

Formation DancAR: Facilitating Formation Dance Practice with Augmented Reality

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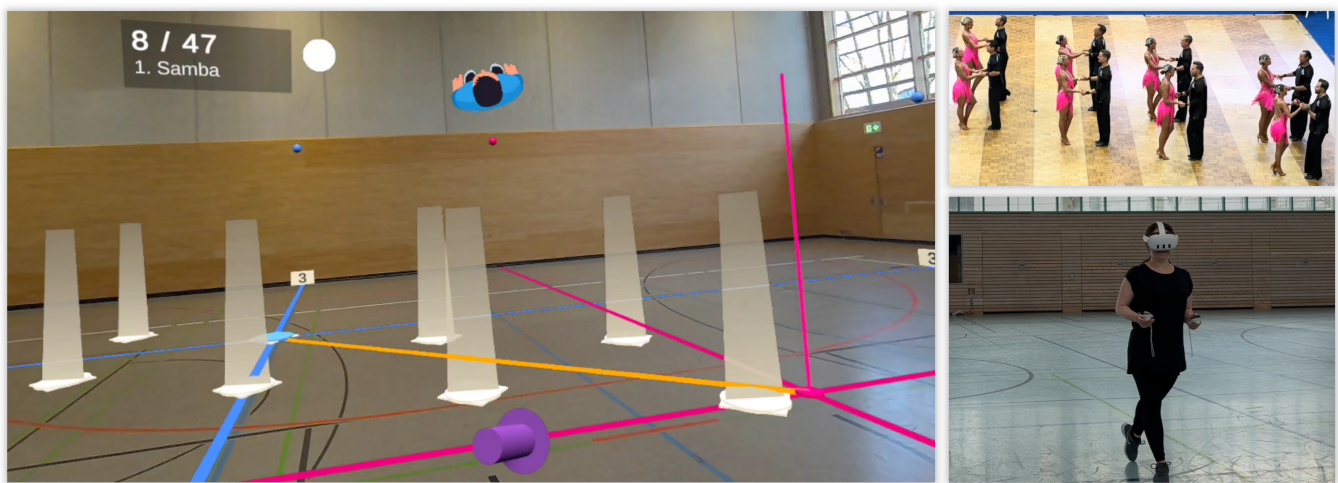


Figure 1: The Formation DancAR interface showing an augmented formation (left), the same formation during a dance competition (top right), and a dancer practicing with the system (bottom right).

ABSTRACT

Formation dancing is assessed regarding synchronicity and symmetry of formations. Accordingly, training and learning new choreographies require significant effort. We propose an augmented reality (AR) system to support the initial practice of formations and transitions for a new choreography. The system provides visual and auditory cues for positions, movement paths, timings, and body orientation, allowing dancers to train individually without teammates. To evaluate its effectiveness, we conducted two exploratory studies with a total of 15 formation dancers, comparing visual guidance methods for practicing transitions in a new choreography. The results showed that both AR position marker design packages were effective at guiding dancers through the formations and that participants perceived the gradual guidance reduction as supporting their learning. Further, participants found the approach valuable and considered it an effective addition to their training routines.

CCS CONCEPTS

• **Human-centered computing** → **Mixed / augmented reality**; *Interactive systems and tools*; *Visualization systems and tools*; • **Applied computing** → *Interactive learning environments*.

KEYWORDS

Augmented Reality, Visual Guidance, Dance, Formation, SportsVis

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1 INTRODUCTION

Latin formation dancing is a competitive team sport in which up to eight couples perform a synchronized choreography, which is judged not only based on technical skill and artistic expression but also on synchronicity and the formations the team creates. They involve dancers occupying predefined positions to form shapes or patterns, either stationary or in motion. Judges assess formations

based on line clarity, shape symmetry, spacing, alignment accuracy, and variety and complexity [11]. Seamless transitions between formations, involving varied directions and distances, are essential for visual flow but pose a significant learning challenge.

Learning and rehearsing a formation choreography involves distinct phases. After internalizing dance steps and body movements, a team moves to the formation training phase, learning positions and transitions. We explore how augmented reality (AR) can assist in this phase, as, in addition to position and transition memorization, coordination within the team is key. This phase is particularly vulnerable to disruptions: even a few absent dancers impair spatial awareness, alignment, and timing for the rest of the team, making effective practice difficult. While prior work has explored how mixed reality (MR) can aid in teaching dance movements (see Section 2), its application to formations and transitions remains largely unexplored. To date, no solution exists to enable dancers to practice dynamic positioning within a formation team on their own.

