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Educational and Cybersecurity Applications of an Arabic CAPTCHA Gamification System

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ABSTRACT

A ubiquitous challenge-response mechanism, the Completely Automated Public Turing test to tell Computers and Humans Apart (CAPTCHA), primarily serves to distinguish between human users and automated bots. The presented work introduces an innovative Arabic CAPTCHA gamification system designed to concurrently address two critical aspects. The first aspect is centered on the pedagogical application of the system, particularly its employment in teaching young learners the Arabic alphabet. This is achieved by posing interactive queries based on displayed word images, thereby facilitating the practice and enhancement of Arabic letter recognition and typing proficiencies. The second aspect integrates a cybersecurity awareness component into the system. As learners engage with the game and advance through its levels, they are concurrently exposed to pertinent information and guidance regarding cyber threats and safe online practices. This dual-purpose approach serves to inform and empower learners, providing them with the necessary skills to navigate the digital landscape securely. The novelty of this work lies in the fusion of these two aspects, offering a uniquely comprehensive learning experience that not only bolsters language skills but also cultivates cybersecurity awareness, a critical facet of digital literacy in our increasingly interconnected world. To the authors' knowledge, this work represents the inaugural implementation of an Arabic CAPTCHA gamification system, making it an advantageous resource for anyone seeking to learn Arabic letters and word formations.

1. INTRODUCTION

In the contemporary digital era, the internet has become an increasingly primary source of knowledge acquisition for the younger generation. This has led to the emergence of a plethora of websites, applications, and games specifically designed to educate children in various disciplines. Additionally, there is a growing trend among parents to utilise educational games as a novel pedagogical method, thereby enabling their children to acquire knowledge while enjoying leisure time.

Coinciding with the rise of the internet's prevalence is the heightened prevalence of cybersecurity issues, impacting users of all ages, including the young demographic. Young users have been targeted by malicious websites for activities such as identity theft, phishing, and other cyber-crimes. To mitigate these threats, the concept of CAPTCHA (Completely Automated Public Turing Test to Tell Computers and Humans Apart) was introduced as a challenge-response test to discern between genuine human users and malicious bots [1].

In this investigation, a novel concept is explored: the integration of educational games with cybersecurity awareness promotion among young users. This paper details the proposed solution: an Arabic CAPTCHA gamification system. The system aims to enhance user engagement while educating young individuals about cybersecurity, with a focus on teaching the Arabic language. This focus is attributed to the substantial number of Arabic-speaking internet users [2] who require awareness about cyber threats, and the unique syntactical features of Arabic script [3, 4] that lend themselves to interactive challenges based on the script itself, thereby providing a fertile ground for building gamification systems based on linguistic features.

The objective is to develop an engaging game suitable for both children and individuals interested in learning Arabic letters. The game will feature numerous levels, each offering diverse problem-solving approaches. The database of the game will include pre-generated images with multiple question types, enabling a single image to be used across various levels with differing question formats.

A variety of functionalities will be incorporated into the game levels, such as posing questions related to Arabic letters and words, with answer options including multiple choice, written responses, and drawing-based answers. Completion of each level's activities will be required before progressing to the next level, ensuring that players gain a solid foundation in writing and spelling Arabic letters.

The game will also disseminate valuable information and guidance regarding cybersecurity and internet risks. The aim is to collect data through in-game research which will be instrumental in the improvement and future debugging of the application. This includes statistics gathered via gamification, such as solving times for different challenges, error rates, and types of errors made by users. These statistics can later be utilized to modify the challenges (if necessary), to determine the sequence of challenges for multi-level authentication, etc.

The end product is an integrated application that amalgamates Arabic language learning and cybersecurity

awareness through solving interactive CAPTCHA challenges. The contributions of this work are as follows:

- Development of an accessible and user-friendly game for individuals of all ages.
- Creation of interactive challenges to enhance Arabic letter typing skills and navigate CAPTCHA tests.
- Compilation of valuable data for research and debugging purposes.
- Advancement of cybersecurity awareness among users.
- Integration of entertainment with learning Arabic letters.
- Provision of advice and useful information throughout the game.

The idea fuses CAPTCHA images with an educational game, delivering knowledge in an entertaining format. Users can engage with the game while gaining awareness of cybersecurity risks. Cybersecurity and internet risk awareness are prioritized as rewards, given the limited knowledge among children in this area. Moreover, user data is leveraged for research to improve the application and generate more effective CAPTCHA challenges. The system is targeted at individuals wishing to learn Arabic letters and word-formations and is suitable for both Arabs and non-Arabs, as the interactive challenges utilized do not assume the ability to speak Arabic.

The remainder of the paper is structured as follows: Section 2 discusses related works. Section 3 elaborates on the methodology used to specify the system architecture. Section 4 provides details on the implementation. Finally, Section 5 concludes the paper.

2. BACKGROUND STUDY

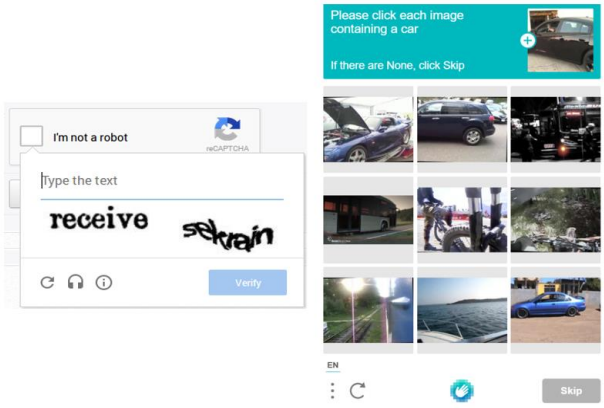
The Arabic language has accrued significant importance over time, owing to its association with the Qur'an, its copious vocabulary, and its sophisticated grammar that bolsters communication and imparts an enchanting and expressive quality. The prominence of Arabic among other languages is undeniable.

