

Markers as Facilitators: The Role of Playful Interactive Markers in Collaborative Mobile AR Games

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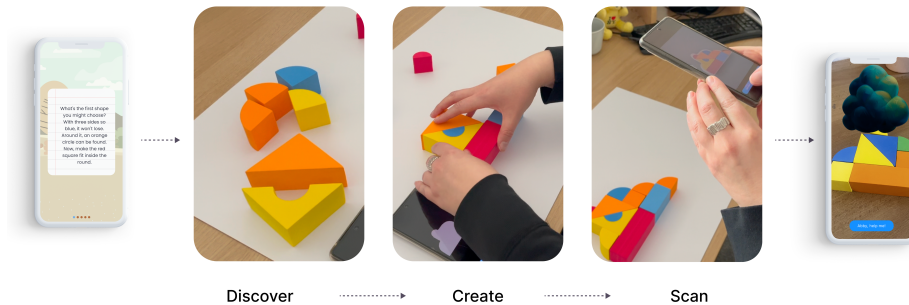


Figure 1: The discovery-creation-scanning loop in the marker-based AR game prototype, showing how players move from encountering an AR prompt, to constructing a physical marker, and scanning it to trigger in-game feedback.

Abstract

Marker-based mobile AR is widely used in playful games that combine digital content with shared physical objects. While prior research shows that mobile AR games can enable co-located collaboration, little is known about how playful markers within games themselves scaffold cooperative action. We examine how experts envision using playful markers for collaboration after hands-on interaction with a marker-based AR game prototype. Survey responses point to three key ideas: markers as shared focal points, collaboration that develops through play, and a preference for small, closely coordinated groups.

CCS Concepts

• **Human-centered computing** → **Participatory design; Mixed / augmented reality.**

Keywords

Mobile AR; Co-located collaboration; Marker-based AR Games

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1 Introduction

Mobile AR games have increasingly been used to support co-located, embodied play where players coordinate actions in shared physical environments (e.g., [5, 10, 14]). Prior research, such as [6, 8, 12], also demonstrates that mobile devices can enable face-to-face collaboration by supporting shared spatial references and joint activity during gameplay. At the same time, QR marker-based AR is often framed primarily as a technical problem of tracking and recognition; however, this view overlooks the role of tangible, physical-object markers, whose form and materiality can actively shape interaction. For instance, tangible 3D markers have been shown to be more intuitive and engaging than 2D alternatives [3], and modular marker designs can expand creative and collaborative possibilities [4]. Recent work calls for a deeper investigation into interactive markers as resources for social collaboration across physical and digital realities [17]. However, how interactive markers are perceived as social artefacts that scaffold coordination in co-located play, and how these perceptions can be translated into actionable implications for cooperative design, remain understudied. In this paper, we address this gap through an exploratory qualitative study in which 18 experts interacted with a marker-based mobile AR game prototype and completed a survey. We report three themes: markers as coordination anchors, a preference for collaboration that



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develops naturally during play, and a preference for small groups. The cooperative design implications derived from this exploratory study are intended for early adolescents aged 10–14 engaging in small, co-located groups. Although the expert participants in this study were adults with professional backgrounds, the long-term goal of this work is to inform the design of socially grounded mobile AR experiences for young players in informal or educational settings. We translate these insights into cooperative design implications for marker-based AR games, showing how playful physical markers can be deliberately designed to support social interaction in gameplay rather than treated only as technical tracking tools. Importantly, this study captures expert expectations and design interpretations after individual interaction with a single-player prototype. The findings should therefore be understood as design implications about how playful markers might scaffold collaboration in future cooperative implementations.