To address this gap, we present *Formation DancAR*, an AR system developed in collaboration with a Latin formation dance team that supports individual dancers in learning and rehearsing formations and transitions using a video see-through (VST) head-mounted display (HMD). The system provides visual and auditory cues for positions, movement paths, timing, and body orientation (Figure 1), with the primary goal of guiding formation movement during initial choreography learning and a secondary goal of enabling solo rehearsal by virtually rendering teammates' positions as references.

Our work makes three contributions: (1) a requirements analysis of dancers' information needs during transition practice, validated with three experienced instructors, (2) the *Formation DancAR* system itself, and (3) two exploratory user studies with 15 experienced dancers, the first comparing two AR position marker design packages and assessing general feasibility, the second exploring whether dancers can perform transitions after gradually reducing visual guidance. Both design packages guided dancers effectively. Study 2 participants performed the transitions without visual guidance and reported a better understanding of their formation positions, indicating that *Formation DancAR* enables independent formation practice in a form impossible with traditional methods.

2 RELATED WORK

Approaches and tools that support sports training cover a wide variety of disciplines [31]. Prior work has explored teaching dancing in virtual reality (VR) or AR, including systems for learning individual moves and body posture [6, 19] and stationary dancing with a virtual partner [18, 29]. Augmented mirror setups have similarly been proposed for learning dance moves and poses [1, 10, 34, 38], as well as floor projection with multimodal feedback [16].

For group dance, Lee et al. [20] highlight the lack of dedicated research, and existing works focus primarily on tracking and visualizing the synchronicity of multiple dancers' posture rather than their positioning within a formation [21, 39]. For formation dancing, both FormationCreator [25] and ChoreoVis [3] are related to our work, supporting the creation or reproduction of dance choreographies. To the best of our knowledge, no existing approach specifically targets practicing formation transitions and positioning, either in a group setting or during individual training. With our

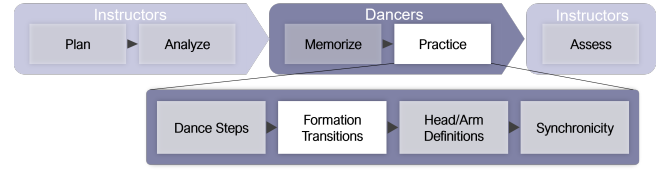


Figure 2: Adapted process of choreographing and practicing dance formations [3], highlighting the formation transition practice step (white).

system, we focus on the *global movement of formations on the dance floor*, to help keep the formation symmetrical and coordinated.

Guiding and directing dancers to new floor positions is integral to our approach. While several works address motion [37] and attention guidance [24] in AR, most focus on practicing limb movements and postures. According to the design space proposed by Yu et al. [37], our system has implicit and abstract levels of indirection and employs a discrete interactive update strategy presented from a first-person perspective.

Out-of-view guidance techniques include 2D approaches such as Halo [2], Wedge [15], and 2D arrows [13], and 3D techniques such as 3D arrows [33], Bezier curves [35], Radar, and MirrorBall [5]. Since we guide dancers to a single target position, multi-target techniques like Radar and MirrorBall are overly complex for our use case, whereas 3D arrows are a widely used and intuitive choice that can point to out-of-view positions [33, 35, 37] and outperform minimap-style bird's-eye views for position estimation [27, 33]. As a minimap additionally provides a global overview of the formation, we include it also as complementary guidance alternative (Section 4.2.4), augmented by cues such as lines indicating relative positioning to other dancers.

3 BACKGROUND AND REQUIREMENTS

To understand the challenges and requirements in learning and practicing formation transitions, we conducted a design study with a local Latin formation team and consulted the German Dance Sport Association's (DTV) scoring guidelines [11]. We additionally conducted semi-structured interviews with three experienced instructors (E1-E3) to validate our requirements. They had ten to twenty-one years of dancing experience and three to eight years of instructing teams in the top three German divisions. We used inductive coding to analyze the verbatim-transcribed and anonymized interviews (supplementary material), and also collected feedback on our *Formation DancAR* system, described in Section 8.

3.1 Practicing Formation Transitions

Practicing formations and transitions is complex, and supporting dancers in this critical practice phase remains an open gap [3]. Teams start the training season by concentrating purely on the dance steps, only moving on to the formation transitions once these steps are fully internalized (see Figure 2). The formation transitions phase is particularly demanding: E1 described formation training sessions as *"among the most demanding sessions we have, especially for the mind"*, and experts estimated that initially learning formation positions takes about a month of bi-weekly training sessions.