In the context of today's technologically-driven world, languages, including Arabic, have adapted to leverage applications and websites for pedagogical purposes. The novel approach proposed herein integrates the CAPTCHA challenge-response system to support Arabic letter learning.

CAPTCHA images are employed to visually instruct beginners on distinguishing between letters or words. Through engagement with questions and activities centring on the CAPTCHA image, learners are enabled to identify and type the represented letters. The questions are structured into activities, which are further consolidated into levels. Progression to subsequent levels is contingent upon completion of the current level, ensuring a sequential increase in complexity.

2.1 Existing CAPTCHAs

In this subsection, pertinent works on handwritten text-based CAPTCHAs for Latin and Arabic languages are discussed, along with some works on interactive CAPTCHAs. Figure 1 depicts examples of existing CAPTCHA systems: a text-based CAPTCHA system (termed reCAPTCHA) utilizing English words (Figure 1 (a)), and an interactive CAPTCHA system (also termed reCAPTCHA) employing images of diverse objects (Figure 1 (b)).



(a) reCAPTCHA (b) hCAPTCHA

Figure 1. Illustrations of some existing CAPTCHA systems

2.1.1 Latin handwritten CAPTCHAs

A considerable body of research has been devoted to exploring the generation of handwritten Latin text-based CAPTCHAs, with a diversity of methodologies being reported [5-12]. Several studies [6, 8, 9] have concentrated on amalgamating characters into non-joined words, mimicking cursive writing. These investigations exploited a database of 4,000 handwritten images of US city names to formulate CAPTCHAs, which were deciphered through the typing of characters. The security of such CAPTCHAs was gauged by automated word recognizers.

In parallel research [11], the Gestalt laws of organization were harnessed to design CAPTCHAs. Further, two investigations [10, 12] presented handwritten CAPTCHAs arranged in a tree structure, with their evaluation being conducted through word recognizers and usability testing involving a select group of volunteers.

2.1.2 Arabic handwritten CAPTCHAs

Research on handwritten Arabic text-based CAPTCHAs has been relatively sparse, with only a few studies addressing this domain [2, 4, 13-15]. One such study [2] leveraged the KHATT database [16] to generate handwritten Arabic CAPTCHAs. A segmentation-validation-based methodology [4] was also proposed, which used synthesized handwritten Arabic texts for CAPTCHA generation. This approach stands out as the only work in the domain of handwritten Arabic text-based CAPTCHAs that deploys validation methods beyond simply writing the characters. However, it faced usability-related challenges [4].

Another investigation [14] employed handwritten letters to pioneer a multilingual approach to CAPTCHA generation, although its usability was not evaluated.

2.1.3 Interactive CAPTCHAs

The field of interactive CAPTCHA schemes, which necessitate user engagement with the presented CAPTCHAs, has been probed to augment security. An exemplar of such schemes is the 3D CAPTCHA proposed by Winter-Hjelm et al. [17], which integrates semantic information and common-sense knowledge. In a separate study [18], a CAPTCHA scheme was introduced that demanded users to draw lines with light pens to join specific points on a screen. The drag-and-drop CAPTCHA approach [19], predicated on mouse events for human verification, was also proposed. For mobile devices, a methodology was suggested [20] that transforms keyboard-

entry CAPTCHAs into clickable formats. Moreover, a game-based image semantics approach [21] was introduced to ensure both security and usability. In a novel development [22], a CAPTCHA system predicated on movie-based quizzes was proposed, taking advantage of humans' capacity to discern unusual storylines in short films.

2.2 Learning Arabic

Numerous applications have been developed for the purpose of facilitating Arabic language learning. One such application, Teach Me Arabic, is specifically engineered for non-native Arabic speakers aiming to acquire proficiency in the language [23]. The app offers a plethora of activities, live sessions, and evaluative tests, enriching the learning experience. Additionally, it features an expansive library that encompasses voice lines, video recordings, diagrams, and educational narratives [23].

Teach Me Arabic presents a comprehensive ensemble of Arabic vocabulary and poses diverse types of questions. However, it may not cater adequately to beginners, particularly children or individuals who have only recently embarked on their Arabic learning journey. Some questions necessitate an understanding of Arabic grammar, even at the nascent stage. Moreover, certain questions demand familiarity with the meanings of specific words to furnish the correct responses.

Another noteworthy application is Learn Arabic with the Quran, designed to streamline Arabic language learning through the vocabulary of the Holy Quran [24]. Its salient feature enables learners to read, comprehend, and memorize the Quran with greater ease. The application also provides additional features, such as intelligent learning, an extensive collection of over 1500 Quranic vocabulary words, and stress-free learning bolstered by online instructors [24].

An exceptional aspect of the application is its interactive approach to learning Quranic words, complemented by effective techniques for Quranic letter memorization, significantly benefiting learners in their Arabic language acquisition. However, the application may lack certain educational features and its usage might be restricted in some aspects.

Existing CAPTCHA systems are typically customized to specific objectives, with each featuring a unique approach. To the best of our knowledge, no existing Arabic CAPTCHA systems incorporate educational facets within their system designs. Furthermore, current Arabic learning games/applications focus primarily on language learning. These two limitations of the existing systems inform the inception of our work. We thus propose a novel approach that amalgamates CAPTCHA solving systems with language learning methodologies in an interactive and intuitive game. Text-based CAPTCHA generation, inspired by reCAPTCHA and hCaptcha, is integrated into the game. Additionally, learning techniques derived from both the Teach Me Arabic and Learn Arabic with the Quran applications are incorporated to augment the learning process within the game.

3. METHODOLOGY

In this section, we provide the detailed survey results for our system analysis and specification. Based on the survey results, we organize the requirements for a CAPTCHA gamification system.