2 Related Work

Existing research has examined how mobile AR can support co-located interaction, shared experiences, and collaboration in physical environments. Studies show that mobile AR can enable face-to-face cooperation [14], support shared attention, and foster engagement when embedded in collaborative activities [5, 10]. Luna et al. [11] analyse communication, collaboration, and coordination in a shared AR game involving Deaf and Hard of Hearing participants, highlighting how shared visual references and embodied positioning shape interaction. Such studies demonstrate the importance of structured coordination mechanisms in shared AR environments, particularly when communication modalities vary. Prior research on interactive markers has largely focused on how different marker forms, materials, and designs affect usability, engagement, and interaction with the physical artefact. Buhion et al. [3] show that tangible 3D markers can be more intuitive and engaging than 2D markers, particularly for novice users. Chen et al. [4] extend this work by introducing modular, stackable markers that expand creative and collaborative possibilities through physical composition. Tawde et al. [18] demonstrated how material affordances influence user engagement and co-design outcomes. However, these studies primarily address usability and material fit rather than the deliberate use of markers as social coordination artefacts in collaborative gameplay. Design research emphasises the importance of iterative, participatory, and human-centred approaches for developing interactive systems [15]. Co-design approaches are particularly valuable for surfacing user expectations and social meanings that may not be evident through system evaluation alone [7, 13]. However, these approaches have limited applicability for examining how physical interaction components, such as markers, shape social collaboration in mobile AR games. While prior research in co-located AR and shared VR [19] has explored shared control and collaborative user experience, these systems typically focus on distributed digital interaction or shared virtual objects. In contrast, this work foregrounds playful physical markers as tangible coordination artefacts that structure interdependence through embodied, material interaction loops. The novelty of this contribution lies in articulating how marker design beyond tracking functionality may intentionally scaffold collaborative dynamics in mobile AR gameplay.

ID	Age	Gender	Country	Field
1	48	Male	Israel	HCI
2	29	Male	India	Games
3	39	Non-binary	Austria	Games
4	46	Male	Austria	AR
5	46	Male	Peru	AR
6	26	Male	Germany	HCI
7	31	Female	Austria	Games
8	25	Female	Germany	HCI
9	43	Female	Germany	Games
10	32	Male	Germany	AR
11	26	Female	Austria	AR
12	32	Male	Austria	Design
13	34	Others	California	HCI
14	26	N/A	Norway	HCI
15	48	Male	Australia	AR
16	54	Male	Japan	Design
17	47	Female	China	Games
18	29	Female	Australia	AR

Table 1: The table shows the following participants' data: identification number (ID), age, gender, country of origin, and field of specialisation.

3 Study

This exploratory qualitative study examines how shared physical markers in a mobile AR game support co-located collaboration through experts' interaction with a marker-based prototype.

Prototype. Experts interacted with a mobile AR prototype Ruh [16] that used physical markers as tangible input for game interaction. The prototype implemented a single-player experience structured around a tangible discovery–creation–scanning loop (see Figure 1). Players first encountered visual cues in AR, then constructed corresponding physical markers using provided craft materials (e.g., whiteboards, foam blocks, puzzle pieces, and Lego® bricks), and finally scanned these constructed markers with a mobile device to trigger in-game feedback and unlock new content. Although the prototype was not cooperative, its use of shared physical objects observed in our user studies [18], off-screen construction, and object-mediated feedback provided a concrete basis for experts to reflect on how such markers might structure collaboration, coordination, and social interaction in a co-located setting.

Participants. We recruited 18 experts with backgrounds in HCI, games, design, or AR (see Table 1). Participants were recruited in contexts where the prototype was exhibited (e.g., conferences and festivals). The following criteria were set for participant selection: 1) The participant has academic or professional experience in HCI, games, design, AR, or a related field; 2) The participant completes the full interaction with the prototype. Our goal was not to obtain a representative sample, but to gather informed, design-relevant perspectives from experts with experience in playful interaction. Recruitment proceeded until thematic saturation was reached. Only participants aged 18 or older were invited to take part in the study, and no personally identifying information was collected. All participants complied with Masaryk University's ethical standards, ensuring voluntary participation and informed consent.

