Comparing Head-Mounted and Handheld Augmented Reality Instructions for Manual Assembly Tasks Under Increasing Spatial Task Complexity

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Abstract

Augmented reality (AR) can support manual assembly tasks by placing instructions directly at relevant objects and positions. Yet it remains unclear how task complexity moderates the relative effectiveness of AR form factors. We report an exploratory within-subject study with 18 participants comparing a monitor-based baseline, handheld AR, and head-mounted AR across an adapted standardized assembly benchmark with three levels of spatial task complexity. Measures included completion time, errors, workload, preferences, and qualitative feedback. While the monitor baseline was fastest at the lowest complexity, consistent with prior work, AR benefits increased with spatial task complexity: head-mounted AR was fastest at medium and high complexity, handheld AR also outperformed the baseline once complexity was highest, and both AR modalities reduced workload at the highest complexity. These findings suggest that hardware choices for AR assembly guidance cannot be generalized from low-complexity benchmarks alone and warrant further study across systematically varied task complexities.

CCS Concepts

• **Human-centered computing → Mixed / augmented reality**; *Empirical studies in HCI*.

Keywords

Augmented reality, manual assembly, assembly instructions, task complexity, benchmarking

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1 Introduction

Assembly instructions require workers to map abstract information to physical parts and positions [9]. Augmented Reality (AR) can support this transfer by presenting assistive instructions in-situ [4], a form of spatially contextualized representation identified as a key performance indicator for industrial AR task guidance [12].

To make comparative research on the benefits of AR assembly instructions more cumulative, Funk et al. introduced a standardized LEGO® Duplo benchmark task in 2015, with a paper baseline and a task model that separates locating parts and assembly positions from task-dependent assembly actions [9]. This setup and its adaptations have since supported focused comparisons for several moderators. Funk et al. reported advantages for in-situ projection across task phases, errors, and workload in a comparison with head-mounted-display (HMD), tablet, and paper instructions [10]. Büttner et al. found that in-situ and paper led to faster task completion times and fewer errors than HMD instructions [6]. Blattgerste et al. found paper fastest, while HoloLens-based in-situ guidance reduced errors [5], and later found that 3D in-situ AR-glasses instructions outperformed side-by-side visualizations when occlusion was handled [4]. Kosch et al. studied tactile, auditory, and visual assembly error feedback [14], and later used a related Duplo setup to evaluate cognitive assistance with mobile electroencephalography [13]. Renner et al. adapted the task for occluded assembly target investigations [16] and Alves et al. compared handheld AR, indirect AR, and see-through HMD visualization methods [1]. Besides their main finding, these works also revealed limitations: the Duplo task prioritizes reproducibility [9], but may be too simple to clearly differentiate AR visualization methods [1]; its paper reference instructions can be ambiguous, including rotated interpretations [5]; and target occlusions are a particularly relevant spatial factor, but are not systematically varied in the task despite their importance for unambiguous in-situ visualization [4].

Together, the mixed performance results and these task-related limitations warrant further investigation into the broader question of when and which type of AR guidance becomes beneficial as task complexity increases, especially given initial evidence that AR benefits can vary with assembly stage and task demands [17]. Because AR can present instructions directly at the object of interest [4], we hypothesize that its benefits become more relevant when placements are harder to infer from conventional instructions; this expectation, however, still requires empirical testing. Prior work often operationalizes increasing task complexity as increasing numbers of steps [8, 9, 11]. Such length-based scaling is useful for reproducible tasks, but mainly increases repetition rather than the spatial inference demands that AR actually supports most. Assembly-complexity research usually treats complexity more broadly as well: final assembly workers perceive complexity through variants, work

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content, layout, tool usage, support tools, and instructions [15], while manual assembly complexity criteria include accessibility, visibility, precision demands, and geometric variation [7]. Workload research similarly links complexity to information processing and choice demands [2].