3.1 Problem specification

The primary challenge of this work lies in providing children throughout the Arab world with an effective and engaging way to grasp the fundamentals of the Arabic language. At the same, we want to make the young learners aware of cyber threats. Therefore, we combine teaching Arabic through solving CAPTCHA images that raise the awareness of cyber security:

3.2 Solving CAPTCHA+cyber awareness=CAPTCHA gamification system

Our proposed solution involves teaching Arabic letters using CAPTCHA images. To achieve this, we need to introduce a novel learning method that greatly assists learners. One such approach involves testing learners on their ability to recognize and identify Arabic letters amidst a cluster of random lines or points, leveraging the utilization of CAPTCHA.

In summary, we have chosen the CAPTCHA method as it ensures that new learners memorize the letters effectively and enables them to differentiate between various Arabic letters. Our objective is to develop an algorithm that generates CAPTCHA images, employ image processing techniques to analyze these images, and establish a well-managed database to store the generated images. Additionally, we intend to gather valuable data through surveys to better understand the desired features of a new Arabic letter game.

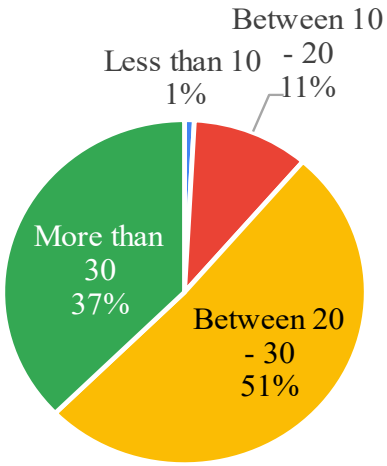
3.3 System analysis

A survey was conducted to gather feedback on the concept of Arabic letters learning through CAPTCHAs, with a total of approximately 115 responses. The survey forms were distributed amongst the students in Qassim University through various student groups and amongst the acquaintances of the researchers. Participation in the survey was completely voluntary and there were no rewards involved in filling the survey. The participants were informed about the goals of the survey before they filled the forms. The analysis presented here focuses on the data collected from students and adults who participated in the survey.

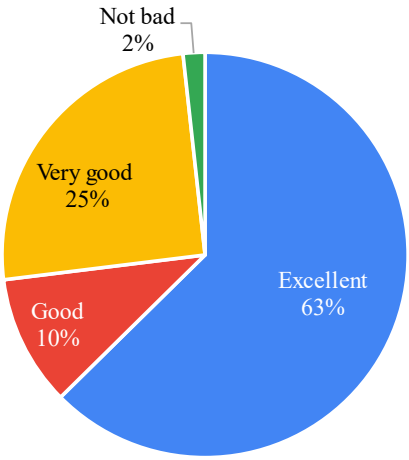
Upon analyzing the data, it was observed that the majority of participants in our survey as depicted in Figure 2 (a) fell within the 21 to 30 age range. Consequently, our game is primarily aimed at young individuals and novice learners, and it is crucial to ensure that the game is engaging and relevant, especially for the younger age group. In Figure 2 (b), it is evident that a significant number of respondents possess excellent Arabic language skills, both in terms of reading and writing. Considering the positive feedback from adult Arabic speakers about the usefulness of our system, we have high hopes that young learners will find it even more valuable. Furthermore, Figure 2 (c) reveals that a considerable portion of the participants are familiar with or have prior knowledge of the CAPTCHA system. This finding is significant as it indicates that the participants' feedback regarding CAPTCHAs is based on their understanding and experience with the system.

Figure 3 reveals positive opinions about the idea of an Arabic learning game with CAPTCHA. Participants expressed excitement and agreement with the concept. Some participants

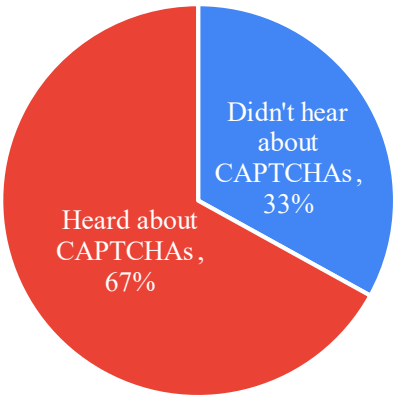
expressed concerns about the game's effectiveness and the difficulty of Arabic letters. They felt that the points on certain letters could be confusing for learners. However, the majority of respondents showed enthusiasm for the game. Despite these diverging opinions, the overall consensus favors the development of an Arabic learning game with CAPTCHA. The excitement expressed by a significant number of participants indicates a genuine interest in such an educational tool. These differing opinions provide valuable insights for us, allowing us to address potential challenges and incorporate necessary modifications to ensure an effective and efficient learning experience.



(a) Distribution of ages of participants



(b) Levels of Arabic skills of participants



(c) People's knowledge about the CAPTCHA system

Figure 2. Summary of survey results

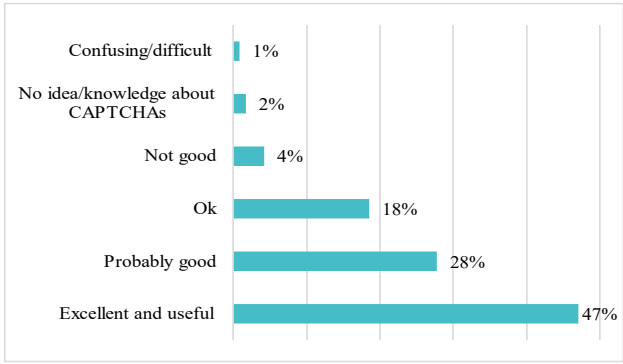


Figure 3. Opinions of participants regarding an Arabic learning game with CAPTCHA

