furthermore, the resulting source code was written in accordance with Oracle's *Code Conventions for the JavaTM Programming Language*, which can be found under [King et al., 1999].

Graphics and images used in JATEF were either taken from free internet collections of public domain cliparts (e.g. http://www.freeclipartnow.com/) or self-created.

CHAPTER 6

Results

6.1 Overview

Following analysis of the original design of the tasks and their necessary modifications in the previous chapter, the aim of this chapter is to present the implemented versions of the tasks both graphically and technically. In this direction, the discussion of each task is divided into two parts:

- 1. The user interface; where the elements and the interaction possibilities are explained.
- 2. The input data; where adjustments regarding difficulty, length and appearance can be set.

As previously mentioned, in common to every task is the *framework*, where basic user interface elements, such as the navigation labels, are contained (see Figure 6.1).

Before analyzing each task in detail, an overview of the program flow and the central element, namely the *ClickElement* (CE), is given.

The program flow

On beginning JATEF, the server simultaneously loads the input data and the description text for all tasks. Subsequently, the following steps are followed in each task, with the aim of structuring the task in a logical way.

- Firstly, after the initializing phase of the task, an image of an animal and the description/instruction of the task are shown to the user on the center panel, as shown in Figure 6.2. The start time is saved in order to have the possibility to compute the total time spent on the task.
- If the user clicks on the description panel, the task specific elements of the first question of the task are displayed.

실 Applet-Ar	nsicht: Trainin	gSession.class	- • •
Applet			
Bewerten		1 von 5	Anleitung
Nurinok			Ye∴+er
Appier gestal	lei		

Figure 6.1: The framework representing the uniform appearance of different tasks

- With help of the west- and east-panels, the user can navigate through the questions, finishing the task (after answering the final question) by clicking the east-panel (see Figure 6.3).
- After completion of the task, the results and the animal from the start-screen are shown in the center panel (see Figure 6.4) and the user has the opportunity to compare their answers with the correct solutions by clicking through the questions again.

The result is represented by yellow, rotating stars for the ratio of correct answers (see formula below) and gray, non-rotating stars for the ratio of wrong answers. This ratio is computed by the number of correct answered questions divided by the total number of questions multiplied by 5 (max. number of displayed stars).

$$Stars_{Rotating} = round(\frac{Answers_{correct}}{Answers_{total}} \cdot 5)$$

The formula's result which should be in the range 0 to 5, is then automatically rounded to the closest number without decimal places.

From a technical point of view, this program flow commonality is aggregated in a superclass called *AppletTask*, which leads to the consequence that the actual task classes become subclasses



Figure 6.2: An example of the start-screen displaying the description (instruction) of the task in the center panel.

of AppletTask, as illustrated in Figure 6.5.

The main functions of the AppletTask class concern the following:

- the creation of an uniform layout (e.g. element dimensions),
- the navigation (e.g. clicking through questions of one task),
- the initialization (e.g. loading of required images) and,
- the input handling (correct loading and preprocessing of the provided parameters).

The ClickElement class

The ClickElement (CE) class represents a JavaTM class that is extended from the *JLabel* class and is especially customized for the requirements and purposes of JATEF. Besides different media content (text, number, image) that can be displayed with a CE, the CE is also able to interact with the user in different ways. As demonstrated in Table 6.1, it is possible to

• mark a CE by encircling the content,



Figure 6.3: The change of the next panel into the finish panel when the last question of the task is being displayed.

- cross out the content,
- connect two CEs or
- enumerate the content.

Furthermore, the CE is configurable if the content can scale its dimensions (with or without keeping the original aspect ratio – as defined) if an enlarged view is necessary. Another adjustment possibility is to enable or disable the reaction (by magnifying the underlying content) of a CE if the (mouse) pointer is over it. If not stated differently, all elements displaying any media content in the following task descriptions were implemented through the ClickElement class.



Figure 6.4: The finish-screen showing the number of correct answers. The button on the bottom right side enables the user to view their and the correct answers.

