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School Start Screening Tool

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Affidavit

I declare that I have authored this thesis independently, that I have not used other than the declared sources/resources, and that I have explicitly indicated all material which has been quoted either literally or by content from the sources used. The text document uploaded to TUGRAZonline is identical to the present master's thesis.

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Abstract

Screenings to assess fundamental skills of children are around long before the introduction of the general compulsory school and are commonly used to determine if children have any special educational needs. These screenings consist out of different assignments and vary in their structure and processing time. The assessed skills usually are needed for the development of different competences like reading, mathematics or writing.

Based on the plan of the Austrian Federal Ministry of Education, a new screening should be introduced in the future to identify if children have a lack of skill in any educational area before entering school. This screening can be carried out in form of a paper-pencil version or with the help of a tablet computer in form of a mobile application.

The aim of this thesis is the development of the mentioned digital screening, in this thesis called "School Start Screening Tool", and its infrastructure, consisting out of a web application and a web server. The major goal was to find out how a tablet application for children at preschool age, without necessary skills in reading and writing, can be developed and how to design the application so that the children stay motivated for several minutes. Furthermore, the assignments, developed by the developmental psychologists, had to meet their different requirements and had to be wrapped within an interesting frame story for the children.

Kurzfassung

Schon vor der Einführung der Pflichtschule existierten bereits Screenings zur Beurteilung der grundlegenden Fähigkeiten von Kindern, um festzustellen, ob diese einen besonderen Förderunterricht benötigen. Diese Screenings bestehen aus verschiedenen Aufgaben und variieren in ihrer Struktur und Durchführungszeit. Die untersuchten Fähigkeiten werden normalerweise für die Entwicklung verschiedener Grundkompetenzen wie Lesen, Mathematik oder Rechtschreiben benötigt.

Laut dem Plan des österreichischen Bundesministeriums für Bildung soll künftig ein neues Screening eingeführt werden, um Kinder, die nicht über ausreichende Fähigkeiten in einem Bildungsbereich verfügen, vor dem Schulbeginn zu identifizieren. Dieses Screening kann in Form einer Papier-Bleistift-Version oder mithilfe eines Tablet-Computers in Form einer mobilen Anwendung durchgeführt werden.

Das Ziel dieser Arbeit ist die Entwicklung des erwähnten digitalen Screenings, welches in dieser Arbeit als "School Start Screening Tool" bezeichnet wird, und dessen Infrastruktur, bestehend aus einer Webapplikation und einem Webserver. Das Hauptziel war herauszufinden, wie eine Tablet-Anwendung für Kinder im Vorschulalter ohne die erforderlichen Lese- und Rechtschreibfähigkeiten entwickelt werden kann und wie man diese Anwendung gestaltet, um Kinder über mehrere Minuten lang motiviert zu halten. Darüber hinaus mussten die von den Entwicklungspsychologen entwickelten Aufgaben ihren unterschiedlichen Anforderungen entsprechen und in eine interessante Rahmengeschichte für die Kinder eingebunden werden.

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1 Introduction

The Austrian educational system is one of the best in the world. This is also visible when looking at the scores of the Program for International Student Assessment (PISA) results from 2018 (FactsMaps, 2021) in which Austria finished in 28th place. The worldwide study by the Organisation for Economic Co-operation and Development (OECD) of 2018-2019 took place in nearly 80 nations. This makes Austria one of the top 36%. Assessed were 15-year-old students of the participating countries on their scholastic performance on mathematics, science and reading.

Every year Austrian newspapers print stories about politicians' plans to enhance the Austrian educational system. Some of the newest changes were the renaming of all secondary schools, except high schools, to "Neue Mittelschule" (Studium.at, 2020) but bigger changes were not visible for people without a connection to the educational system like having children in school or being part of the teaching staff.

One method the ministry of education is looking forward to integrate into every school is the assessment of every child via an educational screening. In many cases, screenings are used for preventive medical check-ups such as cancer screenings. Furthermore, screenings are also used for the early detection of diseases in newborns. The term "screening" is also known as a general method for assessing a broad field of skills of a person, which often takes place at the beginning of a diagnostic process. With the help of a screening, it is possible to make a decision to which group of performance or risk a person can be assigned. The classification of a screening is primarily determined by using specially specified cut-off values. [Petermann F, 2011]

Screenings are especially used for early pediatric examinations to determine the children's level of development. This procedure can be used to assess the children's general development but can also be integrated in the everyday

life of kindergarten for developmental observation and documentation of the children. The American Academy of Pediatrics provides in their guidelines that every tested child with results showing a high risk has to be diagnosed more detailed with specific diagnostic procedures. [Petermann F, 2011]

To make use of screenings in the Austrian educational system the Austrian Federal Ministry of Education has planned to assess every child in advance of their school career in the future. While the already existing school entrance examination the children should undergo a screening to determine their level of skill in the cultural competences which are reading, writing and mathematics (Federal Ministry of Education, Science and Research, 2020). That way children with developmental disorders can be identified early which would later end for them in an impairment in social participation without any educational help. To be able to scale the screening for an usage in every school in Austria and to enable teachers to see the screening results just in time, the screening should be implemented as a mobile application for tablet computers and should display results right after the assessment is finished.

The goal of this master thesis is the development of an tablet app that can carry out exactly this screening which is planned to take place in all Austrian schools in the future. Since the implementation of the screening's assignments required a good collaboration with the developmental psychologists of the University of Graz and the University of Vienna, the good communication with both universities was very helpful. The concept of the assignments was developed by the developmental psychology teams and with the use of digital images designed by designers of the Institute of Interactive Systems and Data Science the assignments could be implemented in a child-friendly way through this master thesis. Furthermore, it also discusses the challenges encountered while the design and development of the tablet application: How to develop a mobile application for children with early stages of reading, writing and mathematically skills while keeping them motivated? How to connect assignments done with the help of paper and other tangible objects? Some technical challenges encountered are described also, like: How to develop a mobile app for users without sufficient internet connection while the app depends on data saved on a server and has to send collected data to the server?

2 Structure

Since a specific background knowledge of some existing screening methods, their structures and processes is advantageous for the development of a new digital screening application, some screening methods are described in the first chapter. Most of the today existing screenings are only available as paper-pencil versions, that is why it was necessary to look also more detailed at digital screening methods or educational apps. Every child must acquire some necessary skills to learn reading, mathematics and writing already before school. Each of these three so-called cultural techniques has different screening methods to assess the child's level of development. Therefore, the first chapter describes screening methods for the assessment of reading, mathematical and writing skills.

The next chapter focuses on the explanation of the new digital screening application. First, the motivation and story of the mobile app is outlined, followed by a description of what to pay attention to when developing an app for children at preschool age with the goal to keep them motivated over the whole screening process. The different assignments, its structures, mockups, and which data is saved for every assignment is described also in the mentioned chapter.

The "Implementation"-chapter deals with the actual implementation of the mobile application, the web application, and the web server. The decisions that led to the web application's and the web server's functionalities and structure, as well as the frameworks and programming languages used for the implementation, are also described in more detail.

The sixth chapter gives attention to the School Start Screening Tool's evaluation, based on the opinions of teachers, children, and the psychologists. Due to the wider usage of the School Start Screening app and due to the developmental psychologists being the main organizers, the best way to

evaluate the application was by gathering their experiences in form of an interview. Which questions were part of the interview and the psychologists' answers can be found in the "Evaluation"-chapter.

The seventh and final chapter summarizes the results of the School Start Screening Tool as well as its possible areas for improvement for further development.

3 Screenings in Education

3.1 History

Long before the introduction of general compulsory schooling, people were thinking about how to recognize when a child has the necessary skills to enter school. In the 16th century 7-year-old children had to pass a test named "Gulden-Apple-Test". The children were given the option to take an apple or a penny. If the child did take the penny over the apple the test was passed. Because this action was seen as an indication of cognitive maturity the child was seen as mature enough for school. [Dietrich Rüdiger, 1976]

In the 18th century in German-speaking countries it was assumed that 5-year-olds would have enough knowledge to enter school to learn to write and read. At this time there weren't any specific scientific studies made to determine the most beneficial age for children to enter primary school. Not until the first half of the 20th century developmental diagnostic tests were introduced. [Wolfgang Schneider, 2018]

These developmental diagnostic tests which measured the children's cognitive, emotional and motivational development caused the school age of five to be increased to six and older. Because of disappointing PISA-results the age of testing was lowered again and adjusted to the average international school age. [Wolfgang Schneider, 2018]

Since then, many new developmental diagnostic procedures were developed and are part of today's screenings. The determination of the fact if a child is ready for school is based on the children's competences in five important educational subjects. These subjects include language, writing, mathematics, motoric and social development. To be sure that most of the children are able to achieve these goals the kindergarten has to prepare the children

according to a specific educational plan. Newest procedures have the goal to measure these basic competences even more accurate and, in a way, that parents and teachers receive important indicators of the children's level of education. [Wolfgang Schneider, 2018]

Due to the big new challenge for children in school to work every day on their skills in reading, writing and math it is important to know when children have developed the necessary requirements to overcome these educational challenges. This was first known by experts as "school-readiness" because of the assumption that a child must have reached a specific maturity. The best indicator therefore was the average age of the child. If a child at this age did not reach the required level of development, it was granted a time of "maturation" to catch up with the average. [Wolfgang Schneider, 2018]

This concept was later disproved by experts and replaced by the "school-capability". The new concept deviated from the age aspect and only focused on the children's capabilities. A child had a "school-capability" when it reached the school's educational requirements. Children which didn't fulfill the requirements were said to have a lack of talent. [Wolfgang Schneider, 2018]

In the 1970s the USA introduced special support programs for children below the standard. These programs showed that the cognitive development of children with lower educational skills could be increased. By undergoing special educational support children were now able to fulfill the educational requirements. Since then the focus of developmental diagnostic procedures was to identify the children special educational needs. [Wolfgang Schneider, 2018]

3.2 Problem Description

At preschool age children already acquire the necessary skills to be able to learn the so-called cultural techniques: reading, writing and math. These necessary predecessor skills include adequate body coordination as well as various non-specific and specific cognitive capabilities, which are considered

as prerequisites for school readiness. Deficits in these predecessor skills and abilities can cause later learning disabilities in school. In order to prevent the development of such learning disorders and the development of behavioral disorders, an early detection of these developmental problems and risks is very important. If these developmental risks are recognized early and diagnosed well, this information can be used to develop preventive actions that enable the child to have better development opportunities and help it to cope with the upcoming development tasks. [Daseking, Lemcke, and Petermann, 2006]

Since pediatric preventive medical examinations for children between 4 and 6 years of age are hardly suitable for determining development problems and not all children have to take this test (Lampert et al., 2005), many children are only classified for school entry through the health examination. Another difficulty in the early detection of developmental disorders is that various cognitive functions can usually only be validly assessed using appropriate test procedures. [Daseking, Lemcke, and Petermann, 2006]

Various arguments speak for the earliest possible time to identify children with developmental risks. If school-related predecessor disorders are only recognized at the time of the school entry health examination, there is not much time left for an intervention. [Daseking, Lemcke, and Petermann, 2006]

3.3 Reading Competences

Research focused on the extent to which early language and literacy skills affect children's acquisition of reading skills. One of the most important findings of science is that the vocabulary plays a central role in the development of reading skills. However, there is no agreement if this association is direct or indirect through phonological and print-related knowledge. The cumulative language approach describes that language skills interact with literacy knowledge and phonological knowledge and that all three are important for learning to read. The cumulative language approach also describes that of crucial importance for the emerging literacy and development of reading skills are different oral language skills. These oral language

skills include vocabulary, phonological awareness, syntax and discourse, which are interrelated skills and form the basis for emergent literacy and subsequent reading skills. [Poe, Burchinal, and Roberts, 2004]

3.3.1 Screening Procedures

For the assessment of a children's reading competences not only vocabulary, phonological awareness, syntax and discourse are important but also the speed a child is able to read. There are a few screening procedures already developed to assess the reading speed of children in the German speaking area. One of the described screening procedures was developed by the German Institute of Psychology at the University of Würzburg and is known as the "Würzburger Leise Leseprobe". Another one is named "Salzburger Lese-Screening" and was developed by the Austrian research organization "Salzburg Research". Both of the described screenings are usually performed with paper and pencil. In order to be able to make a comparison with a digital screening method, a screening named "ELFE 1-6" is described afterwards, which was specially developed for assessing children with a computer.

3.3.2 Würzburger Leise Leseprobe

The Würzburger Leise Leseprobe (WLLP) is a group reading test for primary schools which was developed by the Institute of Psychology at the University of Würzburg in the late 1990s as part of its research. The test is built to require quick reading of individual words such as selecting and marking the corresponding image from four images each. By recording the reading speed, the WLLP makes it possible to differentiate very well between readers of different levels of competence in the German-speaking area. The execution of a test run requires a processing time of only five minutes for all classes of grades 1 to 4. The careful review of the test quality criteria distinguishes the WLLP as a reliable and valid test procedure. The standards were obtained from a large representative sample from German and Austrian federal states. Thus, the WLLP is a comprehensively calibrated, reliable and valid

measuring instrument for recording reading performance in primary school. In addition, due to the rich illustration, it has an exceptional invitation character for elementary school children. [Marcus Hasselhorn, 2000]

Test procedure

The test consists of a total of 140 test tasks. For each task a word is given to be read quietly. For each word there is a series of four pictures given. Only one of the given pictures corresponds to the read word which has to be highlighted. All the other pictures show images of phonologically similar or with the given word semantically related words as distractors. [Marcus Hasselhorn, 2000]

The WLLP is a speed test, therefore the children have a certain amount of time which is by default 5 minutes to work on the test tasks. The number of correctly processed items during this time serves as the variable for the test's evaluation. Since it is a speed test, the individual tasks are of little difficulty. The real differences in performance are measured by the speed at which the children work. The total time required for the WLLP is approximately 15 minutes. The processing time is 5 minutes. The rest of the time is used for instruction, handing out and collecting. The test, for which there are variants A and B, is evaluated by using templets. [Marcus Hasselhorn, 2000]

The test result is calculated by subtracting the number of errors including items without an answer from the number of items processed in total. [Marcus Hasselhorn, 2000]

An example WLLP screening can be seen in figure 3.1.

3.3.3 Salzburger Lese-Screening

The Salzburger Lese-Screening tests the differences in general reading skills. This means the screening tests the ability of error-free and (depending on the class level) quick and effortless reading of the words in a text. The basic reading ability does not mean the understanding of a text which depends on the knowledge and language skills, but the technical aspect of reading.

Taschenmesser				
Pinguin				
Feuerzeug				
Badewanne				
Fallschirm				
Anorak				
Eidechse				
Sonnenbrille				
Kaktus				

Figure 3.1: Example test items of the WLLP (Suchodoletz, 2021)

Without error-free and effortless reading of the words of a text, all further reading functions are impaired. In practice, it is the reading speed that provides information about differences in basal reading skills. [Mayringer and Wimmer, 2005]

This is exactly what the Salzburger Lese-Screening examines. Basic reading skills should be assessed with a natural reading task and in an economical manner. During the screening the children have to read a sequence of simple sentences as quickly as possible. Each sentence needs to be checked by the children if its meaning is true. For example: "bananas are blue". The sentences that are part of the screening task are specially designed to be easy for children to understand. [Mayringer and Wimmer, 2005]

From an economic point of view, the processing time of only three minutes is reasonable. It is also possible to assess multiple children at the same time. The screening's time limit makes it possible to recognize differences in basic reading skills particularly well. [Mayringer and Wimmer, 2005]

As it can already be seen from this brief description, the screenings procedure should quickly provide information about possible reading difficulties of individual children or the performance level of an entire class. Despite the high reliability of the test, there is always a risk that individual children will not be able to perform optimally due to specific circumstances. Therefore, an individual test makes sense to clarify a reading disability. [Mayringer and Wimmer, 2005]

Structure

As already mentioned, the screening should detect differences in the basic reading ability through a natural reading assessment, that is, through the content-related understanding of sentences. Each of the given sentences which should be easily understandable by the children has to be marked as true or false based on its meaning. The raw value of the test is the number of sentences correctly marked in three minutes. [Mayringer and Wimmer, 2005]

Each version of the test contains as many sentences with true statements as sentences with false statements. The consequence is that in case of guessing

only half of the sentences can be expected to be correctly assessed regardless of the strategy used. It makes no difference if the child always marks the sentence as true or as false or alternates. [Mayringer and Wimmer, 2005]

The Salzburger Lese-Screening is available in two versions with different sentences but comparable in terms of reading requirements, which makes it possible to assess each child again in a short period of time. [Mayringer and Wimmer, 2005]

Procedure

As mentioned before, the screening can be performed with all children in a class at the same time or with a single child.

Based on Mayringer and Wimmer (Mayringer and Wimmer, 2005) the following is required for the procedure:

- a stopwatch
- a booklet for each child
- a booklet for the teacher
- two pens for each child (one as reserve)
- a school blackboard

Mayringer and Wimmer (Mayringer and Wimmer, 2005) encourage teachers to pay attention to 10 points, among others:

- hand out the booklets
- children are not allowed to use an eraser or ink killer
- check if the cover sheet is correctly filled out
- all children have to complete the exercise sets according to the instructions
- reading aloud and looking at the neighbors is not allowed
- finish the test after exactly 3 minutes

The description of the Salzburger Lese-Screening by Mayringer and Wimmer (Mayringer and Wimmer, 2005) also comes with two A4 papers with instructions which the teacher should read aloud or repeat as good as possible. These instructions should make it clear to the children how the test should

be carried out. They also instruct the teacher to go through 3 sets of exercise sentences to give the children a feeling for the tasks.

Evaluation

To evaluate the Salzburger Lese-Screening, the raw value of the test result must first be determined. Therefore, the corresponding evaluation foil is placed on each page of the test booklet. The imprint of the foil is printed in such a way that incorrectly marked or omitted sentences can be recognized immediately. In addition, the number of the last processed sentence can be read from the foil. [Mayringer and Wimmer, 2005]

An example test of the Salzburger Lese-Screening can be seen in figure 3.2.

As already mentioned the "Würzburger Leise Leseprobe" and the "Salzburger Lese-Screening" are only available as paper pencil versions. Especially group tests can become very complex because of the manual evaluation of every test when working with paper and pencil. Some newer screening methods are also designed in a more digital way and let children perform the screenings on computers or tablets. One of these screenings is known as "ELFE 1-6" which stands for "Ein Leseverständnistest für Erst- bis Sechstklässler" and means "a reading comprehension test for first to sixth graders".

3.3.4 ELFE 1-6

The reading test ELFE 1-6 by Lenhard & Schneid was developed to enable a comprehensive assessment of reading comprehension. The test takes the reading skills into account to understand individual words, sentences and entire texts. The results gathered are combined and are used to create a strengths and weaknesses analysis. The test is available as a computer version as well as a paper and pencil version. [Lenhard and Schneider, 2006]

The places where deficits in the area of cultural competences should primarily be recognized and trained are usually schools. In schools, however,

Schnee ist rot. ✓ ✗	
Ein Ball hat vier Ecken. ✓ ✗	
Die Taube ist ein Vogel. ✓ ✗	
Haifische leben im Wald. ✓ ✗	
Am Sonntag ist schulfrei. ✓ ✗	
Ein Buch hat viele Seiten. ✓ ✗	
Mit einem Stift kann man schreiben. ✓ ✗	
Ein Blatt Papier ist sehr schwer. ✓ ✗	
Auf einem Sessel kann man sitzen. ✓ ✗	
An einer Hand hat man drei Finger. ✓ ✗	
Die Maus ist ein kleines Tier. ✓ ✗	
Das Schaf hat ein weiches Fell. ✓ ✗	
Das Auto parkt auf dem Dachboden. ✓ ✗	
In der Bücherei gibt es Nudeln. ✓ ✗	
Der Hammer ist ein Werkzeug. ✓ ✗	
In einem Wald stehen viele Bäume. ✓ ✗	
Luftballons kann man aufblasen. ✓ ✗	
Apfelkuchen wird aus Erdbeeren gemacht. ✓ ✗	
Bei Regen werden die Straßen nass. ✓ ✗	
In einem Teebeutel sind Kaffeebohnen. ✓ ✗	
Auf dem Bauernhof leben viele Dinosaurier. ✓ ✗	
Pilze, die giftig sind, darf man nicht essen. ✓ ✗	
In einer Stadt wohnen viele Menschen. ✓ ✗	
Wenn man einen Bären fangen will, braucht man eine Mausefalle. ✓ ✗	
Am schnellsten fahren Autos, die mit Erbsen vollgetankt sind. ✓ ✗	
Menschen mit einer Glatze haben sehr viele Haare auf dem Kopf. ✓ ✗	
Wenn man mit dem Zug fährt, ist man schneller als zu Fuß. ✓ ✗	
Das Spinnennetz wird von Wespen gemacht. ✓ ✗	

Figure 3.2: Example test items of the SLS (Sörös, 2013)

school psychologists usually face an immense number of students. The ratio can even be more than one school psychologist for more than a thousand students. Diagnostic procedures should therefore be highly economical and require little time to familiarize yourself with them. With the reading test ELFE 1-6 a procedure was developed which can be used easily and without deep diagnostical knowledge due to the computer-aided application. It is also possible to evaluate the paper pencil test results of a whole class with the help of the computer for a faster calculation. [Lenhard and Schneider, 2006]

A child-friendly presentation was another criterion which was important to Lenhard & Schneid during the development. Lenhard & Schneid wanted to increase the motivation of the students by using a child-friendly graphical character which should lead through the test. The graphical character chosen for the ELFE 1-6 test is an elf. The elf gives verbal instructions and, if necessary, feedback on the individual tasks. In order not to disturb the students, little other audio instructions or effects are used. The use of the audio instructions makes it fun for the children to complete the test. According to the document, some children liked the reading comprehension test so much that they wanted to take the test twice. [Lenhard and Schneider, 2006]

Procedure

As already mentioned, the ELFE 1-6 test includes reading assessments for understanding individual words, sentences, and entire texts. The task of the word comprehension assessment is to select the right word for a picture from a list of four words. The given words are selected to have a graphemic and phonemic similarity and the same number of syllables. The computer version of the tests gives the possibility to select if the given words should always appear at the same position on the screen or should be listed in a random order. The order of the tasks remains the same. The word comprehension test comprises a total of 72 items, each containing one to four syllable words. [Lenhard and Schneider, 2006]
An example task of the word comprehension assessment can be seen in figure 3.3.
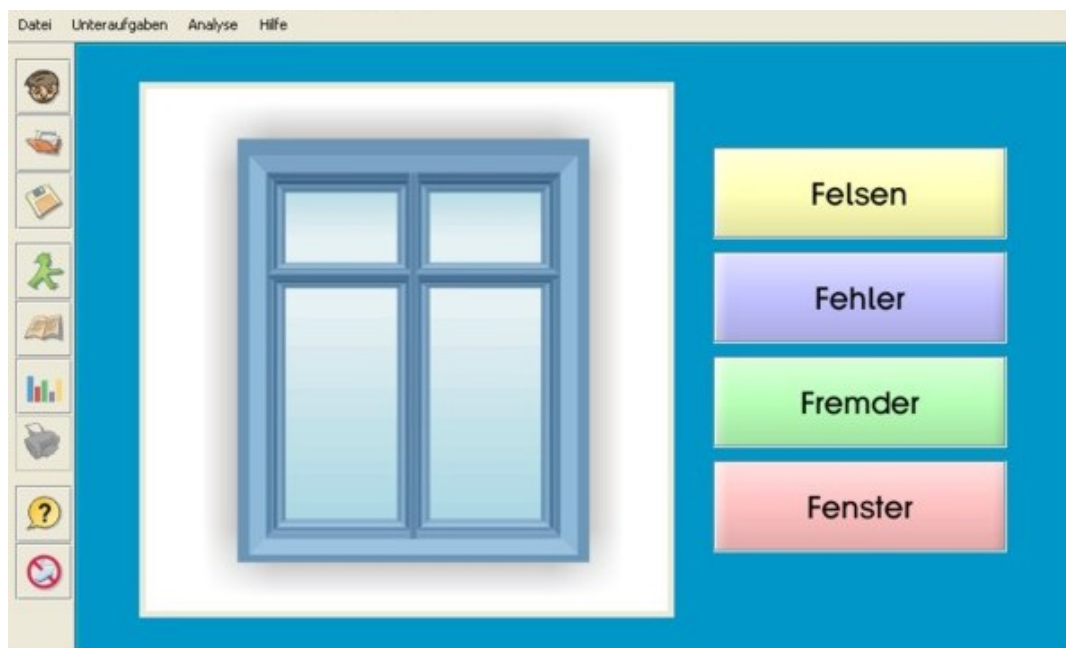
Figure 3.3: Example task of ELFE 1-6's word comprehension assessment (Dres. Alexandra, 2021)

Figure 3.4: Example task of ELFE 1-6's sentence comprehension assessment (Dres. Alexandra, 2021)

The sentence comprehension test consists of sentences, for which one word from the sentence must be chosen from several selection alternatives. The correct answer is to find the word that fits in the sentence out of a list of five words. Similar to the word comprehension test the selectable words are similar in graphemics and phonemics. The sentence comprehension test has a total of 28 test items. [Lenhard and Schneider, 2006]

An example task of the sentence comprehension assessment can be seen in figure 3.4.

The last subtest is the reading comprehension at text level. The children have to read a short text and have to answer a specific question to that text. For each task the children have to choose from four given possible answers. For some tasks the text is the same as for some previous task. In that case the text is repeatedly presented in the computer version. [Lenhard and Schneider, 2006]

An example task of the reading comprehension assessment can be seen in figure 3.5.
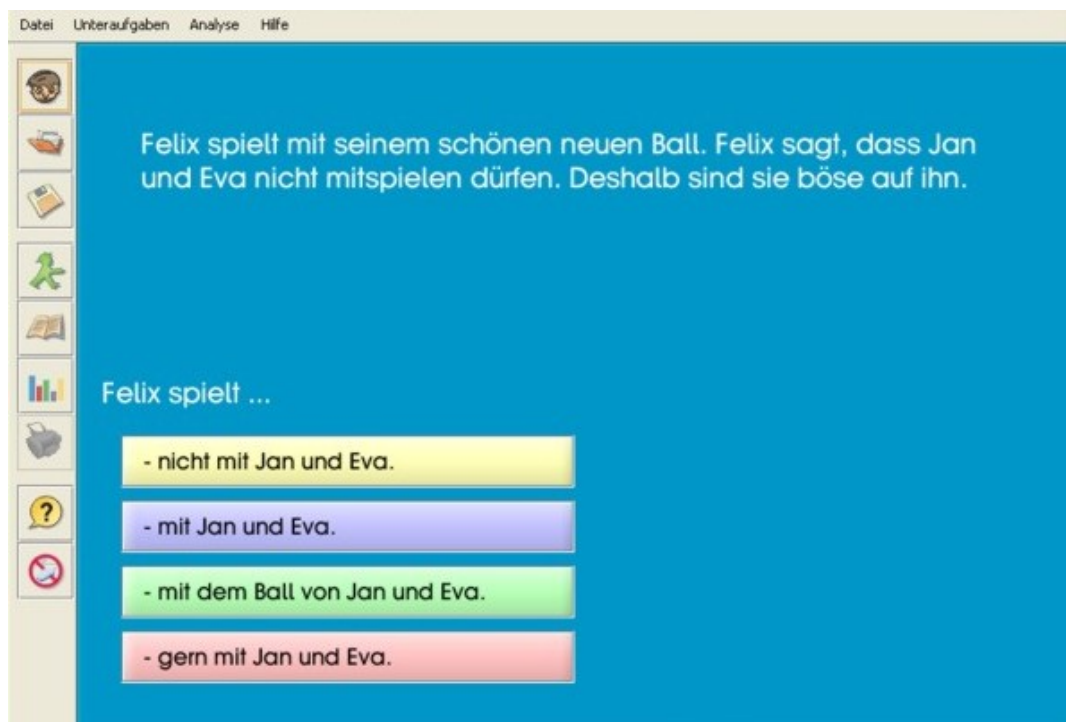
Figure 3.5: Example task of ELFE 1-6's reading comprehension assessment (Dres. Alexandra, 2021)

Figure 3.6: Example task of ELFE 1-6's reading speed assessment (Dres. Alexandra, 2021)

The screening's computer version consists of another reading test which records the reading speed. This subtest displays forenames that are hidden after a limited time. The child has to decide whether it is a boy's or a girl's name. The first four test items are hidden after 900 milliseconds. This time interval is increased if the child has answered zero, one or two items correctly. In the case of four correct answers the time is decreased, otherwise the time stays the same. This way, the maximum word recognition speed can be recorded. [Lenhard and Schneider, 2006]

An example task of the reading speed assessment can be seen in figure 3.6.