Teams follow an incremental approach, rehearsing individual transitions before gradually building up to the full choreography. Accurately positioning oneself within the formation is challenging early on. Teams place distance markers (e.g., cones) around the floor, and instructors often guide dancers manually, a time-consuming process, as formations have up to 16 positions. Rehearsal time could be used more effectively if position information were directly visible to dancers, rather than relying on memorized coordinates.

While it is important that the front dancers hit their assigned positions, dynamic positioning within the team is essential for the other dancers. Beyond absolute positioning, training spatial perception and relative positioning within the team is one of the main challenges, according to all three experts. E1 noted that *“the first thing you notice is when a person in the back does not stand in their line”*. This becomes especially problematic when dancers are absent during a practice session, as relative positioning breaks down without the full team present. As E3 explained, dancers in the back *“orient themselves based on the others”*, making it difficult to practice meaningfully with an incomplete group, or for an individual dancer to fill in for another position on short notice.

3.2 Requirements

We split the requirements into information needs and usability requirements, and validated them with the interviewed experts.

3.2.1 Information Needs. *Current Formation Position (R-Pos)*: Dancers need to know their exact spot in the current formation to position themselves correctly. Experts confirmed that a visual representation would be very helpful, *“especially to check if I am standing on the correct position”* (E3).

Team Formation Positions (R-Team): The DTV’s scoring criteria require precise lines, equal spacing, and symmetry around an imagined center [11], making awareness of teammates’ positions essential for coordination. Visualizing these positions would be *“very good, so that I know where my reference points are later on”* (E2).

Next Formation Position (R-Trans): Dancers must anticipate which position to move to in the next formation, which is complicated by the requirement to maintain head orientation, the short time between transitions, and the next position potentially being outside the field of view. The DTV further rates transitions as more difficult when they involve rotation or body orientation changes [11], making visual guidance [24, 37] particularly valuable here.

Timing Information (R-Time): The scoring guidelines require coherence of movement across formation changes [11], making temporal guidance (particularly the beginning, end, and duration of transitions) essential, especially in early training phases. Experts reinforced this: *“that would certainly be helpful because dancing those transitions uniformly is one of the big challenges”* (E2).

Pose Orientation (R-Orient): The scoring criteria also include uniformity of body orientations in formations [11]. Awareness of head and body direction is important for executing transitions smoothly, although E2 categorized this as just *“nice to have”*.

3.2.2 Usability Requirements. The system must play choreography music with variable playback speed, align the virtual coordinate system with the physical dance floor, and allow navigation of the choreography to select sequences for practice. Experts further

stressed that the system should not constrain dancers’ movements, be portable without permanent hardware installation, and be compatible with existing choreography data models. Finally, the level of guidance should be configurable (*R-Config*) to support different training scenarios and progress stages.

4 SYSTEM DESIGN

Our system displays formation data, e.g., as created with Choreo-Vis [3], and saved as JSON files containing positions, orientations, and timestamps for each formation. In the following, we will explain our design decisions and the system’s individual visualization and guidance elements.

4.1 General Design Decisions

We developed the final design through several iterations, exploring handheld AR (impractical while dancing) and projector-based AR (discarded due to occlusion, visual clutter, and installation constraints in a multipurpose gym) before settling on an HMD application for a single dancer. An HMD enables portable, in-situ, embodied guidance without interrupting practice or requiring additional hardware. Compared to 2D visualizations, AR fosters spatial awareness by presenting instructions from the dancer’s own perspective. Compared to VR, it maintains visibility of real limbs and alignment with the physical dance floor. Additionally, AR allows users to practice with partners who are not wearing an HMD, and supports a form of individual training previously infeasible. The design was refined through informal pilot sessions (two internal, two with formation dancers) in which we observed users and collected verbal feedback without recording data. They shifted the design from visualizing only positions towards richer guidance, motivating the out-of-view guidance (Section 4.2.4), the light columns (Section 4.2.3), and the arrow and avatar defaults in Study 1 (Section 6.1).

4.2 Visual Design Elements

As dancing is fast-paced, visual designs must be clear and intuitive, and make dancers aware of upcoming transitions early without distracting them from other cues. We thus designed the following visual elements, configurable through the main menu (*R-Config*).

4.2.1 Dance Floor Positioning. Users can align the virtual coordinate system with the physical dance floor by placing and rotating it via ray interaction (*R-Config*), after which the main scene launches, augmenting the real environment with virtual formation positions and additional information. Further localization and mapping are handled by the HMD.