ClickElement	1 Frühstück			3
Description	This example	This example	This example	This example
	shows a text	shows a number	shows an image	shows the con-
	that has been	that has been	that has been	nection between
	enumerated.	crossed out.	encircled.	three CEs.

Table 6.1: Various usages of the CE class.



Figure 6.5: Simplified class diagram illustrating the superclass-subclass relation

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6.2 Task I: Bewerten

In this task, the user has to find out whether or not the elements on the right hand side are greater than the elements on the left hand side. It is also possible that the elements on both sides are equal.



Figure 6.6: Question with two opposing numbers, which will be the common case. Note, that the font size of the elements is automatically adjusted to optimally fill the available space.



Figure 6.7: Question with different numbers of images on each side. The number of elements on each side is not restricted. Images are automatically scaled.



Figure 6.8: Question consisting of a combination of text, numbers and images. This question type requires more accuracy and is more difficult to answer because multiple comparisons have to be performed at the same time.

The input data for the *Bewerten*-task (see Listing 6.1) must be provided in accordance with the following scheme:

- 1. Each line represents a separate question in the computerized task. Consequently, one can determine in the given input data example (Listing 6.1) that the applet task contains seven questions as seven valid lines are defined.
- 2. Beginning with the element on the left hand side, further elements must be separated by hyphens where alternating element positions have to be considered (left-right-left-...). After every second element, the position in the center-panel of the task is automatically shifted down to the next row, so that two elements are opposite each other in every row.
- 3. Each line must be ended by one of the following symbols:
 - 'l': if the left hand side is greater
 - 'r': if the right hand side is greater
 - '=': if they are equal

Images are marked by the term 'pic:' followed by the relative image path, including the image name and its file format, as presented in Listing 6.1 at line 5-7.

4. An empty element must be realized by using the transparent image (empty.png) because odd element numbers will not be accepted by the program.

Listing 6.1: Input data of the Bewerten-task reformatted for better readability.

```
1 12-13-r
2 aa-aaa-r
3 12-12-0-0-TT-T-1
4 100-100-=
5 pic:dog.png-pic:dog.png-pic:empty.png-1
6 pic:cone_blue.png-pic:cone_blue.png-123-123-a-a-2-3-r
7 0-pic:empty.png-1
```

6.3 Task II: Detail

In this task, the user has to guess the hidden object that is represented by an image. By doing so, the user can use hints to reveal additional parts of the object.



Figure 6.9: Here, the question is in its initial state where only the first part of the whole image is visible. Elements in the bottom area: (1) a drop down menu with possible answers, (2) a button to unlock new parts of the image (hints), (3) a label showing the number of hints given.



Figure 6.10: Here, four hints have already been used, one hint is left. As one can see, further complementing parts of the image have been revealed.



Figure 6.11: As all hints have been used, the (hint) button becomes disabled. This examples shows that significant characteristics, such as ears, can be held back until the end in order to make the question more difficult.

The input data for the *Detail*-task (see Listing 6.2) must be provided in accordance with the following scheme:

- 1. Each line represents a separate question in the computerized task.
- 2. The first number in each line stands for the number of hints i.e. the number of provided images.
- 3. Separated with hyphens, the file relative paths of the hint-images, including the prefix of the images, have to be specified. In Listing 6.2 at line 1, the applet loads the folder 'details' on the server, where files with the name 'cat1.png', 'cat2.png', 'cat3.png', 'cat4.png' and 'cat5.png' exist according to the number of images as given in rule 1.
- 4. After another hyphen, the answer possibilities are specified (separated by hyphens) where an asterisk symbol is inserted before the correct answer.

Listing 6.2: Input data of the *Detail*-task reformatted for better readability.

¹ 5-details \cat-Hund-*Katze-Maus-Pferd

- 2 5-details \dachshund-Maus-Pferd-*Hund-Katze
- 3 5-details \panda-Maus-Pferd-Hund-*Panda

6.4 Task III: Fehlersuche

In this task, the user must cross out the items not matching the topic (given above the array of elements) by clicking on them.