Benefits of the computer version

In contrast to paper and pencil versions, the computer version of the test offers the possibility for a quick evaluation and makes it possible to carry out precise time measurements. Another advantage of the computer version

is that it is possible to adapt the order of the test items and the order of the possible answers given. [Lenhard and Schneider, 2006]

Economy

For grades one to four, the ELFE 1-6 test's processing time of the paper version takes 13 minutes. The processing time of the computer version takes two minutes longer. For the grades five and six the processing time is only ten minutes for the paper version and eleven minutes for the computer version. However, the paper version also needs to be prepared by handing out test booklets, filling out the children's personal information, instructions and collecting the test booklets. The paper version's preparation usually takes 20 to 30 minutes. [Lenhard and Schneider, 2006]

For experienced teachers the manual evaluation of the paper version only takes about three minutes per test book. Due to the complexity of the differential evaluations, it should primarily be carried out on the PC. When taking the computer version, the evaluation is calculated automatically, which means that it does not take any additional time for the teachers. Not only the time is a difference when comparing both versions but also the costs. The paper version needs to spend money on the test booklets. Since any number of tests can be carried out with the computer version, it is cheaper to choose the computer version when more than approx. 90 test runs are made. Especially in schools, the computer version of ELFE 1-6 is suitable for economical large-scale screening. [Lenhard and Schneider, 2006]

3.4 Mathematical Competences

The developmental disorder, which relates to mathematical skills, is fundamentally referred to as arithmetic disorder or as developmental arithmetic disorder. Among experts, this is also referred to as dyscalculia in the neuropsychological literature. This disorder involves an impairment of all skills associated with mathematical competences. The reason for this is not in

general a deficit in intelligence. The skills affected by the deficit are basic arithmetic skills such as addition, subtraction, multiplication and division. The complete mathematical relationships required for algebra, trigonometry, differential or integral calculations are less affected. [Barth, 2005]

It also applies to the mathematical competencies that children acquire them in a development process that begins long before their first math lessons in school. The children's first insights into the concept of numbers and the ability to operate with quantities also starts developing before school. [Barth, 2005]

For the early detection of a deficit in arithmetic skills it is necessary to identify development areas which are needed for the acquisition of mathematical competences. The examination of these areas should allow to achieve a prediction of the mathematical performance at school. The acquisition of estimating quantities and counting skills in preschool age is seen as the most significant step in the development of mathematical operations. [Barth, 2005]

A number of skills are part of the quantity-related prior knowledge (Barth, 2005):

- The ability to arrange items in an ascending or descending order according to a specific characteristic (large-small; thick-thin).
- The ability of comparing quantities.
- The ability to create one-to-one relations. This means that children have to be able to compare two quantities with each other and assign one element to an element of the second group.
- The ability to create one-to-one relations. This means that children have to be able to compare two quantities with each other and assign one element to an element of the second group.

Multiple skills are also part of the digit-related prior knowledge (Barth, 2005):

- The ability to count up to ten or even 20. Children have to be able to count up and down and need to know which number comes before and after a given number.

- Children need to have a knowledge about the Arabic numbers. Part of the Arabically number knowledge is to know how each number looks like and the ability to assign numbers to acoustically given numbers.
- The ability to solve simple arithmetic problems.

3.4.1 Screening Procedures

For the assessment of children's mathematical competences there are multiple screening procedures available. Most of them only exist as paper pencils versions. One of them which is used in German speaking countries is known as "Das ElementarMathematische BasisInterview". The "ElementarMathematische BasisInterview" is based on the Australian "Early Numeracy Research Project". In order to also have a computer-based treatment of mathematical deficits for comparison, "The Number Race" by Wilson AJ, Revkin SK, Cohen D, Cohen L, Dehaene S is also described in more detail.

3.4.2 Early Numeracy Research Project and "ElementarMathematische BasisInterview"

The "ElementarMathematische BasisInterview" (EMBI) is a diagnostic instrument for determining the learning level of children in mathematics. It was developed for the assessment of children of preschool age and for children in the first and second grade of elementary school. The interview is based on a mathematical diagnostic interview developed as part of the Early Numeracy Research Project (ENRP). In 2001 it was published as an "Early Numeracy Interview" by the Department of Education of the Australian state of Victoria. The content area "numbers" and "operations" of the German version is identical to the Australian one and is also coherent with the German educational standards mathematics for primary education. The concept of the EMBI differs significantly from the methods previously used for elementary and primary education. The EMBI is primarily designed for the specific requirements of diagnostics in mathematical classes. For this purpose, with the help of pre-structured protocol and evaluation sheets based on the solution behavior of the children, degrees of expression of

mathematical thinking in various content areas of mathematical competence are identified in a single interview. This is achieved by interviewing every child individually using protocol and evaluation sheets to identify the children's solution behavior in various areas of mathematical competence. [M. Hasselhorn et al., 2013]

In 1999 the "Early Numeracy Research Project" was developed by a joint venture between Australian Catholic University, Monash University, the Victorian Department of Employment, Education and Training, the Catholic Education Office and the Association of Independent Schools Victoria. To test the screening tool 35 trial schools with 354 participating teachers and 35 reference schools took place in a trial for up to three years. The "Early Numeracy Research Project" aimed at assisting schools to implement the key design elements in their mathematical programs, helping teachers to understand how children develop their understanding of mathematics and integrating the knowledge into their teaching programs and evaluating the effect of the key design elements implementation on student numeracy outcomes. [D. Clarke et al., 2002]

Evaluation

Both screenings procedures use an evaluation strategy named "growth points". For the areas "Number" (for example: counting, addition and subtraction strategies), "Measurement" (length, mass and time) and "Space" (shape, visualisation and orientation) growth points were developed. For every mathematical domain there are four to six growth points. Each of them has a brief description in which way the child has to solve the task to achieve the respective growth point. D. Clarke et al. describes an example to illustrate the notion of a growth point like: "consider the child who is asked to find the total of two collections of objects (with nine objects screened from view, and another four objects). Many young children "count all" to find the total ("1, 2, 3, ... , 11, 12, 13"), even once they are aware that there are nine objects in one set and four in the other. Other children realize that by starting at nine and counting on ("10, 11, 12, 13"), they can solve the problem in an easier way. *Counting All* and *Counting On* are therefore two important growth points in children's developing understanding of

1. Count all (two collections)

Counts all to find the total of two collections.

2. Count on

Counts on from one number to find the total of two collections.

3. Count back/count down to/count up from

Given a subtraction situation, chooses appropriately from strategies including count back, count down to and count up from.

4. Basic strategies (doubles, commutativity, adding 10, tens facts, other known facts)

Given an addition or subtraction problem, strategies such as doubles, commutativity, adding 10, tens facts, and other known facts are evident. 5. Derived strategies (near doubles, adding 9, build to next ten, fact families, intuitive strategies)

Given an addition or subtraction problem, strategies such as near doubles, adding 9, build to next ten, fact families and intuitive strategies are evident.

6. Extending and applying addition and subtraction using basic, derived and intuitive strategies

Given a range of tasks (including multi-digit numbers), can solve them mentally, using the appropriate strategies and a clear understanding of key concepts.

Figure 3.7: Growth points for the domain of Addition and Subtraction Strategies (D. Clarke et al., 2002)

addition.". It is important to note, that these growth points are developed especially for lower primary grades and have to be adapted if the screenings is done by upper grades. An example of the ENRP's growth points for the domain of Addition and Subtraction Strategies is given in figure 3.7. [D. Clarke et al., 2002]

Procedure

The materials provided include a standardized interview guide with 20 pages and a partially standardized protocol sheet with four pages. The protocol sheet is used to document the child's answers during the interview. On the basis of the protocol sheet, the assignment is evaluated, and the best fitting growth point is selected. The interview process was especially developed for repeating assessments at regular intervals. This makes it

possible to record and document the status of the children's learning development in a better way. The interview also describes termination criteria that protect children from being overwhelmed and repeating failures. If such an termination criteria is met, the domain's assignment is canceled and it will be switched to the next one. [M. Hasselhorn et al., 2013]

3.4.3 The Number Race

Wilson et al. (Wilson et al., 2006) describes the advantages of using a computer-based educational game as: "Adaptive game software has the potential to maintain the difficulty of an educational task within the 'zone of proximal development', minimizing failure whilst maintaining adequate difficulty, thus providing a presumably ideal level of cognitive stimulation needed for progress.". Wilson et al. also states that the use of a computer based version allows us to capitalize on the children's fascination for computer games, which makes it easier to motivate them and intensify training on exercises which might otherwise become boring for them.

The Number Race was inspired by cognitive neuroscience research and was the first development of an adaptive game to work on dyscalculia, or mathematical learning disabilities. The goal of Wilson et al. was to develop a fully automatized, computerized, adaptive and entertaining game. [Wilson et al., 2006]

The team concentrated itself to integrate four instructional principles. The principles one to three concentrated at constructing the game's assignments in a way to work on basic mathematical development deficits. The fourth important principle describes maintaining the children's motivation while playing the game. Therefore, it was important to provide sufficient positive reinforcement by using an adaptive algorithm, which continuously changed the task difficulty to maintain the performance at 75%. [Wilson et al., 2006]

Game Development and Design

The software of "The Number Race" was programmed by Anna Wilson and is available in German and French. To be able to run the software on

multiple platforms the software engineer decided to write the software in Java. [Wilson et al., 2006]

The game consists of one quantity comparison task and includes only two main screens. On the first screen the children have to choose the larger of two given quantities. Both of these quantities are presented as a number of gold pieces, in symbolic Arabic format, in verbal words or in a combination of these formats. After the child has selected an answer all three formats are presented. The task starts with some trials which also include a timer. If the child does not select one of the given options before the timer ends the computer automatically selects the right answer and highlights it. In higher difficulties, the child may have to calculate some additions or subtractions to make a comparison. As stated above the difficulty may change based on the child's number of right answers. [Wilson et al., 2006]

Game Design Figures 3.8, 3.9 and 3.10 show the main screens of the application. The figure 3.8 shows the quantity comparison screen. Two treasures with gold coins are visible. The number of gold coins next to the treasures is different and varies between one and nine. The children's task is to choose the treasure with more gold coins. By using the named adaptive algorithm, it is possible to manipulate the difficulty of the task to maintain the children's success rate near to 70 percent. If the child does not select one of the treasures in a specified time, the children's competitor character (controlled by the computer) moves to the largest quantity.

The figure 3.9 shows a higher level of the quantity comparison screen. At a more difficult level the child has to perform simple calculations like add or subtract in order to make a comparison. Before the child selects one of the treasures the quantities can be presented as sets of gold coins, as digits or in symbolic verbal format (spoken numbers) or in a combination of these formats. After the child did perform a selection, the quantity is presented by all of these formats at the same time plus a feedback on who has won the task.

After the child made a selection the board screen becomes visible (shown in figure 3.10). At the board screen the child is able to use its gold coins to advance in the race against the competitor character. The children's and
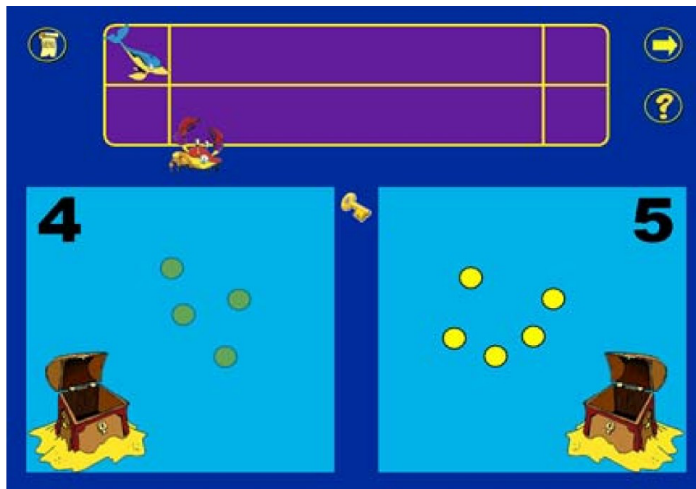
Figure 3.8: Screenshot of the Number Race's quantity comparison screen (Wilson et al., 2006)

competitor's character move the same number of squares as the number of gold coins collected by each character. Therefore, the app counts out loud the number of squares the characters move. The app also plays a sound based on the relative position of the children's character in comparison to the computer's character, like "I'm way behind!" or "Oh no! You've overtaken me!". It is also possible at higher levels that some obstacles are placed randomly on some squares which have to be avoided (like anemones visible in figure 3.10).

When the child reaches the end of the board it wins a reward which unlocks the next character if enough rewards are collected. [Wilson et al., 2006]

3.5 Writing Competences

The development of writing competences overlaps with the development of reading competences. Both have similar meta competences which are important to learn reading and writing. [Irblich and Renner, 2009]

Over the past two decades the developmental psychology research has shown that meta-linguistic skills in particular play an important role in
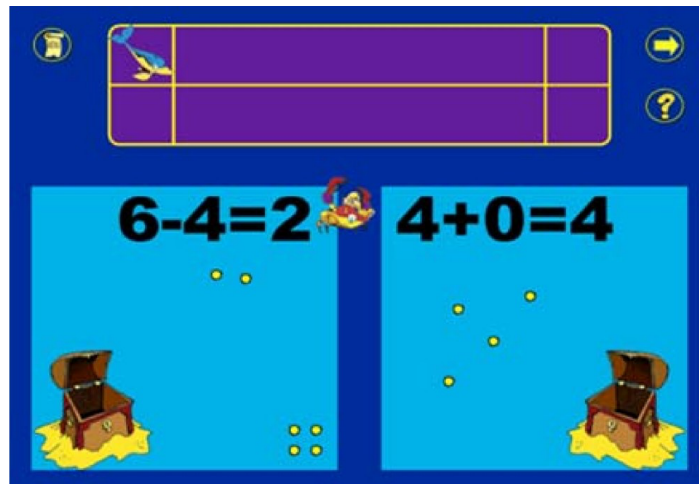
Figure 3.9: Screenshot of a higher level of the Number Race's quantity comparison screen (Wilson et al., 2006)
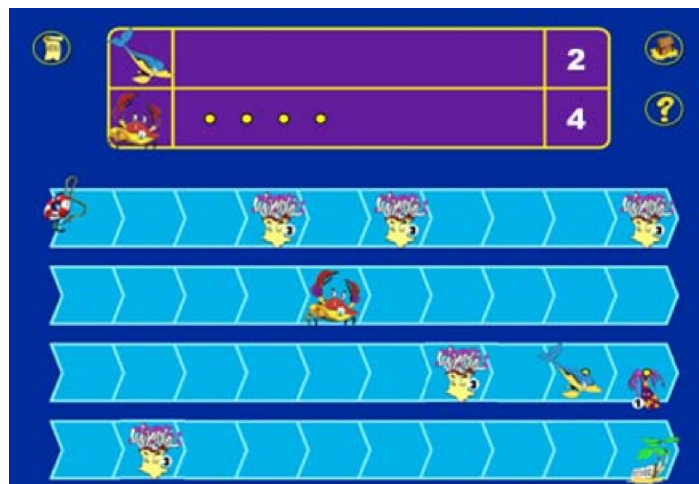
Figure 3.10: Screenshot of the Number Race's board screen (Wilson et al., 2006)

the acquisition of writing competences. Especially features of phonological information processing are relevant for a successful development. The scientists Irblich and Renner (Irblich and Renner, 2009) mentioned three levels of phonological information processing as important:

1. Phonological awareness skills Skowronek and Marx (Skowronek and Marx, 1989) distinguish in German-speaking countries between phonological awareness in the broader sense, which describes the ability to identify rhyming words and to split words into its syllables and in the narrower sense, which includes the ability to analyze words while speaking. To assess the children's phonological awareness in the narrower sense the scientists use assignments for initial and final sound identification, phonemic assignments to analyze words and assignments which concentrate on the word's vocals. According to the researchers, the children's phonological awareness in the narrower sense is more important for the acquisition of writing skills than the ability of phonological awareness in the broader sense.

2. Phonological and semantic memory The phonological and semantic memory describes the speed of linguistic information processing. [Irblich and Renner, 2009]

3. Phonetic recording in working memory The phonetic recording in working memory describes the ability of the children's short-term memory of sounds and sound sequences. [Irblich and Renner, 2009]

3.5.1 Screening Procedures

In the next few paragraphs there is one writing screening procedure described which is used in German speaking countries. One mobile application is also described which focuses on the early training of writing skills and its underlying competences. The mobile app basically concentrates on learning to spell words. Because correct spelling influences the ability of correct writing, the app is also interesting to look at it closer.

3.5.2 DERET 1-3

The in German speaking countries used screening procedures DERET, which stands for "Deutsche Rechtschreibtests", are assessments for the differentiated identification of writing competences of children in primary school age. The main focus of the DERETs is based on writing dictations for children which include only words from a specific list of words used in German primary schools. The evaluation of the children's spelling mistakes enables a reliable and valid classification of the children's tests. In addition, a qualitative evaluation of the spelling performance is possible by integrating of a few blank words which the children have to insert. The DERETs were standardized on over 10,000 children from all German federal states. For the test there are two parallel forms for each class level available. [Schneider, Marx, and Marcus Hasselhorn, 2008]

All of the "Deutsche Rechtschreibtests" are especially developed to concentrate on the basic competences children develop while learning to write. Thus, the texts for the first grade were mainly based on the writing of words in order to understand the children's alphabetical knowledge. In the three higher classes the tests concentrate more on the use of various spelling rules and the correct spelling of words. [Schneider, Marx, and Marcus Hasselhorn, 2008]

Structure

The DERETs are available as individual and as group tests. Both versions are divided into a main part which is a continuous text section and an additional fill-in-the-blank text. For each grade there is also a version A and a version B which take about one hour to finish. [Schneider, Marx, and Marcus Hasselhorn, 2008]

Continuous Text Section   The main part of the DERETs are the continuous texts. Depending on the age group, these texts differ in difficulty and length. In the first and second grade the children have to write a text with at least 52 words, whereas children in the third grade have to write 80 and in the fourth

grade at least 92 words. The text is evaluated by calculating the percentage of the correct written words and in higher classes also the placement of special characters and lower and uppercase letters. [Schneider, Marx, and Marcus Hasselhorn, 2008]

The second part of the test, the fill-in-the-blank text, is used to be able to identify in which areas the child has problems, and which mistakes the child makes more often. [Schneider, Marx, and Marcus Hasselhorn, 2008]

Fill-In-The-Blank Text A fill-in-the-blank assignment is used for additional qualitative error analysis. Especially the need for support because of weak spelling errors can be determined by using the fill-in-the-blank assignment. Children in the first grade have to fill in six, children in upper classes have to fill in between 12 and 15 words, depending on their grade. For the evaluation of the assignment the children's errors are categorized by specific error categories. [Schneider, Marx, and Marcus Hasselhorn, 2008]

3.5.3 Simplex Spelling Phonics 1

Simplex Spelling Phonics 1 is an app developed by PyxWise Software Inc. in the year 2011. It is only available as an iOS app in the iOS App Store and is priced $ 4.99[1]. By combining phonics lessons, spelling and word patterns it teaches children reading the English language and US, UK, and Canadian spelling. [PyxWise Software Inc., 2020]

Only a few days after the app was released it was featured in the section "New & Networthy" in the App Store's educational category. It was also one of the top five ranked educational apps in the US and Canada and was a finalist under the Best App Ever awards' categories "Best Elementary Student App" and "Best Special Needs App" in the 2012. According to the developers the app is used by teachers and educators to successfully enhance their students spelling and reading skills. [PyxWise Software Inc., 2020]

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[1]https://apps.apple.com/us/app/simplex-spelling-phonics-1/id481553580, visited on 2020-11-01

Structure

Simplex Spelling Phonics 1 is a spelling program for the English language. It teaches children spelling and reading skills by using phonics lessons, spelling and word patterns in combination with a unique "reverse phonics" approach and contextually relevant spelling rules. The app has implemented a full year of spelling curriculum and uses over 450 high frequency spelling words to help children to build literacy. In every lesson children have to use skills learned in the previous lesson by piecing the spelling words together through an interactive UI. The previously mentioned "reverse phonics" approach, is a personal spelling coach which helps students to successfully build every spelling word. [PyxWise Software Inc., 2020]

The app uses a hint system which, when used, speaks out the word and lists all the possible ways a word can be spelled phonetically. According to the developers, MRI scans have shown that spelling in the English language comes with a number of difficulties. Many sounds are indistinct and many different letter combinations can make a similar sound. The hint system is built to address these issues. For example, all of the following words are spelled correctly (see - sea, for - fore - four, wait - weight, made - maid, be - bee, to - too - two, rite - write and right). In figure 3.11 a screenshot of the Simplex Spelling Phonics 1's hint system is shown. [PyxWise Software Inc., 2020]

App Design

Because the app was developed in 2011 its design may look a little bit out of date today. The design follows more a realism design approach than the today more present flat design approach. The application's background reminds of a poker table's surface with kind of glossy colored buttons in the foreground as seen in figure 3.12.

The menu of the app includes many texts and selections which makes it a bit hard for children to use. Therefore, the app may has to be operated by adults next to the children.

Figure 3.11: Simplex Spelling Phonics 1 - hint system (PyxWise Software Inc., 2021)

Figure 3.12: Startscreen of Simplex Spelling Phonics 1 (PyxWise Software Inc., 2021)

Figure 3.13: Simplex Spelling Phonics 1 - Spelling "publish" incorrectly with letters in the wrong position (PyxWise Software Inc., 2021)

Figure 3.13 shows the screen of the spelling word "publish" spelled incorrectly by placing a second "b" after "pu". The second "b" gets highlighted in red and the word overlaps with its last letter the brown filled background behind the word. The vowels are highlighted in red and consonants are written in light blue. At the beginning of one assignment, the app shows as many letter input boxes for placing letters as the number of characters of the spelling word (for example seven input boxes for the word "publish"). The app then speaks out loud a word including a letter of the current learning level and a sentence including the word (for example for the word "bag" the app also speaks out loud the sentence "she put her lunch in her bag"). After the audio files are finished, the letters can be placed in one of the available input boxes by drag and drop or by clicking the letter. The assignment's audio files can be repeated by clicking the speaker icon on the right side next to the letters. In the case of the seen screenshot the student selected one letter too much. The app shows which characters are on the right place by changing its background to green, false characters become red and characters after the incorrect used character become blue.

If the students are not able to pass the assignment they can click the hint button seen in figure 3.14 above the letters. The hint system shows beneath

Figure 3.14: Simplex Spelling Phonics 1 - Spelling "publish" incorrectly after using the hint
button (PyxWise Software Inc., 2021)

every given letter input box a blue box with a white star in it. By clicking
one of the blue boxes the hint system shows a hint specific to the spelling
word and the already learned or current questioned phonic skill. This would
be in the given screenshot a hint for "s" and "h" which remembers the child
on the phonic lesson of "sh".

4 School Start Screening Tool

4.1 Motivation and Story

In the year 2018, the Austrian government, with Univ.-Prof. Dr. Heinz Faßmann as its Education Secretary, passed an educational reform. Part of it were five amendments for primary schools, secondary schools, and grammar schools. One goal of the new reforms is to ensure the children's long-term development of competences in school. Another goal is to develop consistent countrywide standards for all schools to make the requirements when switching schools more transparent and understandable. Already at the beginning of 2018, the educational reform was in development and was planned to introduce all changes in all schools till 2024. One of the new reforms was the introduction of multiple countrywide precisely defined school criteria for a successful school start for children. At the time when children move from kindergarten to school, parents didn't have specific approvals if their children were ready for school based on their children's competences. This should be eased out by the introduction of a countrywide school start screening. [Federal Ministry of Education, Science and Research, 2020]

According to Federal Ministry of Education, Science and Research (2020), especially children should benefit from the educational reform. The changes should make the children's switch from kindergarten to school as fair and easy as possible. By using better counseling methods, also parents should benefit from the reform changes. The integration of a countrywide standard for the assessment of children's state of development also supports the work of Austrian teachers. Not only the assessment of the children's state of development is standardized by the new school screening tool, but also the determination of school readiness according to the legal requirements

and the need for remediation teaching in writing, reading, mathematical, and graphomotorical skills and the children's attentiveness and working memory. Teachers also get provided a booklet with evidence-based support measures. This booklet helps teachers support the children's development in their insufficient skills by finding the best possible individual measures for the children.

In the year 2018 the Developmental Psychology Institute of the University of Graz and the University of Vienna have developed a number of assignments which should be implemented in form of a paper-pencil screening and a tablet application. The digital screening method should reduce most of the effort needed to assess children using the paper-pencil screening. The advantages of assessing children with a special developed software over a paper-pencil screening was the foundation of the decision to assign the development of a software for future school start screenings. Austrian schools and teachers were informed about the new screening and could use the screening prototype or the paper-pencil version voluntary in January and September of 2019. By enclosing the screening sheets with a manual, which described how the screening procedure should be handled, teachers were educated about how the children should be assessed. For the paper-pencil screening, the teacher has to be next to the child to speak out loud the screening assignments and has to write down the children's given answers. The teachers also have to send the filled out paper-pencil screening sheets to the developmental psychologists for further calculations and statistics.

Which assignments are part of the screening and how the tablet application was adapted for children at preschool age is described in this chapter.

4.2 Creating a Digital Screening Method for Children

In comparison to the paper-pencil screening, the screening's software solution should reduce the necessary bureaucratic effort and automate some processes. The main concept behind the system was the development of a child-oriented app for tablets which should be able to perform the same

assignments as the paper-pencil screening in a digital way. Therefore, the prototype of the application was planned to be developed for Android tablets, the development of the iOS version was planned after the prototype succeeded. After the application is seen as ready by the developmental psychologists and the Ministry of Education and it is scaled for a countrywide usage, it is planned that the screening is performed before children enter the first class, while visiting the first class and while visiting the second class. This results in a time frame of two years.

4.2.1 Developing an App for Children at Preschool Age

When it comes to the development of an app especially made for children in preschool age without sufficient skills in reading, writing and mathematics there are multiple aspects to keep in mind. Due to the children's incapability to read and understand written texts another solution for presenting the assignments' tasks and answers, as well as a solution to make the children able to input their answers had to be found. It is also important to keep the children motivated so that they do not become bored during the screening process. Due to the fact that some assignments can take up a few minutes of time, the app had to be made funny to play with for the children.

There are already multiple scientific case studies to be found about the usage of tablet computers for the development of game-based apps for children. Yet there is still much more to be understood regarding children multimodal tablet interactions for serious games, according to Ferreira, Gouin-Vallerand, and Hotte (Ferreira, Gouin-Vallerand, and Hotte, 2016). Most researchers show multiple ways to provide instructions for children in preschool age. Most commonly researches do suggest the use of audio and graphics or to choose wordings appropriate to the children's reading level for text instructions (Ferreira, Gouin-Vallerand, and Hotte, 2016). Owing to the fact that a few hundred screenings have to be made by every school, once the app is used in most Austrian schools, it is important to note that there should not be too much time taken to let children read texts slowly by themselves to understand it properly. This resulted in the decision to use mainly audio and image files to communicate instructions by using a visual language. Some assignment's answers also are represented using one

to three characters or digits. How the audio and image files are handled by the app while being completely functional when offline can be read in the implementation chapter, chapter 5.