4.2.2 Position in Formation. A blue floor marker indicates the user’s current formation position (*R-Pos*), with its shape encoding the dancer’s role: diamonds for ladies, circles for gentlemen (Figure 3a). Optional grid lines with coordinate panels and floating spheres enhance peripheral awareness and orientation without requiring the dancer to look down (Figure 3b, Figure 1). During transitions, the marker moves to the next position, conveying the intended movement path and speed (*R-Time*), while a magenta marker and optional light column indicate the upcoming position to support transition preparation (*R-Trans*, *R-Config*).

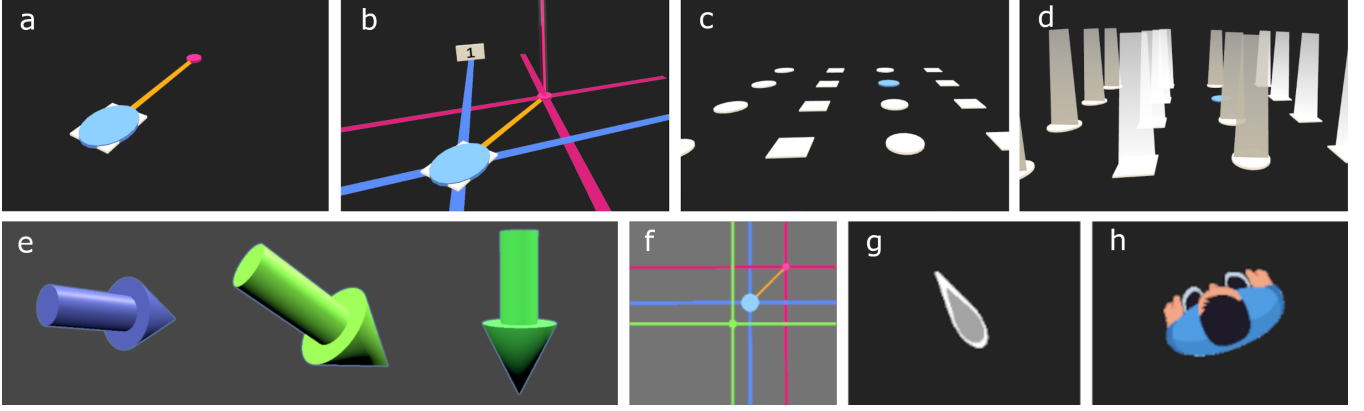


Figure 3: The visual design elements in *Formation DancAR*: floor (a) and spatial (b) markers for the user’s current (blue) and next (magenta) position and movement path (orange line), floor (c) and spatial (d) markers for the team’s positions, 3D arrow with color distance encoding (e), minimap (f), head and body orientation represented by pointers (g), and an avatar (h). Elements are illustrated in VR here, but are shown in AR for end-users.

4.2.3 Team Positions. To practice coordinated transitions and spatial alignment, the system displays teammates’ positions via two alternative representations (*R-Team*, *R-Config*): floor markers mirroring the user’s indicators (white circles and diamonds without grid lines to reduce clutter, Figure 3c), and transparent light columns as spatial dancer proxies that enhance spatial awareness and allow easier alignment (Figure 3d). All markers animate through transitions to support team coordination practice (*R-Time*). We opted for transparent light columns over opaque shapes (which blocked critical cues) and human-like avatars (which would require pose data absent from our model).

4.2.4 Guidance to Next Position. Pilot sessions revealed that additional guidance towards out-of-view positions is needed, so we implemented two alternative techniques (*R-Trans*, *R-Config*): a 3D arrow and a user-centered minimap. The 3D arrow points from the user’s position towards the next formation position, with its angle implicitly encoding distance: the steeper the angle, the closer the target (Figure 3e). The distance is additionally encoded by a purple-to-green gradient (purple: distance to target ≥ 5 m, green: ≤ 0.25 m, matching our measurement tolerance, see Section 6.1). The minimap offers an exocentric bird’s-eye view, with the user represented by a crosshair at the center, current and next positions shown as proxy icons, and rotation following the user’s viewpoint (Figure 3f). Minimaps have been associated with precise direction encoding and fast reaction times, albeit at potentially higher mental effort [24, 33]. Both alternatives can be used individually or in combination (*R-Config*), and are displayed at the center of the user’s view to align with foveal vision, reduce eye movements, and minimize cognitive load [23].