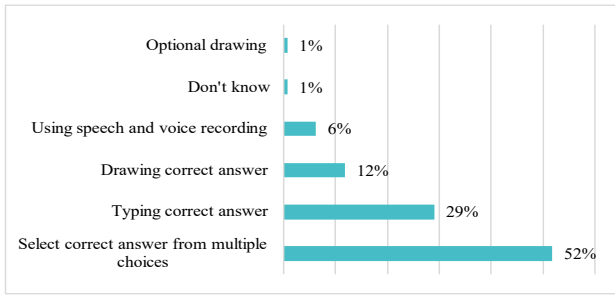


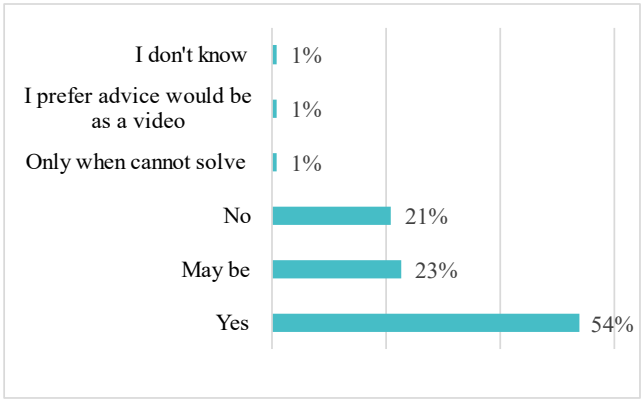
Figure 4. Participants' opinions about the preferred ways to solve text CAPTCHAs

The survey included a question regarding participants' preferred method for answering CAPTCHA challenges. This aimed to gather insights on people's opinions about the most effective way to provide accurate responses at a CAPTCHA level. Figure 4 shows that many participants prefer selecting the correct answer from multiple options. This approach allows for quick and efficient CAPTCHA solving. It would be interesting to see whether challenges based on 'selecting correct answer from multiple options' is also the least difficult one through experimentations.

However, we don't rely on a single method but combine multiple techniques for a comprehensive learning experience. We integrate writing answers, identifying images, and solving noisy images to engage learners and enhance effectiveness. Diverse methods expose learners to various challenges, promoting holistic understanding of Arabic letters.

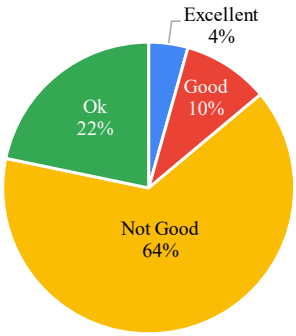
Figure 5 illustrates some more details on the survey results. As can be seen in Figure 5 (a), participants generally had positive opinions about receiving advice on cyber security after passing levels in a game. They recognized the importance of raising awareness about cyber security and appreciated it as a rewarding feature. They believed that such advice would enhance their understanding of risks and promote safer online practices. Some participants expressed concerns about the advice interrupting gameplay or being time-consuming. However, most participants considered cyber security advice valuable for improving their knowledge and online protection abilities.

Moreover, as can be seen in Figure 5 (a), the majority of respondents expressed their agreement with the idea of providing advice after passing a level in a game. Some participants suggested that the advice should be in the form of video clips, while others mentioned that advice could also be given after losing a level, which was considered valuable feedback.



(a) People's opinions about giving advice on cyber security after passing any level inside any game

(b) Samples of CAPTCHA images to be used in the game



(c) Opinions of participants regarding images from (b)

Figure 5. More details from survey results

In Figure 5 (b), we presented a set of text-based CAPTCHA images that included handwritten words. These images were intentionally designed to be noisy and distorted for security reasons. However, based on the feedback we received Figure 5 (c), it became evident that many individuals found the handwritten words to be challenging to solve. Consequently, we have determined that it would be best to refrain from incorporating this particular style of CAPTCHA in the initial levels of the game. Instead, we believe it would be more suitable to introduce this style in the advanced levels, where it can provide a greater level of difficulty and serve as a more challenging task for the players.

During our survey, we requested participants to type the handwritten text shown in Figure 5 (b). The results, as depicted in Figure 6, revealed that a significant number of individuals struggled to accurately transcribe the text, while some managed to provide the correct answers. This observation highlights the inherent difficulty in interpreting and responding to this particular style of CAPTCHA. In light of these findings, we recognize the need for a more legible CAPTCHA format that enables learners to successfully respond to the challenge while also facilitating their learning experience.

In our survey, we presented another type of CAPTCHA images Figure 7 (a), different from those in Figure 5 (b) and collected participants' opinions regarding these images. Notably, in Figure 7 (b), a significant number of individuals expressed a preference for the style of CAPTCHA images in Figure 7 (a). This positive response can be attributed to the perceived simplicity and legibility of the words displayed in Figure 7 (a). As a result, we can conclude that this particular type of generated CAPTCHA image is well-suited for the initial levels within our application, ensuring an accessible and user-friendly experience for learners.

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رقمطه. زبغم رمنسلخ
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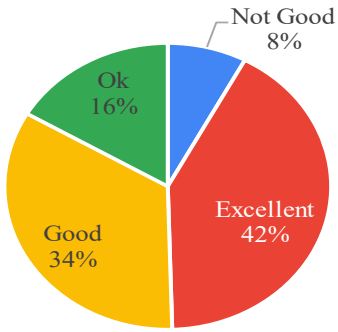
Figure 6. Transcriptions of participants for the CAPTCHA images shown in Figure 5(b)

(a) Samples of different types of text-based CAPTCHA images



(b) Opinions regarding the images from (b)

Figure 7. Different type of CAPTCHA images with opinions about those images

During data collection, we actively gathered participants' suggestions for the Arabic learning game. Many individuals recommended including levels with words written in the old Arabic style, without diacritical marks or points, to expose learners to different script styles. Participants also emphasized the importance of making the game suitable for all age groups, with adaptable content and difficulty levels. By this way, the game can attract a wider audience and effectively serve as an inclusive educational tool.