This paper therefore contributes an exploratory comparison of handheld AR, head-mounted AR, and a monitor-based station-style baseline under increasing spatial task complexity. Here, spatial task complexity refers to placements that become harder to infer from instructions because spatial relations are less obvious or the target is less accessible. We therefore explore the question: **How do these instruction modalities affect completion time, errors, and perceived workload as spatial task complexity increases?**

2 Method

To address the question, we adapted Funk et al.'s benchmark [9] into a 3 (instruction modality) × 3 (spatial complexity level) within-subject study. Figure 1 shows the experimental apparatus, complexity levels, and instruction modalities.

2.1 Apparatus and Task

The apparatus is designed to compare instruction hardware under increasing spatial inference and access demands while retaining a reproducible pick-and-place task. We kept the benchmark's eight-bin/color setup but replaced the paper baseline with a monitor-based workstation-style baseline, closer to a realistic industrial assembly station. The workspace combined a central build plate, two covered side build plates, eight part bins, a workspace marker for AR localization, and keyboard-controlled step advancement.

We compared three instruction modalities. The monitor baseline showed an egocentric virtual view of the accumulated build state up to the current step, with the current brick and source bin highlighted. Handheld AR used an iPhone 16 Pro with LiDAR to overlay the current brick at its target pose in the real workspace. Head-mounted AR used an Apple Vision Pro video-see-through HMD to show the same in-situ current-brick overlay hands-free.

All modalities were implemented in a shared custom Unity project with identical scripted sequences advanced by keyboard input. The current brick was rendered as static 3D geometry and highlighted with an outline shader; when placement geometry was occluded, the outline kept the target identifiable. The source bin for the current brick was highlighted in the brick's color. To control the hardware comparison, the monitor condition used the same current-step and source-bin cues as the AR modalities, unlike the original paper baseline. The Unity application, scripted sequences, and rendering parameters are available in an open-source repository for reproducibility [3].

Spatial complexity was operationalized as three scripted sequences that varied local spatial relations, visibility, and access demands. **Complexity 1 (C1)** retained Funk et al.'s coherent structure, in which placed bricks had clear local spatial relations. **Complexity 2 (C2)** used fixed pseudo-random placements on the central plate, reducing coherent spatial relations between placements. **Complexity 3 (C3)** distributed placements across the central and the covered side plates; the physical target areas on the left and right base plates were hidden from the central view, requiring participants to infer placements from the instructions and move to the sides to inspect and access them. C1 and C2 used 32 steps, C3 used 48 steps, and the same scripted sequence for each level was used across modalities.

2.2 Study Design, Procedure, and Measures

The study followed this 3 × 3 within-subject design: each participant completed all three modalities and all three spatial complexity levels. Instruction modality order was fully counterbalanced, with each of the six possible orders completed by three participants. Within each modality, complexity levels were presented in fixed ascending sequence (C1, C2, C3).

The study was completed by 18 participants (5 female; age: $M = 25.4$ years, $SD = 2.8$, range 20–30). Participants were recruited from our university and received 15 € as compensation. Under our institution's guidelines, formal ethics approval was not required for this low-risk exploratory study without vulnerable groups.

At the start of each session, participants received study information, gave informed consent, completed a demographic questionnaire, and, in line with the benchmark [9], were explained to prioritize accurate assembly of the target model, with the second priority being speed. Before each modality, participants were introduced to the modality and keyboard-based step advancement; for AR modalities, devices were localized to a workspace marker and, when necessary, the experimenter fine-calibrated alignment via keyboard input. After each complexity level within each modality, participants answered NASA-TLX questions read aloud by the experimenter. At the end of the session, participants self-completed a questionnaire in which they ranked the three instruction modalities and answered open-ended free-text questions about the experiment overall, including why they preferred their top-ranked modality and what worked well or could be improved.

