Tinkuy Play: A Cooperative Video Game with Computer Vision for Mother–Child Socio-Emotional Interaction in Children with ASD

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Abstract

Socio-emotional interaction between mother and child is fundamental to the development of social skills in children with autism spectrum disorder (ASD), who may experience difficulties in reciprocal communication and joint attention. Emotional conversations between mother and child contribute to the development of socio-emotional competencies in this population. However, few existing technological solutions incorporate the mother as an active participant, limiting family involvement within the gameplay itself. Therefore, this study aimed to design and implement Tinkuy Play, a cooperative video game based on computer vision intended to promote mother-child socio-emotional interaction in children with Level 1 ASD. A User-Centered Design process was employed through iterative phases of needs analysis, design, implementation, and functional evaluation. The prototype integrates OpenCV, MediaPipe, and Pygame through four modules: video capture, hand detection, gesture classification, and real-time visual rendering. The game mechanics allow the child to control the character's movement by extending both hands, while the mother activates environmental elements by closing both hands. Both participants form a heart-shaped gesture to encourage turn-taking, coordination, and dyadic communication. The game follows the story of a small frog overcoming obstacles to reunite with its mother. A trial was conducted with an 8-year-old child with ASD, accompanied by a teacher acting as caregiver. The system operated at 60 FPS, with a response time of 70–120 ms. Participants completed 13 of 15 complementary cooperation opportunities (86.7%) and 4 of 6 simultaneous cooperation attempts (66.7%), with a mean synchronization difference of 0.63 s. Tinkuy Play represents an inclusive digital health proposal, incorporating the mother as an active participant and providing a technical foundation for socio-emotional interaction activities. The results demonstrate the prototype's technical feasibility and ability to record observable coordination indicators. However, they do not allow conclusions regarding clinical or socio-emotional improvements.

Keywords

Socio-emotional interaction, Autism spectrum disorder, Cooperative video game, Computer vision, User-centered design

1. Introduction

Social interaction, communication difficulties, and restricted or repetitive behavior patterns are characteristics of autism spectrum disorder (ASD). In children with level 1 ASD, these characteristics may manifest as difficulties sustaining communicative interactions, understanding social cues, and participating flexibly in shared activities. The World Health Organization estimated that in 2021 one in 127 individuals was autistic and noted that support needs vary throughout life [1]. Additionally, a review compiling evidence from over 50 countries identified barriers to detection, diagnosis, and access to interventions, particularly in resource-limited settings [2]. These challenges impact both the child and the family that supports their development and participates in their daily experiences.

In Peru, consolidated national data to accurately determine the prevalence of autism spectrum disorder (ASD) is still lacking. A review of the state of autism reported that public services attended to 12,325 people with ASD in 2021, and that 78% were between 1 and 11 years old [3]; subsequently, the Ministry of Health registered 96,512 cases attended and 764,860 visits during 2025 [4]. At the local level,

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the National Registry of Persons with Disabilities counted 22,334 autistic individuals in May 2024, of whom 11,309 (50.6%) were in Metropolitan Lima, and 18,364 (82.2%) were between 0 and 20 years old [5]. These records in Lima and the access gaps justify the development of accessible play-based tools to complement professional follow-up and promote family interaction. In this study, the population is limited to dyads composed of mothers and children aged 5 to 10 years with Level 1 ASD.

It is important to involve parents in conjunction with play-based tools that reinforce the social development of children with ASD. Pi et al. synthesized 16 randomized controlled trials with 748 participants and observed possible improvements in emotional recognition, but no significant differences in social communication, social functioning, or language [6]. In contrast, Cheng et al. integrated 51 effect sizes of interventions implemented by parents and found a moderate overall effect ($g = 0.553$), with results of $g = 0.603$ for positive behaviors and social skills and $g = 0.545$ for language and communication [7]. Taken together, both analyses indicated that technology alone does not guarantee better results; these can be reinforced with the active participation of parents alongside the child.