4.2.5 Movement Path. The movement path is rendered as an orange line on the floor between the user’s current and next position (Figure 3a), currently approximated by linear interpolation due to data sparsity. The floor marker animates along it during transitions to indicate speed and direction (*R-Time*). We disregarded alternatives like animated lines or particle effects to reduce clutter.

4.2.6 Orientation. The system additionally visualizes the required head and body orientations at the start of each formation (*R-Orient*) in two alternative representations (*R-Config*): an abstract clock-like display with two pointers fixed in world space indicating body and head direction (Figure 3g), and a more intuitive top-down 2D avatar whose head and body rotate independently (Figure 3h). In both cases, the user is correctly oriented when aligned with the respective indicator.

4.2.7 Transition Timing. The system plays the choreography’s music at variable speed to dance along (*R-Time*, *R-Config*), with all position markers animating during transitions to convey timing information. Users are alerted to upcoming transitions (*R-Time*) via a four-beat auditory countdown, intuitive to dancers familiar with such cues, and a paired visual indicator (*R-Config*) in the top-left periphery, where a circle fills with blue segments during the countdown and returns to white once the transition ends (Figure 1).

5 STUDIES

We conducted two exploratory user studies with experienced formation dancers from a local Latin formation team to evaluate our design choices and the learning process our prototype enables. Study 1 (Section 6) explored design alternatives for formation position markers and overall feasibility. Study 2 (Section 7) followed up by exploring whether dancers can perform formation transitions after a gradual reduction of visual guidance. Following the requirements in Section 3.2, both studies address two research questions. *RQ1*: How well do the two design packages support dancers’ information needs during transition practice, and how do dancers perceive the AR approach? *RQ2*: Can dancers perform formation transitions without spatial guidance after practicing with stepwise-reduced guidance, and how do they perceive this reduction? We return to both questions in Section 9.

In this early research stage, purely quantitative evaluation and statistical significance testing can be premature [12, 22], and exploratory mixed-method studies are better suited to capture insights about design decisions. Accordingly, we report results using

interval estimation rather than null hypothesis significance testing (NHST) [8, 9], presenting sample means of performance, NASA-TLX, and Likert scale responses with 95% confidence intervals (CIs).

Both studies were conducted in multipurpose gym halls (14×14 m dance floor) using a Meta Quest 3 with VST enabled, with formation data created via ChoreoVis [3]. Both studies were approved by the University of Stuttgart's ethics committee. Participants gave informed consent and were compensated. Questionnaires, raw data, and interview transcripts are provided as supplementary material.

6 USER STUDY 1: DESIGN CHOICES AND AR APPROACH

Study 1 explored the feasibility of practicing formation transitions with our approach and compared how two visual representations of formation positions differ.

6.1 Method

To keep session duration within a 90-minute limit, we compared two design candidates for formation position encoding (the prototype's core feature) with visual guidance and orientation fixed to the 3D arrow and avatar designs based on pilot feedback, and both alternatives for the audio and visual cues used for transition timing. The conditions varied whole design packages rather than single cues: *floor* used flat markers for the dancer's own and the team's positions (Figure 3a, c), *spatial* used grid lines, coordinate panels, and floating spheres plus light columns for teammates (Figure 3b, d). All other elements were identical. Alternative designs were presented in post-experiment interviews for subjective evaluation.

Participants practiced transitions of two short choreographies, one per condition. The order of conditions and choreographies was counterbalanced using a Latin square design, yielding four orderings with 3, 3, 3, and 2 participants (due to a last-minute cancellation), respectively. No participants or trials were excluded. To keep focus on transitions, the experimenter presented the simple dance steps without additional arm or body movements: basic Cha-Cha-Cha (CCC) steps (including turns to simulate orientation challenges, central positioning) and basic Jive steps (front positioning). Each choreography included four formations with three transitions and varying body and head orientations. Following an incremental training procedure (Section 3), participants practiced each transition individually, then combined, and finally the full choreography, with three repetitions per step, completing a questionnaire after each condition and a closing interview.

We measured performance by aligning HMD-logged trajectories to a baseline using DTW [4] and computing the mean point-wise Euclidean distance (MPWD) in the floor plane over the aligned sequences. Because tracking relied on the HMD, deviations were measured at the head rather than at the feet, to which formation positions may refer. As the virtual floor markers were 0.45 m wide, we treated deviations below 0.25 m (roughly half the marker width) as within our measurement tolerance rather than as positioning errors. Users' task load was assessed with an adapted NASA-TLX tool (raw TLX, physical demand omitted to avoid confounding with choreography effort [17]). Participants also completed a questionnaire on effectiveness, usefulness, and likability. Post-experiment interviews were analyzed using inductive coding.