Procedure. Each expert interacted individually with the prototype using a mobile device and a set of physical markers. After a brief introduction to the game's basic mechanics, experts were invited to engage freely with the game. Interaction continued until each expert had completed all four cycles of marker construction and scanning. Immediately after the interaction, experts completed a short survey with closed-ended questions (5-point Likert scales) and open-ended reflections on collaboration, social interaction, and design suggestions for a cooperative version of the experience.

Data Analysis. The analytic focus was on understanding experts' perceptions and deriving design implications from them. Therefore, the open-ended responses were analysed using thematic analysis, as outlined by Braun and Clarke [1, 2], with a reflexive, iterative coding process. The qualitative data were systematically analysed through the stages of transcription, data organisation, familiarisation, coding, theme identification, recoding, and category development [9]. The data was reviewed to support familiarisation and generate initial inductive codes related to collaboration, coordination, and social interaction. Coding proceeded iteratively: earlier codes were revisited, refined, merged, or reorganised as additional responses were analysed and patterns became clearer. Related codes were clustered into themes that captured recurring perspectives across participants. These themes were reviewed against the full dataset to ensure internal coherence and clear distinction between themes, and were subsequently defined and named to reflect their central organising concepts. Close-ended responses were used descriptively to contextualise and support the qualitative findings.

4 Results

The analysis of experts' responses identified three patterns describing how they envisioned collaboration around playful markers

Markers as Coordination Anchors. Experts largely perceived the potential of playful interactive markers as facilitating collaboration, though often in a context-dependent way rather than as an inherent guarantee of social interaction. When asked to what extent playful interactive markers could foster collaboration, 11 out of 18 (61%) experts reported that they "can significantly enhance collaboration," 5 out of 18 (28%) indicated that they "can help a bit, depending on the context," and 2 out of 18 (11%) selected a neutral option. No expert indicated that markers would not help at all with collaboration. This distribution suggests broad perceived potential, while also reflecting an awareness that the effect of markers depends on how they are designed and embedded within the interaction. For example, P18 noted, "*Using these physical toys could be a great opportunity to pull players out of their phones and encourage them to connect in the real world.*" Experts' preferences regarding collaborative interaction further clarify how markers were understood to support social connection. The most frequently endorsed collaborative activities were those centred on shared manipulation and joint problem-solving: 16 out of 18 (89%) experts selected "sharing clues and solving puzzles together," and 15 out of 18 (83%) selected "working together to build or activate a shared object." These activities involve interacting with the same physical artefact and responding to shared feedback, positioning the marker as a common reference point around which attention and action can be aligned. Experts'

responses regarding what makes social interaction meaningful reinforce this interpretation. The most frequently selected aspects were "completing tasks together successfully" (15 experts) and "making decisions or solving problems as a team" (11 experts). In contrast, "emotional connection or empathy" (3 experts) and "shared storytelling or creativity" (3 experts) were selected far less often. As P01 expressed, "*Making the players come together and make objects and then rewarding them where they can share victory together will deepen the social connection and these markers can play a perfect role to do that.*"

Player-Led Collaboration. While experts envisioned markers as shared coordination objects, they preferred collaboration that develops naturally and remains flexible, rather than interaction structured through fixed roles or scripted exchanges. This preference is reflected in the strong endorsement of collaborative activities such as puzzle-solving (16 experts) and shared-object construction (15 experts), alongside comparatively low endorsement of predefined roles (6 experts) and structured dialogue (2 experts). Rather than wanting the game to explicitly orchestrate collaboration, experts valued interaction designs that invite players to discover how to work together through the activity itself. 11 experts (61%) articulated concerns that overly structured collaboration might feel artificial or constrain social learning. For example, P10 noted, "*I think it would really be more organic if the interactions in the real world are not led by the game but instead it's something the players figure out to do on their own, which is an important aspect of social connection that they learn through collaborating.*" This suggests that experts valued collaboration that develops naturally not only because it is more enjoyable, but also because they saw it as more authentic, developmentally meaningful, and socially valuable. Experts also described collaboration that naturally develops during play as enabling players to negotiate roles dynamically, adapt to one another's strengths, and respond to situational challenges as they arise. P07 expressed, "*Designing the markers in a way where it's not possible to easily make these objects can definitely encourage team building or tackling the puzzle together, which would be the most effective in this context.*"