Reciprocity and emotional exchange are central processes in dyadic interaction. Lee and Schertz analyzed recordings of 61 young children with ASD and their caregivers and found a positive relationship between turn-taking and joint attention [8]. Beaudoin et al. studied 49 mothers using questionnaires and regression analysis; a higher frequency of mother-child conversations about emotions predicted better emotion regulation and theory of mind skills ($p < 0.05$) [9]. Although neither study evaluated a video game, their results support the design of activities that require taking turns, attending to the partner, and sharing emotional content in real-life interaction.

The quality of adult participation also influences outcomes. Kulasinghe et al. reviewed 32 randomized controlled trials with 2336 participants; 17 studies reported improvements in the mother-child relationship, with effect sizes ranging from $d = 0.33$ to $d = 2.28$, and the greatest benefits were associated with interventions focused on parental response [10]. Deniz et al. analyzed 26 parent-mediated play interventions and obtained favorable pooled effects on social communication ($d = 0.63$) and language ($d = 0.40$), although they noted heterogeneity among the studies [11]. These findings indicate that the mother should adopt roles of observation, response, and coordination rather than merely supervising the child's activities.

Reviews of serious games highlighted potential benefits, although the evidence remained limited. Hassan et al. analyzed 40 games centered on social and emotional intelligence, noting an emphasis on the recognition or production of emotions as well as small sample sizes, insufficient clinical validation, and limited follow-up [12]. Carneiro et al. utilized PRISMA and PICO criteria on 149 records, of which only nine were included.

Studies have found improvements in emotion management and recognition, as well as in joint attention. However, definitive conclusions cannot be drawn due to the small number of studies and the methodological limitations of some of them [13]. Therefore, these results should be interpreted with caution and compared with directly observable behavioral indicators.

Another limitation identified is how these social outcomes are defined and measured. Walsh et al. screened 3,070 records and retained 17 studies, all of which reported favorable results; however, the authors noted that the specific social skills being trained and the methods used to measure them were often unclear [14]. Kirst et al. evaluated Zirkus Empathico in a multicenter study with 82 children aged 5 to 10 years and reported immediate effects on empathy ($d = 0.71$) and emotion recognition ($d = 0.50$), although the main differences were no longer observed after three months [15]. These findings suggest that parent-assisted serious games may produce short-term benefits while also emphasizing the need for clearly defined indicators and sustained adult participation.

Collaborative video games also offer tools to identify when there is true cooperation and when participants are acting simultaneously. Boyd et al. evaluated Zody with four dyads using an ABAB design and observed that turn-taking, simultaneous actions, and differentiated roles supported goal-directed associative behavior [16]. Zhang et al. developed an intelligent agent for collaborative puzzle activities, obtaining classification accuracies of 89.58% for communication and 75.40% for collaboration [17]. These studies show that interdependent actions can be incorporated into game mechanics and assessed through objective indicators, although their interactions involved child–child or child–agent pairs.

The most recent studies covered only partially the proposed intersection. Bei et al. evaluated StarRescue over three days with 32 autistic children; the experimental group showed improvements in theory of mind ($p = 0.002$) and demonstrated negotiation, task distribution, and peer attention, although parents remained as spectators [18]. Lyu et al. tested EMooly with 24 children and their caregivers; the system improved emotional recognition compared to the control ($t = 2.634$; $p = 0.015$) and involved the caregiver in modeling, turns, and difficulty adjustment [19]. Consequently, it cannot be asserted that there are no cooperative games or those involving the caregiver; the gap lies in integrating mother and child as players with complementary bodily roles, necessary for a common goal, and recording cooperation, turns, simultaneity, and synchronization.

Based on this gap, the general objective of the research was to develop a cooperative video game based on computer vision that fostered socio-emotional interaction between mothers and their children aged 5 to 10 years with level 1 ASD, and to assess its technical feasibility and acceptability as a playful support tool. Tinkuy Play assigned differentiated actions to the dyad: the child controlled the character's movement, the mother activated necessary elements of the environment, and both executed a synchronized heart pose to trigger a cooperative event. The proposal was conceived as a playful support activity rather than as a diagnostic tool or a replacement for professional intervention.