Applet Fehlersuche	n 14	Anleitung
Poli	zist	
Z Strafzettel schreiben	Autos anhalten	w F
Wand	Kuchacken	, i
Räuber fangen	Zährehen	
Ergebnis protokolliert.		

Figure 6.12: Question consisting of text elements only. Depending on the given term in the top area ('Polizist'), the user has to find the elements that do not match and cross them out by clicking on them.



Figure 6.13: Question, where the instruction is represented as text and the answers as images.



Figure 6.14: Here, the question consists of images only, so that no reading skills are necessary at all.

The input data for the *Fehlersuche*-task (see Listing 6.3) must be provided in accordance with the following scheme:

- 1. Each line represents a separate question in the computerized task.
- 2. The first term in each line represents the instruction and appears in the top area of the question. In Listing 6.3, the second question's (at line 2) instruction would be 'Voegel'.
- 3. Separated by hyphens, the possible answers have to follow and an asterisk must be put before the non-matching elements.
- 4. Images have to be specified by the term 'pic:' and the file name (including relative file path and file format).

Listing 6.3: Input data of the Fehlersuche-task reformatted for better readability.

```
Polizist-Strafzettel schreiben-Autos anhalten-*Wand tapezieren
-*Kuchen backen-Raeuber fangen-*Zaehne ziehen
Voegel-Amsel-Meise-*Zitronenfalter-Specht-*Hecht
Tiere-pic:dog.png-*pic:sphere_blue.png-piccat.png-pic:koala.png
pic:cube_blue.png-pic:cube_green.png-*pic:cylinder_blue.png-pic
:cube_orange.png-pic:cube_purple.png
Grueun-pic:cube_green.png-pic:cone_blue.png-pic:sphere_green.
png-*pic:cylinder_orange.png
Baustelle-pic:helmet_1.png-*pic:helmet.png-pic:vehicle_1.png-*
pic:alien_5.png-pic:barrow.png-pic:vehicle_2.png
```

6.5 Task IV: Linien

In this task, the user has to start from the given starting point, follow the line until they reach the end and then mark the reached number.







Figure 6.16: The paths in the center area are represented by an image which can be substituted by other images in order to adjust the difficulty level.



Figure 6.17: This figure shows the possibility of exchanging the characters or numbers by images, if desired.

The input data for the *Linien*-task (see Listing 6.4) must be provided in accordance with the following scheme:

- 1. Each line represents a separate question in the computerized task.
- 2. The first term of each line specifies the path image. After this term, five elements for the left hand side and five elements for the right hand side have to follow. (All elements are separated by hyphens.)
- 3. The starting element is labeled with a plus symbol; the correct answer with an asterisk symbol.

Listing 6.4: Input data of the *Linien*-task reformatted for better readability.

1 pic : pipes1 . png-A-B+C-D-E-1-2-*3-4-5 2 pic : pipes2 . png-A-B+C-D-E-1-*2-3-4-5 3 pic : pipes1 . png-A-+pic : animals \ cat . png-C-D-E-1-*2-3-4-5

6.6 Task V: Planungsschritte

In this task, the user has to put the given elements into a logical order by labeling them with sequence numbers.

Applet-Ansicht: TrainingSession.class Applet Planungsschritte	1 von 6 Arleitung
Mitternachtssnack	Abendessen
r c k 1 4	2
Ergebnis protokolliert.	Willagessen



Figure 6.18: After a click on the element, a pop up menu containing the ordering numbers appears. Another click on the number closes the pop up menu and labels the element with the number.

Figure 6.19: Another example for the the *Planungsschritte*-task.

The input data for the *Planungsschritte*-task (see Listing 6.5) must be provided in accordance with the following scheme:

- 1. Each line represents a separate question in the computerized task.
- 2. In addition, each line is split into two parts (separated by an asterisk symbol):
 - The elements that will be displayed.
 - The ordering sequence.