Dependent variables were task completion time (TCT, seconds), logged by the system; task errors (TE; incorrect or missing placements), counted from corrected or replaced bricks during the task and from remaining errors identified in final assembly photos; and perceived workload, measured with a verbally experimenter-administered, non-validated RTLX adaptation (original NASA-TLX items with an adapted 1–10 scale, transformed to 0–100 without weighting). Additional measures were a preference ranking and qualitative feedback; one researcher summarized open-ended responses descriptively by grouping comments into recurring themes.

3 Results

Table 1 summarizes the descriptive statistics for all quantitative outcomes, and Figure 2 visualizes the mean trends across spatial complexity levels and instruction modalities. For each quantitative outcome, we used a 3 × 3 repeated-measures ANOVA to test whether instruction modality effects varied across spatial complexity levels. Because complexity levels were presented in fixed ascending order and differed structurally in task size, main effects of spatial complexity level are not interpreted independently. Spatial complexity level was retained in the models to test the instruction modality × spatial complexity level interaction. Because Mauchly tests indicated sphericity violations for some effects, ANOVA p-values are Greenhouse-Geisser corrected. Post-hoc paired comparisons are Holm-corrected to adjust for multiple comparisons. Diagnostic

Shapiro-Wilk checks of condition distributions indicated some deviations from normality, particularly for task errors; however, the reported significant post-hoc comparisons met paired-difference normality checks. We retained parametric tests for comparability with prior benchmark studies. Effect-size magnitudes for significant post-hoc comparisons are reported as paired-samples Cohen's $|d_z|$. Repeated-measures ANOVAs indicated no systematic instruction-modality order effects for TCT, TE, or RTLX (all $F(2, 34) \leq 1.31$, $p = .282$–$.587$). All observations were retained for analysis, and no outliers were excluded.

3.1 Task Completion Time

For task completion time, the repeated-measures ANOVA showed a significant main effect of instruction modality, $F(2, 34) = 6.61$, $p = .006$, $\eta_p^2 = .28$, and a significant instruction modality × spatial complexity level interaction, $F(4, 68) = 13.89$, $p < .001$, $\eta_p^2 = .45$. Post-hoc tests indicated lower TCT for baseline instructions than for handheld AR at C1 ($p = .001$, $|d_z| = 1.02$). At C2, post-hoc tests indicated lower TCT for head-mounted AR than for baseline ($p = .009$, $|d_z| = 0.78$) and handheld AR ($p < .001$, $|d_z| = 1.16$). At C3, post-hoc tests indicated lower TCT for handheld AR and head-mounted AR than for baseline ($p = .024$, $|d_z| = 0.58$, and $p = .001$, $|d_z| = 1.08$, respectively), and lower TCT for head-mounted AR than for handheld AR ($p < .001$, $|d_z| = 1.29$).

3.2 Task Errors

For task errors, the repeated-measures ANOVA showed no significant main effect of instruction modality, $F(2, 34) = 0.22$, $p = .739$, and no significant instruction modality × spatial complexity level interaction, $F(4, 68) = 0.13$, $p = .832$. Thus, task errors did not provide evidence for modality-specific differences across complexity levels in this experiment. Because task errors showed normality deviations and qualitative feedback suggested different error sources