To animate the children to complete the screening and to keep the children motivated during the screening process, the app should be using many child-friendly illustrations and animations and should wrap the whole screening into a, for the child interesting, frame story. By looking at the most famous apps in the educational sector, it can be recognized that many of them use a character which guides the user through the whole app. DuoLingo[1] for example uses a green bird as well as a treasure to store gained experience points (xp), as shown in figure 4.1, to motivate the users and to give them instructions. For the development of the School Start Screening app a similar character should be introduced which communicates to children through the use of audio files instead of the use of texts in the DuoLingo app. The character chosen is "Poldi", an elf which lives in a magic world. The frame story in which the screening procedure is wrapped is about Poldi finding a map to a secret treasure which the elf wants to find. Poldi is not able to find the treasure by its own and therefore asks the child for help by solving the upcoming assignments. Every done assignment will result in the child gaining a key which is then used to open the treasure found at the end of the screening. If the child is not able to solve an assignment, the elf and the child can get help by using a magic wand by clicking on it in the upper right corner of the screen. Before the first assignment is shown, an intro of the frame story will be presented to the child which also asks the children only to ask for help if they really do not know the answer to the question. It is not necessary to solve the assignments correctly to gain a key, this is important to not demotivate the child. After the last assignment is done, and independent on how often the magic wand was used or how many assignments were answered incorrectly, the treasure will be shown. By clicking on the treasure, the treasure opens, some fireworks will be shown in the background of the screen and the gold coins contained in the treasure will become visible.

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[1] https://en.duolingo.com, visited on 2021-01-14
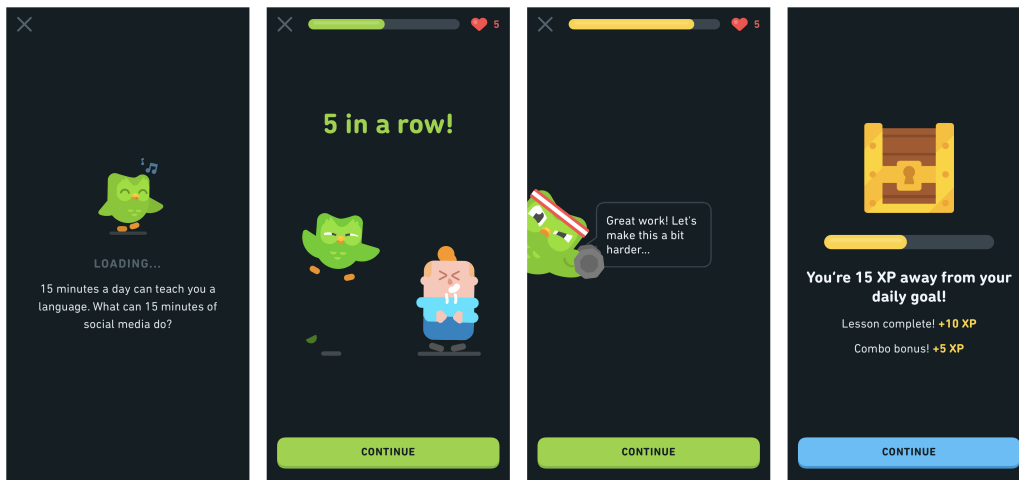
Figure 4.1: DuoLingo uses a bird to guide the users through the app and a treasure to represent their success (screenshots taken from the iOS version of the DuoLingo app, on 2021-01-14)

4.3 Screening Assignments

As described in the first few sections of this thesis, screenings usually concentrate on the assessment of specific skills. These skills mainly are needed to build core competences like reading, writing, mathematics or skills like graphomotorical skills, attentiveness and working memory. The developmental psychologists of the University of Graz and the University of Vienna worked on the development of multiple assignments, especially made for the children's assessment of exactly these competences using a software application in form of a tablet app. The basic underlying concept of each assignment and the data to be stored required for evaluation were given by the psychologists, which resulted in the mockups presented in this chapter.

Some of the developed assignments also include some exercise assignments before the real assignment starts. The goal of these exercise assignments is to make the child familiar with their task. Therefore, no data based on the children's answer needs to be saved for the exercise assignments. How these exercise assignments are handled can very for each assignment.

Most of the screening assignments solely can be done by the child on its own. Some other assignments on the other hand need either the screening supervisor to make some input or even to hold the tablet in their hands without giving the child the opportunity to look at the tablet screen. The screening supervisor is the person in charge of guiding the child through the screening process. These assignments are referred to as "supervisor assisted assignments" in the following chapters.

Some of the first planned assignments were later replaced by another similar assignment or removed from the screening process totally by the development psychologists. These tasks were either replaced because the new structure suited the task better or removed because they did not contribute as much to the child's competences assessment as the other tasks. The assignments which are part of the screening are:

- Phonological awareness
- Knowledge of letters
- Number recognition
- Comparison of numbers
- Repeat numbers (replacement for the number size assignment)
- Quantity comparison
- Quantity knowledge
- Arithmetic problems
- RAN (Rapid Automatized Naming)
- Sorting assignment

The following mockups were especially designed to fit the assignments in the fictional frame story using a colorful landscape as background. The mockups were only the first step towards the real implementation and do only represent the image placements and the basic structure of each assignment. The real implementation of each assignment can be seen in section 5.2.8. The placement of the elf and the way sign, showing the direction to the treasure, are especially chosen to let the child imagine that Poldi has to wander from the left side of the screen to the right side to find the treasure at the end.

4.3.1 Phonological Awareness

The "Phonological Awareness"-assignment is a single choice assignment with three possible answers. Every possible answer only consists of an image of an object. The child's task is to recognize the initial sound of the word spoken and to find the correct answer under the given possible answers. Only one of the possible answers starts with the same letter as the spoken word. The assignment can consist out of multiple phonological awareness assignments shown one after another. When the child selects an answer, they do not get any information if the selected answer was correct. After an answer was selected, the next assignment is shown. After all "Phonological Awareness"-assignments are completed the child has to solve the assignments of the next assignment type.

For every assignment it is required to save specific data based on the given answer of the child. The **data saved** for the "Phonological Awareness"-assignment is:

- which of both choices was selected

Example:

Question asked	"Mouse starts with 'M' which word also starts with 'M'?"
Possible answers	○ Picture of a dog ○ Picture of a human neck ○ Picture of a human mouth

Mockup: The mockup of the "Phonological Awareness"-assignment is shown in figure 4.2.

4.3.2 Knowledge of Letters

The "Knowledge of Letters"-assignment is designed as a single choice assignment with up to six possible answers. Each possible answer contains
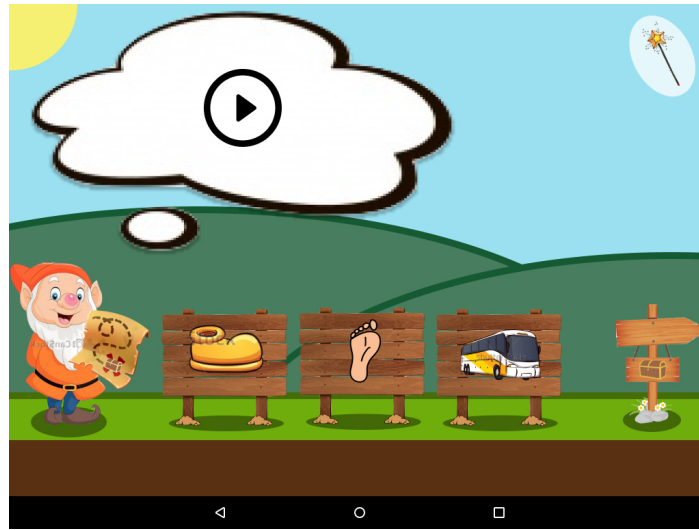
Figure 4.2: "Phonological Awareness"-assignment mockup

one letter or multiple letters as a letter combination which represent a sound, like for example "sch". The child has to identify the answer with the letter searched by Poldi. The elf therefore names the letter or letter combination of the right answer. After the child selected an answer no information about the correctness of the answer is given and the next assignment is shown. The assignment can consist out of several "Knowledge of Letters"-assignments.

Similar to the "Phonological Awareness"-assignment, the **data saved** for the "Knowledge of Letters"-assignment is:

- which of the possible choices was selected

Example:
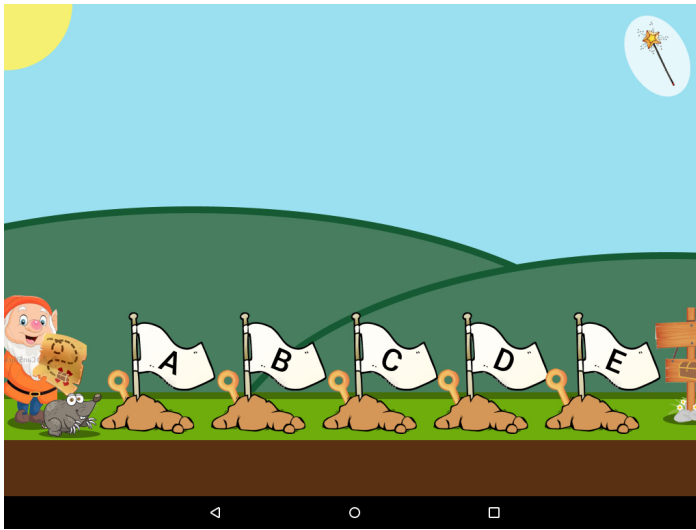
Figure 4.3: "Knowledge of Letters"-assignment mockup

Letter or letter combination asked	"mhm"
Possible answers	○ "m"
	○ "hm"
	○ "n"
	○ "mhm"
	○ "em"
	○ "en"

Mockup: The mockup of the "Knowledge of Letters"-assignment is shown in figure 4.3.

4.3.3 Number Recognition

The "Number Recognition"-assignment is similar in its structure to the "Knowledge of Letters"-assignment. Instead of a letter or combination of letters, Poldi is looking for a number. The searched number can be single or multi-digit. As the same for the "Knowledge of Letters"-assignment, there
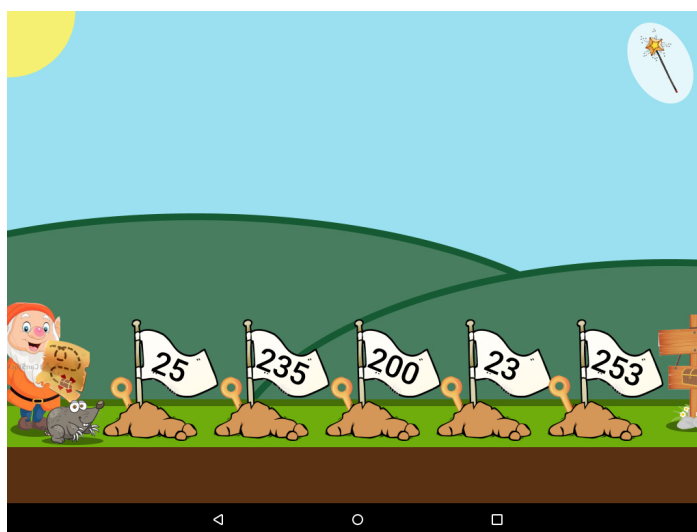
Figure 4.4: "Number Recognition"-assignment mockup

can be up to six possible answers and the assignment can consist out of several "Number Recognition"-assignments.

Since the "Number Recognition"-assignment is similar to the "Knowledge of Letters"-assignment, it requires the same **data to be saved**:

- which of the possible choices was selected

Example:

Digit asked	"10"
Possible answers	○ "1"
	○ "11"
	○ "10"
	○ "100"
	○ "101"

Mockup: The mockup of the "Number Recognition"-assignment is shown in figure 4.4.

4.3.4 Count Till 20

The "Count Till 20"-assignment was planned at first but later removed. It never came to the point of implementation because the developmental psychologists did not require it to be a part of the screening anymore in addition to the already by other assignments collected data. The main task of the planned assignment was to let children count till 20 until a timer runs out or the child has counted to number 20 before the time ended.

4.3.5 Comparison of Numbers

The child's goal for the "Comparison of Numbers"-assignment is to select the larger number out of two shown numbers. This assignment also includes a stopwatch which limits the time the child has to give an answer. If the stopwatch runs out of time, the assignment is saved as failed and the next assignment is shown.

The "Comparison of Numbers"-assignment contains **three exercise assignments** which do not save any data but guarantee that the children understood their task. The exercise assignments are similar to the real assignments but give the children feedback if they selected the correct answer or if they did take too much time. Only if the correct answer was selected, the app moves to the next exercise assignment. If the child clicked on the incorrect answer, the app informs the child to look closer and to try again until the right answer is selected. After all of the three exercise assignments are completed successfully, the child can answer the real "Comparison of Numbers"-assignments.

In addition to the stopwatch, the "Comparison of Numbers"-assignment requires not only to save if the correct answer was selected but also the time the child took to give an answer. **Data saved** for every assignment:

- which of the two choices was selected
- time till an answer was given
- if time did run out

Figure 4.5: "Comparison of Numbers"-assignment mockup

Example:

Task	"Please help Poldi to pick the larger of the two numbers."
Possible answers	○ "6" ○ "7"

Mockup: The mockup of the "Comparison of Numbers"-assignment is shown in figure 4.5.

4.3.6 Repeat Numbers

The "Repeat Numbers"-assignment is one of the **supervisor assisted assignments** and is mainly done by the supervisors holding the tablet in their hands. While the start of the assignment the child and the supervisor are informed that the supervisor needs to place the tablet in front of him without making it possible for the child to look at the tablet's screen. The

task of the "Repeat Numbers"-assignment is to let the child repeat a se-
quence of numbers correctly in the right order. However, the structure of the
assignment is a bit more complicated. Each "Repeat Numbers"-assignment
has a sequence of numbers consisting out of two to five numbers. Starting
with two numbers, every time an assignment is completed successfully
the next, more difficult, assignment, consisting out of one more number,
starts. If the child is not able to correctly repeat the numbers, the child gets
another chance using another sequence of numbers consisting out of the
same number of digits. If the child fails to repeat both sequences of numbers
correctly, the assignment ends (for an example see the example bellow). The
task of the supervisor is to click the specific buttons on the tablet's user
interface according to the correctness of the children's answer. If the answer
was incorrect, the tablet automatically goes to the second chance or in case
of a correct answer to the next assignment. In case the second chance is also
answered incorrectly or one of the very last number sequences is answered
correctly the assignment ends automatically.

The **data** which is **saved** for the evaluation of the "Repeat Numbers"-
assignment consists out of:

- correct, incorrect or no answer given
- based on the data structure it is also possible to relate:

  - which number sequences were processed
  - which number sequence did end the assignment
  - how many second chance sequences needed to be answered

Example:

Task	"Please repeat the following numbers."
2 numbers Child's answers	"6", "9" "6", "9"
3 numbers Child's answers **3 numbers - second chance** Child's answers	"5", "3", "18" "5", "3", "8" → incorrect "7", "2", "11" "7", "2", "11"
4 numbers Child's answers **4 numbers - second chance** Child's answers	"12", "10", "3" "12", "9", "3" → incorrect "14", "1", "21" "14", "1", "11" → incorrect
assignment ends	sequence including five numbers is not shown because both, the first and second chance of the sequence with four numbers was answered incorrectly

Mockup: The mockup of the "Repeat Numbers"-assignment is shown in figure 4.6.

4.3.7 Quantity Comparison

The "Quantity Comparison"-assignment is similar to the "Comparison of Numbers"-assignment. However, instead of looking for the larger of two given numbers, Poldi needs to find the large of two shown quantities. The quantities are illustrated by gold coins. The assignment can contain answers with an obvious right answer (using small quantities) and answers with a less obvious right answer (using bigger quantities with small differences). Similar to the "Comparison of Numbers"-assignment, a stopwatch is implemented to limit the time the children have to select an answer. Especially for the "Quantity Comparison"-assignment the stopwatch is important to prevent the children from counting the gold coins. The children's task is to try to select the bigger of the shown quantities without counting the gold coins.

Figure 4.6: "Repeat Numbers"-assignment mockup

Like the "Comparison of Numbers"-assignment, the "Quantity Comparison"-assignment also contains **three exercise assignments** which guarantee that the children understood their task without saving any data. The exercise assignments also are similar in its structure to the real assignments but give the child feedback about the correctness of their answer. In comparison to the "Comparison of Numbers"-assignment's exercise assignments, the "Quantity Comparison"-assignment's exercise assignments also make use of a stopwatch to prevent the child from counting the shown gold coins. In case the available time runs out, the next exercise assignment is shown. On the other hand, if the child selects the incorrect answer the child is informed to look more carefully and has another chance to find the correct answer until the exercise assignment is completed successfully. Only after all three exercise assignments are answered correctly, the app moves to the real "Quantity Comparison"-assignments.

The **data saved** for the "Quantity Comparison"-assignment is:

- which of the two choices was selected
- time till an answer was given
- if time has run out

Example:

Task	"Please help Poldi to find the suitcase with the most gold coins in it."
Possible answers	○ a suitcase with 7 gold coins ○ a suitcase with 9 gold coins

Mockup: The mockup of the "Quantity Comparison"-assignment is shown in figure 4.7.

4.3.8 Quantity Knowledge

The "Quantity Knowledge"-assignment is one of the **supervisor assisted assignments** which needs the help of the screening supervisor to perform
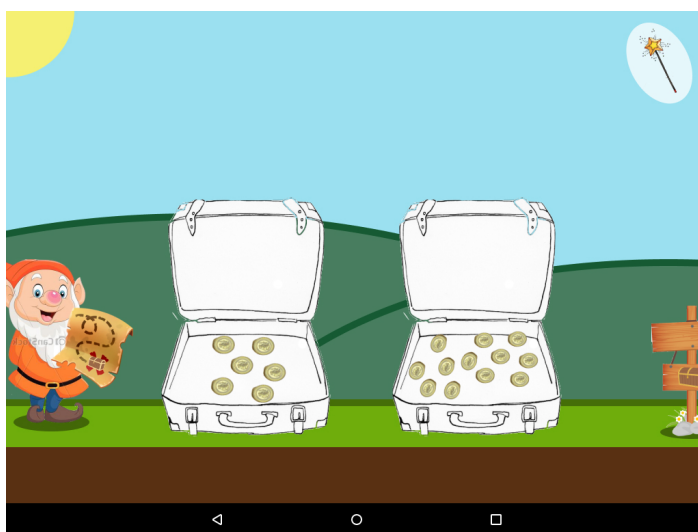
Figure 4.7: "Quantity Comparison"-assignment mockup

some input. At the moment the "Quantity Knowledge"-assignment starts, the app informs the children to count all visible keys and to tell their answer the screening supervisor. The screening supervisor then needs to take the tablet and either has to click the "correct" or the "incorrect" button to indicate the correctness of the children's answer.

The only **data saved** for every of the "Quantity Knowledge"-assignments is:

- correct or incorrect answer given

Example:

Task	"How many coins do you see? Tell it to the adult."
Answer	Based on the children's answer, the screening supervisor clicks the "correct" or "incorrect" button

Mockup: The mockup of the "Quantity Knowledge"-assignment is shown in figure 4.8.
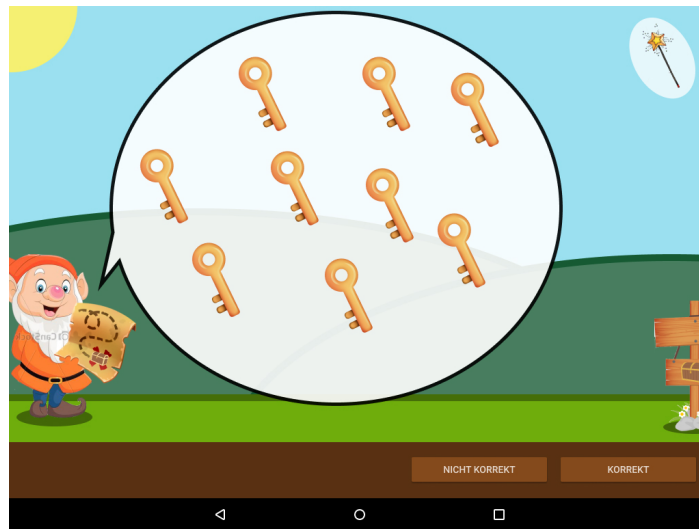
Figure 4.8: "Quantity Knowledge"-assignment mockup

4.3.9 Arithmetic Problems

The screening's "Arithmetic Problems"-assignment is the combination of multiple mathematical assignments. Similar to the "Quantity Knowledge"-assignment it is one of the **supervisor assisted assignments** which needs the screening supervisor to perform some inputs. Before the assignment starts, the app informs the supervisor and the child that the next assignment is developed to be handled by the supervisor without the child seeing the assignments. The supervisor has to read out loud the mathematical questions to the child. After the child speaks out loud its answer, the supervisor enters the child's answer into the app's specific input field. In case the child does not have any answer to the question, the supervisor has to select the "no answer given"-checkbox.

For every "Arithmetic Problems"-assignment the app saves the answer entered by the screenings supervisor. The **data saved** for the assignment:

- answer given by the child
- if the "no answer given"-box is selected

Figure 4.9: "Arithmetic Problems"-assignment mockup

Example:

Task	"How many gold coins does someone have if they win three and already had two before?"
Answer	The child's answer is entered in the assignment's input field by the screening supervisor.

Mockup: The mockup of the "Arithmetic Problems"-assignment is shown in figure 4.9.

4.3.10 RAN (Rapid Automatized Naming)

"RAN" stands for "Rapid Automatized Naming" which refers to the ability to name items like pictures, numbers, colors, letters or objects as quickly as possible (Understood, 2020). The "RAN"-assignment developed for the screening belongs to one of the **supervisor assisted assignments**. At the moment the "RAN"-assignment starts, the app prompts a message to inform the supervisor to place the tablet in a way the child cannot see the tablet's

screen. Furthermore, the screening comes with a sheet which includes a few items the child has to name, to make the child familiar with the assignment. This training items do not require any interaction with the app. After the items are done, the supervisor starts the real assignment. The "RAN"-assignment consists out of one assignment in which the child has to name objects and another one in which the child has to name numbers. The objects or numbers the child has to name are printed on another sheet of paper in exactly the same order as seen on the tablet's screen, except showing an image of the objects the child has to name instead of the object's name. The mockup of the "RAN"-assignment shows 35 items, displayed in five columns and seven rows, which show either the name of the objects or the numbers printed on the assignment sheet in front of the child. By clicking on the start button, the app informs the child to start naming the objects and the timer of the assignments starts to count down. For every misnamed object or number, the supervisor selects the wrongly named item on the tablet's screen to capture the child's mistakes. At the moment the timer runs out, the app informs the supervisor and the child to stop the current assignment and the supervisor has to select the last-named item, if the child did not name all objects or digits in time. After the supervisor clicks the go-ahead button, the app opens a modal view containing a plus and a minus button with the option to increase or decrease the number of mistakes the child made. If the supervisor confirms the entered number, the app moves to the number-"RAN"-assignment. Similar to the object-"RAN"-assignment the supervisor first asks the child to name numbers shown on the paper sheet which comes with the screening. In case the child cannot name all numbers correctly which are also used in the number-"RAN"-assignment, the assignment is skipped. Otherwise, the number-"RAN"-assignment processes in the same way as the object-"RAN"-assignment.

The be able to evaluate the "RAN"-assignment the following **data** needs to be **saved**:

- number of wrongly named objects or numbers
- last named item, if time did run out before all items were named
- remaining time if all items were named before time did run out
- only for the number-"RAN"-assignment:
    - if assignment was not performed
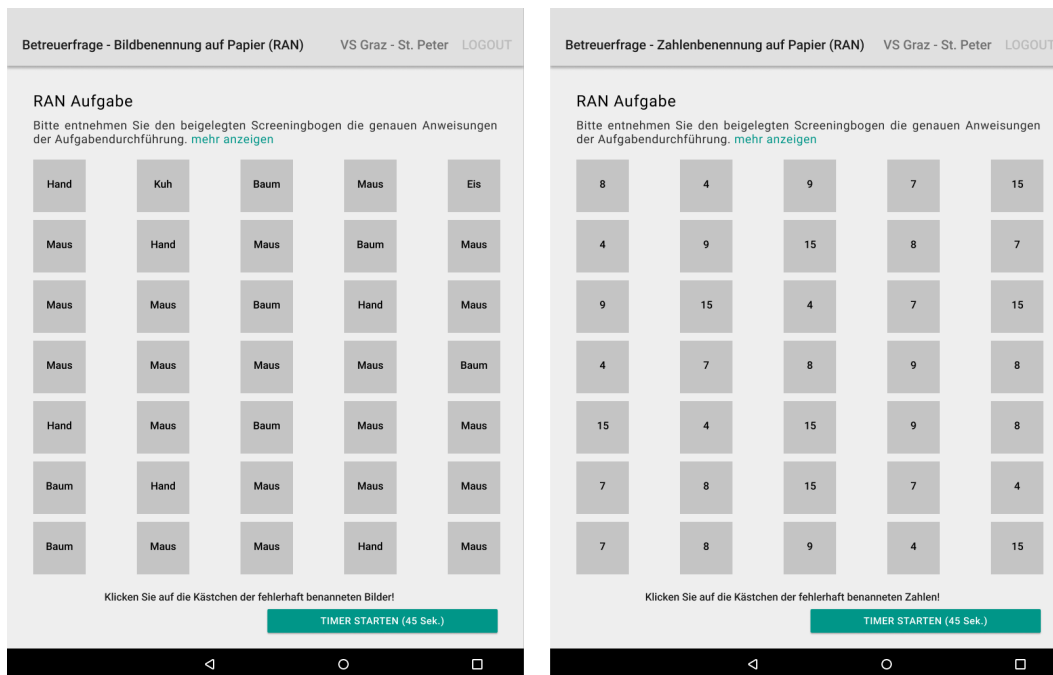
Figure 4.10: Object and number-"RAN"-assignment mockup

Example and Mockup: An example of the object and number-"RAN"-assignment is shown in the assignment's mockups in figure 4.10.

4.3.11 Sorting Assignment

The "Sorting Assignment" is one of the biggest assignments implemented and only one "Sorting Assignment" can be part of a screening. It is also one of the **supervisor assisted assignments** which needs the tablet to be held by the supervisor. When the assignment starts the supervisor places the cards belonging to the assignment in front of the child. The first few cards are used to show the children how the assignment works and what the children have to do, which is to assign each card to one of three options based on the 12 items printed on the card. An example card can be seen in figure 4.11. The first two possible options to select contain one single item, and the third option contains both items of the first two options. After the

training cards are done, the assignment can be started by the supervisor by clicking on the "start"-button, presented on the tablet's screen. When clicking the "start"-button the supervisor informs the child to start assigning one card after another to one of the three possible choices. Every time a card is assigned by the child, the supervisor clicks the specific box visible on the tablet's screen. Above these boxes the current card, the child is working on, is shown, this is possible because the cards are numbered and should be performed in the same order for every screening. If the child should change the assignment of a previous card, the supervisor is able to go back and change the selection by clicking the back-button and selecting another box.

A click on the "start"-button also activates an implemented timer to count down. If the timer runs out of time before the child is done assigning all cards, the assignment ends automatically by prompting a modal view alerting the supervisor. After the last card is done, the assignment's timer stops automatically but the supervisor is able to change the selection of the last cards until clicking on the "go-ahead"-button. Because it is also important for the evaluation of the assignment to know how often the supervisor had to motivate the child to try to assign every card as fast as possible, another button to increase the number of spoken motivations can be found in the bottom left corner.

Because of the complexity of the assignment, the following **data** is **saved** based on two levels:

- the assignment's base data:

    - number of motivations needed
    - if time did run out or how much time was left
    - last assigned card number if time did run out
    - if the assignment was aborted
    - last card if assignment was aborted

- for every card:

    - if the card was assigned correctly

Figure 4.11: ″Sorting Assignment″ mockup

Example and Mockup: An example of the ″Sorting Assignment″ is shown in figure 4.11.

5 Implementation

The following chapters describe the implementation and development of the School Start Screening App's prototype.

While the process of planning there were already some technical difficulties faced. One was the need to make the app work without internet connection, which means it should be able to perform and save screenings while being offline. Another one was that different schools should be able to perform different screenings. The memory intense automatic creation of a downloadable file, containing all already uploaded screening results, also was difficult to solve first. The solution to these problems and which technologies were used, is described in the following chapters.