All elements are separated by hyphens.

3. In Listing 6.5, at line 1, the first element of the ordering sequence is a 4 which means that the first displayed element has the ordering number 4, the second displayed element has the ordering number 3 and so on.

4. The number of displayed elements and the length of the ordering sequence have to be equal.

Listing 6.5: Input data of the *Planungsschritte*-task reformatted for better readability.

Mitternachts Snack-Abendessen-Fruehstueck-Mittagessen*4-3-1-2 5-7-8-9-3-2*3-4-5-6-2-1 fuenf-sieben-acht-neun-drei-zwei*3-4-5-6-2-1 pic:nine.png-pic:three.png-pic:two.png*3-2-1

6.7 Task VI: Puzzle

In this task, the user has to replicate the pattern on the left hand side onto the area on right hand side. Therefore, they have to drag and drop the tiles from the bottom area to the desired location.







Figure 6.21: Another example for the *Puz-zle*-task.

The input data for the *Puzzle*-task (see Listing 6.6) must be provided in accordance with the following scheme:

- 1. Each line represents a separate question in the computerized task.
- 2. Each line consists of exactly 20 numbers (in the range of 0 to 5). The first four numbers represent the first row, the second four numbers the second row, up to row 5.
- 3. The values of the numbers are encoded in a certain pattern, as presented in Table 6.2. Thus, Listing 6.6 line 1 codes the pattern as illustrated in Figure 6.21 and line 2 codes the pattern as illustrated in Figure 6.20.

Listing 6.6: Input data of the Puzzle-task reformatted for better readability.

```
1 34344343343443433434
2 31312424000031312424
```

 Table 6.2: Coding table of the puzzle tiles.

Pattern						
Coding	0	1	2	3	4	5.

6.8 Task VII: Schlussfolgerung

In this task, the user has to cross out the non-matching elements. In contrast to the *Fehlersuche*-task, no topic is given.



Figure 6.22: Five text elements are displayed where the user's aim is to find out which of them does not fit.



Figure 6.23: It is also possible to adapt this task to test mathematical and logic skills. In this example, the only odd number ('5') is crossed out.



Figure 6.24: A younger target group can be reached by using images instead of text or numbers. In this example, the only element not representing a construction vehicle is crossed out.
The input data for the *Schlussfolgerung*-task (see Listing 6.7) must be provided in accordance with the following scheme:

- 1. Each line represents a separate question in the computerized task.
- 2. Elements have to be separated by hyphens.
- 3. The correct answer is marked with an asterisk symbol.
- 4. Images have to be labeled with the prefix 'pic:' followed by the relative image path, including the image name and its file format (see Listing 6.7 at line 4).

Listing 6.7: Input data of the Schlussfolgerung-task reformatted for better readability.

```
1 2-4-*5-8-10-12
```

2 * Affe-Hund-Katze-Maus

```
3 Rot-Blau-*Weich-Schwarz-Gruen
```

```
4 pic:vehicle_1.png-pic:vehicle_2.png-*pic:boss.png-pic:vehicle_3
.png-pic:Vehicle_4.png-pic:vehicle_5.png
```

6.9 Task VIII: Suchen

In this task, the user has to connect the elements (numbers or characters) in ascending order.



Figure 6.25: During the connection process (after pressing the mouse button), an imaginary line appears as long as the user holds the button down.



Figure 6.26: After releasing the mouse button over a correct element, both connection ends turn green. Additionally, the connection is marked permanently.



Figure 6.27: A wrong connection (here, a connection between 6 and 9 was tried) is shown by changing the wrong element to red.

The input data for the *Suchen*-task (see Listing 6.8) must be provided in accordance with the following scheme:

- 1. Each line represents a separate question in the computerized task.
- 2. Each line has exactly 3 numbers, separated by hyphens:
 - The lower bound
 - The upper bound
 - The number of desired elements

In Listing 6.8 at line 2 for example, 5 random numbers between 1 and 10 are generated.