As for the validity and reliability of the survey results, the following comments can be made. Most of the participants of our survey are not from the target age group of the proposed application. This is expected, as those who are just learning Arabic cannot reliably suggest suitable challenges for learning Arabic! However, we expect that, Arabic speaking adults (who already have passed through the learning phase) can share their experiences in learning Arabic, which in turn would help us in

designing challenges in the proposed game. Another issue that should be addressed is the demographic distributions of the survey participants. In our survey, the participants are all from Saudi Arabia. The question is whether this demographic distribution affects the design of challenges or not. The answer to this question can be safely said as a 'No'. This is because, the challenges used for CAPTCHA images are based on Standard Arabic, and thus suitable for any person willing to learn Arabic through our game.

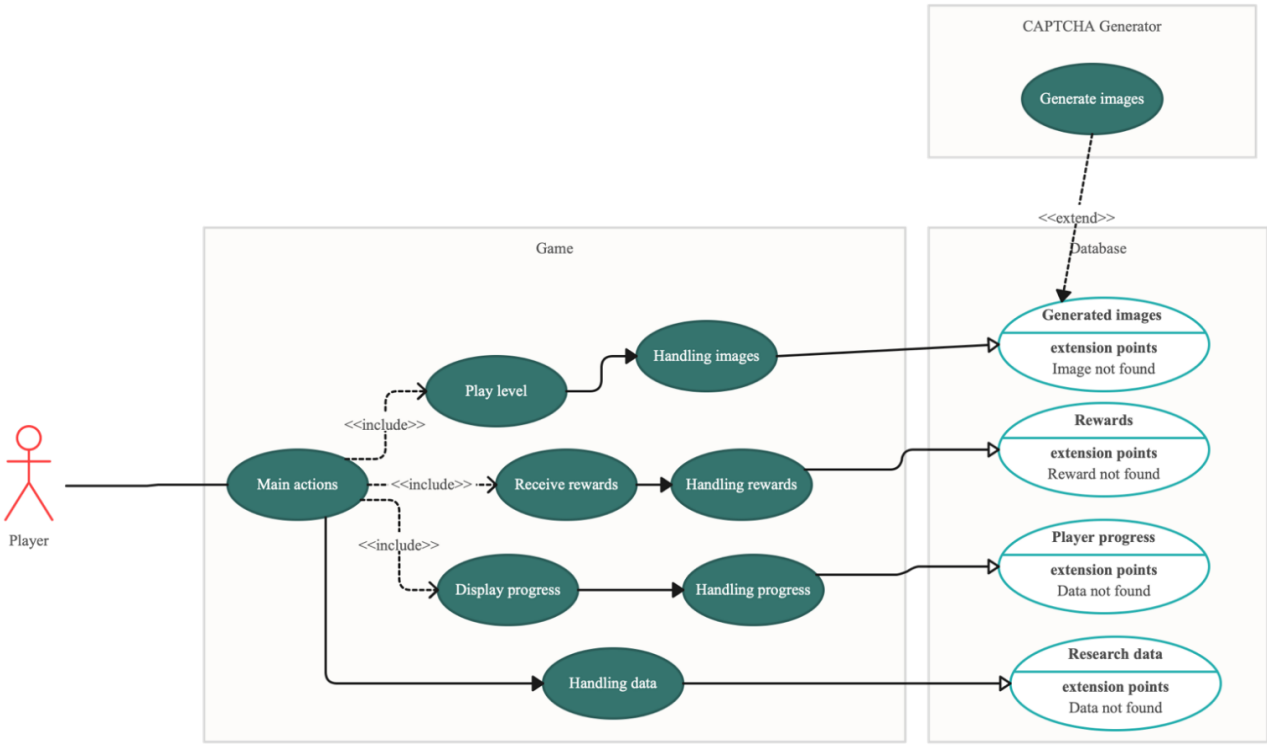


Figure 8. Use case diagram of the proposed CAPTCHA game

3.4 Requirement analysis

The following functional requirements have been identified:

- Users should be able to engage in levels that offer various activities.
- Access to new levels should be granted upon successful completion of previous levels.
- The system should provide users with advice or guidance upon successfully solving a level.
- Collected data about level progression and user responses should be stored for research purposes.
- Difficulty levels should be determined and progressively increased as users advance through the game.
- A random question selector should be implemented to ensure variety within levels.
- Multiple worlds should be incorporated to introduce additional activities and challenges.

3.5 Requirement organization

The use case diagram depicted in Figure 8 illustrates the core components of the CAPTCHA game. Players have the ability to engage in levels, earn rewards upon successful completion, and track their progress. User information, images, rewards, and research data will be stored in a database.

Brief descriptions of the various components in Figure 8 are given as follows. We use 'CAPTCHA Generator' as an offline (pre-processing) phase where synthesized Arabic words are distorted using various noises to build CAPTCHA images. During this phase, we also generate the ground truth values for various challenges related to each CAPTCHA image. During game-time, a user (player) is involved in four different kinds of activities. A player plays the game through various levels, where each level involves pre-generated CAPTCHA images stored in the database. The player also earns rewards while progressing through the levels and these rewards are stored in the database as well. The player can view his current status in the game and his progress in the game is also stored in the game database. Finally, statistics of solving various CAPTCHAs are collected from the players while they play the game and these statistics are used to further improve the game itself.

4. SYSTEM DESIGN AND IMPLEMENTATION

In this section, we present the design architecture of our Arabic CAPTCHA gamification system. We also show some screen shots from the developed application for the gamification.

4.1 Design specifications

Figure 9 illustrates the main design of the CAPTCHA game and player interaction. The 'Generator' creates CAPTCHA images, which are stored in the game database. The database includes the generated images and research data. The game features different levels, rewards with cyber security advice, and player progress indicating the current level.