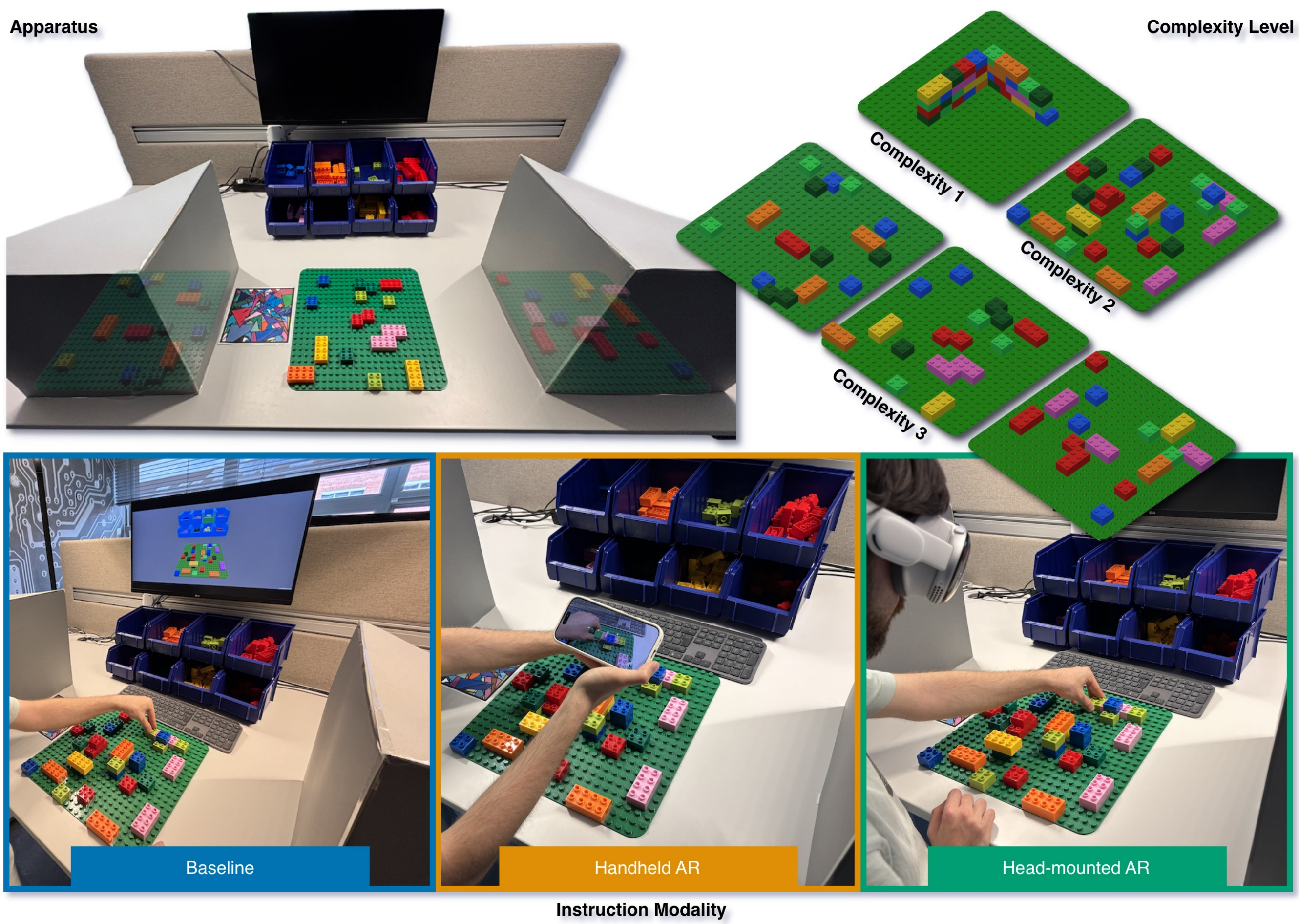

Figure 1: The experimental apparatus and two within-subject factors. *Top left:* adapted assembly workspace based on the benchmark by Funk et al. [9], extended with two side plates, opaque occlusion covers, and a monitor for a workstation-style baseline; side-platform contents are visualized schematically through the covers for illustration. *Top right:* final target models for the three spatial complexity levels (C1–C3). *Bottom:* the instruction modalities compared: monitor baseline, handheld AR, and head-mounted AR.

Table 1: Mean ± SD values for task completion time (TCT), task errors (TE), perceived workload (RTLX), and preference rank by instruction modality and spatial complexity level; lower preference ranks indicate stronger preference.