3. The letter mode can be activated by setting the lower and the upper bound to zero. In Listing 6.8 at line 1 for example, 3 random letters of the alphabet are generated.

Listing 6.8: Input data of the Suchen-task reformatted for better readability.

1	0-0-3
2	1 - 10 - 5
3	50-100-6
4	1 - 50 - 10
5	0-0-10

6.10 Task IX: Umstellfähigkeit

In this task, the user has to mark the element which is related to the topic in the top area.



Figure 6.28: The user has to follow the instruction in the top area and mark the correct answer by clicking on it.



Figure 6.29: Alternatively, an image can be used as instruction. In which case, the user has to find the identical image.



Figure 6.30: This example shows a mixture of text and images. The textual instruction has to be translated into a property which again has to be found within the given possible answers.

The input data for the *Umstellfähigkeit*-task (see Listing 6.9) must be provided in accordance with the following scheme:

- 1. Each line represents a separate question in the computerized task.
- 2. The first element represents the instruction element.
- 3. The answer possibilities have to be separated by hyphens where an asterisk symbol preceeds the correct answer.
- 4. Images have to be labeled with the prefix 'pic:' followed by the relative image path, including the image name and its file format (see Listing 6.9 at lines 3 and 5).

Listing 6.9: Input data of the Umstellfähigkeit-task reformatted for better readability.

```
Werkzeug-*Hammer-Maus-Katze-Tisch-Wasser-Brot
Katze-Computer-Lineal-*pic:cat.png-Maus
pic:cat.png-pic:dachshund.png-pic:frog.png-pic:koala.png-*pic:
cat.png-pic:leopard.png-pic:pug.png
Ungerade Zahl-30-14-6-*3-2-10
Kugel-pic:cube_blue.png-*pic:sphere_green.png-pic:cylinder_blue
.png-pic:cube_orange.png-pic:cube_purple.png-pic:
cylinder_green.png
```

6.11 Task X: Vergleichen

In this task, the user has to compare the elements on both sides and then mark if they are equal or not.

1	റ	റ	w
1.	2	3	eiter
		\checkmark	
	4		≈ ✓

Figure 6.31: The user has to compare the opposing elements and mark if they are equal (check symbol) or not (cross symbol). Note that the font size is adjusted automatically in order to optimize use of available space.



Figure 6.32: Depending on the desired
difficulty level, multiple elements can be
placed on each side. In addition, the use of
similar images can make the question more
difficult.

Applet Veraleichen		3 von 4	2	Anleitung
	ich		ich	
	3		3	
z	0		0	w
u r ü	er		sie	1
c k	99.9		99.9	÷
	es		es	
				\checkmark

Figure 6.33: As already presented in other tasks, questions of this task can also consist of multiple elements containing different media contents (text, numbers, images).

The input data for the *Vergleichen*-task (see Listing 6.10) must be provided in accordance with the following scheme:

- 1. Each line represents a separate question in the computerized task.
- 2. Elements have to be separated by hyphens and the number of elements has to be even.
- 3. Beginning with the element on the left hand side, further elements must be separated by hyphens where alternating element positions have to be considered (left-right-left-...). After every second element, the position in the center-panel of the task automatically shifts down to the next row, so that two elements are opposite each other in every row.
- 4. Images have to be labeled with the prefix 'pic:' followed by the relative image path, including the image name and its file format (see Listing 6.10 at line 4).

Listing 6.10: Input data of the Vergleichen-task reformatted for better readability.

1 123-132 2 4-4-3-3-1-1

```
3 ich-ich-3-3-du-du-er-sie -99.9-99.9-es-es
```

4 pic:alien_2.png-pic:alien_2.png-pic:alien_1.png-pic:alien_2.png -pic:alien_2.png-pic:alien_2.png

CHAPTER 7

Evaluation

One of the challenges in developing JATEF was to ensure that the resulting training framework is flexible enough for adaptations and future extensions. It was also of great importance that the implemented tasks actually cover certain executive functions whilst the basic idea of the original tasks was preserved during the development and adaption process. As JATEF represents a training program for children suffering from ADHD, the suitability for this target group also has to be ensured.