The major aspect of the implementation was to make the main part of the application understandable and usable for children without sufficient skills in reading, writing, and mathematics. This was achieved by wrapping the whole screening into a fictional frame story based on Poldi the elf and by using audio files, as described in section 4.2.1. The audio files were recorded in German by an employee of the University of Graz's Institute of Psychology, Developmental Psychology. The recording took place in a sound studio of the Graz University of Technology's Educational Technology Unit. How the app's layout and design, including all implemented user interfaces and the implementation of the previous described screening assignments, was implemented, is described more detailed in chapter 5.2.

5.1 Problems Faced

At first the application was specified to be implemented natively, which means with the use of Kotlin or Java and to have one central web application

with access only available to the developmental psychology teams of the University of Graz and of the University of Vienna. By using the web application, the users should have the possibility to view and download all already collected screening results. After the first meetings with the developmental psychology institute, it became clear, that the specifications would become more complex than first thought.

While the planning process, the developmental psychologists decided to be able to create different sets of screening assignments for different schools. Since it was important for the developmental psychologists to get the most information about the effectiveness of each screening assignment possible, more than one set of assignments needed to be tested. These test screenings were later known as screening A and screening B. For the prototype of the application several schools volunteered to be part of the new screening method. Which schools were part of which test screening was decided by the developmental psychologists. While the planning process, it was not clear how many different screenings would be created. So, it was not possible to think about implementing two different versions of the app with screening data of screening A or screening B. Due to the need to create different screenings for different schools, it became clear that schools needed to have a specific identifier to be able to relate which school was using the application. It was therefore necessary to expand the functionality of the server and the web application, in order to be able to manage screenings and the school's user profiles. The new planned functionality of the server and the web application now included a user interface to add school profiles with the ability to edit it later, a user interface (UI) to create multiple screenings and to assign each screening to multiple schools. Since the number of schools taking part in the prototype screenings was limited, schools were manually created by the psychologists. To add a school profile to the database only a name and a password are needed to be filled in. The login credentials were then sent manually to the schools by the psychologists via a second channel. The web application is described more detailed in section 5.2.1.

Of course, it was also necessary to give the developmental psychologists a way to access the collected screening data. Since the developmental psychologists usually used Excel for different scientific calculations of screening data, it was decided to structure the saved screening result data in an Excel file which can be downloaded only by the psychologist teams through the

web application. The Excel file had a specific given structure containing different Excel sheets for different assignment types, cells with sum functions, easy and more complex if-functions, percent calculations and different text and color styles. The screening result download is described more detailed in 5.2.12, as well as an example structure of the Excel file can be found in section 5.2.12.

According to the psychologists, some schools in Austria do not have a reliable or fast internet connection yet. Supposedly there are also some schools without an internet connection at all. New schools built in Austria already have a WLAN connection. In 2019 the Austrian government planned to upgrade every remaining school with a WLAN connection till 2022. Therefore, a budget of 40 million Euro should be used (der STANDARD, 2020). That meant it was not possible for some schools to upload the collected screening data directly to the server, after the screening was finished. Not only the data upload is affected by a not sufficient internet connection but also the app's login process and the download of the assigned screening assignments. As already mentioned the schools receive their assigned login credentials via a second channel. This login credentials are used on the first visible screen of the tablet application, the login view. The login credentials get authenticated using the server's API and the school data including school name, assigned screening identifier, et cetera is fetched. Also the, via the web application created, screening assignments need to be downloaded on the tablet before screenings can be carried out. It was therefore necessary to implement the app with an offline functionality. This means that the screening assignments and the screening results have to be saved locally on the app. Once the app has a stable internet connection, the schools can login to the app, download the screening assignments and upload the screening results to the server. The mobile application is described more detailed in section 5.2.4. How the app was developed to support offline functionality can be read in section 5.4.

5.2 Layout and Design

As already described in the previous section, the structure of the application needed a central web server for the management of schools by the admins of the University of Graz and the University of Vienna and to communicate with the mobile apps using an Application Programming Interface (API).

5.2.1 The Web Application

At first it was planned to use the central user manager of the Educational Technology Institute of the Graz University of Technology. Due to the changes on the specifications the user manager did not really fit the demands of the developmental psychologists. Therefore, it was necessary to develop an independent web server which is responsible for the user management. The web server consisted out of a central web application and an Application Programming Interface (API). The API was necessary to communicate with the tablet apps for fetching data including login processes, sending audio and images files, sending screening data and screening results. The role of the web application was to have a central interface to manage schools and screenings as well as to download the screening results. All functionalities of the web application are:

- registration of schools
- creating new screenings
- creating new assignments for a screening
- editing and deleting assignments of a screening which is not used by a school yet
- assigning screenings to schools
- downloading saved screening results

English was the web application's language of choice because of the possibility of foreign employees working for the development psychology institutes. By using a standard Bootstrap[1] design, the design effort could be kept low while the user interface could also be made very clean. The first screen after opening the web application's URL only consists out of a login mask,

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[1] https://getbootstrap.com, visited on 2021-01-21

Diagnostic School Screening Tool v1.5.0   logged in as admin_kfu   Logout

Main Menu

Edit Schools   Edit Screenings   Download Results
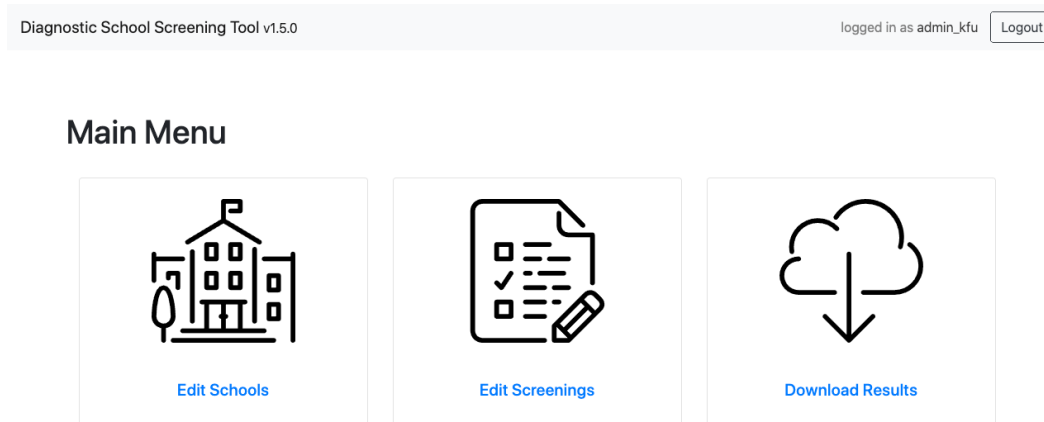
Figure 5.1: Screenshot of the School Start Screening's web application menu

including a username and password input field. After a successful login the menu of the web application is shown. In figure 5.1 a screenshot of the web application's menu can be seen. Once the School Start Screening's web application was online, only developmental psychologists of the University of Graz and the University of Vienna had valid login credentials to gain access to it. These login credentials were created when the server's database was setup and the passwords were chosen randomly with at least eight characters of size. A person with access to the web application is named "admin" in the following UML Sequence Diagrams.

5.2.2 Registration of a School

Figure 5.4 shows a UML Sequence Diagram describing the process of registering a school. For the prototype of the School Start Screening application multiple schools volunteered to be part of it. It is planned by the Austrian Government to use the digital screening in all Austrian schools in the future. However, how this will be handled is not part of this thesis.

For a school to be able to login to the mobile app, first its login credentials have to be created. This only can be done by people with access to the

Figure 5.2: Screenshot of the web application's "Add Schools"-screen

web application, the admins. To do so, it is necessary to login to the web application and to select the first menu item "Edit Schools". The "Edit Schools"-screen (shown in figure 5.3) includes a table with all already registered schools, showing the school's ID, the school's name, the assigned screening and the screening's date of creation in every row. After clicking on "Add School" in the right corner of the screen, a form including an input field for the school name, username, password as well as an input field to repeat the password is shown (see figure 5.2). By filling out and submitting the form, the web application sends a POST request containing the form data. The web application then validates the sent data and either saves it to the server's SQL database or sends a response containing a meaningful error message.

The entered school name is later visible for the school when logged in to the mobile app. The username and the password are sent to the school via a second channel by the developmental psychologists and have to be filled in the mobile app's login form.

For every registered school the web server saves:

- an auto incremented unique ID
- the school's name

Figure 5.3: Screenshot of the web application's "Edit Schools"-screen

- the school's username to login to the app
- the hashed school's password (using PHP's `password_hash`[2] function, configured to use the "bcrypt"-Algorithm[3] and a cost value of 11)
- the date of registration
- the assigned screenings

5.2.3 Creation of Screenings and Assignments

To be able to assign screenings to a school, it is necessary to create the screening with its assignments first. This can be done by clicking on the second menu item "Edit Screenings", when logged in to the web application. The next screen, the "Edit Screenings"-screen (see figure 5.5), shows a table with the same number of rows as the number of saved screenings for each screening type. Every row represents a screening and shows the screening's ID, date of creation, type, the number of saved assignments and if a screening is editable. For every row there is also a button in the

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[2]https://www.php.net/manual/en/function.password-hash.php, visited on 2021-01-05

[3]https://www.usenix.org/legacy/publications/library/proceedings/usenix99/full_papers/provos/provos_html/node5.html, visited on 2021-01-05
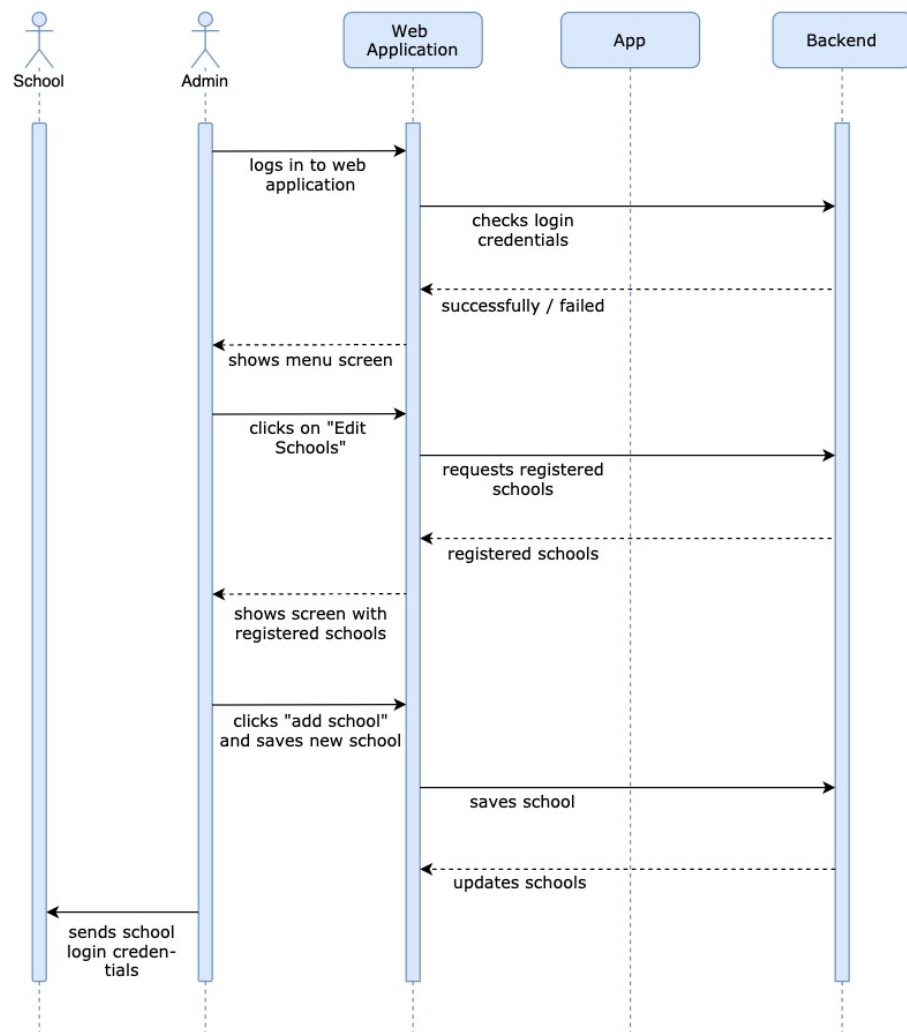
Figure 5.4: Sequence Diagram of the school registration process

last column to open a more detailed view of the screening or to open the screening-edit-view if it is still editable. The screening-edit-view of the screening with ID 3 can be seen in figure 5.6. The content of the screening-edit-view shows the main information of the selected screening including its ID, screening type and the schools the screening is assigned to, as well as information about the screening's assignments, visible in the table under "Screening assignments". Every assignment of the screening is listed in the "Screening assignments"-table and shows some information about the assignment itself, like for example the entry of the phonological awareness assignment shows the name of the assignment's audio file and the names of the image files used for the assignment's answers.

The type of the screening represents the time the screening is done. This can either be before the first class, in the first class or in the second class. To make it easier for the screening supervisor to select the right screening for the assessment, the screening type is used in the app's screening selection screen to show the assigned screening for every type.

A screening is editable as long it was not assigned to a school. At the moment a screening gets assigned to a school, it would be possible that at least one mobile app already downloaded the screening data. If so, there would be no way, using the current data structure, to let the school know about changes made to the assigned screening because of the offline working app requirement. As long as a screening was not assigned to a school, it is possible to edit it, edit its screening assignments or to create new assignments. Not editable screenings can only be copied and saved under a new ID by clicking the "Copy Screening"-button in the screening's detail view's top right corner. This function duplicates the screening itself and all assignments which are part of the copied screening. This was a requirement set by the developmental psychologists because the time to create a screening with all its assignments can take up some time and can be done much faster by copying an already created screening and changing some of its assignments.

For every created screening the web server saves:

- an auto incremented unique ID
- the screening's date of creation
- the screening's type

Diagnostic School Screening Tool v1.5.0   logged in as admin_kfu   Logout

Main Menu / Edit Screenings

Edit Screenings

Add Screening

Screenings can be edited until they get assigned to a school.

Screenings before 1st class

ID	Created	Type	Saved Assignments	
2	13.02.2020	Screening before 1st class	9/9	SHOW DETAILS
3	13.03.2020	Screening before 1st class	9/9	SHOW DETAILS
4	23.03.2020	Screening before 1st class	9/9	EDIT SCREENING
6	23.03.2020	Screening before 1st class	1/9	EDIT SCREENING
7	23.03.2020	Screening before 1st class	1/9	EDIT SCREENING
8	17.12.2020	Screening before 1st class	1/9	SHOW DETAILS
9	17.12.2020	Screening before 1st class	1/9	SHOW DETAILS
10	18.12.2020	Screening before 1st class	1/9	SHOW DETAILS
11	21.12.2020	Screening before 1st class	1/9	SHOW DETAILS
12	21.12.2020	Screening before 1st class	1/9	SHOW DETAILS
13	06.01.2021	Screening before 1st class	1/9	EDIT SCREENING

Screenings in 1st class

ID	Created	Type	Saved Assignments
		no screenings exist	

Screenings in 2nd class

ID	Created	Type	Saved Assignments
		no screenings exist	

Figure 5.5: Screenshot of the web application's "Edit Screenings"-screen

Figure 5.6: Screenshot of the web application's "Edit Screening"-screen for the screening with ID 3

      1. before first class
      2. in first class
      3. in second class

- if the screening is editable
- all correspondent assignments

Creating Assignments

Every screening can consist out of multiple assignments. The assignment types were already described in section 4.3. By clicking the "Add More"-button next to the assignment type in the screening detail view, the browser opens the assignment-creation-screen of the selected type. The assignment-creation-screens include a form with all required input fields for creating a new assignment. The required input fields are different for every assignment and primarily include file upload input fields, to upload audio or images files, or normal text input fields for the assignment question and its answers the child can select from. By filling in all the necessary input values and clicking the save button, the server creates a new assignment for the currently selected screening. A screening can have multiple assignments of one assignment type, except the sorting assignment. In case any input value is invalid, the web application shows the user a specific error feedback.

Assigning Screenings to Schools

After the user has created the screening assignments, the next step would be to assign the screening to one or multiple schools. As already mentioned, there are three screening types. Every school can have one screening of each screening type assigned which results in three possible assigned screenings per school. To assign a screening to a school, it is necessary to open the school-detail-view of the school a screening should be assigned to and to click the "Add More"-button next to the screening type of which a screening was created. The next screen shows a table including all existing screenings of the selected screening type. The user then can select the desired screening by clicking on the screening's "Select"-button displayed at the end of every row. This causes the server to make the screening not editable anymore

to prevent a user from making changes to the screening and to make it downloadable for the apps.

Because of the UML Sequence Diagram's size displaying the process of creating a screening, adding assignments to it and assigning it to a school the diagram is split in two images visible in figures 5.7 and 5.8. The loop shown in figure 5.8 represents the process of creating one or more assignments.

5.2.4 The Mobile App

As described in section 4.2.1, the main and most important part of the whole thesis was the creation of a child-friendly app which can collect screening data using the given assignments while also entertaining children and enrich their first impression of school by transforming the screening process into a playful adventure for them. Based on the application's requirements, the app had the following tasks of which the main part of the app had to function also while being offline properly:

- only can be used after being logged in using valid login credentials
- download the assigned screening including all audio and images files used for its assignments and their possible answers
- performing screening runs with children and save the data locally
- uploading locally saved data of all performed screenings

The whole process of all actions that a school carries out with the app are visible in the UML Sequence Diagram in figure 5.10.

When starting the app, it first checks for a saved JSON Web Token (JWT)[4] created by the server and sent to the app within a successful login API response. If the token is still valid, the app automatically shows the menu screen. In case the token already expired, or no token can be found, the app shows the login screen, containing only a login mask and a label showing the app's current version. After valid login credentials, given to the school by the developmental psychologists, are entered into the login form, the app sends a POST request to the server which then checks the database for the sent username and compares the hashed password against the hashed

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[4]https://jwt.io, visited on 2021-01-13
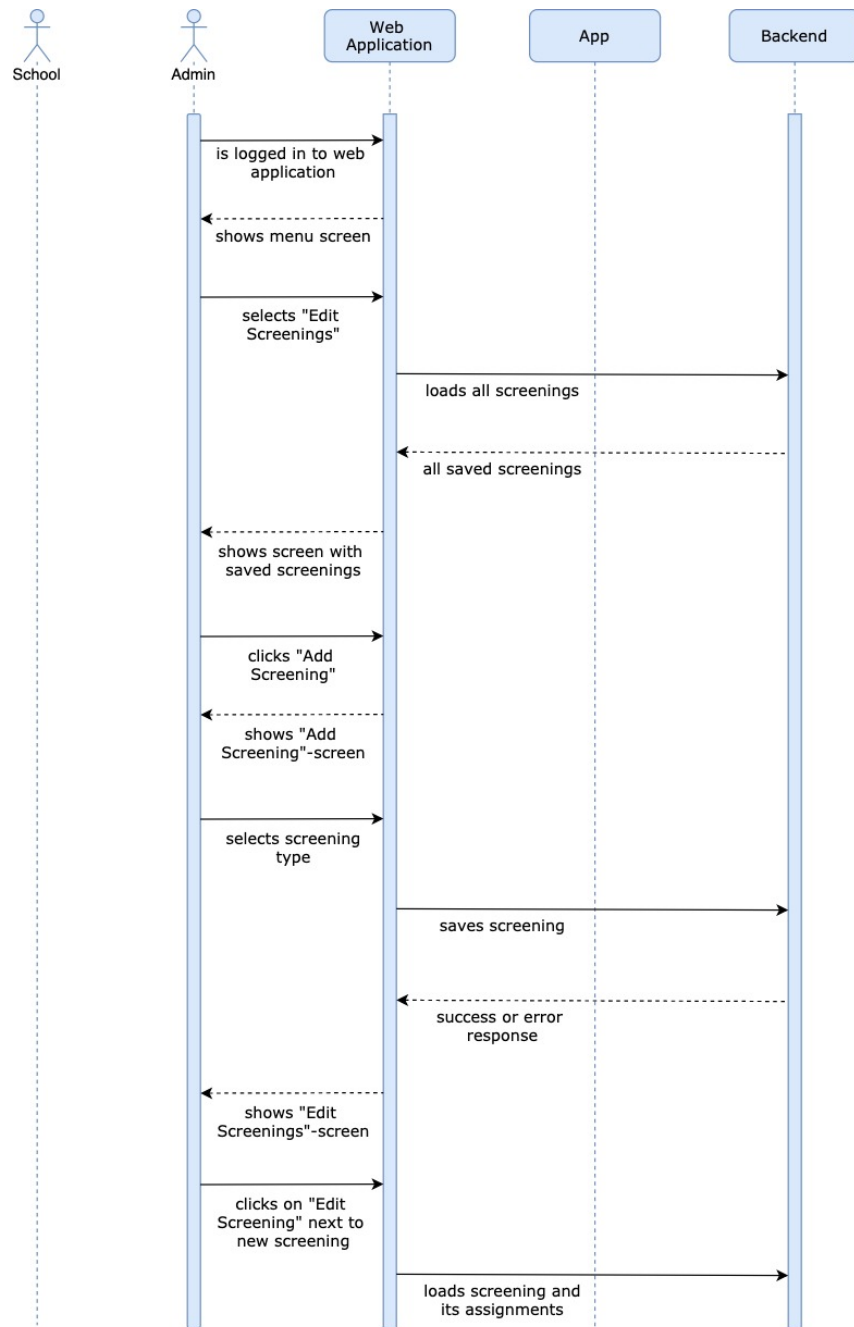
Figure 5.7: Sequence Diagram of a screening creation and assignment to a school - Part 1
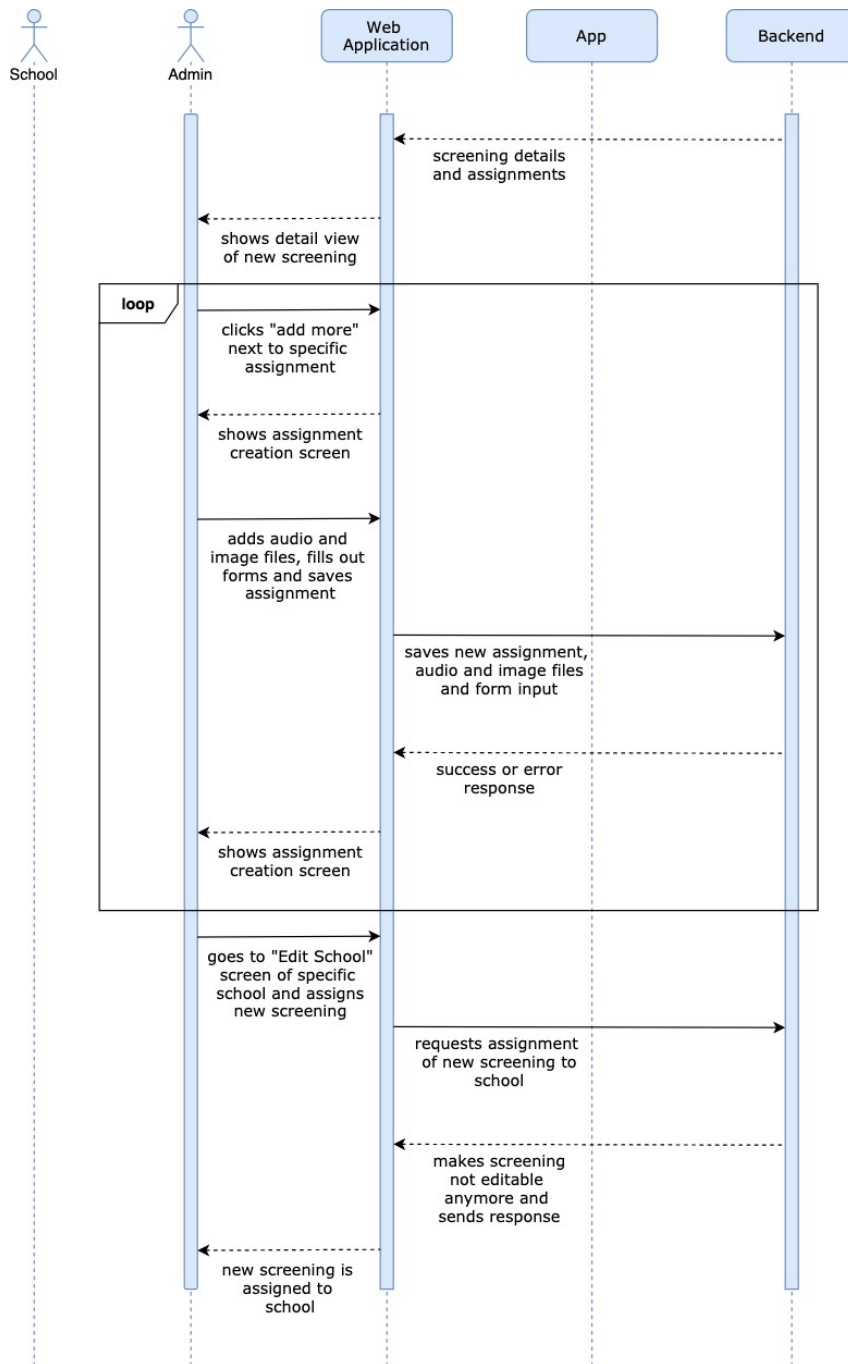
Figure 5.8: Sequence Diagram of a screening creation and assignment to a school - Part 2
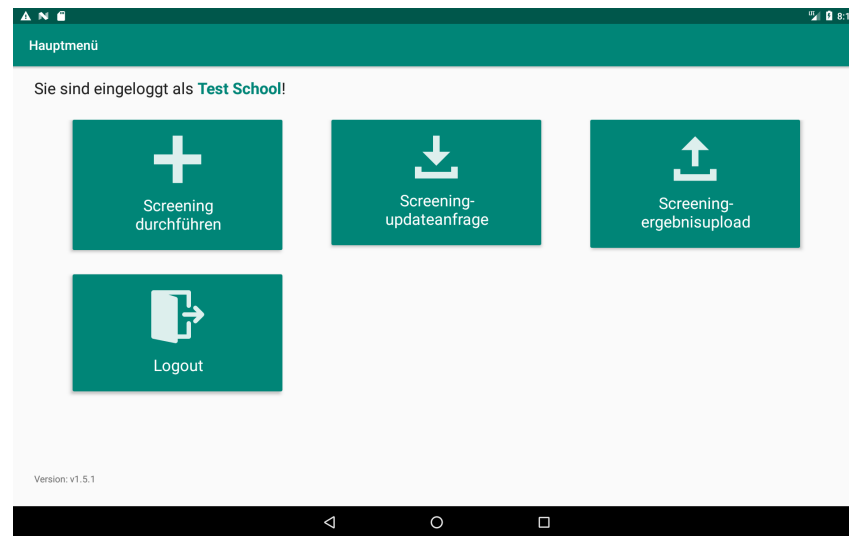
Figure 5.9: A screenshot of the School Start Screening app menu

password linked to the school's account. Due to the communication with the server, the app needs to have a stable internet connection at the moment the user clicks on the login button. If the server returns a successful response, the app opens the menu screen of which a screenshot is visible in figure 5.9.

