GAPTCHAs: Playful Exploration of the Limitations of Human Verification CAPTCHAs

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Abstract

CAPTCHAs are commonly used online to protect websites from AI bots by verifying that the user is human. Evolving from simple checks like swipes to the right, CAPTCHAs have become increasingly complex as the abilities of AI to escape detection increase, often leading to frustration amongst human users who just want to get through. Instead of frustration, we wanted to bring back the Gameful side of CAPTCHAs to bring joy into the human verification process and raise awareness about their limitations. We designed CAPTCHA-like games, such as scenario-based multiple-choice questions and item categorization, for an interactive installation. We found low rates of successful human verification in these experience-based CAPTCHAs, suggesting the need for design of more accessible CAPTCHA systems in the future.

Keywords

CAPTCHA, AI systems, Human Verification, internet security, interactive installation.

Introduction

CAPTCHA is a security mechanism that distinguishes people from bots by requiring users to recognize distorted characters, numbers, or pictures. CAPTCHA, which is designed to defend websites from automated assaults, reduces spam and abuse while increasing security. Its efficacy is based on humans' greater ability to detect complex pictures and words, which have previously been difficult for bots to perform[28]. However, as AI develops in pattern recognition, traditional CAPTCHAs have grown susceptible, and some malevolent actors have even used crowdsourcing to circumvent them.

In response, CAPTCHA systems have become increasingly complicated in order to prevent automated access. However, this intricacy frequently irritates genuine users, especially the elderly and crippled, resulting in a trade-off between security and usability[1]. Some CAPTCHAs use behavioral data for verification, which raises privacy problems. This CAPTCHA dilemma prompts a reexamination of what "human" means in the context of digital security. We investigate the impact of overly complex authentication on user experience and whether CAPTCHA complexity is truly necessary, with the goal of guiding designers toward user-friendly human verification systems. This led to the creation of CAPTCHA Games that make the human verification process amusing for interactive installation.

Background

History and Evolution of CAPTCHAs

The term CAPTCHA was first introduced by McNulty and his colleagues in 2000, standing for "Completely Automated Public Turing test to tell Computers and Humans Apart"[31]. Its original design was intended to defend against online bot attacks on websites, such as automatic account registration, data theft, and spam posting. Early CAPTCHAs primarily relied on visual tests or puzzles that humans could easily complete, but were far beyond the analytical capabilities of computers. For example, distorted text required users to recognize and input the characters to prove they were human[14].

The evolution of CAPTCHAs is closely tied to advancements in the very technology used to break them. As AI technology has advanced, CAPTCHAs have shifted from simple text-based tests to more complex image-based forms, such as dragging or selecting specific images[21]. However, research from 2013 to 2018 showed that computer vision and deep learning could bypass image CAPTCHAs with a 70.78% success rate[10]. Increasing the complexity of CAPTCHAs alone doesn't deter AI attacks; it often results in higher user error rates and frustration, reducing user acceptance[17]. While these developments aim to make CAPTCHAs more resilient against bots, they also add to their overall complexity[24].

Analysis of Existing CAPTCHA Mechanisms

The current types of CAPTCHAs mainly include text CAPTCHAs, image CAPTCHAs, audio CAPTCHAs, and behavioral CAPTCHAs(Figure 1).

In the early days of the internet, text-based CAPTCHAs were widely used. The text is often displayed in a distorted image format, requiring users to input letters to determine if they are human[6]. According to premise research, humans can easily read the text, but robots using optical character recognition (OCR) technology find it difficult[7]. The different renderings of text can be categorized into three types: 2D, 3D, and animated.

One of the most common examples of image CAPTCHAs is Google reCAPTCHA V2. In this system, users are often asked to select all the images containing boats from a grid of small squares. To pass the verification, users need to click on all the squares that include boats[26]. In 2015, Google also

introduced Invisible reCAPTCHA, which is closer to behavioral CAPTCHAs, as it determines user authenticity based on behavioral patterns rather than requiring users to complete specific image tests.