Measure	Baseline			Handheld AR			Head-Mounted AR		
	C1	C2	C3	C1	C2	C3	C1	C2	C3
TCT (s)	175.0 ± 42.6	277.5 ± 115.8	841.8 ± 365.4	228.5 ± 60.6	276.4 ± 76.1	660.1 ± 159.5	284.5 ± 232.6	199.4 ± 70.1	488.6 ± 128.9
TE	0.3 ± 1.0	3.1 ± 4.5	14.2 ± 8.6	0.3 ± 1.2	3.7 ± 3.6	14.6 ± 3.6	0.9 ± 2.5	4.2 ± 3.3	14.2 ± 5.0
RTLX	20.1 ± 11.1	29.9 ± 16.4	48.4 ± 22.3	20.4 ± 15.9	25.3 ± 15.3	39.2 ± 22.0	15.4 ± 8.1	17.9 ± 12.5	29.7 ± 13.9
Preference		2.22 ± 0.88			2.11 ± 0.76			1.67 ± 0.77	

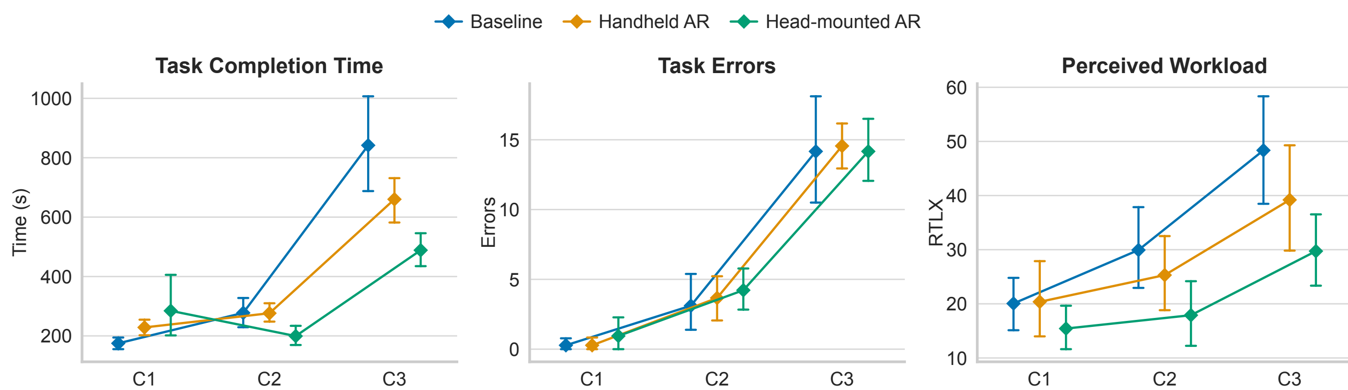

Figure 2: Mean trends in task completion time (TCT), task errors (TE), and perceived workload (RTLX) across spatial task complexity levels (C1–C3) by instruction modality in the within-subject study; error bars show 95% confidence intervals.

across modalities, TE should be interpreted cautiously and the Discussion will elaborate on this aspect in more detail.

3.3 Perceived Workload

For perceived workload, the repeated-measures ANOVA showed a significant main effect of instruction modality, $F(2, 34) = 7.05$, $p = .003$, $\eta_p^2 = .29$, and a significant instruction modality × spatial complexity level interaction, $F(4, 68) = 3.73$, $p = .036$, $\eta_p^2 = .18$. Post-hoc tests showed no significant modality differences at C1 or C2. At C3, post-hoc tests indicated higher perceived workload for baseline instructions than for handheld AR ($p = .044$, $|d_z| = 0.56$) and head-mounted AR ($p = .003$, $|d_z| = 0.95$); they also indicated higher perceived workload for handheld AR than for head-mounted AR ($p = .044$, $|d_z| = 0.59$).