5.2.5 Download Screening Data to App

After being logged in, the next step for the school would be to update the assigned screenings by clicking on "Screeningupdateanfrage" (German for "screening update request") in the app's menu. This would bring the user to the screening-update-screen containing only information if a screening is currently saved by showing the date of the last update beneath the update button. In case no screening is saved at the moment, the same label would contain no data about the last update. In case a school selects "Screening durchführen" (German for "perform a screening") while no screening is currently available locally, the app would show no available screening in the screening-selection-screen, which is described in the following section.
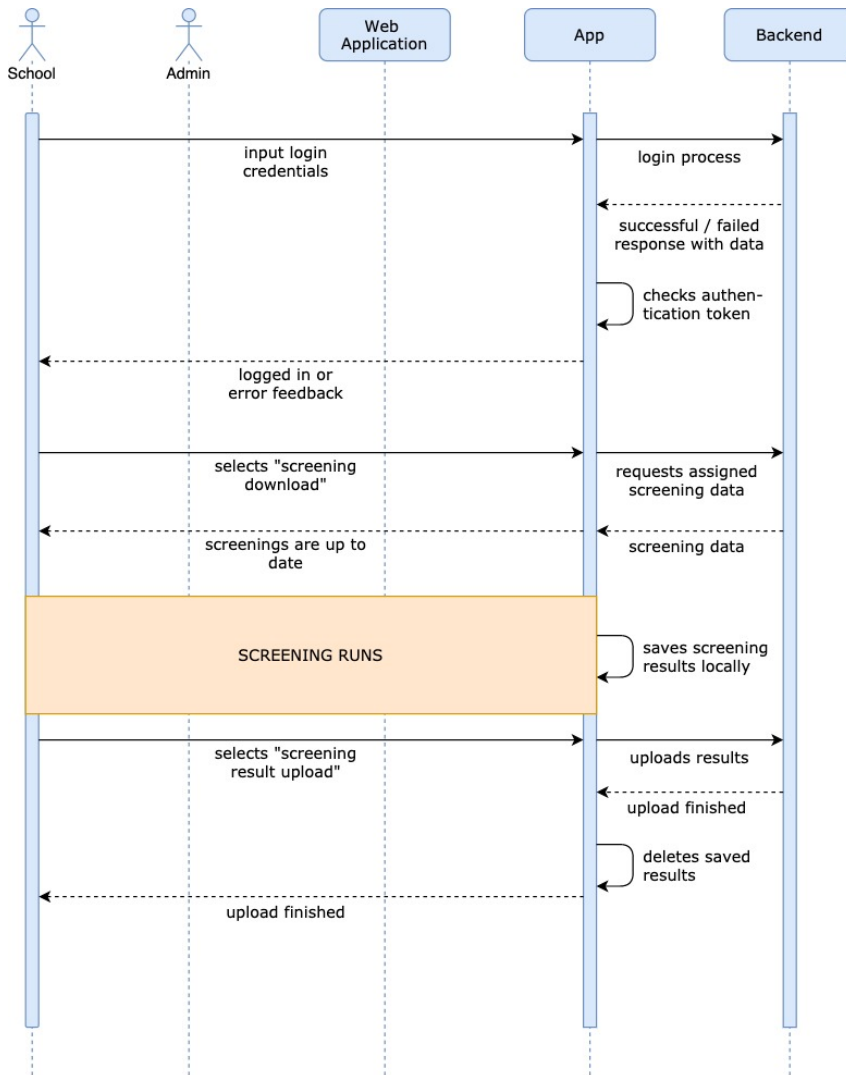
Figure 5.10: Sequence Diagram of the whole process a school carries out using the app
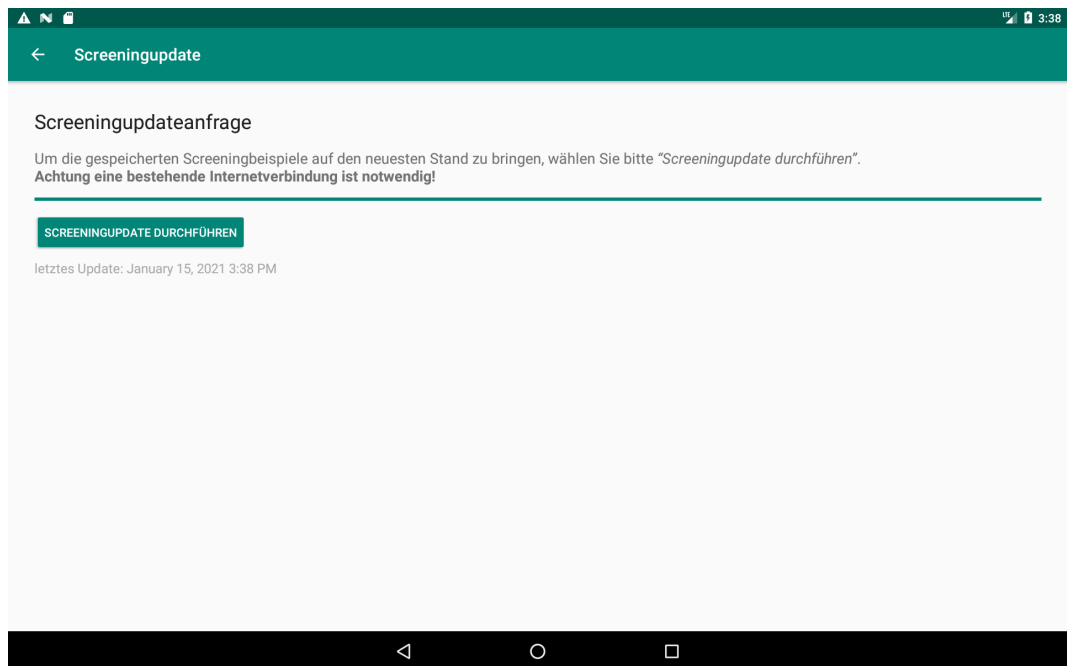
Figure 5.11: A screenshot of the app's screening-update-screen

When the user clicks on the button for performing an update of the local screening, the app sends a GET request to server to which the server responds with data of all assigned screenings, their audio and images files linked to them and their assignments. Due to the need of a necessary internet connection to be able to perform a screening update, the app automatically checks if the app is currently connected to the internet by checking the current WLAN settings and tries to connect to the server. If the app is not able to connect to the server, a stable internet connection cannot be assumed, and the app shows a label containing information about the need to connect the device to the internet. The text beneath the "Screeningupdateanfrage" heading also contains information about a necessary internet connection. A screenshot of the screening-update-screen can be seen in figure 5.11.

5.2.6 Performing a Screening

The main task of the app is to carry out screenings, which is done between the screening supervisor and a child. The screening supervisor is in control of the tablet before a screening is started and welcomes the child with one or both of its parents. The process of starting a screening contains the following steps (also shown in the UML Sequence Diagram split in figure 5.12 and figure 5.13) which are more detailed described in the paragraphs below:

- signature of the privacy and data policy by the child's parents
- enter screening identifiers
- starting a screening
- performing the screening
- finish screening

At the moment a screening starts, until the end of the screening, it is possible to cancel the screening procedure every time by clicking the Android specific back button. This will show an alert view asking the screening supervisor if the screening really should be canceled, to prevent unintended back button clicks. In case a screening is canceled, the app returns to the screen with the identifier input fields and does not save any data of the unfinished screening.

Before a screening actually can be done at least one of the child's parents has to agree the privacy and data policy which is necessary to be allowed to assess the child and save the data collected. For future calculations, done by the developmental psychologists, not only data about the screening results is needed by also information about the child's background. This allows the psychologists to create more detailed statistics for screening and educational changes in the future. Important background information, which was planned to be collected by the app (in addition to the data collected by the screening itself), includes for example the child's name, year and day of birth, if the child can speak more than one language and some other information. It is important to note here how the connection between the child's personal information and the screening results is actually managed. Owing to the new European General Data Protection Regulations (GDPR) the signature of a detailed privacy and data policy is mandatory to collect the data about the child's background information and the data collected by
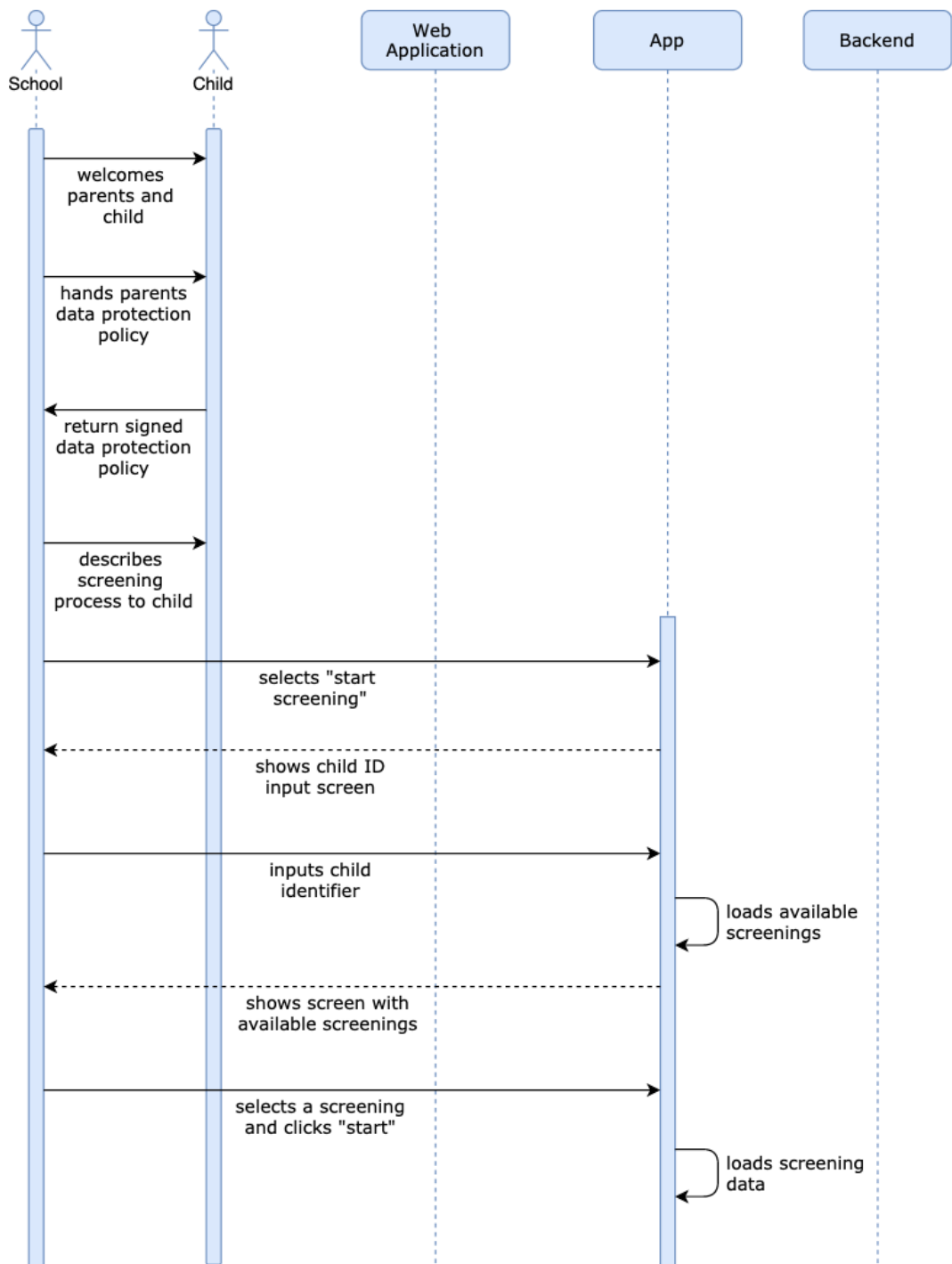
Figure 5.12: Sequence Diagram of a app's screening procedure - part 1
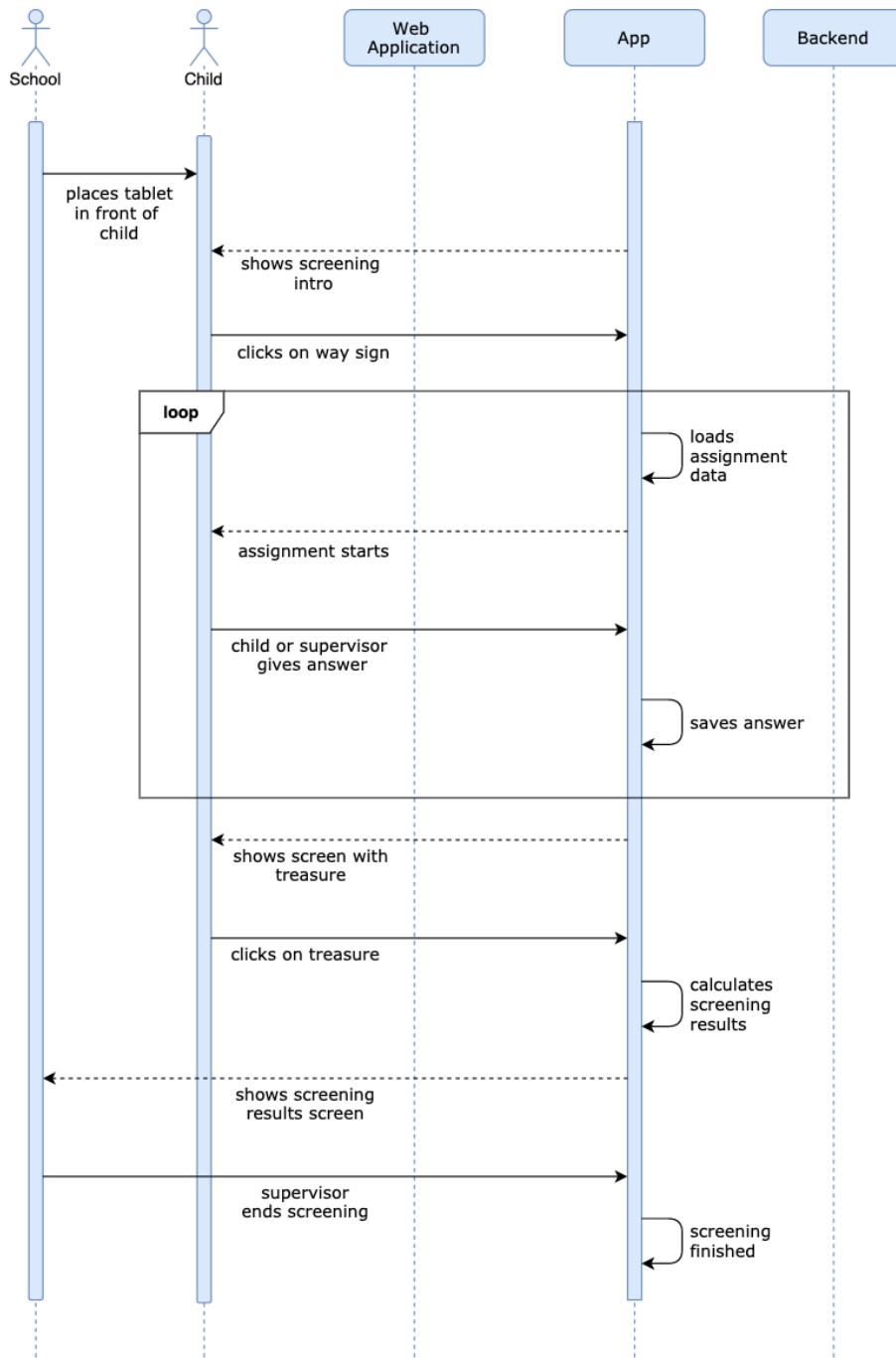
Figure 5.13: Sequence Diagram of a app's screening procedure - part 2

the screening. Since data about the child's background information belongs to personal data, according to the European General Data Protection Regulations (GDPR Article 4(1)), it is very important that the child's parental authorities consent the processing of the data by signing the privacy and data policy, which is handed to them by the screening supervisor in a printed format. Furthermore, the paper-pencil version also had to have a possibility to link the paper-pencil results to the child's background information. This was handled by using an additional sheet with a form to fill out all the needed data. Since the app's prototype had to be released a few weeks after the actual implementation started, it was difficult to develop an individual structure and individual processes to handle the data storage of the child's personal data in accordance with the data protection regulations. This resulted in the decision to use the additional sheet used for the paper-pencil screening to link the child's background information to the digital screening results which saved time because no individual privacy and data policy had to be developed for the tablet application. This was possible because the handed paper forms included a unique identifier in form of a number which had to be filled in one of the app's first forms before starting a screening. This identifier is then saved linked to the screening result, sent to the server when the user uploads the locally saved results and used by the developmental psychologists to reference every screening run to a child.

After the privacy and data policy is signed, the screening supervisor gives the child a short explanation of the screening process itself. By clicking on "Screening durchführen" (German for "perform a screening") a screen with two text input fields opens, as seen in figure 5.14. This input fields expect the identifier which comes with every privacy policy as previously mentioned. As know from some password or email input fields of various websites, a second input field to repeat the identifier is placed beneath the first one to decrease the chance of misspelling the identifier. The button with the text "SCREENINGTESTDURCHLAUF" (German for "screening test procedure") was integrated to let screening supervisors perform a test screening without entering any identifier and without the app saving any data to become familiar with the screening and its assignments. By clicking "Weiter" (German for "go ahead") the next view opens which shows a selection view for all currently installed screenings. Figure 5.15 shows such a selection screen, including only one screening of the type to assess children
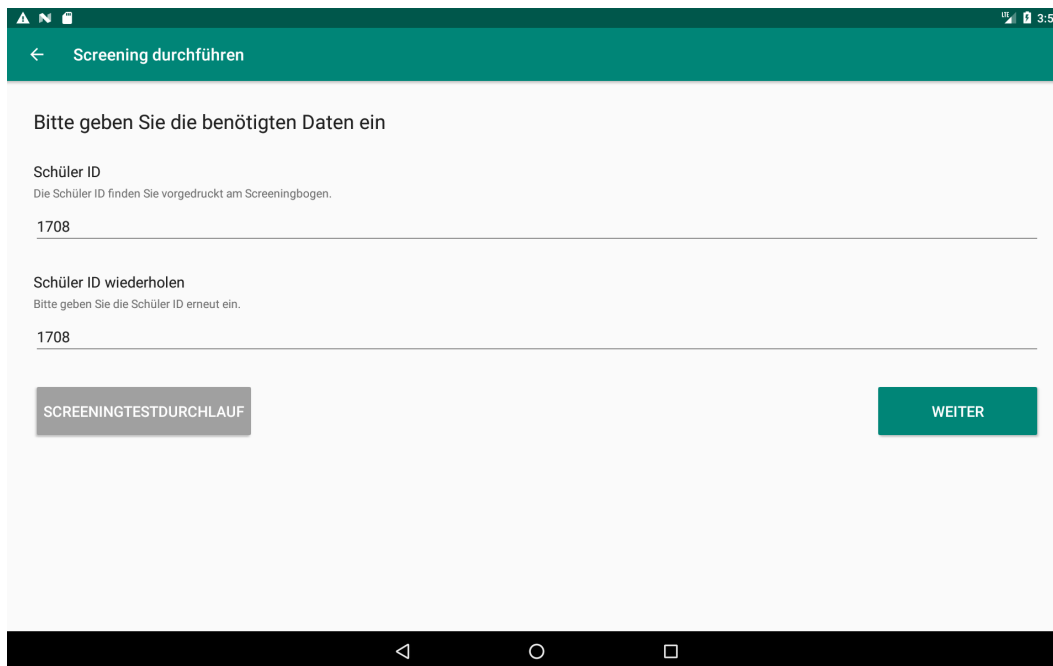
Figure 5.14: A screenshot of the app's screening-start-screen

before first class. By selecting one screening and clicking on "Screening starten" (German for "start screening") an alert view opens which informs the screening supervisor that the screening starts by clicking on the alert's "Weiter"-button.

5.2.7 Screening Intro

By starting the screening, the screening supervisor should place the tablet in front of the child. The tablet app automatically plays a screening intro which presents the elf's fictional frame story to the child. The audio file plays back the following sentences: *"Hello, my name is Poldi. In my magic forest there is a treasure hidden. This treasure is locked in an old chest. To open it we need many keys. We are going to collect these keys now and therefore I need your help. On the way we need to solve various tasks, for every task solved correctly we get keys. Are you ready? I am already existed! Here we go!"*. A screenshot of the
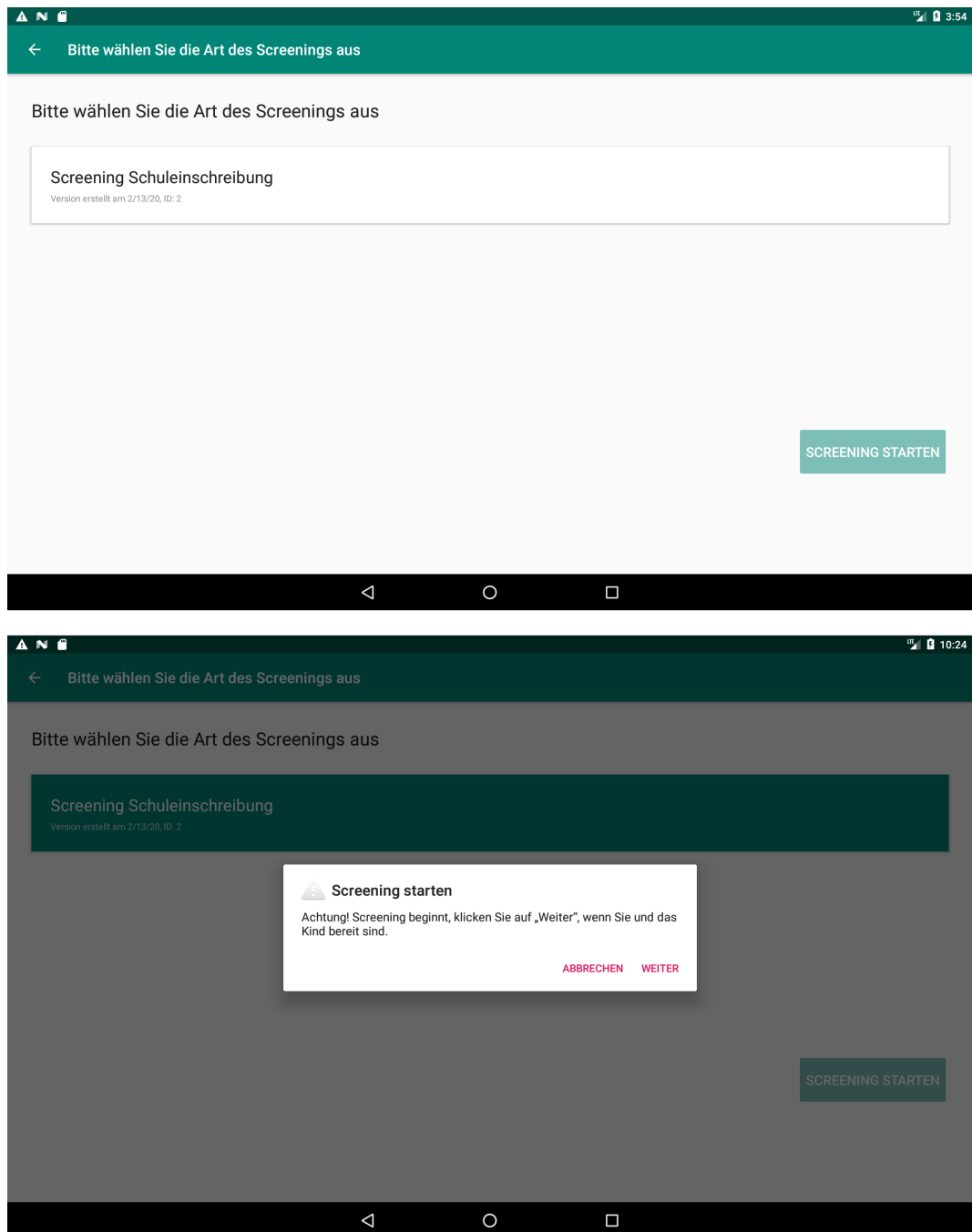
Figure 5.15: A screenshot of the app's screen with the selection of one of the currently installed screenings
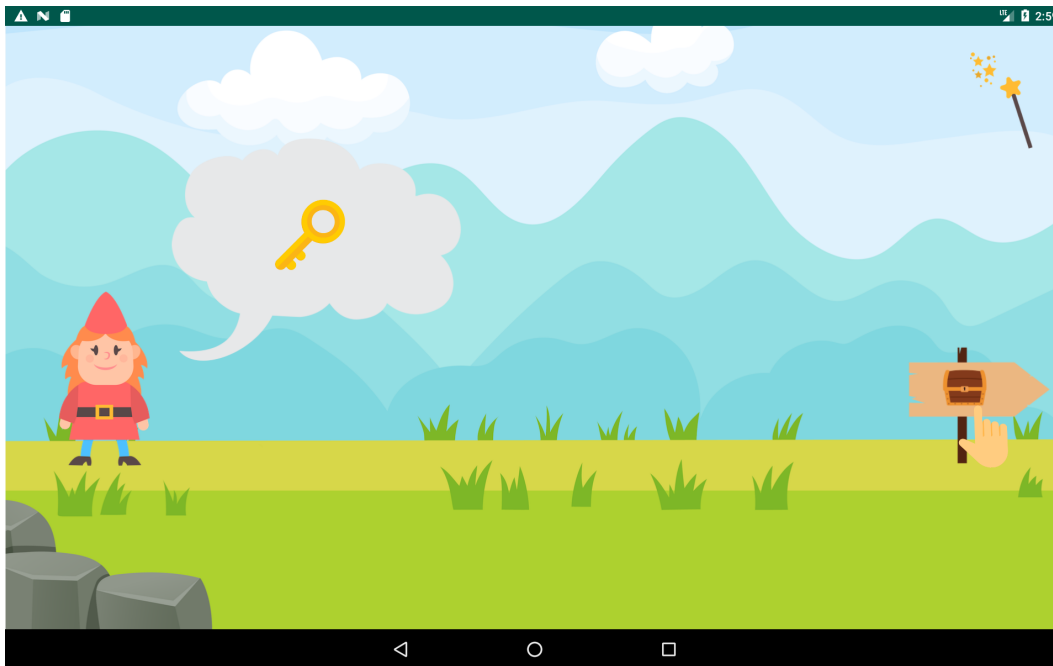
Figure 5.16: A screenshot of the app's screening intro

screening intro is shown in figure 5.16. The screenshot shows the state of the screen when the audio file already ended, this is the reason why a hand is visible above the way sign showing the way to the treasure. This should signal the child to click on the way sign to go ahead after the audio file is finished. The content of the dialogue balloon above Poldi's head changes with the time and adjusts to the audio file's current topic. For example, at the moment the audio file talks about the treasure, the bubble shows a chest as well as when the keys are mentioned, the bubble shows a key which is also the last item shown in the bubble as seen in the screenshot.

5.2.8 Implementation of Screening Assignments

All assignments described in section 4.3, except the "Count till 20"-assignment, were implemented similar to their mockups. With the help of two digital designers of the Institute of Interactive Systems and Data Science the charac-

ter, background and other objects used in the mockups were designed more beautifully and made the app's appearance look more interesting. The login screen, menu and its sub screens were realized using standard Material Design[5] components. The attention was to be able to deliver a properly working prototype in the few weeks until the first prototype's use.

All assignments basically consist out of an assignment intro, the assignment question, the assignment choices and the presentation of the achieved key or keys. Some assignments, including the "Comparison of Numbers"-assignment and "Quantity Comparison"-assignment, also make use of some test assignments after the assignment intro and before the real assignment begins. At the end of every assignment, at the moment the key or keys are shown, the app plays another audio file which points out that the child should click on the key or keys to collect them and to continue. The following assignment descriptions describe more detailed how the assignments itself were implemented, which audio files are played in which order and how the screens were structured.

The following screenshots of the app are part of a screening created with example assignments and are not part of any screening done by schools.

Phonological Awareness

The "Phonological Awareness"-assignment's specifications are described in section 4.3.1. Based on its mockups presented in the referenced section and the image files created by the designers, the assignment was implemented as seen in figure 5.17. At the start of the assignment the assignment-intro plays back the following audio file in the table below. After the audio file finished, the app waits for the child to click on Poldi, which is indicated by a hand floating over Poldi, as visible in the screenshot in the upper left corner of the shown image. By clicking on Poldi, the assignment question is played back using an audio file, followed by playing every possible answer's audio file and showing the according image one after another. The second screenshot in the upper right corner shows the assignment's state after the second possible answer is presented. After all answer audio files are played,

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[5]https://material.io, visited on 2021-01-20

the app points out that the child has to click on one of the images or to click on the magic wand to ask for help. In case the child did not hear all answers or was distracted, it is possible to replay all answers by clicking on the replay button shown in the though bubble in the lower left screenshot. This will replay all answer audio files while the images on the answer boards stay visible. The click listeners waiting for the child's answer by clicking on one of the wooden boards showing the answer images, are not active until all answer audio files are played at least once. Regardless of whether the correct answer was selected, the app fades out all shown images and presents the found key as shown in the lower right screenshot.

Assignment intro	"Here we have to find words which begin with a certain sound. Listen carefully!"
Assignment question	"'Maus' starts with 'm'. Which word does also start with 'm'?"
Choices	○ "'Hund'" (dog) ○ "'Hals'" (neck) ○ "'Mund'" (mouth)
Selected answer	"You did really well! Here is your first key!"