Section 2 describes how the system was designed, including the user-centered design process, system requirements, and cooperative mechanics implemented with OpenCV, MediaPipe, and Pygame. The preliminary evaluation and the measures used to assess cooperation are also presented. Section 3 focuses on the technical and interaction results, while Sections 4 and 5 address the main findings, limitations, conclusions, and future work.

2. Methods

2.1. Methodological Approach and User-Centered Design

The software development employed a user-centered design approach, as the video game is aimed at children with ASD. This methodology was structured in four iterative phases: understanding the user context, specifying user requirements, designing solutions, and evaluating the design through preliminary testing [20]. As illustrated in Figure 1, these phases create a continuous cycle in which each iteration offers feedback to progressively enhance the system, ensuring that the user remains central to the project.

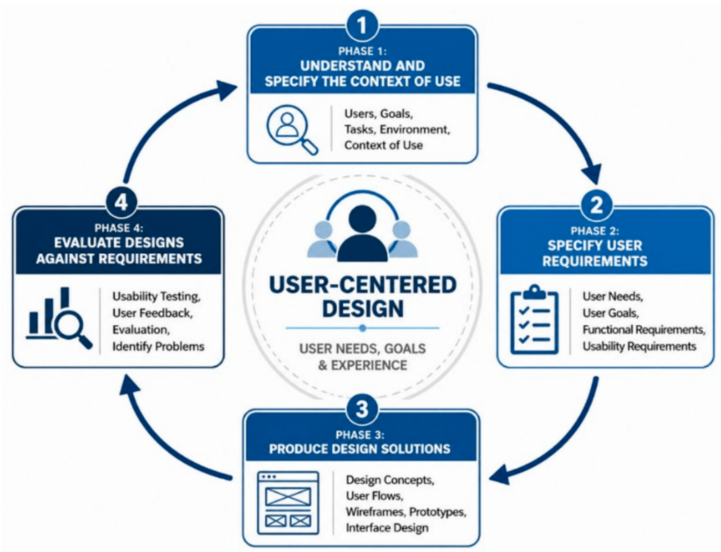

Figure 1: User-Centered Design (UCD) methodology applied to Tinkuy Play.

The first phase of User Centered Design (UCD) involved a literature review that aimed at identifying needs concerning socio-emotional interactions, collaboration, and involvement of families in technologies meant for neurodivergent people. The results of the literature review showed that while some digital solutions exist for the population in question, there is a lack of evidence of adult involvement in the game process itself; most of the time, adults are required to supervise or provide assistance.

To deepen the understanding gained from the literature review, some results of the previous formative evaluation of Tinkuy Play were also considered. This evaluation included 120 adult caregivers with direct experience caring for or living with a child with Level 1 ASD, as well as five specialists.

2.2. System Requirements

Based on the objective of fostering cooperation, communication, and coordination between mother and child, the functional and non-functional requirements of Tinkuy Play were defined. These requirements include real-time gesture interaction, active participation of both players (mother and child), immediate visual feedback, and controlled audiovisual stimulation. The main requirements considered for the development of the prototype are shown in Table 1.

Table 1
Main system requirements for Tinkuy Play.

ID	Requirement	Type
R1	Capture and process video of the participants in real time.	Functional
R2	Detect hand landmarks and recognize the predefined gestures.	Functional
R3	Translate recognized gestures into corresponding game actions.	Functional
R4	Support individual actions for the child and mother, as well as joint cooperative actions.	Functional
R5	Provide immediate visual feedback when an interaction is recognized.	Functional
R6	Maintain sufficiently responsive processing for real-time gameplay.	Non-functional
R7	Use simple and clearly distinguishable gestures for interaction.	Non-functional
R8	Maintain controlled visual and auditory stimulation through simple interfaces, smooth animations, and moderate sounds.	Non-functional