3.4 User Preference and Qualitative Feedback

Participants ranked the modalities after the study, with lower ranks indicating stronger preference. We analyzed these matched ordinal rankings with a Friedman test, which did not indicate a statistically reliable difference between modalities, $\chi^2(2) = 3.11$, $p = .211$; mean ranks are reported in Table 1. Descriptively, head-mounted AR was ranked first by 9 participants (50.0%), baseline instructions by 5 participants (27.8%), and handheld AR by 4 participants (22.2%).

Open-ended responses indicated different reasons for the preferences: participants who ranked head-mounted AR first emphasized direct spatial guidance (5/9), lower effort or reduced counting (5/9), and hands-free ergonomics (3/9); baseline-first participants emphasized confidence in exact placement or correctness (2/5) and familiarity or absence of device handling (2/5); and handheld-first participants emphasized fewer practical issues (2/4) and reduced counting (2/4). Across modalities, participants described AR as reducing display-to-workspace transfer through direct spatial guidance (10/18) and highlighting relevant bins, boards, steps, or colors (5/18), with some also reporting lower mental load or faster work from reduced display switching and checking (4/18). AR-specific limitations centered on tracking or alignment problems (13/18), virtual overlays occluding real bricks during placement, prompting requests for transparency or occlusion handling (4/18), handheld AR's small viewport and one-handed fatigue (6/18), and head-mounted AR comfort issues such as blur, heat, or nausea (3/18). Monitor comments valued stable, clear placement views but also requested placement aids such as grids, distance cues, or arrows (7/18).

4 Discussion

This exploratory study compared a workstation-style baseline, handheld AR, and head-mounted AR across increasing spatial task complexity levels. It provides an initial empirical indication that the relative value of AR instruction modalities may depend on the spatial demands of the task, warranting further systematic study. The results point less to one universally best instruction modality than to a trade-off between representational transfer and device overhead. At the lowest complexity level (C1), the coherent and visible structure may have made the monitor baseline comparatively easy to interpret with fair information and visualization parity. Here, TCT was lower for the baseline than for handheld AR, while the baseline and head-mounted AR did not differ reliably, suggesting that the AR instruction modalities first had to offset device overhead. Handheld AR introduced handling costs, and head-mounted AR may have been affected by display unfamiliarity and novelty, reflected in its higher C1 TCT variance. At C2, less coherent placements increased the need for actual spatial inference; here, head-mounted AR showed lower TCT than both other instruction modalities, although perceived workload did not differ reliably. At the highest complexity level (C3), occluded side plates and physically distributed target areas further increased display-to-workspace transfer demands; here, handheld AR showed lower TCT than the baseline despite its handling costs, while head-mounted AR showed lower TCT and perceived workload than both other instruction modalities. This pattern suggests that both AR instruction modalities became more useful when direct spatial cues reduced spatial search, display switching, and mental transformations. This interpretation is consistent with qualitative feedback about direct spatial guidance and reduced effort, even though the preference ranking was not significant.

Regarding task errors, the absence of significant differences should be interpreted cautiously because TE likely captured different error sources across modalities. Descriptive observations and final-assembly inspections suggest different error patterns: baseline C3 errors often involved miscounting, rotated side-plate constructions, or swapped left/right plates, including one 37-error trial, whereas AR C3 errors more often appeared as small shifts or alignment-, tracking-, and calibration-related placement issues. Because these modality-specific error sources were not systematically coded or statistically tested, TE is best interpreted as a complementary outcome rather than as evidence that the modalities were equally robust. Notably, in the open-ended responses, 13 of 18 participants reported AR tracking or alignment problems; these issues did not correspond to higher total error counts, but likely contributed to AR-specific error patterns and practical device overhead. Because these technical issues were reported frequently, they may also have contributed to device overhead and could have influenced completion time or perceived workload; this should be considered when interpreting the results.

Observations also clarify the handheld/head-mounted difference: handheld AR often required participants to hold the phone in their dominant hand, while head-mounted AR avoided this cost and provided a larger field of view.