Knowledge of Letters & Number Recognition

As already mentioned in section 4.3.3 the "Knowledge of Letters"-assignment is similar to the "Number Recognition"-assignment and was therefore implemented as one assignment in the app with the only difference of using letters instead of numbers. All relevant information about both assignments is already mentioned in the sections 4.3.1 and 4.3.3. The screenshots in figure 5.18 show an example "Number Recognition"-assignment. The assignment itself is wrapped in the story of the mole "Willy" who is searching for his home-molehill but is not able to find it because he does not see that well. Poldi asks the child to help him by looking for the molehill with the flag containing the searched letter or digit. After the assignment intro is played back, the app waits for the child to click on Willy, as it is also mentioned by the audio file and visible by a hovering hand in the upper left screenshot. The click on Willy triggers the app to play the audio file which speaks out
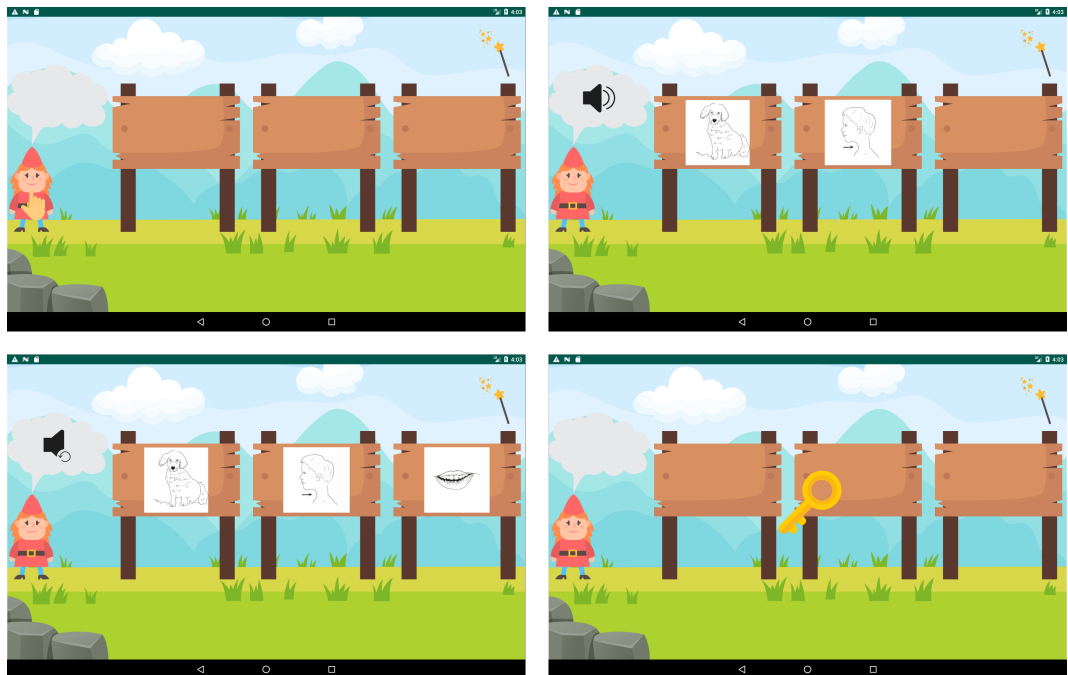
Figure 5.17: Implementation of the "Phonological Awareness"-assignment

the letter or digit to find and to display all possible answers at once. Only after the intro's audio file and the audio file of the searched item is finished, the answers' and the magic wand's click listeners become active and let the child choose its answer. The last screenshot of the figure shows the end of the assignment, displaying the key the child received from Willy.

Assignment intro	"Ah, there is Willy the mole. Unfortunately, he does not see that well and can no longer find his molehill. If you help him, you will get a key. I'll give you a letter or a number, listen carefully and tap the appropriate flag! Willy thanks you at the end with a key. Are you ready? Tap Willy and off you go!"
Assignment question	"'9'!"
Selected answer	"Willy thanks you with a key. Thanks! Juhu, we were able to collect a key!"

Comparison of Numbers

The "Comparison of Numbers"-assignment specifications were already described in section 4.3.5. This assignment belongs to one of the assignments which include some test assignments. The test assignments are hard-coded and are therefore the same for every screening run. After a short audio file played back while the assignment-intro, the three test assignments are asked one after another. In comparison to the real assignments there is no timer used for the test assignments and therefore no ladybugs shown. Another difference between the test and real assignments is, that based on the child's answer the app gives some feedback about the correctness of the selected answer using audio files. By clicking on a leaf the app decreases the opacity of the not selected leaf, to highlight the selected answer, as seen in the upper right screenshot in figure 5.19. If an incorrect answer was selected for a test assignment, the app plays back an audio file warning the child to look more carefully, sets the leaves' opacity to normal and waits for the next answer. The same behavior is used for all three test assignments. After all
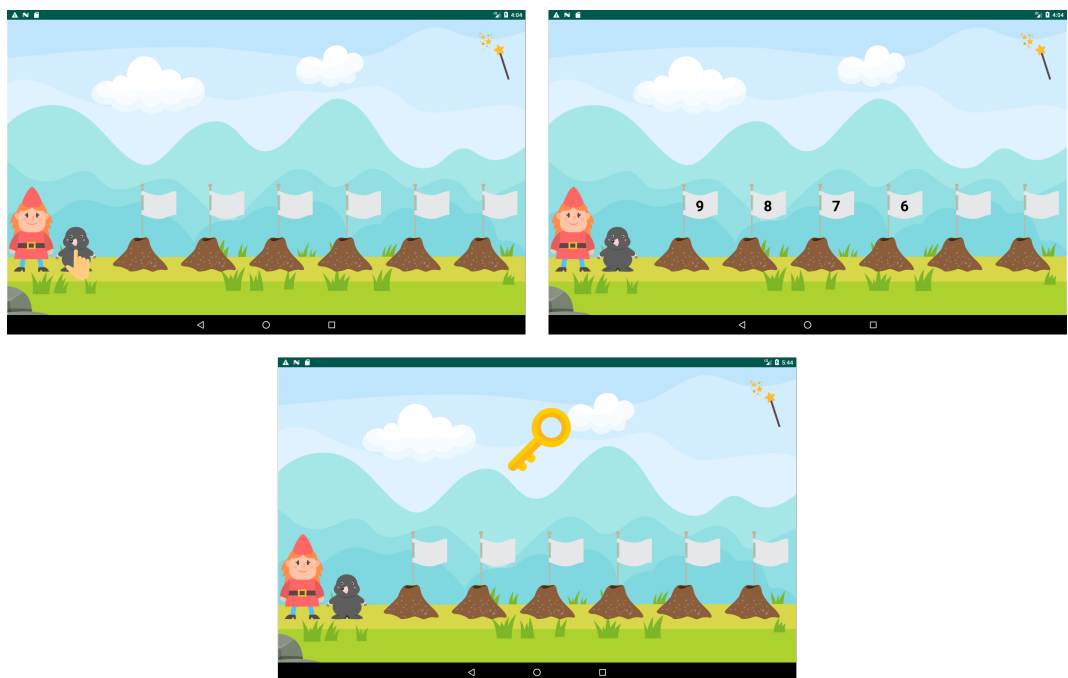
Figure 5.18: Implementation of the "Number Recognition"-assignment

test assignments are answered correctly, the app plays another audio file which announces the start of the real assignments and warns the child to be as fast as possible because the hungry ladybugs want to eat the leaves and the child has to be faster then them. The state of the app, while the intro of the real assignment questions is played, can be seen in the middle left screenshot. If the child takes longer than five seconds to answer the assignment, the app displays the leaves as they were already eaten by the ladybugs instead of the leaves containing the numbers. After all answers are done, the app presents the obtained key and waits for the child to select it.

Assignment intro	"Here you can see two numbers next to each other. Tap the larger number. Let's try it now!"
Assignment test question	Correct → "Correct! Exactly!" Incorrect → "Oops, look again"
Real assignment question	"Attention, now it gets a little more difficult! We have to be very quick, otherwise the ladybugs will come and nibble the numbers before we found the answer. Ready, Set, Go!"
Assignment answer	"Time ran out → "Oje, too slow!"
Assignment end	"Very well! Look, we're getting a very special key!"

Quantity Comparison

Like the "Comparison of Numbers"-assignment, the "Quantity Comparison"-assignment also makes use of a timer and utilizes test assignments to make the child familiar with the assignment itself. The "Quantity Comparison"-assignment specifications were already described in section 4.3.7. Before the test assignments start, the assignment-intro audio file is played while the answers of the first test assignment are already shown. Similar to the "Comparison of Numbers"-assignment, an incorrect answer to one of the test assignments sets back the app's click listeners until the correct answer was selected or the child did take longer than the timer. The owl sitting on the branch, visible in the screenshots of figure 5.20, plays a major part for
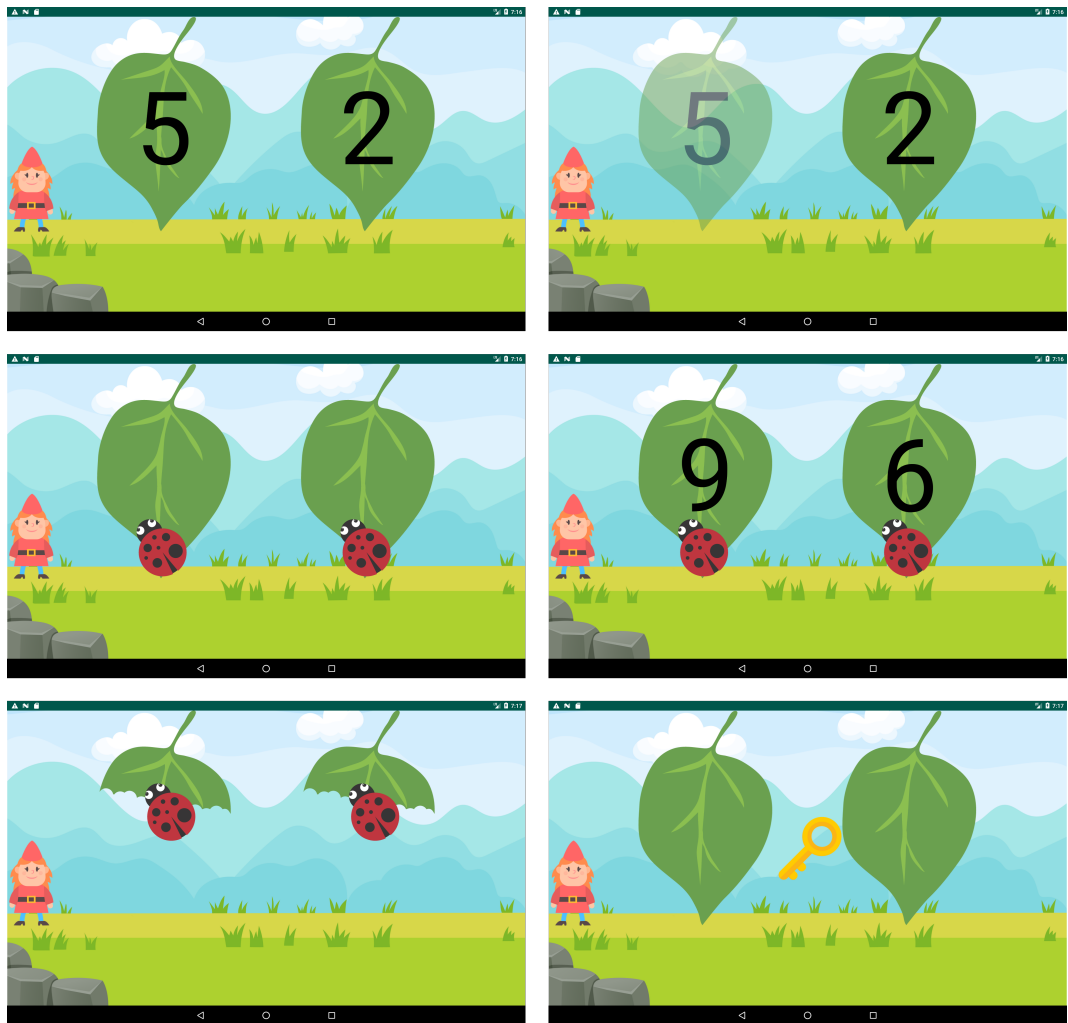
Figure 5.19: Implementation of the "Comparison of Numbers"-assignment

the frame story used for the timer. In comparison to the "Comparison of Numbers"-assignment, not only the real assignments but also the test assignments make use of this timer. If the child takes longer than six seconds, the suitcases are hidden and the owl taking off with the suitcase becomes visible (lower left screenshot). In case the timer did run out before the child did select an answer for the test or the real assignments, the app has four different audio files to inform the child to be as quick as possible. These audio files can be found in the table below listed in the same row as the "Assignment test question"-cell. Every time one of these audio files is played, an implemented counter iterates between 1 and 4 to play one audio file after another. Due to that, this is the same for the test and real assignments, it is possible that all four audio files are played multiple times. In order to highlight the selected answer, the same behavior as for the "Comparison of Numbers"-assignment is used by changing the answer's opacity. Between the test and real assignments, the app informs the child once again to be as fast as possible. The last screenshot, in the bottom right corner, shows the end of the assignment which also displays the next obtained key.

Assignment intro	"Oh, what do I see there? Somebody lost suitcases with gold pieces. Quick! We have to save them from the owl and collect as many gold pieces as possible. Unfortunately you don't have much time. Always take the suitcase with more gold pieces. Remember to be as quick as possible. Ready, Set, Go!"
Assignment test question	Correct → "Correct! Exactly!" Incorrect → "Oops, look again" Time ran out → 1. "Hopla, the owl was faster than you. Be careful with the next one!" 2. "Ohoh, the owl snatched that from you. Try to be a little bit faster!" 3. "Oje, too slowly!" 4. "Choose quickly, do not count!"
Real assignment question	(Only in case the time did not run out for the last test assignment) "Super! It is important no to count but to decide as fast as possible."
Assignment answer	Time ran out → (makes use of the same audio files as for the test assignments)
Assignment end	"Well done! We got another key. Wow, it goes well with our collection!"

Quantity Knowledge

The "Quantity Knowledge"-assignment was one of the simpler assignments to implement. For a description of its specifications see section 4.3.8. The assignment is the only assignment which rewards the child with more than one key. The child's goal is to name the screening supervisor the correct number of keys visible by counting them. Due to that the child must see the tablet screen and the data saved for the assignment should only consist
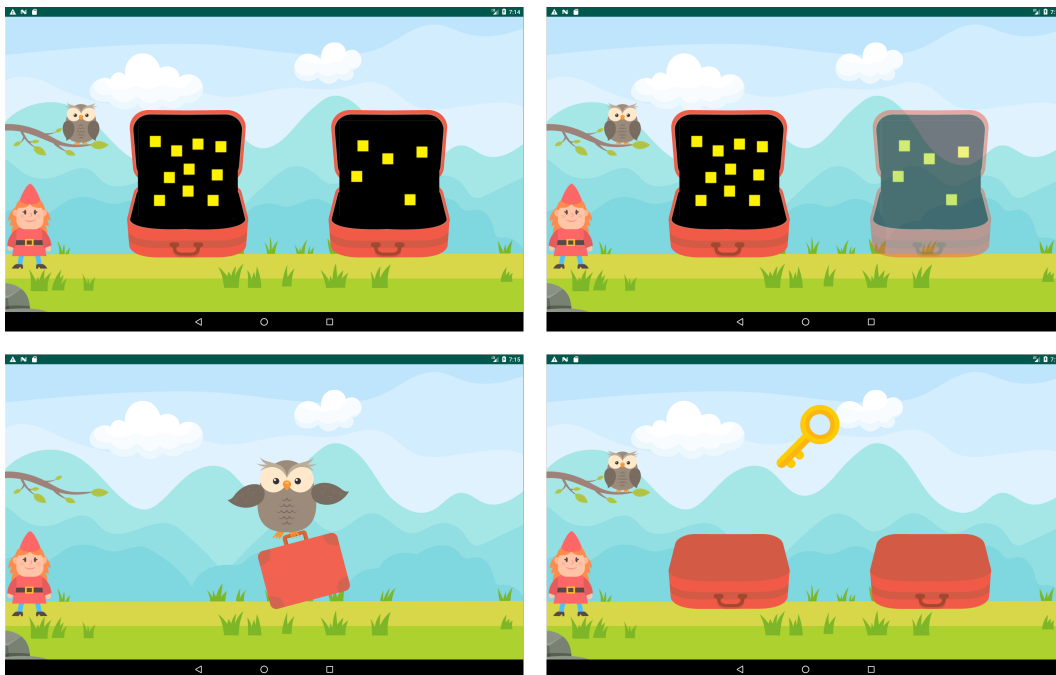
Figure 5.20: Implementation of the "Quantity Comparison"-assignment
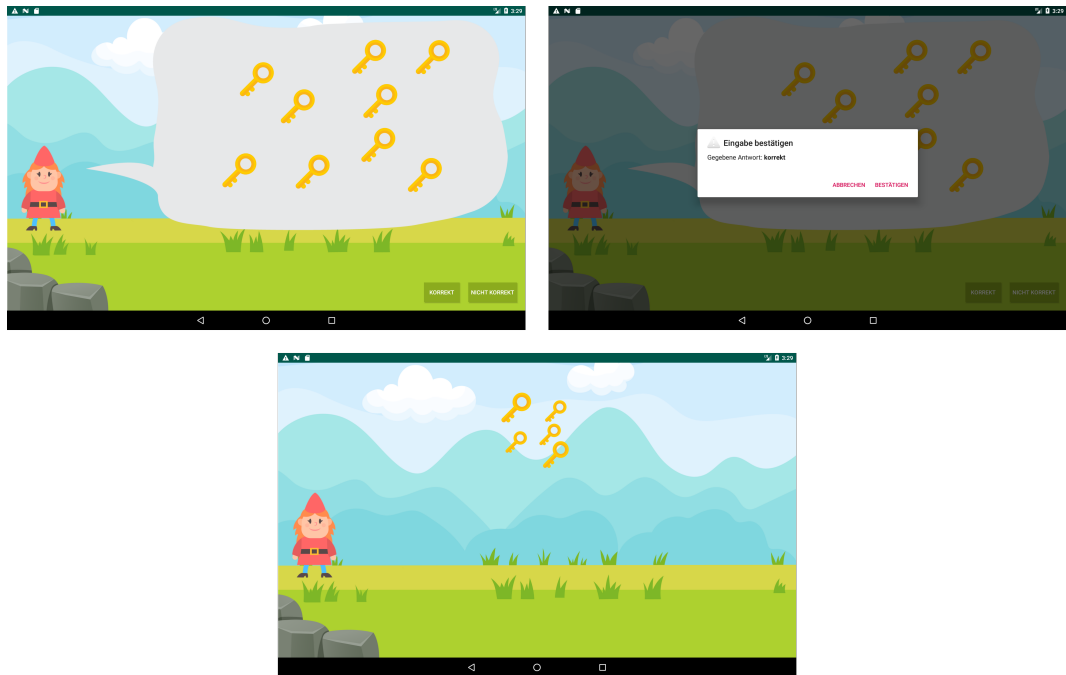
Figure 5.21: Implementation of the "Quantity Knowledge"-assignment

out of the correctness of the child's answer, the buttons had to be hidden somewhere on the screen. The buttons to select a correct or an incorrect answer are hidden within the grass, as visible in the first screenshot in figure 5.21. After the assignment intro is done, the buttons become active and should be used only by the screening supervisor. In case the child did recognize the buttons and clicks one of them, there is another confirmation alert view which has to be confirmed by performing another user input, see therefore the upper right screenshot. After all assignments are done, the app displays multiple keys the child gained by solving the assignment.

Assignment intro	"What do i see there? We get keys for free. How many keys do you see? Tell it to the adult."
Assignment end	"Super! Look how many keys you did collect!"

Supervisor Assisted Assignments

As already mentioned in chapter 4.3 for the assignments "Repeat Numbers", "Arithmetic Problems", "RAN" and "Sorting Assignment", there are some assignments which are performed while the supervisor is in control of the tablet. Since the tablet is usually in front of the child, the app has to view some sort of alert which informs the child and the supervisor to change the position of the tablet. This is solved by showing Poldi in front of a clean landscape view, as seen in the app's screenshot 5.22, while also playing an audio file announcing the next assignment is a supervisor assisted assignment. In case of the "Arithmetic Problems"-assignment the audio file plays: *"Now we have to solve a few riddles. The adult tells you the riddles!"*, right before an alert view with the text: "Please take the tablet and carry out the task together with the child.". After the alert view is closed by clicking on the "go ahead"-button, the supervisor confirms to hold the tablet in his hands and the assignment can be started.

Right after the assignment is done and the last answer is saved, the app shows another alert in front of the last view of the supervisor interface instructing the supervisor to place the tablet in front of the child again. After the alert view is confirmed, the app displays another screen with Poldi in front of a clean background next to the key which the child has gained. For each supervisor assisted assignment, the alert view displays the text: "The supervisor assisted assignment is over. Please give the child the tablet again.", which can be seen for example in the last screenshot of figure 5.23.

Arithmetic Problems

The "Arithmetic Problems"-assignment is one of the supervisor assisted assignments, described in the previous section. The views belonging to the supervisor interface are implemented using only Material Design components, as seen in figure 5.23. The supervisor's task when holding the tablet, is to read out loud the assignment question beneath "Fragestellung" (German for "problem description") and to input the child's answer by entering it into the text field next to "Bitte Antwort eingeben" (German for
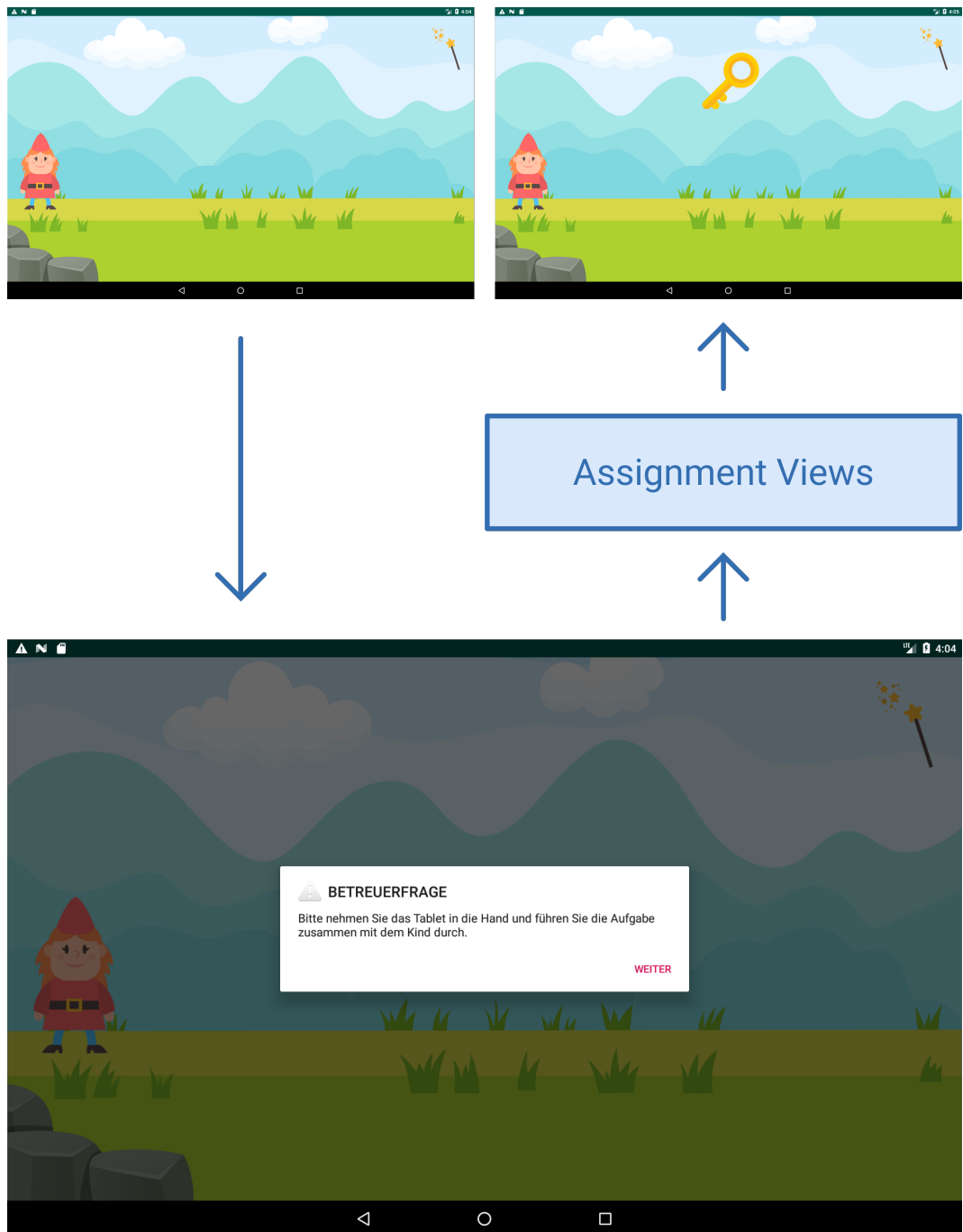
Figure 5.22: Main screens of the supervisor assisted assignments

"please, fill in answer") or to select the "Keine Antwort gegeben"-checkbox (German for "no answer given"). After the supervisor confirms his input, a click on the "go ahead"-button in the bottom right corner saves the answer. In case the last assignment question was done, an alert view opens in front of the supervisor interface with the text described in the previous section. By clicking on the alert's "go ahead"-button, the supervisor interface closes, the child's interface appears again and the audio file announcing the received key is played.

Assignment intro	"Now we have to solve a few riddles. The adult tells you the riddles!"
Assignment end	"Puh, pretty difficult! In return you get another great key."