4.2 Design architecture

Here, we will explain the main components of the game's systems and their relationships with each other. We will explore the flow of data between games and the structure of the database, as well as how game components are categorized into classes. The abstract data flow in the game's components is depicted in Figure 10. Notably, the CAPTCHA generator is distinct from the game itself, allowing for the pre-generation of game images. This approach is implemented to optimize the game's performance.

Figure 11 illustrates the detailed data flow within the level component. Within this flow, the 1.2 Random Question Generator randomly selects a CAPTCHA image from the image database. Subsequently, it generates questions based on the selected CAPTCHA image, taking into account the specific question type. In Figure 12, we observe that research data is directed towards the database for storage purposes. On the other hand, advice is stored separately from the game's database in order to enhance the overall performance of the game.

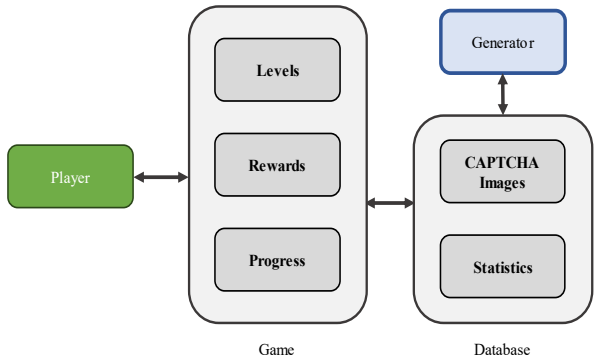


Figure 9. Relationship of a player with the CAPTCHA game

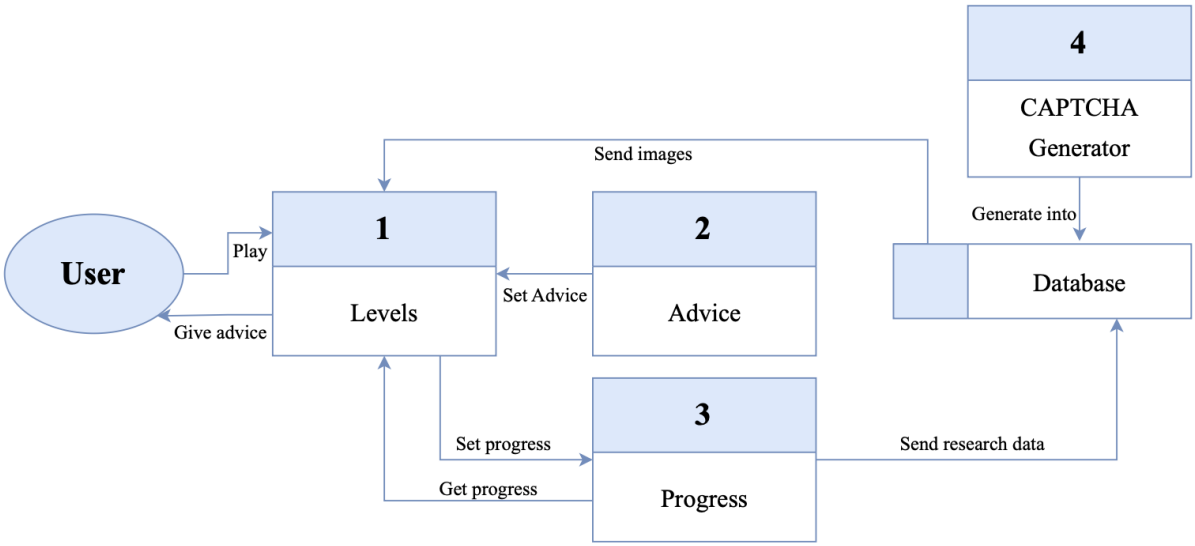


Figure 10. Data flow diagram of the game at level 0

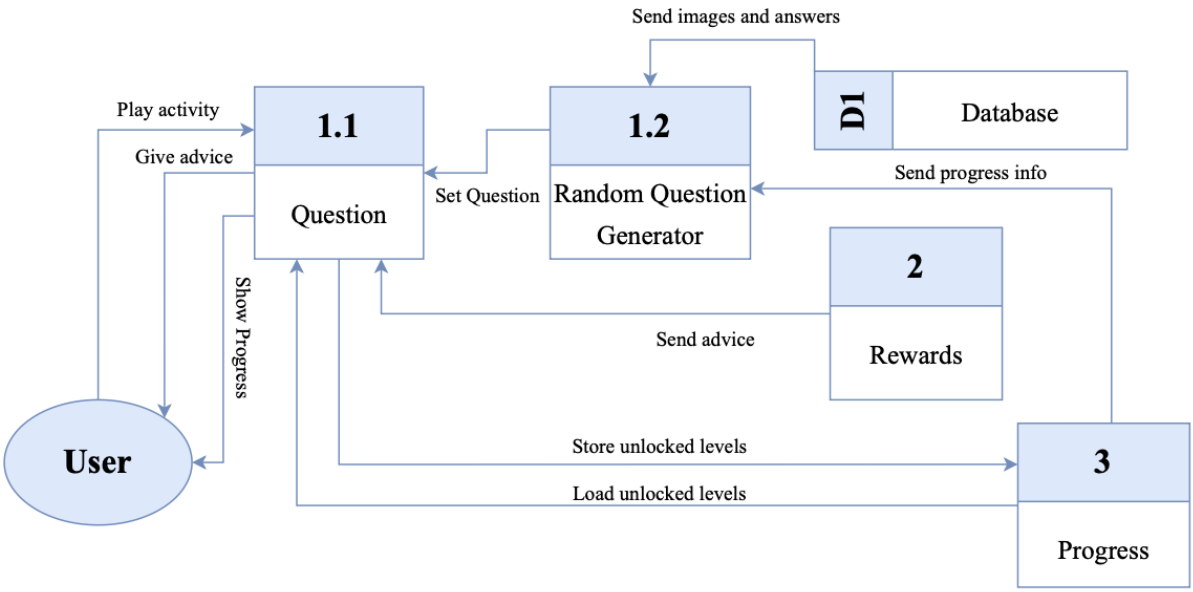


Figure 11. Level 1 of DFD shows the detailed data flow in the levels

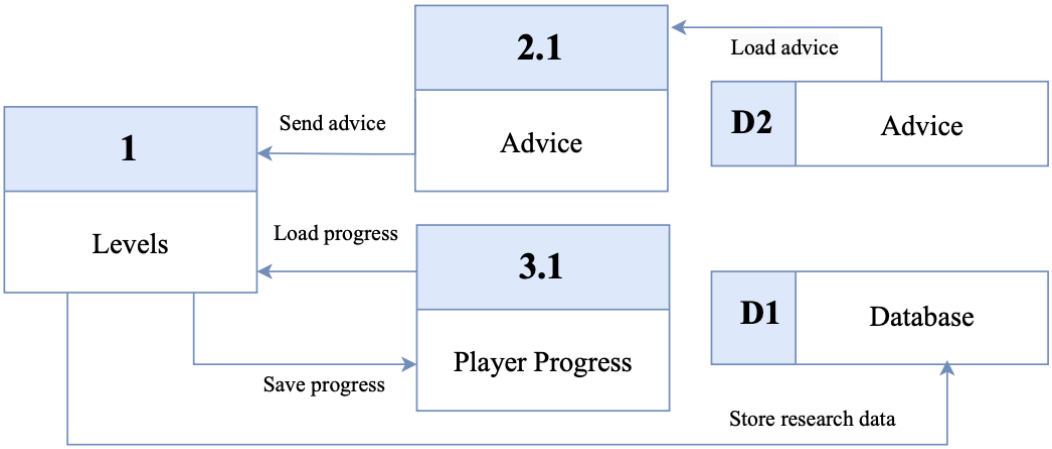


Figure 12. Level 1 of DFD shows the detailed data flow in rewards and player progress

4.3 Implementations

In this section, we describe the details of implementing the CAPTCGA game.

4.3.1 Generation of CAPTCHA images

In our CAPTCHA gamification system, we generate CAPTCHA images using synthesized handwritten Arabic words. These synthesized words are created by combining isolated or broken characters previously written by different writers. The synthesis process enables us to generate a vast number of meaningless words with accurate data on the number of characters and their joining points.

The synthesis model utilized in this work is based on the system described by Parvez and Alsuhibany [4]. Figure 13 illustrates an example of a synthesized Arabic word. Broken characters can be generated through segmentation of images of written words or by requesting writers to produce characters in broken forms.

(a) Arabic characters in broken form (b) Broken characters joined to synthesize a word

Figure 13. Demonstration of the synthesis process for creating a handwritten Arabic word

4.3.2 CAPTCHA challenges

Table 1. CAPTCHA challenges in each level

World	Level	Challenge to Solve for a CAPTCHA Image
1	1	How many dots are there in the image?