Preference for Small Groups. Experts expressed a clear preference for collaboration in small groups. When asked about the ideal group size, 11 experts selected 1–2 players, 6 selected 2–3 players, and only 1 selected 4–5 players. This distribution suggests that experts associate effective collaboration around shared markers with small groups and manageable coordination effort. Smaller groups were perceived as more conducive to maintaining shared awareness of the physical artefacts, negotiating actions in real time, and sustaining a sense of joint ownership over the activity. As P12 stated, "*It would be more meaningful for 2 players to get together and make the marker. I think the connection will be deeper, and it will not overwhelm some players who find it difficult to work with others.*" Experts also expressed concerns that larger groups might introduce social and coordination challenges that undermine collaboration. Larger group sizes were associated with risks such as unequal participation, lower engagement, and the emergence of passive roles. For example, P04 remarked, "*Having more than 2–3 players construct a physical marker will lead to additional challenges where some players might make the marker and the others just quietly watch.*"

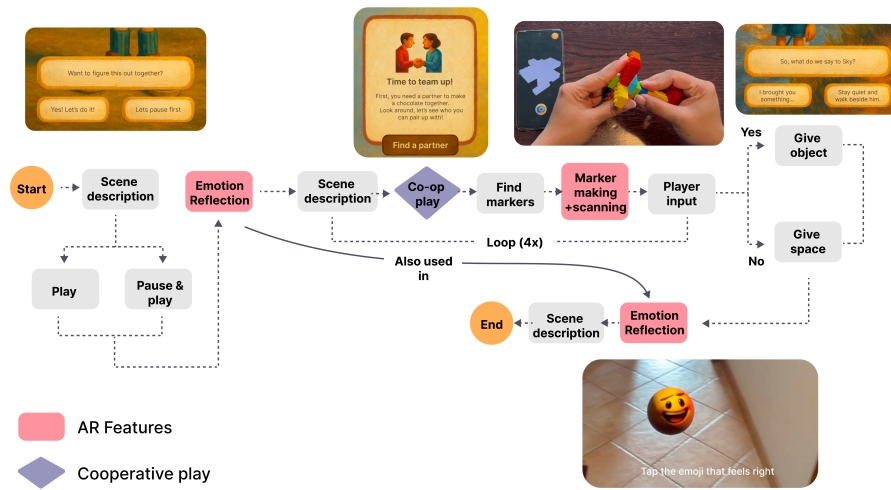


Figure 2: From exploratory study to cooperative game design: insights from an expert study of playful markers were translated into three design implications, which informed the development of the cooperative AR game.

5 Design Implications

We translate insights from the exploratory qualitative study into cooperative design implications (see Figure 2) that informed the development of 'Jiwa'. These are framed as preliminary design assumptions rather than validated evidence to guide future multi-user implementations. Experts consistently viewed markers as shared focal points anchoring joint attention and coordinated action. Based on these expectations, we formulated the first design implication that **physical objects should not be treated as individual interactions but as central progression elements within cooperative gameplay**. In practice, this means structuring gameplay around activities that require players to jointly attend to, manipulate, and reflect on the same physical artefacts. As a result, cooperative tasks were designed such that progress depends on the successful construction and joint handling of a tangible object, rather than on parallel individual actions. This operationalises the notion of markers as coordination anchors by ensuring that the physical object becomes a site of shared reference, discussion, and negotiation. Experts expressed a strong preference for collaboration that develops naturally through interaction, rather than collaboration prescribed through fixed roles or scripted dialogue. This informed a second design implication: **collaboration may feel more meaningful when it emerges from interdependence and shared challenge rather than from externally imposed structure**. Accordingly, cooperative mechanics were designed to create asymmetries in knowledge, capability, or physical reach that naturally invite coordination, without explicitly instructing players how to divide labour or communicate. This allows players to adapt the interaction structure to their social dynamics, developmental stage, and comfort with collaboration. Experts' preference for small group sizes translated into a design focus on pair interactions rather than larger group coordination. From this, we derived a third design implication: **marker-based cooperation may be most effective in small groups where mutual awareness and**

shared ownership can be sustained. This implication reflects the understanding that markers can support collaboration most effectively when embedded in interactions that allow experts to remain mutually responsive and visibly engaged with one another and with the shared artefact.