2.3. Cooperative Interaction Design

The interaction mechanics were designed so that each participant has an assigned gesture to perform, and the game also requires joint cooperation to complete the level. The child (P1) controls the frog's movement by extending both hands, while the mother (P2) can modify the environment at specific moments during the game; when she closes her hands, a leaf bridge is activated over a mud puddle, allowing the frog to continue its path. A progressive increase in difficulty and a variety of moving obstacles, such as dogs, cats, chickens, and rabbits, were added. These mechanics aim to promote teamwork and encourage coordination between both participants.

To reward coordination between participants, a cooperative gesture can be performed, which, when correctly recognized, activates a protective shield that provides an extra opportunity in case of an error. The actions assigned to each player and their effects in the video game are summarized in Table 2.

Table 2
Cooperative interaction mechanics implemented in Tinkuy Play.

Participant	Physical action	Game command	Effect
Child (P1)	Raise both hands	ADVANCE	Frog moves forward
Mother (P2)	Close both hands	LEAF BRIDGE	Creates a leaf bridge over the mud puddle
Both	Simultaneous heart pose	COOPERATIVE EVENT	Activates the protective shield

2.4. System Architecture

The Tinkuy Play architecture consists of four main modules that work sequentially to process participant interaction, as shown in Figure 2. In the first stage, the video capture module uses OpenCV to acquire images from the camera and perform the corresponding preprocessing. Subsequently, the hand detection module, based on MediaPipe, locates and tracks hand landmarks. The data is then sent to the gesture classification module, where the landmarks are analyzed, and the recognized gesture is determined according to the logic defined for the video game. Finally, the visual rendering module, developed in Pygame, receives the identified gesture, executes the game action or command, and displays the corresponding visual feedback in real time.

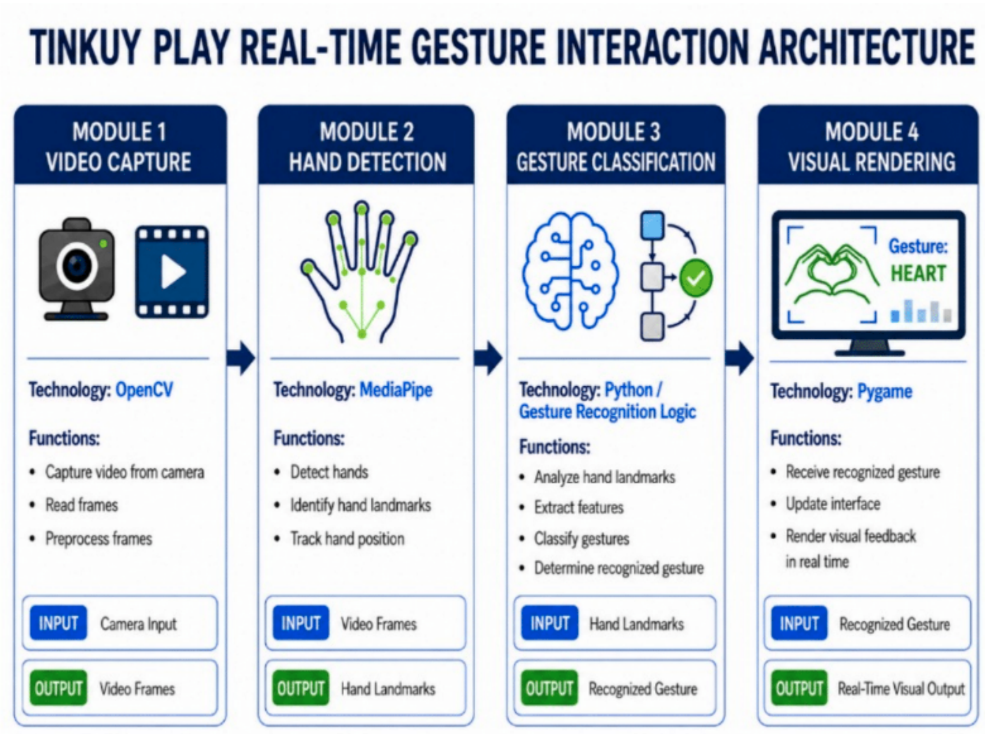

Figure 2: System architecture and real-time gesture processing flow of Tinkuy Play.