	2	Are there any dots in the image?
	3	How many letters are there in the image?
2	1	Are the letters (equals-less than-more than) (number) in the image?
	2	What is the order of the letter (random letter will be chosen)?
	3	Is there a letter (random letter to be chosen)?
3	1	How many Madd letters?
	2	Is there any Madd letters?
	3	Are the letters connected (متصلة)?

Table 1 lists the challenges used in each level of the game. These challenges were selected based on the survey results discussed earlier. Overall, the game has three modules (called 'Worlds'). Each world contains three levels. Each level contains a specific kind of question, which is called as a 'challenge' in our game. Note that, the difficulty levels of challenges increase as the player moves through the levels and worlds. The difficulty levels for CAPTCHA challenges are based on the researchers' personal experiences with the Arabic language and based on a similar work reported [25].

4.3.3 The application

To implement the game, we use Flutter development framework with Dart language. We select Flutter as the development framework, as Flutter is a cross-platform development framework. Thus, our developed application can be easily released for Android, iOS, Windows, Linux, MacOS and Web platforms. The database of the application is stored as SQLite database, as this type of database is the most-supported local backend for Flutter framework. Alternately, we could have used a web backend, but that would require the application to be always connected to Internet. In the following we show some of the screen shots from the developed application.

(a) Home screen (b) World selection screen

Figure 14. Home screen and world selection screen in the developed CAPTCHA game

Figure 14 showcases two screens: the left screen represents the home menu seen by players upon launching the game, while the right screen displays the world and level selection (after clicking the start (ابدأ) button). Players must complete all levels within a world before progressing to the next one, and

once a level is completed, they cannot return to previous levels but proceed directly to the next level.

The progress of each level is stored in the research table of the database to track player interest and ensure their engagement throughout the game. By examining the player's progress, we can identify ways to enhance their experience and maintain their excitement, particularly among young players. The options (خيارات) button on the left screen in Figure 14 leads to an options screen where players can reset the game if they wish to replay previous levels.