Finally, our findings also help contextualize the mixed results from prior work using the assembly benchmark [9], where conventional instructions often remained competitive and AR advantages varied [1, 4–6, 10]. Our C1 result broadly aligns with this pattern, while C2 suggests that head-mounted AR may already reduce TCT when mental transformations increase, before C3 adds side-plate occlusions and access demands, where post-hoc comparisons also indicated lower TCT for handheld AR than for the baseline.

4.1 Limitations and Outlook

Several limitations qualify these exploratory findings. Most importantly, spatial task complexity, presentation order, and task size were confounded: C1–C3 were always presented in ascending order within each instruction modality, so C1 also captured device onboarding and later levels may reflect learning, fatigue, or familiarity; counterbalancing modality order does not remove this within-modality confound. C3 also added 48 instead of 32 steps, side plates, occlusion, and access demands, so the results cannot isolate which component specifically shifted modality performance. Accordingly, the significant interaction effects show that modality differences varied across task levels, but not which aspect of the bundled levels drove this variation. Further limitations are the small, homogeneous sample with limited prior AR/MR experience, task-errors with floor effects, an adapted experimenter-administered non-validated RTLX-style workload measure, and qualitative feedback summarized descriptively by a single researcher. Both the AR modalities and the assembly task remain laboratory abstractions: handheld AR is a constrained form-factor comparison, video-see-through head-mounted AR operationalized wide field of view despite being unrealistic for actual industrial use, and the benchmark supports standardized comparison rather than realistic industrial assembly. Task-error analysis was also affected by AR-specific misalignments: the lack of a significant difference in error counts across modalities may partly reflect modality-specific error sources, with AR errors driven partly by technical limitations rather than by participants' interpretation or execution of the assembly task.

Ultimately, these findings suggest that the comparative effectiveness of AR assembly instruction modalities cannot be generalized from low-complexity benchmarks alone. Follow-up studies should test whether the pattern found in this exploratory study holds under systematically varied task complexities, including but not limited to spatial task complexity, with larger and more diverse samples and more realistic assembly tasks and constraints.

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References

[1] João Bernardo Alves, Bernardo Marques, Carlos Ferreira, Paulo Dias, and Beatriz Sousa Santos. 2022. Comparing Augmented Reality Visualization Methods for Assembly Procedures. *Virtual Reality* 26 (2022), 235–248. doi:10.1007/s10055-021-00557-8

[2] Dominic Bläsing and Manfred Bornewasser. 2021. Influence of increasing task complexity and use of informational assistance systems on mental workload. *Brain Sciences* 11, 1 (2021), 102. doi:10.3390/brainsci11010102

[3] Jonas Blattgerste, Felix Krumstroh, and Thies Pfeiffer. 2026. *BrickBench.* Retrieved July 17, 2026 from https://github.com/jblattgerste/BrickBench Open-source software developed and used for the study.

[4] Jonas Blattgerste, Patrick Renner, Benjamin Strenge, and Thies Pfeiffer. 2018. In-situ instructions exceed side-by-side instructions in augmented reality assisted assembly. In *Proceedings of the 11th PErvasive technologies related to assistive*

environments conference. Association for Computing Machinery, New York, NY, USA, 133–140. doi:10.1145/3197768.3197778

[5] Jonas Blattgerste, Benjamin Strenge, Patrick Renner, Thies Pfeiffer, and Kai Essig. 2017. Comparing Conventional and Augmented Reality Instructions for Manual Assembly Tasks. In *Proceedings of the 10th International Conference on PErvasive Technologies Related to Assistive Environments* (Island of Rhodes, Greece) *(PETRA '17)*. Association for Computing Machinery, New York, NY, USA, 75–82. doi:10.1145/3056540.3056547