2.5. Prototype Development and Integration

Based on the defined architecture, a functional prototype was developed, integrating the modules and implementing the game mechanics. The Python Pygame library was used for the main character's movement, obstacles, player-specific actions or commands, and cooperative events. All of this is activated through gestures, which are reflected in the game's behavior.

The game interface is divided into two sections. The left side displays the main game environment, showing elements such as the number of steps remaining to reach the goal, the shield bar that progressively fills with each step, and the number of available attempts. The right side displays the camera along with visual feedback from the gesture recognition, allowing players to see the detected hands and the actions assigned to each player, as shown in Figure 3. The game involves a baby frog finding its mother by overcoming a series of non-aggressive obstacles along the way. This reunification narrative functions as a symbolic reflection of the cooperative dynamics of the game, since the encounter between the baby frog and its mother represents the emotional interaction that is sought to be promoted between the child and his own mother during the activity.

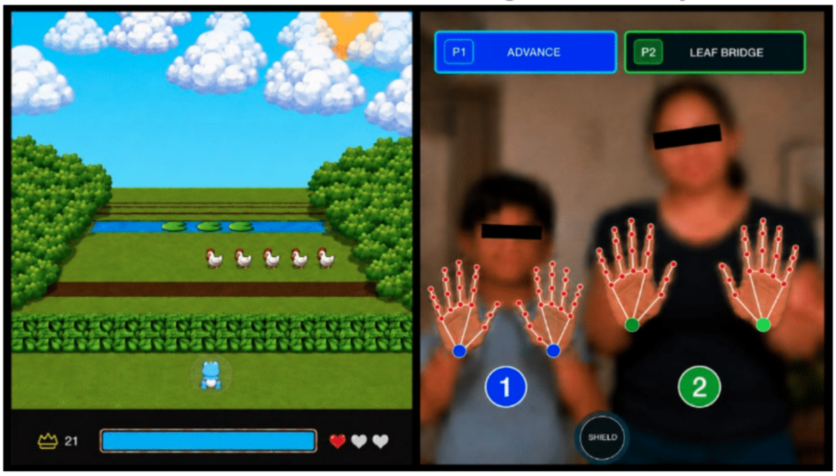

Figure 3: Cooperative video game interface with gesture recognition and visual feedback.

2.6. Preliminary Evaluation Protocol

The preliminary evaluation of Tinkuy Play was conceived as a new iteration within the User-Centered Design process. For the development of the functional version, data previously obtained through a survey of 120 adult caregivers and an evaluation by content judges and specialists were used as a reference. Their assessments and observations were used as feedback to make adjustments to the interaction, cooperative mechanics, clarity of controls, and the system's visual response before conducting the preliminary test.

Subsequently, a preliminary test was carried out with an 8-year-old child with ASD, accompanied by a teacher who assumed the role of caregiver during the interaction. The child's participation was authorized by their parents. Both participants completed a level of Tinkuy Play using the gestural actions corresponding to P1 and P2, allowing observation of the system's functionality in a real-world interaction and recording of the cooperative metrics defined in Section 2.7.

2.7. Evaluation Metrics

To evaluate cooperative interaction during the video game, the Relationship Skills dimension of the Social and Emotional Learning (SEL) framework proposed by CASEL was used as a reference. This dimension refers to skills related to cooperation, teamwork, cooperative problem-solving, and support from fellow participants [21]. In Tinkuy Play, it was measured based on the quantitative measures of cooperation and coordination used in the process of playing the game by the mother and child.