Therefore, an evaluation with two mental-health professionals (Christian Popow (child psychiatrist) and Susanne Ohmann (neuropsychologist)) who reviewed and tested the functionality and suitability of JATEF, was carried out. Both professionals work at the Department for Child and Adolescent Psychiatry at the Medical University of Vienna and were also involved in the development process. In the following, the evaluation result was structured into three sections:

- 1. Which executive functions are covered with JATEF, which not?
- 2. How flexible (adaptable) is JATEF?
- 3. Is JATEF suitable as a training tool for children with ADHD?

7.1 Evaluation of the coverage of executive functions

As already specified in the Task selection section on page 37, and due to the great variety of different executive functions, it was beyond the scope of this study to cover executive functions in their entirety in JATEF. The following areas and abilities are thus covered by JATEF:

Decision-making, determining differences, equality etc.

When it comes to training possibilities of decision-making, several JATEF tasks can be used to cover this area: Firstly, the *Bewerten*-task (see Task I: Bewerten on page 52), where the user is

confronted with elements on both sides and has to decide which side is greater (in many different meanings) or if they are equal.

Secondly, in the *Vergleichen*-task (see Task X: Vergleichen on page 70), which can be seen as an easy version of the *Bewerten*-task, the user is simply asked for a decision whether elements are equal or not.

Furthermore, the *Umstellfähigkeit*-task (see Task IX: Umstellfähigkeit on page 68) and the *Schlussfolgerung*-task (see Task VII: Schlussfolgerung on page 64) are clearly capable of covering such abilities.

Visual skills

As all tasks are capable of exclusively using images in order to represent the exercise, each task can be configured in such a way that visual skills are required and tested. However, the *Detail*task (see Task II: Detail on page 54), the *Puzzle*-task (see Task VI: Puzzle on page 62) and the *Linien*-task (see Task IV: Linien on page 58) are especially designed for exercising visual skills.

Planning and sorting

These two abilities can be trained by the *Planungsschritte*-task (see Task V: Planungsschritte on page 60) and the *Suchen*-task (see Task VIII: Suchen on page 66). Both tasks require the user to identify the elements, remember them and then put them into a correct order.

Additionally, the *Fehlersuche*-task (see Task III: Fehlersuche on page 56) can also be configured as a planning task. A simple way to use this task as a planning exercise can be reached by showing a topic, (e.g. hiking tour) on the top of the screen and then by asking the user to find the element that one does not need for the given topic.

Linguistic skills

One of the areas that JATEF intentionally does not cover are *linguistic skills*. The main reason therefore is that this area is strongly linked to a high degree of ambiguity. This ambiguity, on the one hand, is very important for individual expression, but on the other hand, also very hard to evaluate automatically. Especially when working with children, where room for interpretation has to be considered, it is nearly impossible to properly assess task results programmatically.

Nevertheless, there are some implemented tasks where linguistic skills can be trained when configured in a certain way. For example the tasks *Schlussfolgerung* and *Umstellfähigkeit* are adaptable for the training of linguistic skills, if required.

7.2 Evaluation of the flexibility of JATEF

As each implemented task of JATEF receives its input through freely adjustable parameters, a very high level of flexibility could be ensured. While a more detailed description of different adjustment possibilities for each task was already specified in Section 6.1 on page 46, the aim of this section is to evaluate the flexibility of JATEF in general.

A big benefit of JATEF is that it can be easily adapted to suit a wide age range of users. Through the variety of choosable input content (starting from simple images to three-digit numbers and words), kindergarten children will be able to benefit from JATEF as well as children at the end of elementary school. Many tasks are also capable of covering mathematical skills by setting the command text to a term like 12+2= and providing several numbers (e.g. 10, 15, 14, 13) representing possible answers.