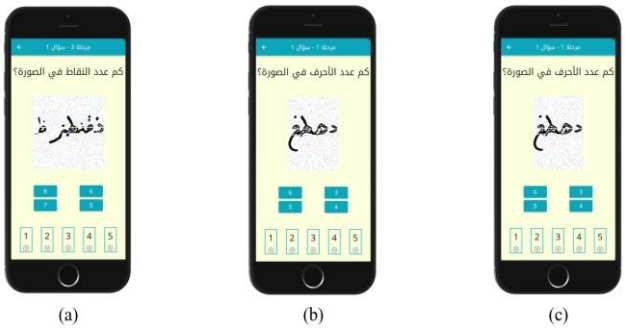


Figure 15. Level views with different questions in the developed CAPTCHA game

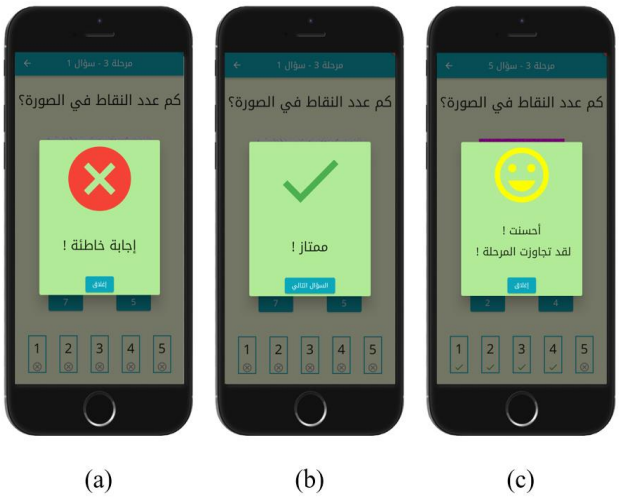


Figure 16. Level actions for any choice of answers in the developed CAPTCHA game

In Figure 15, we examine the level view, which features three question categories displayed from left to right: counting the points in the image, counting the letters in the image, and identifying the presence of a Madd letter. Players will progress through the levels by answering these questions accordingly. Upon selecting an answer, Figure 16 illustrates the corresponding dialog: a correct answer will advance the player to the next question, while an incorrect answer triggers a fail-screen and increases the number of fails for the current question. When all the questions in a level are successfully completed, the level will be closed, and the player will return to the world selection screen.

Upon completing a level, players will be presented with cyber security advice, as depicted in Figure 17. Each level offers new advice to raise awareness among children who have successfully solved CAPTCHA images. The purpose of this advice is to equip them with the knowledge of how to navigate CAPTCHA challenges on any website, while also encouraging caution and vigilance when utilizing online resources.

The application is tested by several users, testing the usability and correctness of the system. The testers provided direct feedback on the UI design of the application. The correctness of the presented CAPTCHA challenges was checked manually by selecting around 100 CAPTCHA images and checking their ground truths manually.

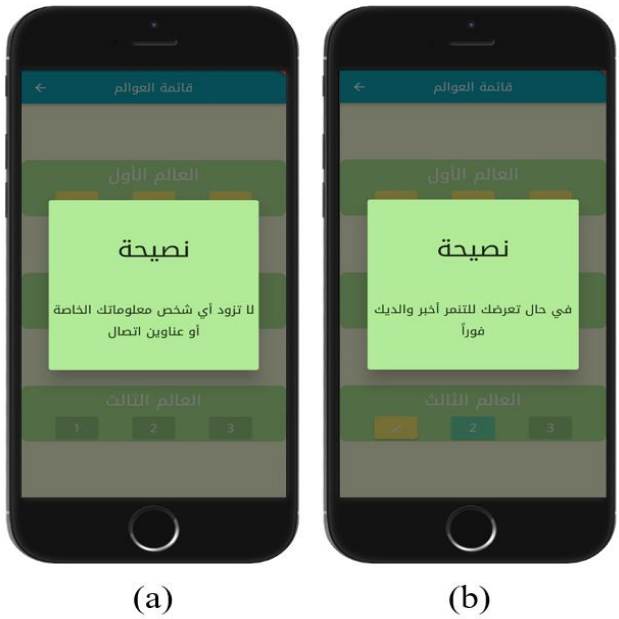


Figure 17. Cyber security advice showing up after completing a level in the developed CAPTCHA game. In (a), the advice is read as 'Do not reveal your personal or contact information' and in (b) the advice is read as 'Inform your parent immediately when you are cyber bullied'

As for the performance issues related to the Sqlite database (which is generally very efficient and industry standard), one can refer to some experimentations reported [26]. As for the accessibility and usability perspectives of the system, designing a complete accessible system for all kind of users (like blind or disable users) remains as a future work. However, we have used Material Design Guidelines [27] to ensure industry standard accessibility for the widgets. The application doesn't collect any personal data from the users. The statistics collected are for the CAPTCHA challenges only and are completely anonymous.

5. CONCLUSIONS AND DISCUSSIONS

This work introduces an Arabic CAPTCHA gamification system that combines teaching Arabic letters with raising awareness of cyber risks during Internet usage. As presented in Section 4, we have built an application with the two objectives in mind and tested the application with real users. Currently, the application uses only three 'worlds' with nine different challenges. Designing more usable challenges remain as an open work.

To assess the impact of the application, we aim to create some social media groups for application users to report their experiences and suggestions. In addition, we aim to introduce in-app feedback system to collect user feedbacks.

We have several future plans to enhance the work and take advantage of its extendibility. One of the main enhancements we plan to implement is the addition of activities that utilize CAPTCHA audio and the creation of a new database for this purpose. Using audio-based CAPTCHAs will make the application more accessible. However, cultural and religious context will be considered while creating the audio CAPTCHA database. For example, different Arab countries use different dialects for spoken Arabic. A proper audio CAPTCHA system would need to cater for all dialects of spoken Arabic.

Additionally, we aim to incorporate a reporting feature for players to notify us of any technical issues they encounter. Moreover, we intend to introduce user account registration functionality, allowing players to save their progress. A detailed privacy policy will be released in this case to ensure user-data safety. Furthermore, we aim to expand the application's compatibility to run on multiple platforms.

In terms of additional features, we plan to organize challenges and competitions throughout the year, implement a score list to compare players' progress, and provide insights into their performance in terms of speed and accuracy. We also aim to offer customizable background themes. These enhancements will improve the overall user experience, give the project a modern touch, foster a sense of community among players, and further support research efforts.

The presented system can be further enhanced by incorporating novel Arabic CAPTCHA schemes, as outlined in a recent work [28].

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