Behavioral CAPTCHAs typically include sliding puzzles and text selection, using the capture and analysis of user interaction behaviors to determine whether a bot is attempting to mimic human actions for attacking the website. Compared to the other CAPTCHAs, behavioral CAPTCHAs enhance interactivity in digital human verification.

To assist visually impaired users, researchers have proposed audio CAPTCHAs in addition to text and image ones. Audio CAPTCHAs generate and play a segment of speech, and users must listen to this audio and input the corresponding sequence of numbers or letters to complete the verification.

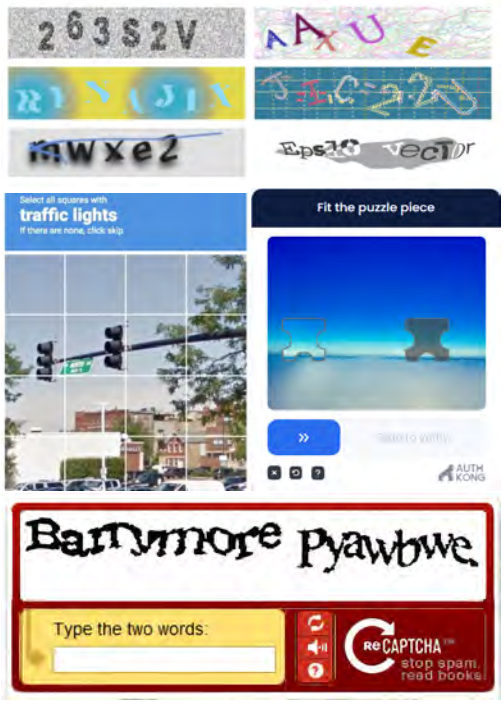

Figure 1: Different types of CAPTCHAs

Limitations of CAPTCHA: How AI Challenges Current Verification Systems

CAPTCHA systems are increasingly vulnerable as AI technology advances. According to New York University's Phillip Mak, AI could soon solve most CAPTCHA challenges effortlessly [18]. OpenAI's technology recently tricked a human into solving CAPTCHA, exemplifying AI's growing capability in overcoming these systems. While human success rates on CAPTCHA range from 50% to 85%, bots can achieve nearly 100%, emphasizing AI's superiority[22]. Additionally, plugins like NopeCHA automatically solve CAPTCHA, and large firms sometimes outsource CAPTCHA-solving to inexpensive human labor[32]. This trend undermines CAPTCHA's purpose, as it has become both less effective and more frustrating for users.

User Experience Issues: The Impact of Existing CAPTCHA Systems on Accessibility

CAPTCHA systems can alienate certain users, particularly those unfamiliar with Latin script or Western imagery. Google's reCAPTCHA v2, for example, often asks users to identify objects like buses, which may be unfamiliar to some. Dan Woods from F5 Inc. notes that while people generally recognize these objects, many struggle with image subtleties, leading to repeated errors and frustration. Graham-Cumming adds, "CAPTCHA is a nightmare for people; better solutions need to emerge" [18]. Although reCAPTCHA v3 aims to reduce disruptions, it cannot fully adapt to all user experiences, especially with factors like VPN use, leading to inconsistent CAPTCHA encounters. Developing verification systems based on human emotions and knowledge could improve accessibility[20].

Case Study

Breaking reCAPTCHA v2 and the Future of CAPTCHA Design

ETH Zurich PhD student Andreas Plesner and his team bypassed Google's widely used reCAPTCHA v2 using the YOLO model for object detection and image segmentation. Despite Google's shift to reCAPTCHA v3, reCAPTCHA v2 remains common, especially as fallback verification for low-credibility users[8]. To evade detection, researchers utilized VPNs, a human-like mouse movement model, and simulated browsing behavior with cookies and histories[2].