Another parameter that is freely adjustable in each task is the task length (the number of questions). By choosing an appropriate task length, it is possible to take the users focus ability and concentration span into consideration.

It is also possible for the mental-health professionals to freely decide which tasks a user should perform. The selection of certain tasks instead of the entirety (all 10 tasks) may be useful if the therapists already have a diagnosis on the patients deficits and want to focus on certain types of exercises (e.g. visual, mathematical). These task combinations can be saved as *task packages* for further use.

It should be mentioned, that the graphical user interface for adjusting the tasks and the creation of task packages which should simplify the adaption process for mental health professionals, was not scope of this work. Nevertheless, JATEF can already be configured by a person with technical background (not necessarily a programmer) in order to fulfill the requirements of mental health professionals.

Due to the flexibility of the framework, JATEF can be used in future studies in order

- to collect different training results caused by different adjustment setups,
- to localize the main deficit of a certain patient and
- to find the optimal difficulty level, training length and task combination for a patient.

7.3 Evaluation of the suitability for children with ADHD

Because of time constraints of this work, an evaluation by patients was not possible. Instead, JATEF was tested by the above mentioned mental-health professionals.

Concerning suitability for children, the testers stated that the fragmentation of the total area into smaller components was well chosen. As the total area was restricted to a certain resolution (see 5.1), the dimensions of each component had to be reduced to the essentials. In their opinion, it was a good decision not to show several questions at the same time as it was the case in the original exercise book, but to limit the display to one question at a time.

The testers also favoured the fact that the elements enlarge when the pointer (e.g. mouse pointer, finger (when using a touch screen)) is hovering over them. Due to enlargable elements, the children do not only receive feedback on the actual position of the pointer but also recognize whenever an interaction with an element is possible.

According to their expert opinion, the navigation components on both sides should be designed in a clearer way. Instead of using *arrow*-images (e.g. arrow pointing to the right for *next*), the navigation component should have the actual word (*next* or *previous*) written on it. The problem with the images is that some children may not be aware of the association that an arrow can also be used as a navigation tool. (This improvement has already been implemented in the recent version of JATEF.)

Another improvable issue mentioned by the testers concerns the feedback and motivation mechanism. As shown in Figure 6.4, the animal at the end of the task is the same as the one on the start screen (see Figure 6.2). In order to motivate the user, the one at the end should give positive feedback (e.g. by smiling) to the user. Additionally, sound effects (e.g. animal sounds, applause) were suggested to amplify the motivation effect.

Regarding the design of JATEF, the evaluation yielded that the used colours and images were appropriate when exercising with children suffering from ADHD. The bright colours and modern images were perceived positively as they are likely to gain the attention of the child.

Furthermore, each task proved to be easily understandable and simple to navigate, which is of great importance when working with children. No ambiguities were recognizable in the task designs which has a positive effect on the solution finding process of the user and also improves the fluency of the tasks.

CHAPTER **X**

8

Future Work

The work described in this thesis represents a useful task framework that can be developed further in several directions.

Firstly, it would be even more comfortable and user friendlier if the input files could be modified/adjusted through a separate editor-tool (e.g. web interface) instead of the traditional text editor. With the help of this interface, mental-health professionals would be able to manipulate text elements or load images (simply be choosing the image from a file chooser) more effectively and, thus, save a lot of time. Another advantage that arises when using an especially developed tool for input manipulation is the prevention of formal errors. Clerical errors, such as the absence of the hyphen symbol between two elements, which would have led to non-execution or misinterpretation of the task, could be detected automatically.

Secondly, the difficulty level of each task could be adjusted without the involvement of medical trained staff. This 'adaptive' behaviour can be found in many games and quizzes in modern times and leads to a more challenging game experience. While advanced users will never become bored by tasks that are too easy, adaptive games also give beginners a chance to achieve success.

JATEF can also be improved and enhanced by the implementation of further tasks. As the JATEF framework provides the option of adding further tasks without great effort, the range of covered deficits can be easily widened. Additionally, an English version of JATEF could be implemented for the US market, so that it can compete with products such as mentioned in the state of the art chapter.