Repeat Numbers

The supervisor assisted "Repeat Numbers"-assignment is the only assignment which can vary in its processing time. As already described in the assignment's specifications in section 4.3.6, the assignment has multiple levels of difficulty. For each level the child has two chances to repeat the numbers spoken out loud by the audio file. Since it should be possible to have different number sequences, the web application enables the admins to upload different audio files for every number spoken which are then appended by the app and played one after another. Based on the level of difficulty the length of the number sequences can vary from two numbers to up to five numbers. If the child and the supervisor are ready, the audio can be played by clicking on the green button containing the text "AUDIO DATEIEN ABSPIELEN" (German for "play audio files"), as it can be seen in the screenshots in figure 5.24. Beneath the button there is a text label warning the supervisor that the audio can only be played once, to be sure the children were not able to hear the audio files a second time. To enable the app to know about the correctness of the child's repeated number sequence, the screening supervisor has to click the "correct" or "incorrect"-button based on the numbers the child told the supervisor. To make it easier for the supervisor to check the child's answer, the asked number sequence is
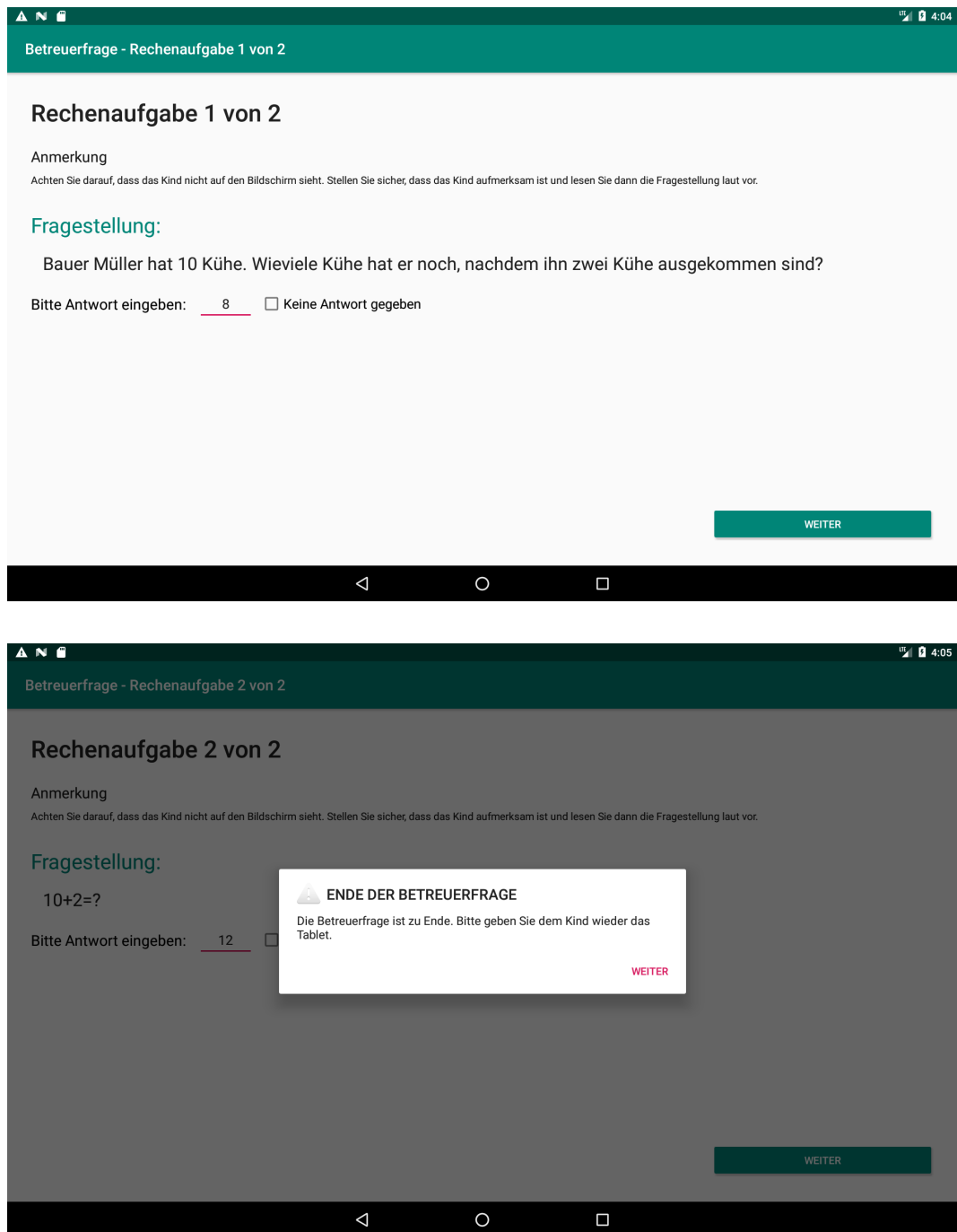
Figure 5.23: Implementation of the "Arithmetic Problems"-assignment

visible on the tablet screen next to the "play audio files"-button. If the child did not give any answer, there is also a checkbox integrated which should be selected in case the child was not able to repeat any numbers. The app automatically shows the next number sequence based on the supervisor's input and automatically ends the assignment if the child could not repeat the numbers correctly or did not give any answer. The last screenshot in the referenced figure shows the alert view which is displayed at the end of every supervisor assisted assignment.

Assignment intro	"Listen to me very carefully on the next task. I will tell you a few numbers and I would like to know if you can remember them. Please always wait until I am done speaking and then repeat the numbers for me."
Assignment questions	• 5, 3 (1st level, 1st chance) • 9,2 (1st level, 2nd chance) • 9,6,8 (2nd level, 1st chance) • 2, 13, 6, 16 (3rd level, 1st chance) • 39, 158, 9, 52, 85 (4th level, 1st chance)
Assignment end	"You did very well! Because you worked so hard, you get an extra key."

RAN (Rapid Automated Naming)

The "RAN (Rapid Automated Naming)" is not only a supervisor assisted assignment but also needs to supervisor to have the assignment's manual in front of him. As already mentioned in section 4.3.10, the assignment consists out of an image-naming-assignment and out of a number-naming-assignment. It is necessary for the child to solve a test assignment for both the image and the digit assignment type by using a small paper version of the assignment and by naming the images or digits shown on the paper. The image test items have to be named before the image assignment type starts and the digit test items have to be named after the image assignment
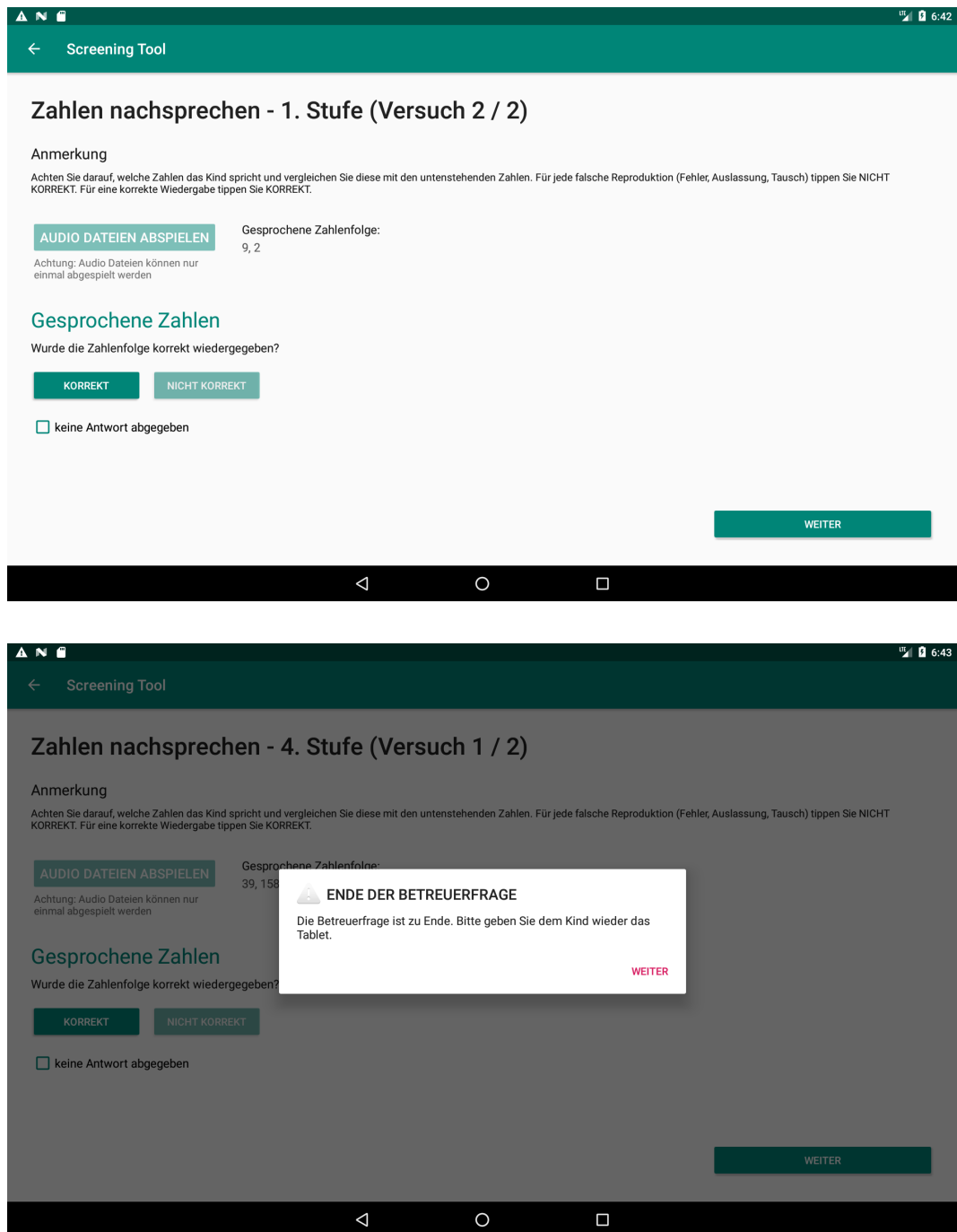
Figure 5.24: Implementation of the "Repeat Numbers"-assignment

type but before the number assignment type. The app opens an alert view after the assignment intro is finished and the supervisor interface is shown, containing the text: "Please edit the exercise items first with the child (for instructions see manual) and only then click on 'go ahead'.", as visible in the first screenshot in figure 5.25. By clicking the "go ahead"-button, the next view disappears and the assignment itself can be started by clicking the timer-start-button, which also shows the time the admins entered for the assignment. A click on the start button starts the app to play the audio "Ready, Set, Go!" and the timer starts counting down. While the child names the items shown on the assignment's paper, the supervisor has to click the item fields the child did name incorrect. In case the child is faster than the timer, the supervisor has to click the stop-timer-button, otherwise if the time runs out, an audio file instructs the child to stop naming items by saying: "Stop!". In both cases the supervisor has to select the last item named by the child and has to click the "go ahead"-button. This will open a modal view which lets the supervisor change the number of incorrectly named items. After the image assignment type is done, the app shows Poldi in front of a clean background and plays the audio: "Wow you are good. Now I have a similar task for you.". This will make the number assignment type start similar to the image assignment type with the only difference that the correct naming of the numbers asked by the paper assignment test is necessary to be able to perform the number-assignment. In case the child was not able to name the test assignment items correctly, the supervisor has to click the "no"-button of the alert window (visible in screenshots of figure 5.26) asking if the child was able to solve the test items. This will skip the number assignment type and will make the app jump to the assignment's end. Otherwise, the number assignment type is handled exactly as the image assignment type.

Assignment intro	"For the next task, we need the help of an adult. Listen carefully how the assignment has to be done!"
Between the assignments	"Wow you are good. Now I have a similar task for you."
Assignment end	"I am delighted. You will get a particularly nice key for your work."
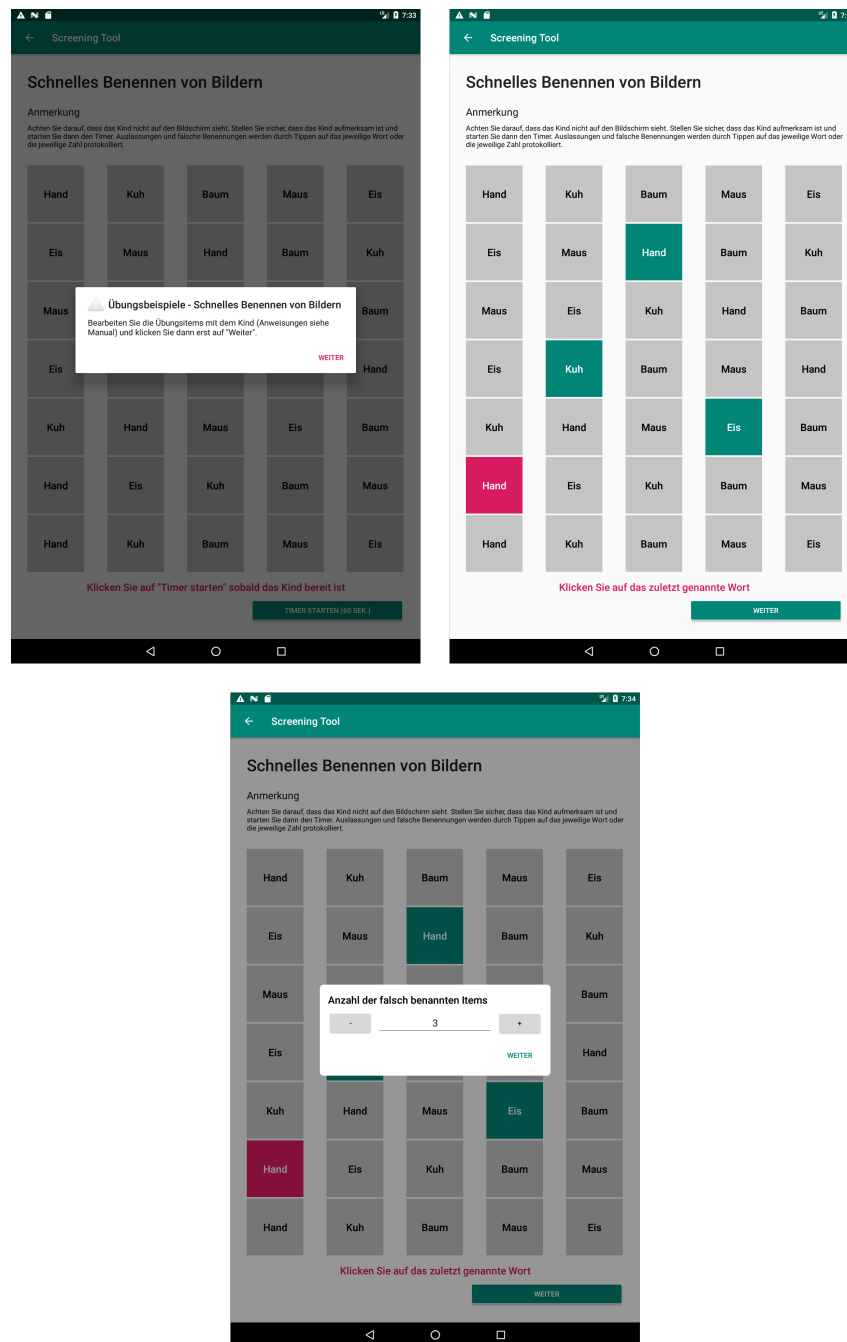
Figure 5.25: Implementation of the "RAN-Image"-assignment
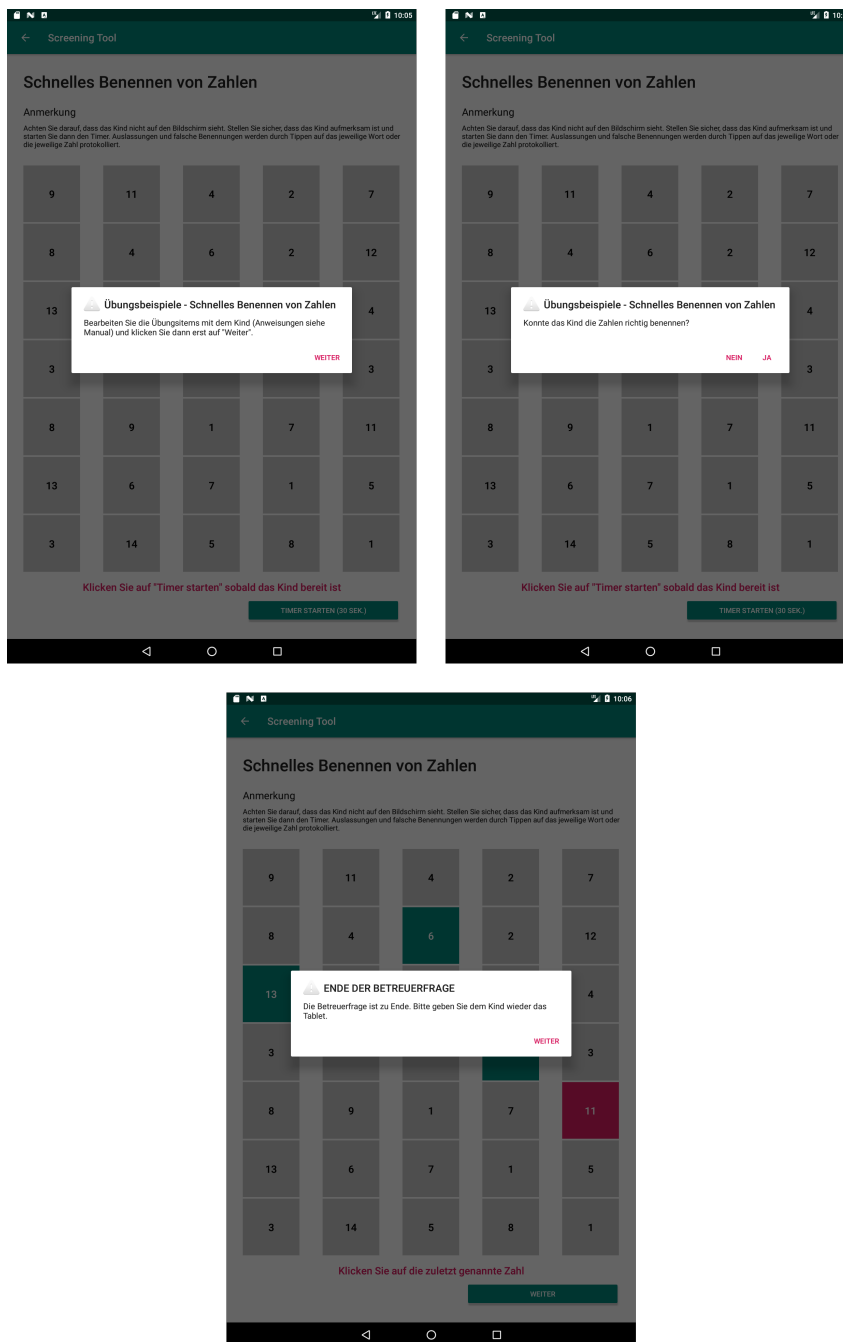
Figure 5.26: Implementation of the "RAN-Number"-assignment

Sorting Assignment

The "Sorting Assignment" is the last assignment part of the screening process and also the longest one. Its task is to sort 45 cards containing 12 items as already described in section 4.3.11. The first six cards are used to make the child familiar with the assignment itself which is done by using the cards which come with the screening. After all test cards are sorted, the screening supervisor has to click the "start"-button to begin the assignment. This will make the app start the integrated timer counting down form 7 minutes which is the maximum time the assignment is allowed to take. The task of the supervisor is to click the box to which the child has assigned every card. Since it would be possible that the child changes the card's assignment after the supervisor had already selected a box, a button with the function to go back to the previous cards is implemented which makes it possible to change the box already selected. At the bottom right of the screen there is a button which increases the counter of how often a child had to be motivated to continue sorting the cards. In case the child did not sort every card until the timer is finished, an alert window opens which informs the supervisor that the time did run out and it is not possible to assign any new cards anymore. Otherwise, the timer stops counting at the moment the last box was clicked but gives the supervisor the possibility to change any previous card's assignment. By clicking the "AUFGABE ABSCHLIESSEN"-button (German for "finish assignment") the assignment's answers are saved and the assignment end is displayed showing the received key. Due to that the goal of the assignment is to test the child's attention, it is possible that some children do not want to finish the assignment. Therefore it was necessary to implement also a button to cancel the assignment, which is shown in the screenshots' bottom left corner.

Assignment intro	"For the next task, we need the help of an adult. Listen carefully how the assignment has to be done!"
Assignment end	"You have been a really great help! Thank you. Because you have been so hardworking, you get an extra key."
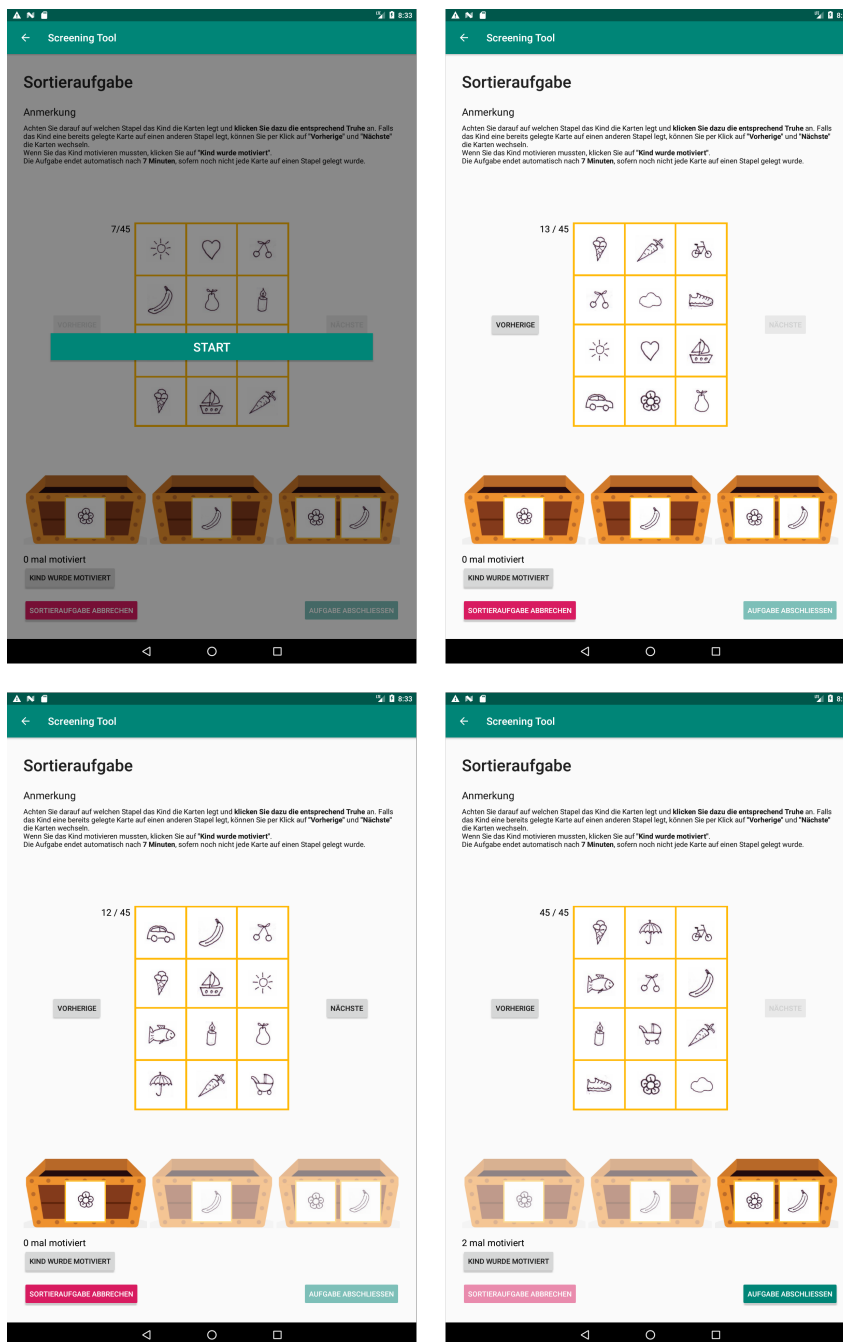
Figure 5.27: Implementation of the "RAN"-assignment
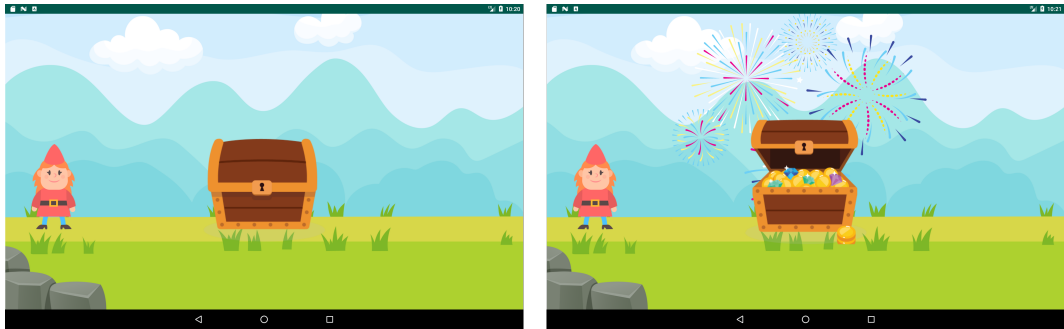
Figure 5.28: Implementation of the screening outro

5.2.9 Screening Outro

After collecting the last key, the app automatically switches to the treasure-view (visible in figure 5.28) showing Poldi next to the treasure the elf was looking for. *"We have found the treasure! Let's see if the keys fit!"*, is played to celebrated with the child the successful treasure hunt and to request the child to open the chest by clicking on it. By opening the chest, a sound effect imitates the sound of the lock opening while the chest reveals the gold in it. This is followed by fireworks fading in in the background while playing according exploding sound effects. Poldi congratulates the child by saying: *"Yeah! You did it! Congratulations, you have done really well."*. Another click inside the view, ends the screening for the child. However, there is another view important for the screening evaluation which is shown becomes visible.

5.2.10 Automatic Screening Evaluation

After the screening outro is shown, the app calculates all screening results gathered and evaluates them automatically with the use of calculations and cut-off values based on formulae developed by the developmental psychologists. The screen shows the child's special educational needs in seven different areas, as seen in the screenshots in figure 5.29. These areas are:

1. "Phonology" based on "Phonological Awareness" and "RAN"-assignment

2. "Letters and sounds" based on "Phonological Awareness", "Knowledge of Letters" and "Number Recognition"-assignment
3. "Quantity and number knowledge" based on ""Knowledge of Letters", "Number Recognition", "Comparison of Numbers" and "Quantity Comparison"-assignment
4. "Counting" based on ""Knowledge of Letters", "Number Recognition", "Comparison of Numbers" and "Quantity Comparison"-assignment
5. "Working memory" based on "Quantity Knowledge" and "Arithmetic Problems"-assignment
6. "Attentiveness - stamina and accuracy" based on "Sorting Assignment"
7. "Attentiveness - motivation" based on "Sorting Assignment"

The areas "Attentiveness - stamina and accuracy" and "Attentiveness - motivation" only are calculated by using the results of the "Sorting Assignment" but differentiate in the data used of the calculations.