Previous research achieved 68-71% success in bypassing reCAPTCHA, but this study achieved a 100% success rate, emphasizing the need for CAPTCHA solutions beyond current methods. The team suggests effective CAPTCHA design should balance AI capabilities and minimal human skills. The study highlights reCAPTCHA v2's declining effectiveness and increased user frustration[15]. Future CAPTCHA designs must prioritize usability and inclusivity, aligning with CAPTCHA's core purpose[27].

The Form of "The Captcha Game"

"The Captcha Game by EterDelat" transforms CAPTCHA verification into an interactive puzzle game, where players solve image or text recognition challenges to prove their humanity, contributing data to enhance CAPTCHA accuracy. It also features entertaining elements like robot battles and unique failure hints[11][13]. Inspired by this concept, we designed a CAPTCHA game emphasizing user interaction and gameplay while exploring innovative trends in future CAPTCHA design.

Logic of Test Questions Based on Users' Daily Life Scenarios

CAPTCHA questions rely on human cognition and visual recognition to distinguish humans from bots[23]. Future designs may use narrative-based tasks rooted in daily scenarios

or emotions, enhancing engagement and challenging AI with context-rich, common-sense reasoning[5].

Methods

Based on the survey results and case study, we designed an interactive system simulating a CAPTCHA verification process to explore its impact on user experience and to investigate innovative CAPTCHA designs based on emotions and life experiences. The interactive system includes a fully developed web-based game and an Arduino control system include receipt printer and led light. After completing the game, participants' interactions were recorded, and the system-generated data was collected. Additionally, interviews with the participants were conducted to gather qualitative in-sights. This analysis aimed to evaluate the impact of CAPTCHA complexity on user experience, as well as to assess the usability and user feedback regarding emotion-based and life experience-based CAPTCHA systems.

Questionnaire Survey

Before developing the game, we designed and distributed a questionnaire to collect participants' opinions on existing CAPTCHA systems, their frequency of use, the challenges encountered, and user preferences. The questionnaire comprised 11 multiple-choice and open-ended questions aimed at gathering feedback on users' acceptance, experience, success rates, and frustration with different types of CAPTCHA systems. It also explored users' acceptance of emotion- and life experience-based CAPTCHA designs[25].

The survey was conducted anonymously on two online platforms: Wenjuanxing (a popular survey tool on WeChat) and Google Forms. The data collection period lasted one week. A total of 514 participants covering various age groups and regions were recruited to ensure a broad representation of perspectives.

Game Design

We selected React as the front-end framework for developing the CAPTCHA simulation web game. The game is designed with different verification levels of progressively increasing complexity to demonstrate the challenges that today's CAPTCHA system poses to users. The player's task is to solve various types of CAPTCHA challenges. At the end of the game, the user receives a result showing whether they have successfully passed as a human.Players interact through mouse clicks, as required by the game (Figure 2). Each level introduces different types of tasks, enhancing the interactive nature of the game.

In each level, we utilize React's state management hooks (useState and useEffect) to track user metrics, such as completion time, success rate, and error count. The state management system also records whether each task was successfully completed, along with user feedback. To ensure data accuracy, a timer is implemented at the start of each level to capture the time taken for task completion. Upon completion of each level, the collected user input and performance data are sent to a back-end API for processing and storage, enabling future quantitative analysis of user interactions and performance.

Figure 2: Sketch

Interview Procedure

We randomly selected 15 volunteers who had participated in the game to interview, aiming to gather qualitative feedback on their user experience. Through these interviews, we sought to gain a deeper understanding of how users experienced the different types of CAPTCHA challenges, including emotion- and life experience-based CAPTCHA, and explore potential areas for improvement.
The questions we focused were:

- Can you describe your overall experience during this game?
- Do you find emotion-based CAPTCHA simpler compared to the CAPTCHAs you've encountered before? Why or why not?
- Do you find life experience-based CAPTCHA simpler compared to the CAPTCHAs you've encountered before? Why or why not?
- What improvement suggestions do you have for the CAPTCHA?