CHAPTER 9

Conclusion

The Attention Deficit Hyperactivity Disorder (ADHD) together with executive function (EF) deficits leads to academic and social disadvantages as described in the section entitled Academical Impact. Caused by limited intervention possibilities especially designed for children, many children are typically treated with medication which clearly has some major drawbacks (e.g. side effects and presence of only short term benefits). The importance of early diagnosis and intervention, including their aggravating factors, has also been demonstrated in this thesis. The introduced computerized training of children with ADHD represents an alternative/supplementary approach to existing intervention types, without claiming to be *the* exclusive correct solution.

Literature research on existing computerized interventions in ADHD treatment has led to the conclusion that only a few training tools are especially designed for children aged between 6 and 10 years. In addition to the limited variety, almost every examined training software was associated with high acquisition costs or high license fees, which might be an insurmountable obstacle for families with low parental income.

By implementing 10 different training tasks, I have developed a free supporting tool that can be used in therapy for patients with deficits in certain executive functions. While each task has been analyzed and adapted to children's requirements individually, a uniform and consistent basic framework has been designed in parallel.

One of the most challenging assignments during the development process was determining the optimal trade-off between motivation and effectiveness of each task. This challenge could only be solved with continuous feedback and expert knowledge, which was provided by mentalhealth professionals. Due to its high levels of flexibility and expandability, patients outside the target group can be treated using JATEF. In response to the research question '*How can Java*TM applets support the training of children with EF deficit?' it is necessary that a training system, used for EF deficits compensation, must have the following properties:

- (a) Effectiveness: In order to be sure that a training system has a certain positive impact on the users, medical expert knowledge is required. It has to be clear, from the beginning, which EF deficits are covered by the application. Further, the requirements and the expected output of the training should be properly specified.
- (b) **Usability**: When working with children, it is of great importance to ensure that the user interface is well designed and easy to handle. Special attention should be be paid to following items:
 - The tasks should include child specific features.
 - The tasks must not be ambiguous.
 - The navigation has to be intuitive.
 - Interacting elements should provide a feedback mechanism.
- (c) Motivation: As many children (and particularly those with ADHD) get distracted/bored very quickly, it is essential to keep them motivated while playing. Regardless of the training result, the feedback should always be formulated in a positive manner. Introducing a reward system (e.g. one little toy after completing a certain number of tasks) is also recommended, in order to keep the interest of the child to the training.
- (d) **Adaptability**: Because of the wide variety of EF deficits, a generally designed solution is required. Another reason why adaptability plays an important role in such a training is that the application should be able to take the users preferences into account.

As the evaluation by mental health professionals attested, JATEF not only represents a versatile training system applicable for the training of children with executive function deficits, but it also meets the above mentioned criteria, as follows:

- (a) **Effectiveness**: JATEF covers several executive function deficits as presented in 5.1 and approved by mental-health professionals. This approval does not only serve as a medical justification for the use of JATEF in real therapy, but also forms the base for subsequent result analysis and interpretation.
- (b) **Usability**: JATEF uses an easily understandable, but also appealing and modern design (as follows), giving it an advantage over conventional training methods (applications).
 - Each task provides colourful elements and images.
 - The task descriptions were checked from experts and improved where required.
 - JATEF consists of only two navigation elements, which are placed at an intuitive location. Furthermore, these elements are clearly labeled as navigation elements.

- Each displayed element is capable of automatically giving feedback by enlarging its content when the (mouse) pointer hovers over it.
- (c) **Motivation**: In JATEF, feedback is automatically provided after finishing a task (represented by rotating stars) and additionally after the whole training session (represented by a golden trophy).
- (d) **Adaptability**: Each task of JATEF is adaptable to a very large extent which makes it applicable to many different areas. Furthermore, each task can be customized in terms of length, difficulty and representation content (text, numbers, images).

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