6 Discussion

The findings suggest that playful interactive markers can enhance co-located social engagement by shifting attention from individual screens to shared physical activity. However, their social value depends on how they are integrated into game interaction. Experts perceived markers as meaningful primarily when they functioned as shared focal points for joint action rather than as purely functional objects [4]. Activities that required shared manipulation, joint problem-solving, and mutual feedback were consistently associated with stronger perceived social connection than expressive or narrative forms of interaction. At the same time, the results indicate that increased structure does not necessarily lead to better collaboration. While markers support coordination [18], experts expressed a clear preference for collaboration that develops naturally through interaction, rather than collaboration prescribed through fixed roles or scripted dialogue. Experts felt that collaboration that arose naturally during play was more authentic and engaging, while highly structured interaction felt artificial and limiting. This suggests that designing for collaboration is less about specifying social behaviour and more about creating conditions, such as shared challenges, interdependence, and physical co-presence, under which collaboration can arise. Group size also shaped how markers were perceived as supporting collaboration. Experts strongly favoured small groups and expressed concerns that larger groups could lead to passive participation, uneven contribution, and a reduced sense of joint ownership. This suggests that playful markers work best when the interaction keeps players aware of each other, responsive to one another, and visibly engaged around the shared object.

These findings highlight a tension between engagement, structure, and control. Markers and tangible interaction can make collaboration more visible and engaging in games, but too much control from the game over social interaction can reduce the kinds of collaboration players value [13]. Designing collaborative mobile AR games, therefore, means providing shared tasks and constraints while leaving enough openness for players to shape the interaction themselves. Unlike prior tangible interaction research that primarily examines the usability or engagement of physical artefacts, this study foregrounds the social-coordination role of playful markers as structuring elements in collaborative mobile AR gameplay. From a design perspective, the study shows how an exploratory qualitative approach can inform early-stage design decisions by translating experts' perspectives into cooperative design implications for playful, socially grounded AR games.

Limitations and Future Work. This study has several limitations. Experts reflected on the potential of playful interactive markers after individual interaction with the prototype, so collaboration was discussed in terms of expectations rather than observed social dynamics. As a result, claims about collaboration in this paper should be interpreted as design implications rather than empirical evidence of collaborative behaviour. Future work must validate these implications through controlled multi-user studies observing real-time co-located interaction. The findings are constrained by the small, expert-only participant sample. While expert participants were intentionally recruited to provide informed design reflections, the sample does not represent the intended end-user population of early adolescents (10–14 years old), nor does it reflect broader player demographics. Instead, they represent expert-informed design perspectives that require empirical validation with representative participant groups. Future work will involve larger and more diverse participant samples, including early adolescent players, to examine how collaborative dynamics unfold in practice and to assess the robustness of the proposed design implications across populations.

7 Conclusion

This paper explored how playful interactive markers can facilitate co-located collaboration in mobile AR games. The findings show that players perceived markers as particularly effective for shared manipulation and joint problem-solving during gameplay, but less effective for scripted roles or structured dialogue. Preferences for collaboration that develop naturally through play, together with a preference for small-group play, indicate that close, flexible coordination is especially valued in collaborative AR gaming. Experts also associated larger groups with reduced engagement and uneven participation in play. Overall, the results highlight design implications regarding how playful interactive markers may support social interaction in collaborative AR games, while underscoring that this potential depends on how markers are integrated into game mechanics and playful interaction structures.

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