Design

Gamification of Traditional CAPTCHA Design

Our design draws inspiration from the traditional CAPTCHA model and style, enabling users to quickly recognize the familiar verification format (Figure 3). The underlying logic continues to align with the core goal of traditional CAPTCHA—distinguishing between humans and bots[16]. We innovatively gamified the traditional CAPTCHA by leveraging uniquely human characteristics, aiming for a user-friendly experience that resonates with human emotional logic[9]. Through a series of interactive tasks, users are guided to complete the verification process, which not only improves the effectiveness of verification but also adds an element of fun, offering a fresh perspective on future CAPTCHA interactions.

The Logic of CAPTCHA Game

The logic of our CAPTCHA game significantly departs from traditional approaches. Unlike conventional CAPTCHAs that provide immediate feedback and require users to retry until the correct response is given, our game allows progression through tasks without indicating whether an answer is right or wrong. A single error in any task results in the user being

Figure 3: The first page of the game

classified as non-human. This design fosters a more user-friendly and engaging experience by minimizing frustration and preventing users from being stuck on a single task[30]. By leveraging human emotions and basic common sense, the tasks are designed to be straightforward for humans but challenging for bots, thereby reducing the success rate of machine learning-based exploits.

The Content of CAPTCHA Game

The game contains multiple tasks, each of which tests the user's different abilities(Figure 4). The first task is situational selection. Users make judgments based on social common sense in different scenarios, and the task can be completed by making the correct choice.

Figure 4: The game tasks

The second task is logical matching, where users need to identify and match items with similar relationships based on everyday knowledge. This task tests user intuition and is often difficult for automated systems to accomplish[19].

The third task is music matching. The user selects appropriate background music based on the scene description and makes judgments based on the understanding of emotion and atmosphere. The fourth task is item classification, where the user needs to correctly classify items into specified categories. The task exploits human familiarity with objects, a task in which automated systems face difficulty.

The fifth task is character dressing. The user chooses appropriate clothing according to the scene, not only considering the appearance but also making reasonable judgments based on the needs of the character.

Finally, the truck navigation task requires the user to accurately control the truck to cross obstacles and make timely adjustments to complete the goal, testing the user's reaction and coordination abilities.

To provide a more comprehensive understanding of the interactive processes within the game, a video demonstration of the gameplay is available. This video showcases the operational flow of each task and the corresponding user interactions, offering a visual guide to the user experience. You can access the video here: Project Demonstration Video.

User Interaction

User interaction process: the user enters into the installation and plays the captcha game, after the game is completed the user will get the corresponding game result, and at the same time the device will light up the corresponding light and print out a small ticket of the user's game result (Figure 5&6).

Figure 5: The interaction process

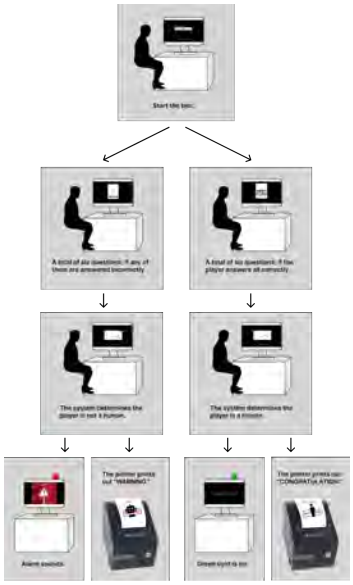

Figure 6: The interaction process

The installation looks like a small room, we set the height and width of the room that only one person can sit in the closed

space, and the only light source that the user has access to after entering the space comes from the monitor where the test is being conducted.

At the start of the test, the user is required to read through the questions within the web page and click or drag with the mouse on what they believe to be the correct answer. The user has to go through logic questions, music questions etc. These questions are designed based on user suitability and apply the CAPTCHA model, where the user can experience the limitations of CAPTCHA in the test.