Cooperative coordination was measured based on two kinds of interaction, which are complementary cooperation (A) and simultaneous cooperation (B). The first refers to situations when both agents perform various but dependent actions to accomplish a common goal. The second refers to situations when joint action must be performed at the same time.

2.7.1. Complementary Cooperation (A)

This metric quantifies the successful completion of situations in which the game requires different but interdependent actions from both participants. A successful sequence occurs when P1 reaches a cooperative obstacle, P2 responds by activating the leaf bridge, and P1 then continues along the path. The complementary cooperation rate is calculated as follows (1):

$$C_A = \frac{N_{AS}}{N_{AT}} \times 100 \tag{1}$$

Where:

- C_A: percentage of complementary cooperation.
- N_{AS}: number of successfully completed complementary cooperation events.
- N_{AT}: total number of complementary cooperation opportunities.

2.7.2. Simultaneous Cooperation (B)

This metric allows us to evaluate the level of coordination between both participants during the voluntary execution of the cooperative movement. When the progress bar is full, the heart gesture is enabled for P1 and P2. However, its execution is optional and does not affect the continuation of the level; therefore, the decision not to activate it is not considered a failed attempt. Both participants must maintain the heart-shaped hand position for one second to activate the protective shield, if they wish. The success rate of simultaneous cooperation is calculated as follows (2):

$$C_B = \frac{N_{BS}}{N_{BT}} \times 100 \tag{2}$$

Where:

- C_B: percentage of simultaneous cooperation.
- N_{BS}: number of successfully completed simultaneous cooperation attempts.
- N_{BT}: total number of simultaneous cooperation attempts.

2.7.3. Synchronization Time

Synchronization time quantifies the temporal difference between the onset of the gestures performed by P1 and P2 during simultaneous cooperation attempts. For successfully completed events, the system records the instant at which the beginning of the heart pose is recognized for each participant. A smaller difference indicates greater temporal synchronization during the execution of the joint action (3).

$$T_{sync} = \frac{1}{N_{BS}} \sum_{i=1}^{N_{BS}} |t_{P1,i} - t_{P2,i}| \tag{3}$$

Where:

- $t_{P1,i}$: onset time of P1's gesture.
- $t_{P2,i}$: onset time of P2's gesture.
- T_{sync}: mean synchronization time, expressed in seconds
- N_{BS}: number of successfully completed simultaneous cooperation events.

3. Results

3.1. Caregivers' perception of the potential use of Tinkuy Play

The formative evaluation conducted with 120 adult caregivers revealed a favorable perception of the potential use of Tinkuy Play. For this analysis, the categories "Agree" and "Strongly Agree" were considered favorable responses. As shown in Figure 4, 78.3% of participants felt that the proposed design had the potential to support socio-emotional interaction activities between the adult caregiver and the child. Furthermore, 82.5% indicated that a future functional version could be used as a complementary activity at home, while 83.3% expressed willingness to use a functional version of Tinkuy Play with the child in their care. These results demonstrate a favorable assessment of the system's usefulness and suggest potential for acceptance for future implementation and use. Furthermore, the findings obtained during the formative evaluation provided support for moving from the initial design stage to system development and the subsequent preliminary evaluation of the functional version presented in this study.