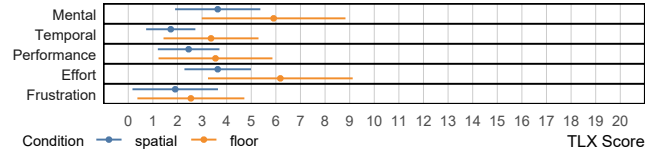


Figure 4: NASA-TLX results with 95% CIs.

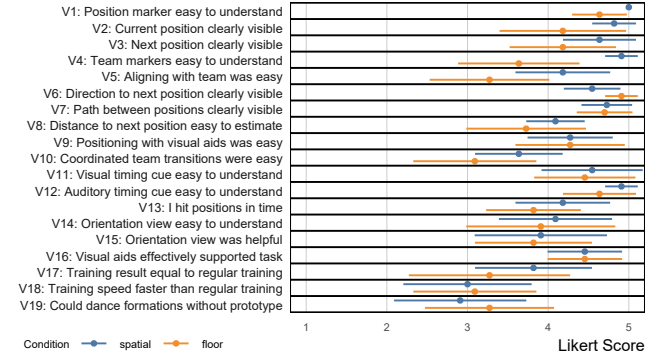


Figure 5: Visualization design questionnaire results with 95% CIs. Likert scale from 1 (fully disagree) to 5 (fully agree).

We recruited 11 dancers (5 female, 6 male; ages 18–39; formation dancing experience 1–18 years, mean = 6.5, SD = 5.11) from the first through fourth division ($n = 2|1|3|5$) of the German competition system. Eight were somewhat familiar with AR, three not at all.

6.2 Results

Below, we report the participants' performance and answers to our questionnaires regarding task load, visualization design, and our approach in general.

6.2.1 User Performance and Task Load. Mean MPWD to the baseline was 0.24 m (floor, 95% CI [0.17, 0.30] m) vs. 0.23 m (spatial, [0.15, 0.32] m) for CCC, and 0.16 m ([0.09, 0.23] m) vs. 0.13 m ([0.09, 0.16] m) for Jive. Differences between conditions were small relative to the intervals, which overlapped substantially in both choreographies and lie within our measurement tolerance. Task load was rated low in both conditions, with slightly lower scores for *spatial* (mean = 2.67, SD = 1.5) than *floor* (mean = 4.31, SD = 2.73) but overlapping intervals (Figure 4). Neither performance nor task load varied systematically with participants' division or years of experience, and the same held for the questionnaire ratings and interview comments reported below.

6.2.2 Visualization Design. Participants rated both conditions favorably across 19 Likert-scale statements (Figure 5), with slightly higher ratings for the spatial condition. Understanding of position representations, visual guidance, and timing cues was consistently high across conditions. Spatial team markers were rated superior for relative positioning (V4), with P11 noting they always knew where teammates were. Coordinated transitions remained comparatively challenging (V10), and while orientation cues were comprehensible (V14), their usefulness was rated more variably (V15). Participants

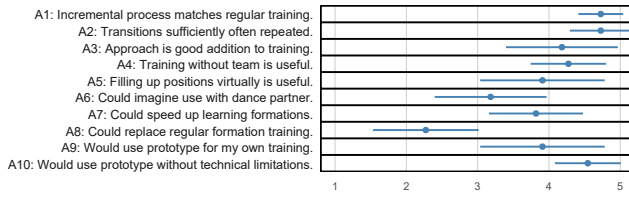


Figure 6: AR approach questionnaire results with 95% CIs. Likert scale from 1 (fully disagree) to 5 (fully agree).

agreed that visual aids supported learning formations and transitions (V16), with P6 reporting faster and more precise learning than alone. Ratings for learning outcome, speed, and retention were more variable (V17–V19): P8 felt over-reliant on the aids, while P3 could repeat the choreography without assistance. Nine of eleven participants preferred the spatial condition for the overview of the full team. The 3D arrow was the most favored guidance element for its intuitive distance encoding (P9), while the minimap was considered too complex by most (P5, P8). The orientation view was the most confusing feature (P7), largely ignored in favor of positioning cues, while the magenta light column for the next position (P5) and the 3D arrow (P4) were rated most helpful.