For every calculated area there are three different states of the child's special educational needs, consisting out of "Leichter Förderbedarf" (German for "slight special educational needs"), "Deutlicher Förderbedarf" (German for "obvious special educational needs") and a checkmark representing no educational needs. For each state there are different cut-off values given by the developmental psychologists. Some of the cut-off values are defined by percentages and some other by the absolute number of correct or incorrect answers. The code for calculating the state of the child's educational needs in the "Attentiveness - stamina and accuracy"-area can be seen in listing 5.1. The supervisor then can inform the child's parents about the screening's evaluation and can exit the screening by clicking anywhere at the screen. This will open an alert view showing that the screening's evaluation cannot be viewed after the screen is closed which the screening supervisor has to confirm to go ahead to the lower screenshot in figure 5.29. This screenshot informs the screening supervisor that the screening results are saved locally and can be uploaded later via the screening-upload-screen.

```
private fun computeWorkPostureStaminaEvaluation(): EducationalNeedType {
    ...

    val sortingAnswerWrapper =
    ↪  this.testRun.sortingAssignmentAnswerWrapper
        ?: return EducationalNeedType.ComputationFailed

    val numberOfCorrectCards =
    ↪  sortingAnswerWrapper.sortingAssignmentAnswers.count {
        it.correctAnswerGiven == true
    }

    if (numberOfCorrectCards < 9) {
        return EducationalNeedType.Obvious
    } else if (numberOfCorrectCards < 20) {
        return EducationalNeedType.Little
    }

    return EducationalNeedType.None
}
```

Listing 5.1: Code for calculating the child's special educational needs in the "Attentiveness - stamina and accuracy"-area
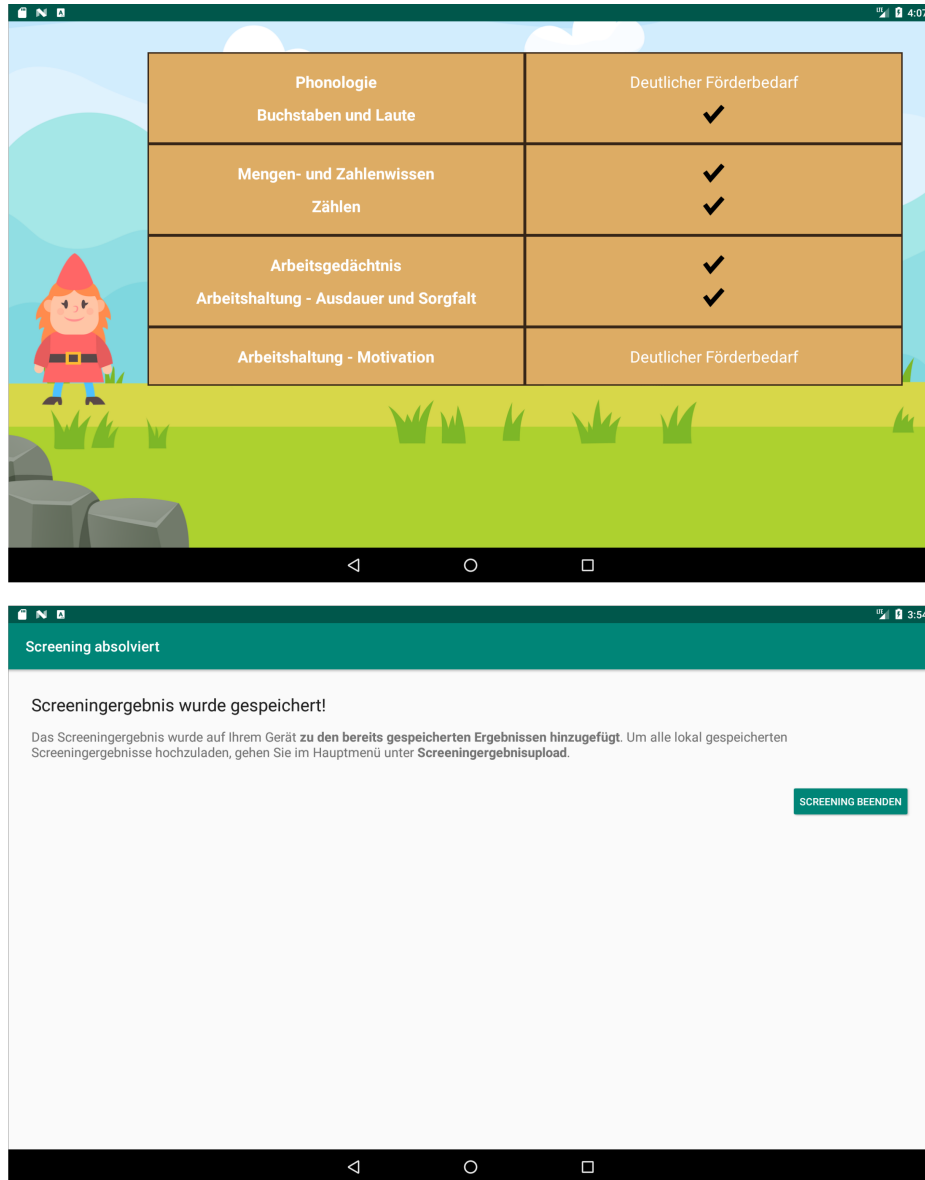
Figure 5.29: Screenshot of the app's screening-evaluation-screen
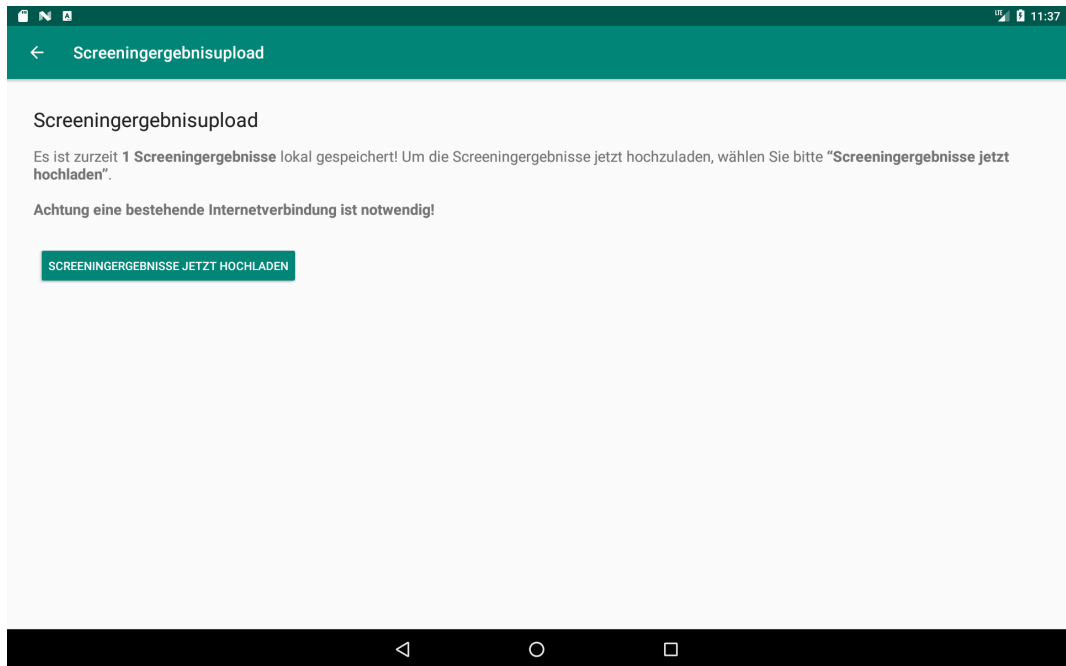
Figure 5.30: Implementation of the screening upload screen

5.2.11 Screening Results Upload

The last part of the UML Sequence Diagram in figure 5.10 shows the process of uploading the locally saved screening results. By clicking on the "Screeningergebnisupload" (German for "screening result upload") menu item the app opens the view shown in figure 5.30. The view contains information about the number of currently saved screenings and a label informing that all screenings can be uploaded by clicking the upload button with the text "SCREENINGERGEBNISSE JETZT HOCHLADEN" (German for "upload screening results now"). Another label also informs the user that the upload only can be done when there is a stable internet connection.

At the moment the user clicks the upload button, the app sends all locally saved data by performing a POST request to the server's API. The server then saves all data in its MySQL database. After all data was uploaded successfully, the app triggers an internal callback function which deletes all saved database entries belonging to the data that has just been uploaded.

5.2.12 Screening Results Download

The goal of the screening software is to create a more effective and efficient way to collect the newest data of the current level of education in Austria and to discover early developmental handicaps of children. The first point can only be achieved by using the collected data for scientific calculations and to create and examine multiple statistics. To access the data, another screen was integrated in the web application for the developmental psychologists. The "Download Results" menu item, seen in figure 5.1, brings the users to the "Screening Result Download"-view. The screen includes a number of check boxes, relative to the number of schools created and a download button. The view's functionality enables the admins to select the schools of which all collected test results should be compiled together and downloaded within an Excel File. Due to the quickly increasing numbers of screening results, the functionality had to be adapted by performing some changes to its first prototype implementation. The used framework for creating the Excel File is a GitHub[6] project named "PhpSpreadsheet"[7]. It makes it possible to edit and create Excel, XML, CSV files and more. The frameworks documentation includes a paragraph under its FAQs stating: "PhpSpreadsheet holds an 'in memory' representation of a spreadsheet, so it is susceptible to PHP's memory limitations"[8]. The increasing number of screening result data also increased the processing time and memory needed to create the Excel Files, which resulted also in out of memory (OOM) exceptions after a few weeks the prototype started to get used. Since this was a major problem, the web application's result-download-screen had to be revised a bit. The screenshot in figure 5.31 shows a HTML selection field to select the number of results to download. "1-100" therefore means that the first hundred screening results will be compiled in one excel file and will be downloaded. This resulted also in another advantage which makes it possible to only request the Excel File with the screening results needed, in case the first few hundred results were already downloaded and the next hundred were just been uploaded.

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[6]https://github.com, visited on 2021-01-22
[7]https://github.com/PHPOffice/PhpSpreadsheet, visited on 2021-01-22
[8]https://phpspreadsheet.readthedocs.io/en/latest/faq/, visited on 2021-01-22

Figure 5.31: Implementation of the screening result download screen

Structure of the Excel File

The developmental psychologists need to perform different statistics and calculation based on the screening results. Therefore, the psychologists need a specific structure of the data downloaded. This was achieved by showing the results of different assignments in different Excel Sheets. The psychologists requested a specific structure for each assignment. Every row of every Excel Sheet contains some standard information like the child's ID, the date and time of the screening run, the screening's ID, the school's ID and the school's name, and some assignment specific fields which vary for every assignment.

Some example results of the "Quantity Comparison"-assignment can be seen in figure 5.32, each row showing the child's answer to the screening's single "Quantity Comparison"-assignment. In case multiple assignments were part of the screening with ID 2, multiple answer entries would be displayed one underneath the other. The referenced figure is split in two images because of the Excel Sheet's horizontal size. The first three columns belong to the already mentioned standard fields, followed by some assignment specific entries. The "trial_number" is another entry which is part of most Excel Sheets and contains a counter increasing for every answer to every

assignment of the same type of the same screening run. Since the screening with ID 2 did only have one "Quantity Comparison"-assignment, the trial counter is always "1". In case another assignment of the same type was part of the screening, the answer to it would be printed beneath and would have a trial counter of "2" and so on. The column for the "item_type" does contain information about the difficulty of the used images and is mostly the same as the first few characters of the image file names. The remaining columns have the following meaning:

name_left and name_right	the image file names used for the left and right choice, the highlighted one indicates the correct one
expected_choice	also indicates the correct choice, "1" stands for the left and "2" for the right choice
given_choice	shows the child's selection
accuracy	contains one of Excel's "IF"-functions and compares the previous two columns with each other, "1" stands for correct answer given
reaction time	the time the child took to select an answer
RT_correct_answer	contains the value of the previous column, only if the child did answer correctly

5.3 Development of the Web Application and API

The API and web application were built with a PHP framework named "Zend Framework 3"[9] which is described more detailed in chapter 5.3.1. For managing the data storage, a MySQL[10] database is used. The data storage uses Doctrine's[11] Object Relational Mapper (ORM) (see chapter 5.3.2) which is able to create important migration files in case of changes in the data structure. The web server itself runs Debian[12] as its operating system.

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[9]https://framework.zend.com, visited on 2021-01-05
[10]https://www.mysql.com, visited on 2021-01-06
[11]https://www.doctrine-project.org, visited on 2021-01-06
[12]https://www.debian.org/index.en.html, visited on 2021-01-06

	A	B	C	D	E	F	G
1	Child ID	Date	Test-ID	trial_number	item_type	name_left	name_right
96	1842	13.01.2021, 15:43	2	1	E3	E3_3a.png	E3_3b.png
97	8331	13.01.2021, 15:43	2	1	E3	E3_3a.png	E3_3b.png
98	5433	13.01.2021, 15:43	2	1	E3	E3_3a.png	E3_3b.png
99	6638	13.01.2021, 15:43	2	1	E3	E3_3a.png	E3_3b.png
100	3494	13.01.2021, 15:43	2	1	E3	E3_3a.png	E3_3b.png
101	7960	13.01.2021, 15:43	2	1	E3	E3_3a.png	E3_3b.png

	H	I	J	K	L	M
1	expected choice	given choice	accuracy	reaction time	RT_correct_answer	School (ID)
96	1	1	1	4630	4630	Test School (2)
97	1	1	1	3591	3591	Test School (2)
98	1	2	0	4249		Test School (2)
99	1	1	1	4973	4973	Test School (2)
100	1	2	0	2698		Test School (2)
101	1	2	0	3640		Test School (2)

Figure 5.32: Excel Sheet of some example "Quantity Comparison"-assignments (data has no connection to real persons)

5.3.1 Zend Framework

The Zend Framework is a PHP framework which is now continued under the name "Laminas Project"[13]. It is mainly sponsored by the company "Zend Technologies", which was founded by the creators of PHP 3 and PHP 4, Andi Gutmans and Zeev Suraski, in 1997. Other well-known companies like Google and Microsoft also have taken part in the development of some of Zend's components and features. For the development of the server Zend Framework 3 was used, the successor of Zend Framework 1 and 2. [Zend by Perforce, 2021]

5.3.2 Doctrine ORM

To make use of Object Relation Mapping, the web application was developed by making use of Doctrine ORM 2.5 and Doctrine's Migration library.

According to the Doctrine Project's website (Doctrine Project, 2021), Doctrine is a set of multiple PHP libraries which mainly focus on database storage and persistence. According to one of the blog posts on Doctrine Project's website (jwage, 2021), the first stable version of Doctrine 1.0 was released in September 2008. The most important PHP libraries of the project are the Object Relational Mapper (ORM) and the Database Abstraction Layer (DBAL). With the help of these libraries, it is possible to provide transparent persistence and straightforward database management of PHP objects for projects based on the Object-Oriented Programming Paradigm. This enables the programmer or programmers to concentrate more on the implementation of the application's business logic.

The DBAL library offers a lightweight API and additional features like database manipulation by communicating with the library's enhanced database abstraction layer built on top of PHP Data Objects (PDO). Doctrine ORM makes use of the Data Mapper Pattern, which describes an interface with a Data Access Layer performing data transfers between persistent data and in-memory data representations in both directions. The ORM library enables the programmer to create the application's PDOs and

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[13]https://getlaminas.org, visited on 2021-01-22

to let Doctrine manage all database communications to store the objects'
data by communicating with the library's API. By creating, updating, delet-
ing or searching database entries, Doctrine will execute the specific SQL
queries and return their results in form of a PDO.

The web application was developed locally and hosted on one of the TU
Graz's servers. Since the application was updated continuously after the first
deployment, it was necessary to update the server's database multiple times
if database changes were made locally. Since Doctrine was managing the
database communications it was usually not necessary to implement SQL
queries. Another project of Doctrine, Doctrine Migrations, became handy.
It provides migration files for the versioning of database schemas. In case
code of a stored model was changed, Doctrine did create new SQL queries
and bundle them in the according migration file. By updating the server's
database by running all migration files, it could be made sure the local and
server's database structure was the same and the server would function
properly after the update.

5.3.3 JSON Web Tokens (JWT)

The Internet Engineering Task Force (IETF) (Internet Engineering Task Force
(IETF), 2021) describes JSON Web Tokens (jwt) as a secure way to transfer
data between parties encoded in form of a JSON object sent as a payload of
a JSON Web Signature (jws) or as the plaintext of a JSON Web Encryption
(jwe). This results in the data being digitally signed with the use of a
Message Authentication Code (mac) or a public and private key. Each token
consists out of a header, payload and signature. The header includes the
cryptographic algorithm which is used to generate the signature. The data
sent with the token is contained in the payload and includes standard as
well as custom fields. Standard fields include:

- "jti" → JSON Token Id: a unique identifier for the token
- "iss" → Issuer of the JWT
- "exp" → The token's expiration time
- "nbf" → The time before the token must not be accepted

The token is created and signed by the server and sent to the app within a successful login response. For every subsequent request, the app has to send the JWT in the "Authorization"-header which lets the server verify if the sender has the required access rights. The JWT created by the server includes the token's standard fields and the following custom fields:

- "id" → ID of the authenticated school
- "name" → Name of the authenticated school
- "username" → The authenticated school's username used in the login mask

The JSON Token ID is initialized by the server using the PHP function "random_bytes" to create 32 pseudo-random bytes which get encoded into base64. The token's expiration date was set to 200 days at the time the prototype was released. This way schools did not have to authenticate often which makes it easier for schools without sufficient internet connection. The server name used for the "iss"-field and the secret key used for the encoding of the token are both loaded from a configuration file. The secret key is created by a pseudo-random string generator and has a length of 86 chars. Every time an API-request is received, the server checks for the token in the "Authorization"-header, checks its signature and expiration date to validate it and to authenticate the sending school.

The code to create the token while processing a successful login can bee seen in listing 5.2.

5.4 Developing an Offline Working Android App With Kotlin

Before starting the implementation of a project, it is important to answer the question which programming language and frameworks to use and which of the device's APIs will be important. In terms of the programming language and frameworks, there were multiple possible options but first it was necessary to know for which operating system the tablet app should be developed. By gathering information from schools which tablets are usually used in Austrian educational institutions it was decided to develop the

```php
<?php

public function authenticate($username, $password)
{
    ...

    try {
        $tokenId = base64_encode(random_bytes(32));
    } catch(\Exception $e) {
        return null;
    }
    $issuedAt   = time();
    // should expire after 200 days
    $expire     = $issuedAt + 60*60*24*200;
    // Retrieve the server name from config file
    $serverName = $this->serverName;
    // Retrieve the secret from config file
    $secretKey = $this->secretKey;

    // Create the token
    $data = [
        'iat'  => $issuedAt,
        'jti'  => $tokenId,
        'iss'  => $serverName,
        'exp'  => $expire,
        'data' => [
            'id'   => $school->getId(),
            'name' => $school->getName(),
            'username' => $school->getUsername(),
        ]
    ];

    // Encode the array to a JWT string.
    $jwt = JWT::encode(
        $data,
        $secretKey,
        'HS512'
    );

    return $jwt;
}
```

Listing 5.2: The code used to create the school's JSON Web Token

app's prototype for Android tablets and to start the implementation of the iOS app after the prototype has been proven successful. It was decided early on not to develop the app using a cross platform framework for iOS and Android because it was not clear how such frameworks would be able to handle the use of many audio and image files. It is also known that such frameworks often have problems when the underlying operating system installs bigger updates which change the user interface and other graphics (Juhani Lehtimäki, 2021).

The next step was to decide if the Android app should be implemented using Kotlin or Java as programming language of choice. Due to Kotlin's advantages over Java, described in the next section, the choice fell on Kotlin.

5.4.1 Kotlin

Kotlin was designed by JetBrains, a company which is known for its wide range of Integrated Development Environments (IDES) and tools, and Open-source Contributors. It can be used for the development of servers, mobile apps and also web front end applications when transpiled to JavaScript (JetBrains, 2021). Kotlin tries to address some issues in Java which can also result in faster development time if the developer has the same amount of knowledge in working with both programming languages. Some new functionalities the programming language offers:

- **Null-safety** which brings nullable references with it and simpler null-checks
- **High-order functions** which are capable of taking functions as arguments or as return values
- **Coroutines** for the usage of asynchronous operations
- **Data Classes**, **Singletons** and **Companion Objects**

Especially the new concept of Coroutines, Null-safety, Data Classes and Companion Objects become handy while the development.

Null-safety and Null-checking

Due to other programming languages already having Null-safety and Null-checking implemented in some way or another, like Swift or the new version of JavaScript under the ECMAScript 2020 standard (Ecma International, 2021), it will be seen more recently in the future. These features make it more easily for the developer to check multiple chained objects for null values which has to be done with multiple lines of code in some other programming languages. The ability to check multiple values against null in a few lines can make the code more readable and can result in faster development time.

Coroutines

Kotlin's Coroutines were mainly used in the implementation to access the application's UI-thread within a background thread or to fetch, save or delete data from the local database asynchronously.

Data Classes, Singletons and Companion Objects

Data Classes have the purpose of holding data and come with some standard functions like `equals()`, `toString()` and `copy()`. In the Android application's code Data Classes were especially used for the implementation of Room's Entities but retrospectively could have been applied more often.

Singletons are already known from other programming languages and were only used for defining classes of services, like the APIManager.

Something new about Kotlin is the "`companion`" identifier. Since Kotlin does not have a "`static`" keyword, defining a static function has to be done by using a Companion Object. Inside a class with the need of static functions, the developer has to wrap all implementations of the functions which should be able to be called without initializing the object, inside the "`companion`" identifier's brackets.

5.4.2 Local Storage of Screening Data and Files

As already mentioned in section 5.1 one of the app's requirements was to function properly also while being completely offline. This resulted in the requirement to save the results of all done screenings locally and to have the functionality to upload it at a later point of time. To store data locally there are three possibilities when developing Android applications[14]:

1. **App-specific storage** which can only be accessed by the app itself
2. **Shared storage** which can be shared between apps
3. **Preferences** which can be used to store simple data in key value pairs, it can only be accessed by the app itself
4. **Database** which lets the developer store more structured data that cannot be accessed by other apps

For the development of the app, it was necessary to use the database storage for storing the data of the screening itself, its assignments and the screening results. The database of the Android app can be accessed using Android's Room[15] library. The assignment's audio and images files are stored using Android's app-specific storage to save a local copy of them.

Room Library

For the persistent storage of structured data Android offers a library called "Room". It is based on an abstraction layer over a underlying SQLite database offering compile-time verified SQL queries, database migrations and convenience annotations in form of "Data Access Objects" (DAO) and "Entities". [Google Developers, 2021]

The Entities are used to define the data structure of the underlying object. By using the annotations "`@PrimaryKey`", "`@ColumnInfo`" and some other ones, the developer is able to set specific information about the object's fields without the need of writing SQL queries to setup the app's database.

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[14]https://developer.android.com/training/data-storage, visited on 2021-01-12

[15]https://developer.android.com/training/data-storage/room, visited on 2021-01-12

Room's DAOs offer to define methods to fetch, find, insert or delete data objects. Room already provides convenience methods that perform simple inserts, updates and deletes without the need of writing own SQL queries. If the developer wants to fetch data from the database in form of a specific query, every query method can be linked to a SQL query which can access the arguments provided by the method.

Due to some database changes on the server while the prototype was already used, also the app database had to deal with changes in the data structure. Therefore, it was also necessary to handle migrations in the app's implementation. Room's "DatabaseBuilder" offers a method to pass database migrations in form of bundled SQL queries to handle database updates. Every migration awaits the current database version of the app performing the migration and the version of the database to which the app should migrate. In case the app did not perform some database updates before and the newest app version is loaded, all meanwhile migrations are run one after another. One example migration is shown in listing 5.3.

```kotlin
private val MIGRATION_1_2: Migration = object : Migration(1, 2) {
    override fun migrate(database: SupportSQLiteDatabase) {
        // Since we didn't alter the table, there's nothing else to do
        ↪  here.
        database.execSQL("CREATE TABLE IF NOT EXISTS
        ↪  `PhBAssignmentEntity` (`id` INTEGER NOT NULL, `test_id`
        ↪  INTEGER, `audioFileName` TEXT, PRIMARY KEY(`id`))")
        database.execSQL("CREATE TABLE IF NOT EXISTS `PhBChoiceEntity`
        ↪  (`id` INTEGER NOT NULL, `assignment_id` INTEGER, `imageName`
        ↪  TEXT, `audioName` TEXT, PRIMARY KEY(`id`))")
    }
}
```

Listing 5.3: An example migration used with Room's "DatabaseBuilder"

6 Evaluation

The very first prototype of the School Start Screening app has taken part at the beginning of 2019 and did only consist out of the first three assignments. While the screening took part, the app was in constant development of the remaining assignments. In September 2019 the next screenings, with all of its planned assignments, happened to assess the same children as at the beginning of 2019 as well as some multiple children which were not assessed before. With the screening at the end of 2019 there were assessed more than 800 children in 25 schools altogether.

To evaluate the web application and the mobile Android app, two employees of the University of Graz's Institute of Developmental Psychology were interviewed about their experiences using the web application and the reviews they got from schools which were using the School Start Screening app. Furthermore, the Austrian Ministry for Education, Science and Research made a survey about the schools' experiences using the new tablet-screening in June 2020. The asked questions and their associated answers, including data from the survey are described below.

Q: Did the app's and web application's implementation conform the expected requirements?

Since the tablet app and the web application were developed while an employment at the University of Graz's Institute of Developmental Psychology, every change in the applications' software was first discussed with the developmental psychologists. Therefore, the developmental psychology team was able to give feedback immediately and was up to date throughout the whole implementation process. This resulted in the assignments being implemented as good as possible to match the expected requirements, except some technical problems which are described more detailed later.

Q: Where there problems when assessing children with the tablet app?

As already described in the implementation chapter, the web application's screening results download had to be adapted because of the quickly increasing number of screening results uploaded by the schools. The new functionality to download every few hundred results was a quick solution to enable the psychologists to download the results again but was not that intuitive according to them. Furthermore, while the screenings took part there were some technical problems encountered for some assignments which happened every now and then.

The very first prototype at the beginning of 2019 happened to crash if multiple screenings were done one after another. This was because of an Out Of Memory (OOM) exception due to image files created inside the code instead in one of Android Studio's layout files. This problem was fixed immediately by deallocating the memory used for the image files after the assignment was done.

A problem whose origin could not be found during the implementation, was that some audio files sent by the server while a screening update, were not saved locally on the app. Since the problem only occurred sometimes, although the Android app did check for HTTP errors while the file download, the problem became known not until the first schools had problems because the app did show an alert view implemented to catch errors and to display them. Since the source of the problem could not be found and the problem needed to be resolved as soon as possible, a workaround had to be implemented quickly. To be sure that indeed all files have been saved, the app checked if it was able to access every file right after the screening update finished. In case at least one file could not be found, the app displayed an error and asked to user to try to run the screening update again.

Q: What were the teachers' experiences using the tablet app?

With the exception of the few technical issues that may arise in some screenings, the majority of teachers was really satisfied with the app and its user experience. The teachers also would choose the app over the paper-pencil screening to assess the children because of its better usability and advantages like less paper work. Some teachers only had problems with the length of the screening which could take up to 40 minutes. However, this is not influenced by the app's implementation but by the number of assignments and by the time the child takes to solve an assignment.

Q: What were the children's experiences using the tablet app?

The children got along very well with the app and most of them did not have any problems using it. However, teachers reported that some children which were not familiar with tablet computers needed some help first. Since the screening supervisor is next to the child while the whole screening, these children could be helped and were able to work normally with the app afterwards. Nevertheless, no child was overwhelmed using the app.

Q: Do you believe that the new digital screening will actually be used in all Austrian schools in the future?

Since the current situation of the schools being partly or fully closed because of the current coronavirus pandemic, a fully detailed evaluation by developmental psychologists has yet to be carried out. Teachers from schools which already made use of the new screening method vary in their opinion on its future utilization at children's school start. 70% of teachers see the new School Start Screening as an additional helpful basis for decision-making, according to the Ministry's survey. However, less than half of the school principals surveyed would primarily base their decisions on its results and only 8% believe that the new screening would be used by most schools if the use is voluntary.

Q: How was your (the developmental psychologists) experience using the web app?

Due to some restrictions implemented for the web application, like the restriction to delete saved schools and to edit already assigned screenings, the developmental psychologists had to become familiar with some of the web application's functionalities first. Furthermore, the developmental psychologists reported that the screening creation would take up too much time, therefore the function to copy a screening and its assignments was implemented, as reported in section 5.2.3. Other functionalities like the possibility to delete assigned screenings or schools could not be implemented because there could already be some screening results saved for the screening or school to delete.
According to the developmental psychologists, more filter options implemented in the screening result download also would improve the user experience and be beneficial for the psychologists' handling of the collected

results. This could include the possibility to filter by the day the screenings were done or for example only to download screening results of one assignment.

Q: How well did you (the developmental psychologists) get along with the app yourself?

The developmental psychologists reported that they found the assignments' implementation intuitive and well designed.
However, it would help to create assignments and test them before the screening can be performed by schools, if it would be possible to test the new assignment with the app without the need to perform a whole screening. This could be solved for example by integrating a test environment only accessibly for admin users when logged into the mobile app in the future. A pause button integrated into the screening process would also be beneficial in case the screening has to be stopped. This feature would be useful in the future in case the child has to go to the toilet or the screening is interrupted by something.

7 Conclusion

This thesis focuses on the implementation of a new way to assess children at preschool age in Austria by using a tablet screening application. As described in the first chapters, screenings are used for early pediatric examinations to determine the children's level of development, if needed. Digital screening methods are also already present for some years but are not yet common. On the one hand it is new to assess every child in Austrian schools at their school start in the future and on the other hand it is new territory to use a complete software infrastructure to manage and carry out screenings in Austria. The prototype application could be used by voluntary schools which could choose between the School Start Screening app and the paper-pencil screening, both consisting out of the exact same assignments. This made it possible to compare the schools' opinions on both screening versions and to look closer on the reviews of the screened children.

After the School Start Screening app's structure and layout was designed, the tablet and web application were implemented and discussed with the developmental psychologists to meet their requirements for their developed assignments as good as possible. Furthermore, the illustrated graphics, made by the designers, and the recorded audio files helped to create a motivating and entertaining tablet app for children. Since the development time for the first prototype was limited and the prototype had to be ready to use in a few weeks, only the API could be tested automatically but there was not enough time for automatic unit and user interface tests for the tablet app. In case more automated tests could have been implemented, some bugs may have been prevented.

The evaluation of the new School Start Screening app showed that the children as well as teachers welcome the new screening method in form of a tablet app. Only very few children had first problems to use the app because

they were not familiar with tablet computers. According to screening reviews from schools, the children as well as the teachers liked the mobile app and would it prefer over the paper-pencil screening. Except some technical problems in form of bugs during some screening runs and some areas for improvement, the app's prototype did perform very satisfactorily and convinced that it would outperform the use of the paper-pencil screening, especially when working on the suggestions for improvement from teachers and the developmental psychologists.

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