[6] Sebastian Büttner, Markus Funk, Oliver Sand, and Carsten Röcker. 2016. Using Head-Mounted Displays and In-Situ Projection for Assistive Systems: A Comparison. In *Proceedings of the 9th ACM International Conference on Pervasive Technologies Related to Assistive Environments* (Corfu, Greece) *(PETRA '16)*. Association for Computing Machinery, New York, NY, USA, Article 44, 8 pages. doi:10.1145/2910674.2910679

[7] Ann-Christine Falck, Roland Örtengren, Mikael Rosenqvist, and Rikard Söderberg. 2016. Criteria for assessment of basic manual assembly complexity. *Procedia CIRP* 44 (2016), 424–428. doi:10.1016/j.procir.2016.02.152

[8] Markus Funk. 2016. *Augmented Reality at the Workplace: A Context-Aware Assistive System Using In-Situ Projection.* PhD thesis. University of Stuttgart. https://elib.uni-stuttgart.de/handle/11682/9014

[9] Markus Funk, Thomas Kosch, Scott W. Greenwald, and Albrecht Schmidt. 2015. A benchmark for interactive augmented reality instructions for assembly tasks. In *Proceedings of the 14th International Conference on Mobile and Ubiquitous Multimedia* (Linz, Austria) *(MUM '15)*. Association for Computing Machinery, New York, NY, USA, 253–257. doi:10.1145/2836041.2836067

[10] Markus Funk, Thomas Kosch, and Albrecht Schmidt. 2016. Interactive Worker Assistance: Comparing the Effects of In-Situ Projection, Head-Mounted Displays, Tablet, and Paper Instructions. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing* (Heidelberg, Germany) *(UbiComp '16)*. Association for Computing Machinery, New York, NY, USA, 934–939. doi:10.1145/2971648.2971706

[11] Natalia Irrazabal, Gastón Saux, and Debora Burin. 2016. Procedural Multimedia Presentations: The Effects of Working Memory and Task Complexity on Instruction Time and Assembly Accuracy. *Applied Cognitive Psychology* 30, 6 (2016), 1052–1060. doi:10.1002/acp.3299

[12] Jérôme Jetter, Jörgen Eimecke, and Alexandra Rese. 2018. Augmented Reality Tools for Industrial Applications: What Are Potential Key Performance Indicators and Who Benefits? *Computers in Human Behavior* 87 (2018), 18–33. doi:10.1016/j.chb.2018.04.054

[13] Thomas Kosch, Markus Funk, Albrecht Schmidt, and Lewis L. Chuang. 2018. Identifying Cognitive Assistance with Mobile Electroencephalography. *Proceedings of the ACM on Human-Computer Interaction* 2, EICS, Article 11 (2018), 20 pages. doi:10.1145/3229093

[14] Thomas Kosch, Romina Kettner, Markus Funk, and Albrecht Schmidt. 2016. Comparing Tactile, Auditory, and Visual Assembly Error-Feedback for Workers with Cognitive Impairments. In *Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility* (Reno, Nevada, USA) *(ASSETS '16)*. Association for Computing Machinery, New York, NY, USA, 53–60. doi:10.1145/2982142.2982157

[15] Sandra Mattsson. 2013. *What is perceived as complex in final assembly?* Master's thesis. Chalmers University of Technology.

[16] Patrick Renner, Jonas Blattgerste, and Thies Pfeiffer. 2018. A Path-Based Attention Guiding Technique for Assembly Environments with Target Occlusions. In *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*. IEEE, Piscataway, NJ, USA, 689–690. doi:10.1109/VR.2018.8446127

[17] Zhen Yang, Jinlei Shi, Wenjun Jiang, Yuexin Sui, Yimin Wu, Shu Ma, Chunyan Kang, and Hongting Li. 2019. Influences of augmented reality assistance on performance and cognitive loads in different stages of assembly task. *Frontiers in psychology* 10 (2019), 1703. doi:10.3389/fpsyg.2019.01703