6.2.3 AR Training Approach. Participants fully agreed that the incremental process matched their regular training and provided enough practice opportunity (A1–A2, Figure 6). The prototype was received positively as a supplement to regular training, particularly for solo practice and potentially substituting missing team members (A3–A5), with P11 highlighting its value for practicing formations without the full team. Opinions on joint use with a partner were mixed due to hardware concerns (A6), though participants saw potential for faster learning (A7). Most could not imagine the prototype replacing full-team training (A8), but expressed willingness to use it if technical limitations were addressed (A9–A10).

7 USER STUDY 2: LEARNING PROCESS

Study 1's mixed confidence in unaided performance (Section 6.2.2) motivated User Study 2, exploring whether stepwise guidance reduction leads to unaided performance. According to the *Guidance Hypothesis* [26, 28, 30], continuous guidance aids performance but impedes learning when performers rely on the cue rather than their own references, paralleling the *Guidance-fading Effect* [32]. Since principles from simple skills do not transfer directly [36], we follow the *Challenge-point Framework* [14]: difficulty rises with skill, here by reducing guidance at a self-chosen pace [7].

We implemented three guidance levels that participants could switch between freely. *High* shows all visual aids (Study 1's spatial condition). *Medium* shows only the 3D arrow, position markers on the dance floor's sides rather than directly on it, and light columns for teammates, requiring more attention to the team and surroundings. *None* removes spatial guidance entirely, retaining only reference points equivalent to those in ordinary team training (evenly spaced side markers and light columns for other dancers) while UI color feedback indicates correct positioning.

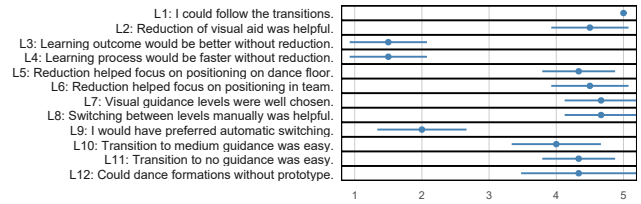


Figure 7: Learning effectiveness questionnaire results with 95% CIs. Likert scale from 1 (fully disagree) to 5 (fully agree).

7.1 Method

The experimental setup largely followed Study 1. Participants learned three formation transitions of a short Samba choreography with the adapted prototype in a more exploratory design to observe how they approached the task. No specific instructions on repetitions or guidance level switching were given, except to start with guidance level *high* and progress when comfortable.

Trajectory data were collected as in Study 1, with participants' best performance on level *high* serving as a reference. We consider a paired *high–none* difference within our 0.25 m measurement tolerance as indicating that performance did not depend on the visual guidance. User experience was assessed via questionnaires on the revised learning process, followed by post-experiment interviews.

Six experienced Latin formation dancers (3 female, 3 male; ages 18–35; experience 1.5–6 years, mean = 4.08, SD = 1.79) participated, two of whom had taken part in Study 1. They competed in the third ($n = 4$) and fourth ($n = 2$) divisions of the German system; one was unfamiliar with AR, four were somewhat familiar, and one was very familiar. No participants or trials were excluded.

7.2 Results

All six participants completed the full choreography at guidance level *none* in their final run, with a mean MPWD of 0.18 m (95% CI [0.15, 0.21] m), within our measurement tolerance. They followed the incremental training procedure and reduced guidance as they progressed, adopting varying strategies: some gradually reduced guidance while combining segments, others only progressed after completing a section without guidance, with occasional temporary performance drops that typically recovered within a few attempts.

Crucially, performance remained stable across guidance levels. The mean paired difference between participants' best *high* and best *none* runs was 0.4 cm in favor of *high* (95% CI [4.7 cm in favor of *high*, 3.9 cm in favor of *none*]), with individual differences ranging from 3.8 cm in favor of *high* to 7.3 cm in favor of *none*. The interval's bounds lie well within our measurement tolerance, suggesting that final performance did not depend on the visual aids. We observed no relation between division or experience and performance or feedback. Most participants stated they could now perform the choreography without the prototype (Q12), compared with Study 1. Further details are provided in the supplementary material.

Participants rated the stepwise guidance reduction positively across 12 Likert-scale statements (Figure 7), with narrow 95% CIs indicating high agreement. All could follow transitions and found the guidance reduction helpful (L1–L2). They disagreed that learning would have been better or faster without the reduction (L3–L4).

P2 highlighted how switching to a lower guidance mode revealed over-reliance on floor markers and the importance of attending to other reference points, while P4 appreciated the gradual reduction for encouraging self-reliance. Participants further agreed that the reduction improved focus on spatial positioning (L5–L6), with P6 noting it helped develop a spatial feel for transitions rather than merely memorizing coordinates. Freely choosing between modes was rated positively for supporting self-paced learning (L8, P2), and mode transitions were not considered disruptive (L10–L11). Finally, five participants expressed that individual AR practice could help prepare for team training (P3) or onboard new dancers to a choreography (P6).