When the user finishes the test and gets the result, our web page will send a result to the computer's serial port.The Arduino will read the serial port information and react according to the serial port information to light up the led and drive the printer to print the result receipt.The red/green light corresponds to the user's test results, and in the lit room, the user will notice that the desktop printer is printing their result receipts(Figure 7).The receipt will show the identity of user, showing them as human user or non-human user, e.g. robot, cat, etc (Figure 8).

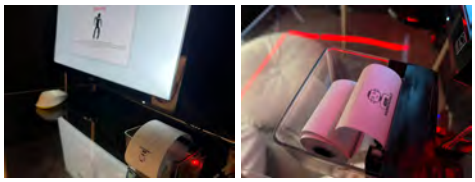

Figure 7: The test result showing

Figure 8: The different forms of receipt

Outcome

When visiting the work, the user needs to drill into the relatively small installation then start the CAPTCHA test in the dim and narrow space. At the moment of the result, the lights arranged in the space will be lit, and the user will be surrounded by lights and get their own test results(Figure 9).

Qualitative Results

Based on our CAPTCHA design, we were able to review the participants' pass rate data from the backend records. Additionally, we conducted brief interviews with 15 participants immediately after they completed the CAPTCHA test. We analyzed their responses and observed their reactions. The findings are as follows.

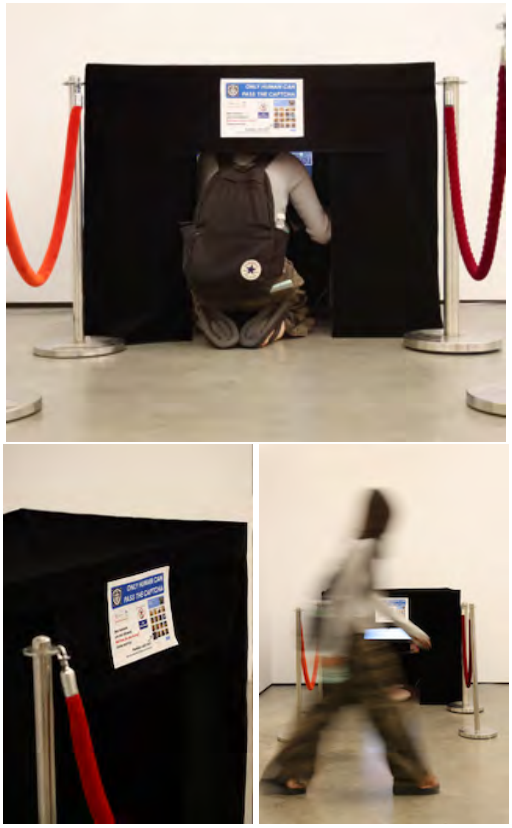

Figure 9: Installation display

Curiosity and Freshness in the Face of an Emotion- and Life-based CAPTCHA

Through on-site observation, we found that many participants were drawn to the unique design of our CAPTCHA, seeing it as a change from the traditional CAPTCHA's tedious and complex format. They described it as a "more humanized interactive experience." Interview feedback showed that many participants were highly interested in using emotions and common sense to complete the test, with some even tried doing it multiple times to challenge their own "human identity verification". Additionally, some participants specifically mentioned that the uninterrupted, smooth process made them feel as if they were participating in an interactive game rather than just a verification, adding a layer of entertainment and exploration. Furthermore, even among participants who received a "non-human" identity, such as "cat" or "puppy", most still maintained a positive attitude toward the test. This design successfully broke away from the tedious and complex nature of traditional CAPTCHAs.

