Human Aspects of Advanced Manufacturing, Production Management and Process Control, Vol. 184, 2025, 12–20
https://doi.org/10.54941/ahfe1006445

Perceived Augmented Reality Affordances in Logistics

Stella Kolarik

Fraunhofer Institute for Material Flow and Logistics, Germany

ABSTRACT

Augmented reality (AR) promises to transform logistics operations by enhancing real-world processes and supporting workers in dynamic environments. This study investigates the perceived affordances of AR in logistics and examines how these perceptions differ between AR developers and logistics workers. Based on semi-structured interviews with a balanced sample of five AR developers and five logistics workers, a qualitative content analysis following an adapted affordance framework was conducted. The analysis revealed 11 affordance categories, with enhancing affordances emerging as the most prominent. While developers identified a broader spectrum of potential affordances, logistics workers focused on practical, task-related benefits. These findings extend affordance theory by introducing logistics-specific affordances and highlight the need for AR designs that bridge the gap between technical potential and everyday operational requirements. The insights offer valuable guidance for AR system development within Industry 4.0 contexts and suggest directions for future research.

Keywords: Augmented reality, Affordance, Logistics, Technology perception, Use case, User experience, Industry 4.0

INTRODUCTION

The logistics sector, Germany's third-largest industry (Stamerjohanns and Stubbe, 2024), faces challenges such as high employee turnover and low motivation (Czernin and Schocke, 2016). Augmented Reality (AR) offers transformative potential by directly supporting workers at their workspace, enhancing skills, and improving efficiency (Lagorio et al., 2022; Wu et al., 2013). Despite this promise, research on AR applications in logistics remains limited (Rejeb et al., 2021), especially regarding how users perceive AR's action possibilities, or affordances. Affordances take both the user and the technology into account, influencing why users choose to use a certain technology (Steffen et al., 2019). Understanding these affordances can bridge the gap between AR developers' intentions and the actual needs of logistics workers, ensuring effective technology adoption.

THEORY

Augmented Reality and Logistics

AR has been defined in different ways. Azuma (1997, p. 2) described AR systems as those that: "1) combine real and virtual content, 2) are interactive in real time and 3) registered in three dimensions". Unlike Virtual Reality (VR), AR enhances physical reality without fully detaching users from it, providing both physical context and adaptable virtual elements (Azuma, 1997; Scaravetti and Doroszewski, 2019; Steffen et al., 2019). In 2023, the German logistics sector had a turnover of 327 billion Euros (Stamerjohanns and Stubbe, 2024), underscoring its economic significance. Despite automation, human expertise is critical for tasks requiring decision-making (Wang et al., 2020). AR can alleviate repetitive work, boosting engagement and efficiency (Hense et al., 2014).

Affordance Theory

Gibson (1986) originally defined affordances as "action possibilities", combining user goals and technical features (Faraj and Azad, 2013; Steffen et al., 2019). There are varying views on affordances: some see them as inherent to a technology's materiality, while others consider them shaped by user interaction. Stendal et al. (2016) identified six types of affordances: Intended, emerging, potential, actualized, functional and non-functional. This research aligns with the view of potential affordances as action possibilities, influenced by both artifact and user. This study focuses on potential affordances, as actualized affordances require direct interaction with technology.

Research on AR affordances remains limited, with most studies emphasizing AR's role in education (Arici, Yilmaz and Yilmaz, 2021; Wu et al., 2013), work-related AR applications remain underexplored. Steffen et al. (2019) proposed a framework comparing AR and VR affordances, identifying four categories:

- Enhancing positive aspects of the physical world
- Diminishing negative aspects of the physical world
- Recreating aspects of the physical world
- Creating aspects that do not exist in the physical world

Their findings suggest that AR excels in enhancing affordances. Individual affordances, such as facilitating additional information, further differentiate AR from VR. However, research dedicated solely to AR affordances, particularly in work contexts like logistics, remains unexplored. Given the differences between AR and VR, separate examination of their affordances is warranted.

RQ1: Which affordances are perceived of AR in logistics?

Differences in Affordance Perception

Affordance theory explains why technology impacts users differently (Markus and Silver, 2008; Steffen et al., 2019). Gibson (1977) proposed that affordances depend on both the environment and the individual's ability to utilize them. Developers may design systems with intended affordances, yet users' interpretations can vary, sometimes leading to workarounds when goals are obstructed (Koopman and Hoffman, 2003). Differences between developers and users in perceiving affordances can affect technology's effectiveness (Lei, Wang and Law, 2019). By identifying these differences in AR affordances within logistics, applications can be better tailored to user needs.