8 EXPERT FEEDBACK

In the expert interviews (see Section 3), we showed a video of our prototype and asked for feedback. All three experts agreed that dancers could use *Formation DancAR* to prepare for team training or learn new positions independently, which is a capability E1 identified as otherwise unavailable in formation training. They also envisioned broader use cases, such as previewing choreographies and team movements in AR. All three stated they would incorporate the system into their training methods, given the necessary hardware, and E2 was confident it would appeal to most dancers.

9 DISCUSSION

Regarding RQ1, Study 1's results suggest that both design packages effectively guide dancers to their formation positions and that the AR approach was well received. Regarding RQ2, Study 2 indicates that dancers could perform the transitions without visual guidance after stepwise reduction and perceived this process as supporting their learning. In the following, we discuss several implications drawn from the results.

9.1 Design and Learning Insights

Study 1 left participants' confidence in unaided performance mixed. Like many AR dance systems, maximizing guidance helps users quickly perform new movements [6, 19, 29, 34], but eventually hinders learning. Study 2 is consistent with this view: participants reached comparable performance once guidance was removed, although without a comparison group practicing under constant guidance, this cannot be separated from the effect of repeated practice. To the best of our knowledge, none of the related systems reviewed in Section 2 follow this approach. Investigating its transfer to other AR guidance scenarios is a promising research direction.

Both design packages (RQ1) proved effective, without notable differences in performance or task load. However, the spatial package was clearly preferred, with teammate positions rated easier to understand, possibly because of the more immersive light columns. As the packages differed in several elements (grid lines, coordinate panels, floating spheres, and light columns), this preference reflects the integrated design rather than marker spatiality alone. Across both studies, participants' MPWD to baseline trajectories ranged from 0.13 m to 0.24 m in final runs, at or below our measurement tolerance. Observed deviations were partly inflated by in-place dance movements during static formations not represented in the linearly interpolated baseline data, as participants noted themselves. This

also plausibly explains the larger deviations for CCC, whose steps involved more in-place movement than Jive. Together with the head-based tracking, the reported distances should thus be read as comparative measures rather than as absolute foot positioning accuracy. More detailed choreography data would improve both prototype usefulness and result validity.

9.2 Limitations

The relatively small sample sizes (11 and 6 participants) reflect a deliberate trade-off between generalizability and ecological validity. Formation dance requires expertise, and only skilled dancers can meaningfully engage with the system while eliminating confounds like learning basic steps. Future work could expand the participant pool and validate results across other formation disciplines or coordinated group activities such as folk dance, marching bands, or cheerleading, which would require activity-specific visual cues.

Our exploratory designs prioritized ecologically valid practice over isolating individual factors, as discussed above for Study 1. Study 2 shows that dancers performed the transitions without visual guidance after the fading process. However, as all participants progressed from high to reduced guidance without a comparison condition, this may also result from repeated practice rather than from the fading itself, and a delayed retention test would be needed to confirm lasting learning. Both studies focused on early-stage positioning and transition practice, deliberately excluding aspects like dance steps and body postures, which are typically trained separately. Integrating them into a holistic AR training approach remains future work.

Current HMDs like the Meta Quest 3 may hinder training due to weight and strain during fast rotational movements, although no motion sickness was reported; more lightweight devices should make the approach increasingly practical. Visual cue visibility posed minor challenges across varied gym environments with existing floor markings, mitigated by using easily visible, adjustable colors. Finally, while the Meta Quest 3 tracking worked well in our experiments, its precision was not formally evaluated, and performance in other large open spaces may vary.

10 CONCLUSION

We presented *Formation DancAR*, the first approach enabling solo practice of formation transitions with real-time AR guidance, keeping dancers informed about team movements without requiring the full team to be present. Two AR position marker design packages were evaluated: while both proved effective, the spatial package was clearly preferred. After gradual guidance reduction, participants were able to perform transitions without visual guidance and rated the process positively, although a controlled comparison and a retention test are needed to attribute this to the fading itself. Expert interviews confirmed the system's suitability for the targeted training phase and its potential as a valuable supplement to conventional team training.

Future work could enhance immersion through more detailed trajectory data capturing dancers' in-place steps, add post hoc analysis of training runs, and explore cooperative scenarios in which multiple dancers practice together in AR.

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