Unintentional Deviation and Understanding Gaps Caused by Individual Knowledge Differences and Algorithm Conflicts

We collected backend data and combined it with feedback from the interviews, discovering a failure rate of 73.33%, with the system categorizing these participants as "non-

human". Some participants indeed followed their personal common sense and emotional expressions when answering, but the system adhered to a fixed standard for correct answers. For instance, one participant mentioned that "choosing this option seemed completely reasonable in this scenario", but the system's evaluation standard did not recognize this as a "typical human response". This indicates that in an emotion- and common-sense-driven CAPTCHA, individual differences pose a challenge to system judgments and reveal the limitations of emotion-based CAPTCHAs in accommodating wide individual variability. This also suggests that future CAPTCHA designs should strive to balance a "human common sense" standard that incorporates a broader range of cultural and individual differences.

Contrast Between Confidence and Actual Results in Testing

During the interactive test, nearly all participants were confident in their choices, believing that they could pass based on this universal common sense and emotion. Surprisingly, most participants expressed shock and confusion upon being classified as "non-human", especially given their initial confidence in their performance.

In interviews, some participants mentioned, "I thought this would be a simple question, but I actually didn't pass"; others said they "fully understood the scenario" and "emotionally resonated" with it, basing their answers on this alignment. Some participants even commented, "I ended up finding the result funny and thought it was a very interesting interaction". This contrast broke their expectations of what a traditional CAPTCHA should be, highlighting a gap between testing standards and human perception. When the system cannot fully grasp the diversity of human emotional expression, it can lead to unexpected failure results. This phenomenon not only provides directions for reflection and optimization in future CAPTCHA design but also indicates that future CAPTCHAs will need to continually adjust their evaluation criteria to better recognize the complexity of human response characteristics. This approach should ideally balance a straightforward testing model with a user-friendly testing logic.

Discussion

Project Uniqueness

This project introduces a unique CAPTCHA approach by integrating playful experiences as core elements of human verification systems, creating a new CAPTCHA format through a web-based game combined with Arduino. Unlike traditional CAPTCHAs focused on visual and logical recognition, this approach leverages human emotional responses and life experiences—areas challenging for AI to replicate. With advancements in AI, especially in image and pattern recognition, traditional CAPTCHAs are losing effectiveness, and emotion-based gameful CAPTCHAs offer a fresh approach.

We propose that the complexity of emotions and life experiences creates a natural barrier for machines. For instance, in an emotion-based CAPTCHA, users might make selections based on the emotional tone of music, requiring emotion recognition and comprehension—tasks where AI lacks precision. This approach aims to guide users to verification via human emotional responses, rather than solely relying on visual or logical cues.

Through designing emotion- and experience-based CAPTCHA tasks, we aim to show that this approach could make verification more natural and aligned with human cognitive processes. Though in early stages, this method shows potential as a uniquely human verification method, posing significant challenges for machines to imitate.

Limitations and Weaknesses

While this project aimed to create a verification method aligned with human cognition through emotion and life experience, experimental results indicated no significant improvement in user success rates. Although we hypothesized that this approach would enhance intuitiveness and reduce frustration, the data revealed a lower-than-expected success rate for users classified as "human".[29] Interviews showed that participants often felt confident in certain tasks but ultimately failed the verification, leading to frustration and prolonged attempts to understand their "mistakes".

In our survey, we selected 15 participants aged between 20 and 25, 90% of whom are Chinese individuals proficient in English, with their work or study fields related to art. This presents a limitation in our research. Expanding the participant pool to include more age groups and individuals from diverse backgrounds might provide different perspectives. Additionally, cultural background could influence their participation experience, which is another constraint we encountered.

Another limitation is that the design primarily targeted a younger user group, overlooking age and cultural diversity, potentially introducing bias. Cultural differences in interpreting emotional scenarios also impacted pass rates, suggesting that the current design may not adequately serve diverse user groups, thus affecting fairness and verification effectiveness.