RQ2: How do perceived AR affordances differ between developers and potential users of AR in logistics?

RESEARCH APPROACH

The participants in this study included both developers of AR applications and logistics workers, who represent potential users of AR applications. Each group consisted of five male participants, selected based on their expertise. Users were logistics workers from the shop floor. The developer group consisted of professionals in Mixed Reality (MR) application development. The study was approved by the ethics committee for applied cognitive and media science at the University Duisburg-Essen.

Semi-structured interviews (Myers and Newman, 2007) were conducted individually to capture personal perceptions. The interviews followed this structure: The participants were asked questions about their roles and experiences. The concept of AR was introduced, followed by example videos to provide concrete illustrations, similar to past research (Steffen et al., 2019). Affordances were then explained. Then, participants were asked to identify affordances of AR in logistics. Different open follow-up questions were used to encourage participants to think of more ideas. The interviews averaged 29.94 minutes ($SD = 6.52$), excluding video explanations and introductory segments.

The analysis supported by QCAmap followed the qualitative content analysis methodology (Mayring, 1994, 2015, 2019), combining quantitative and qualitative elements in a systematic approach based on explicit rules. This stepwise process aims to ensure intersubjective understanding (Mayring, 1994). For RQ1, all mentioned affordances were coded using relevant definitions. Affordances were originally defined as action possibilities (Gibson, 1977); they combine user goals and technology features (Faraj and Azad, 2013) and they are latent until they are perceived and actualized. The abstraction level chosen was higher than specific features (e.g., scanning a QR code) but lower than overarching tasks (e.g., improving overall picking efficiency). Categories were inductively formed due to the lack of a pre-existing system and later grouped into supercategories based on Steffen et al. (2019). For RQ2, the analysis built on the coded affordances from RQ1, eliminating the need for a new process. For the application of content-analytical quality criteria, the following steps were taken. To ensure semantic validity, it was checked whether all text passages assigned to certain category actually fit that category and were overall homogenous (Krippendorff, 2018; Mayring, 2015). Intercoder reliability could not be calculated because only one researcher conducted the analysis (Mayring, 1994).

RESULTS

Descriptive Results

Quantitative data was analyzed using SPSS 28.0.1. All interviews were conducted in German, quotes included in the results were translated into English.

Table 1: Descriptive results.

Group	Av. Age (in Years)	Av. Work Experience (in Years)
Developers	28.4 (SD = 6.15)	9.7 (SD = 6.54)
Logistics workers	37 (SD = 12.08)	11.1 (SD = 2.44)

Identified Affordances

Overall, 11 different categories were identified. Those categories were grouped into supercategories based on the categories developed by Steffen et al. (2019). Table 2 presents the affordances found in the interviews.

Table 2: Found affordances.

Category	Ability	Examples
Enhancing positive aspects of the physical world		
With AR I can find the right object or way	Directability	"Show a kind of navigation system, that you say 'Okay, I'll go with the camera, I'll point to the warehouse and then in corresponding places the pallets I'm looking for will be blinking." (Developer 03)
With AR I can access additional information regardless of location	Informability	"Not having to rely on other media, meaning everything is on the body. […] You have glasses on, you see all the information you need" (Worker 02)
With AR I can pack things in an optimized way	Packability	"That you might be able to use AR to show the optimal way to stow the packages in a particularly clever and space-saving and efficient way." (Developer 02)
With AR I can document actions	Documentability	"Documentation of the individual steps via the camera." (Developer 03)
With AR I can keep contact with others directly or indirectly	Communicability	"These calls, that I call people and then they see what I see and then he says, 'Do this and this"'(Developer 05)
With AR I do not have to count myself	Countability	"It would make counting easier if the glasses perceive I need 10 pieces and I take each thing out […] and then it's automatically perceived by the glasses" (Worker 01)
With AR I can work with free hands	Flexibility	"The employee has both hands free when picking and does not have to carry any tools or devices with him." (Developer 01)
Diminishing negative aspects of the physical world		
With AR I can monitor mistakes, damages and quality	Monitorability	"And in the glasses that you then have on, that tells you whether you scanned correctly or not, or whether you made the right decision or not." (Developer 01)