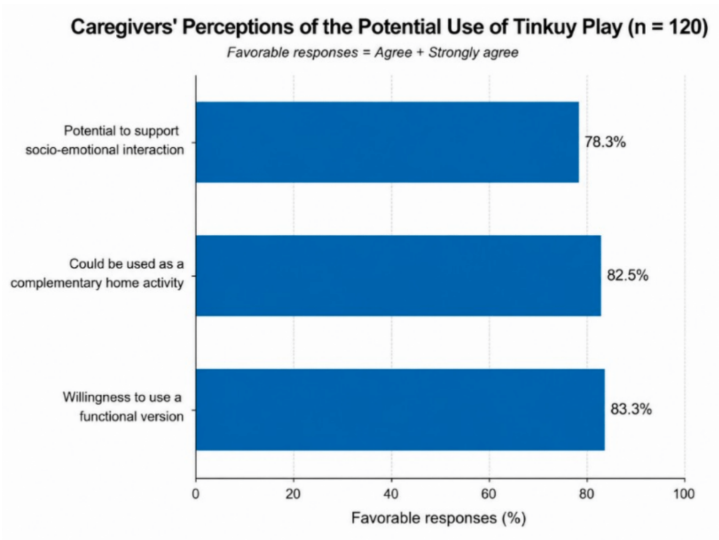

Figure 4: Caregivers' perceptions of the potential use of Tinkuy Play ($n = 120$). Favorable responses correspond to Agree and Strongly agree.

3.2. System performance and gesture recognition latency

To maintain the game at 60 FPS, the configured frame rate, each frame must be processed in approximately 16.67 ms or less. In testing, the average processing time for each logical game update was 0.09 ms, while scene rendering took 6.02 ms, ensuring that both processes remained within the required time limits for smooth gameplay. For gesture recognition with MediaPipe, the average processing time was 27.02 ms, with a median of 26.71 ms. In 95% of the measurements, the processing time remained below 29.92 ms. To avoid processing every frame and maintain stable gameplay, gesture recognition was performed every 70 ms, corresponding to approximately 14 recognitions per second. Under this configuration, the estimated time between gesture execution and system response ranged from 70 to 120 ms (approximately 0.07 to 0.12 seconds), excluding camera latency. This response time may vary depending on the camera model, capture rate, controller, and ambient lighting conditions.

3.3. Evaluation of cooperative interaction

Throughout the game sessions, participants progressed through the different stages by performing specific gestures assigned to each player. A total of 15 cooperative collaboration situations were recorded, 13 of which were successful, representing an 86.7%. success rate. In these situations, task completion involved the sequential execution of distinct but complementary actions by both participants. For example, P2 activated the leaf bridge, thus enabling P1 to advance to the next stage.

In the collaborative coordination actions, six attempts were made to jointly perform the heart gesture, four of which were completed correctly, representing a 66.7%. success rate. In the successful events, the average time required to achieve synchronization between the two participants was 0.63 seconds. At the end of the level, the system displayed a victory screen with a summary of the cooperation metrics obtained during the session, as shown in Figure 5. In general terms, the results show a higher success rate in complementary actions compared to those that required simultaneous and synchronized execution by both participants.

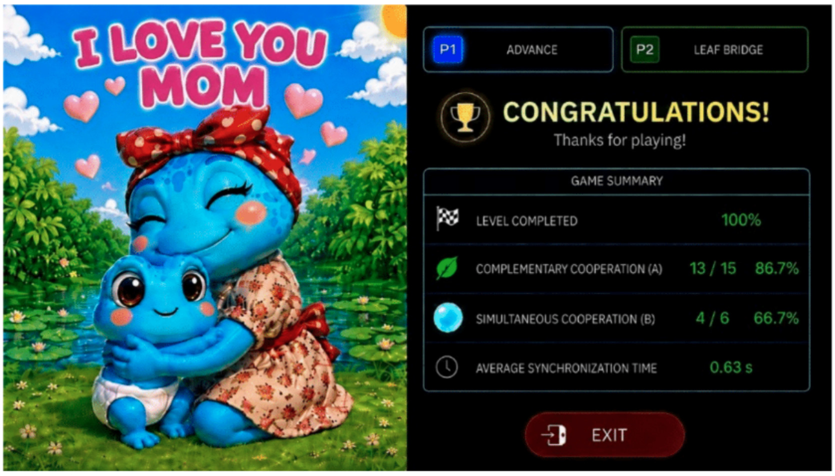

Figure 5: Victory interface and cooperative interaction metrics in Tinkuy Play.