Additionally, technical challenges arose during installation development. For example, due to the browser security restrictions, the system could not automatically select the serial port to output information to Arduino, requiring participants to manually select the port, which added complexity to the user experience. Furthermore, a lack of clear guidance led to confusion among some participants, as they were unsure about the purpose and functioning of the project. These challenges highlight areas for improvement in both technical integration and user instruction to enhance the overall accessibility and intuitiveness of the experience.

Different user understandings put challenges on the design of CAPTCHA games. People will interpret it the task in accordance with their lived and cultural experiences, it is hard to enforce a single correct answer for every tasks. Gamification makes the users to get involved but repeated failure may make them irritable. Change task difficulty dynamically may increase the experience and decrease the bad emotion. Cultural factors produce interpretation and pass rate biases.CAPTCHA systems need to not just be fairness and accuracy., but inclusive and globally designed for this reasons.A possible future research direction could be toward systems

that respect this level of diversity without sacrificing the accuracy of verification.

Future Work

Multicultural Adaptability and Personalized Design

The design of emotion and life experience-based CAPTCHAs should be able to adapt to diverse cultural backgrounds and user characteristics to ensure broad applicability and fairness. In cross-cultural contexts, users' interpretations of emotions and life experiences may differ due to cultural differences. Additionally, factors like age, education level, and personal experience can also influence a user's resonance with specific emotions and life scenarios.[12] This personalization would make CAPTCHAs more intuitive for users, helping to reduce confusion and frustration during verification. Personalized and culturally adaptive design not only improves fairness but also supports the wider adoption of emotion and life experience-based CAPTCHAs, making them a more inclusive verification method.

Enhanced Data Privacy and Security

Since this type of CAPTCHA involves users' emotional responses, cultural backgrounds, and personal life experiences, data privacy and security become an important consideration in its application. Future designs should ensure validity of authentication while enhancing data privacy protection to prevent misuse or leakage of user data[3].

Accessibility Improvements

In terms of accessibility, the design should also give full consideration to the experience of visually impaired, hearing impaired and other users with specific needs. For example, voice guidance can be provided to visually impaired users through speech recognition technology, or tactile feedback (e.g. vibration) can be used to allow hearing impaired users to complete authentication tasks to meet the needs of different user groups[4]. By improving accessibility, the emotional and life experience class CAPTCHA is expected to be rolled out to a wider user group, providing a fair and convenient verification experience for users with diverse needs.

Conclusion

This project explores a game-based approach for human verification CAPTCHAs that leverages human emotion and life experiences. We aimed to be more aligned with human in situ interaction than traditional text or image-based CAPTCHAs. While this new CAPTCHA showed some intuitive and human-like qualities, the data revealed no significant improvement in success rates. This indicates that despite its innovative concept, it still faces challenges like subjectivity and cultural differences.

Gameful CAPTCHAs based on human emotion and experience offer a fresh perspective for making human verification processes more engaging. The findings suggest that improving this approach will require further design for other modalities and customization. This study highlights the potential of human-centered verification methods that make the experience more engaging than often tedious online CAPTCHAs.

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Linqi SUN is an MFA student in the School of Creative Media, CityUHK. With a background in digital media art, her work explores the beauty of art through programming, merging digital and physical aesthetics in interactive and generative media. Through interdisciplinary approaches, she seek to bridge technology and artistic expression, redefining the relationship between code, form, and perception.interactions, and critical reflections on digital culture.

Lin WANG is an MFA student in the School of Creative Media, CityUHK. Her work explores mixed-media art, generative design, and human-computer interaction, blending technology with playful and unconventional ideas. With a background in product development and marketing, she aims to create engaging, curious, and fun experiences through her art.

RAY's practice investigates how humans adapt to novel environments in creative expression with machines. His research in neuroscience (Nature Communications) and HCI (CHI, CSCW, HRI, DIS) are reflected in his artistic practice (NYSCI, Ars Electronica, Taikwun, Science Gallery, ACC Gwangju, IEEE VISAP, SIGGRAPH). RAY founded Studio for Narrative Spaces: https://recfro.github.io