Continued

Table 2: Continued

Category	Ability	Examples
With AR I can protect myself from dangers	Protectability	"The paths of the robots are displayed even before they start moving." (Developer 05)
Recreating aspects of the physical world		
With AR I can get individual support in the form of instructions, tasks or action recommendations	Instructability	"That I can see it all already, for example how I have to assemble it and then how I can or have to put it in." (Worker 01)
With AR I can train	Trainability	"New employee training will probably also be easier" (Worker 02)
Creating aspects that do not exist in the physical world		

Differences in Affordance Perception

Table 3 summarizes the distribution of identified affordances. The Enhancing supercategory was cited by all participants, while Diminishing (80%) and Recreating (90%) affordances were also widely recognized. The Creating supercategory was not mentioned.

Table 3: Distribution of perceived affordances.

Category	Absolute Count	% of Sum	% of Documents	N in Developer Group	N in Logistics Group
Enhancing	122	63%	100%	5	5
Directability	40	20%	100%	5	5
Informability	34	17%	100%	5	5
Packability	18	9%	60%	4	2
Documentability	8	4%	50%	1	4
Communicability	7	3%	50%	3	2
Countability	3	1%	20%	0	2
Flexibility	12	6%	60%	4	2
Diminishing	37	19%	80%	3	5
Monitorability	30	15%	80%	3	5
Protectability	7	3%	40%	2	2
Recreating	34	17%	90%	5	4
Instructability	30	15%	80%	5	3
Trainability	4	2%	30%	2	1
Creating	0	0%	0%	0	0

The participants of the developer group named M = 11.8 enhancing affordances on average (SD = 5.42). For diminishing affordances, the average was M = 4 (SD = 3.52). Recreating affordances were named M = 5.4 times on average by the developer participants (SD = 2.65). Overall, the participants of the developer group named M = 21.2 affordances on average (SD = 8.54). The participants of the logistics worker group named M = 17.4 affordances on average (SD = 7.17). They named M = 12.6 enhancing affordances on average (SD = 6.18). The average for diminishing affordances was M = 3.4 (SD = 1.36). Recreating affordances were named M = 1.4 times on average (SD = 1.02).

DISCUSSION

This study investigated AR affordances in logistics using an adapted framework from Steffen et al. (2019). The analysis revealed two key findings: (1) AR in logistics primarily offers enhancing affordances—with directability and informability emerging as the most prominent—and (2) there is a marked difference in perception between developers and logistics workers.

Identified Affordances

This study identified 11 affordances of AR in logistics, categorized within three supercategories by Steffen et al. (2019):

- Enhancing affordances: These dominated the responses, underscoring AR's role in augmenting the physical work environment (Steffen et al., 2019). Novel affordances such as directability—which improves navigation and object localization and is applicable in various sectors—and packability, a logistics-specific benefit for optimizing material handling, emerged alongside more established affordances like informability (Steffen et al., 2019).
- Diminishing affordances: The affordances monitorability and protectability were recognized for their potential to enhance safety and quality control. They are especially beneficial as they are applicable in real-life scenarios through AR.
- Recreating affordances: The affordances instructability and trainability highlight AR's capability to support on-the-job guidance and training, extending its relevance to workforce development.

This study did not find any creating affordances. This might be explained as Steffen et al. (2019) focused on both VR and AR. VR seems to be more focused on creating completely new aspects (Steffen et al., 2019), while AR enhances physical reality. These findings confirm that AR's primary contribution in logistics is to enhance existing processes rather than to create entirely new functionalities—a distinction that supports prior research differentiating AR from VR (Steffen et al., 2019).

This study is the first to comprehensively examine AR affordances in logistics. The results suggest that widely mentioned affordances indicate clear benefits, while less frequently mentioned affordances may have niche applications. Applying AR in logistics for actions that do not relate to any of the affordances found should be done cautiously, as adding AR in situations where it provides little benefit could have negative consequences (Steffen et al., 2019).

Differences in Affordance Perception

Developers identified a more diverse spectrum of affordances on average compared to logistics workers, likely due to their familiarity with AR technology. Developers emphasized diminishing and recreating affordances, while logistics workers focused more on enhancing affordances, which aligns with AR's primary association with enhancement (Steffen et al., 2019). Developers' focus on packability, instructability, and trainability reflects their broader understanding of AR's capabilities. Conversely, logistics workers prioritized practical affordances like documentability and countability, which simplify routine tasks. This divergence suggests that while developers envision AR's full potential, end users may focus on immediate, tangible benefits. Thus, effective AR system design must balance these perspectives to ensure that advanced features are not only technically feasible but also align with the workers' practical needs. These findings echo Lei et al.'s (2019) comparison of hotel app affordances, where users often failed to perceive the full value of applications.