4. Discussion

The prototype combined video acquisition, gesture recognition, and real-time game rendering while maintaining smooth gameplay. Although the average MediaPipe processing time was greater than the 16.67 ms available for processing every frame at 60 FPS, recognition was executed at 70 ms intervals rather than on every frame. With this configuration, the game remained at 60 FPS and the estimated response delay was 70–120 ms. These values correspond to the hardware and conditions used in the present evaluation and may change with another camera, computer configuration, or lighting environment. The automatic recording of player actions and timing information is consistent with the use of computational measures in previous collaborative gaming studies [16, 17].

Complementary actions were completed more often than the simultaneous cooperative action. During this trial, the participants therefore succeeded more frequently when they acted in sequence and performed different roles than when both had to coordinate the same action in time. A similar emphasis on turns and differentiated roles was reported for Zody, where these mechanics supported behavior directed toward a shared objective [16]. StarRescue likewise included activities in which progress depended on a partner's action, encouraging negotiation and attention toward the other participant [18]. Nevertheless, the present observations come from only one dyad completing one level and should not be generalized to other users.

Caregivers' perceptions also show a favorable evaluation of the proposal. Between 78.3% and 83.3% of participants positively valued aspects related to the game's design, its potential use at home, and their willingness to use it. These results are consistent with other studies that highlight the importance of active parental involvement and shared play [9, 11]. However, it is important to consider that the survey was conducted before the fully functional version of Tinkuy Play. Therefore, these responses mainly reflect caregivers' expectations regarding trial versions of the video game.

In comparison to other serious games aimed at emotional recognition or individual skill training [12, 15], Tinkuy Play incorporates the adult as a necessary part of the gameplay dynamic since some activities require the joint participation of both the mother and child to continue. This feature is also present in EMooly, which involves the adult through modeling, turns, and difficulty adjustment [19]. The difference with Tinkuy Play lies primarily in the use of complementary bodily actions and the recording of indicators of cooperation, simultaneity, and synchronization. Therefore, the results obtained at this stage allow for the evaluation of these measurement mechanisms, but they should not be interpreted as a clinical validation of the video game.

The interpretation of the results takes into account the limitations of the study. Only one 8-year-old child participated, with a teacher assuming the caregiver role, and the level was completed after several attempts. Some limitations were identified, such as the sample size and the lack of continuous follow-up and longitudinal measurements, aspects that were also present in other serious games aimed at children with ASD [12, 14]. Additionally, gesture recognition depends on the characteristics of the camera, the distance between players, and lighting conditions.

5. Conclusion

Tinkuy Play enabled the integration of computer vision and interdependent cooperative mechanics into a functional prototype. The system maintained 60 FPS and an estimated response time of 70 to 120 ms. During the level, an 86.7% success rate was achieved for complementary actions and a 66.7% success rate for simultaneous actions, with an average synchronization difference of 0.63 s. Taken together, these results show that the prototype can execute the proposed mechanics and record actions related to coordination between players.

The main contribution of this work is incorporating the child and the adult as players with different but necessary roles to achieve a common goal. The higher success rate for complementary actions suggests that this mechanic can facilitate turn-based participation and coordination between both players. Furthermore, the caregivers' evaluations show a favorable perception toward the continued development of the system. However, these responses primarily reflect their perception of the potential use of the proposal and do not allow for determining the acceptability of the functional version or establishing whether clinical or socio-emotional changes occur.

Future work will extend the prototype with emotion recognition, improved lighting support, and additional game levels. These additions are intended to create further opportunities for socio-emotional interaction while preserving the mother's active role in the activity. A subsequent evaluation is planned in specialized centers with children with ASD and appropriate standardized instruments. Before that stage, approval from an ethics committee and the corresponding institutional permissions will be required, together with parental informed consent and measures to protect participants' images and personal data.

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Declaration on Generative AI

During the preparation of this work, ChatGPT (OpenAI) was used for grammar and spelling checks, as well as for translating texts from Spanish to English. ChatGPT was also used to translate the text content of the game interface screenshots, which were originally developed in Spanish, into English. All AI-assisted corrections and translations were reviewed and edited by the authors as needed.

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