CONCLUSION

This research contributes to affordance theory by offering a comprehensive analysis of AR affordances in logistics.

Key contributions include:

- Identification of AR affordances in logistics, including both recognized and novel affordances.
- Highlighting the importance of aligning developers' technical visions with the real-world requirements of logistics workers.

For future research, larger and more diverse samples—including hands-on AR trials—are needed to validate these findings. Future studies would benefit from multiple coders to ensure intercoder reliability. Additionally, incorporating other stakeholder perspectives (e.g., managers or safety officers) could further refine our understanding of AR's impact in industrial settings.

In summary, this study not only enriches our theoretical understanding of AR affordances but also emphasizes the necessity of a user-centric design approach to fully harness AR's potential in logistics. The results of this study demonstrate AR's potential to enhance logistics processes, addressing sector-specific challenges like low employee motivation and high task monotony. Organizations and developers can leverage these findings to promote AR adoption and maximize its benefits, fostering innovation in logistics and beyond.

ACKNOWLEDGMENT

I want to thank Katharina Ziolkowski and Jennifer Fromm, who provided guidance and feedback for this paper. I also want to express my gratitude to all the participants for their valuable time and experience.

REFERENCES

Arici, F., Yilmaz, R. M. and Yilmaz, M. (2021) ‘Affordances of augmented reality technology for science education: Views of secondary school students and science teachers’, *Human Behavior and Emerging Technologies*, 3(5), pp. 1153–1171. doi: 10.1002/hbe2.310.

Azuma, R. T. (1997) ‘A Survey of Augmented Reality’, *Presence: Teleoperators and Virtual Environments*, 6(4), pp. 355–385. doi: 10.1162/pres.1997.6.4.355.

Czernin, J. and Schocke, K.-O. (2016) *Handlungsfelder der Personalarbeit in der Logistik - Studienbericht*.

Faraj, S. and Azad, B. (2013) ‘The Materiality of Technology: An Affordance Perspective’, in *Materiality and Organizing: Social Interaction in a Technological World*, pp. 237–258. Available at: https:// www.researchgate.net / publication/ 236591952_ The_ Materiality_ of_ Technology_ An_ Affordance_ Perspective.

Gibson, J. J. (1977) *The theory of affordances. Perceiving, acting, and knowing: Toward an ecological psychology*.

Gibson, J. J. (1986) *The ecological approach to visual perception*. Boston: Houghton Mifflin.

Hense, J. et al. (2014) ‘Using Gamification to Enhance Staff Motivation in Logistics’, *International Simulation and Gaming Association Conference:* Springer, Cham, pp. 206–213. doi: 10.1007/978-3-319-04954-0_24.

Koopman, P. and Hoffman, R. R. (2003) ‘Work-arounds, make-work, and kludges’, *IEEE Intelligent Systems*, 18(6), pp. 70–75. doi: 10.1109/mis.2003.1249172.

Krippendorff, K. (2018) *Content Analysis: An Introduction to Its Methodology*: SAGE Publications.

Lagorio, A. et al. (2022) ‘Augmented Reality in Logistics 4.0: Implications for the human work’, *IFAC-PapersOnLine*, 55(10), pp. 329–334. doi: 10.1016/j.ifacol.2022.09.408.

Lei, S. I., Wang, D. and Law, R. (2019) ‘Perceived technology affordance and value of hotel mobile apps: A comparison of hoteliers and customers’, *Journal of Hospitality and Tourism Management*, 39, pp. 201–211. doi: 10.1016/j.jhtm.2019.02.006.

Markus, M. L. and Silver, M. (2008) ‘A Foundation for the Study of IT Effects: A New Look at DeSanctis and Poole’s Concepts of Structural Features and Spirit’, *Journal of the Association for Information Systems*, 9(10), pp. 609–632. doi: 10.17705/1jais.00176

Mayring, P. (1994) ‘Qualitative Inhaltsanalyse’, in Boehm, A., Mengel, A. and Muhr, T. (eds.) *Texte verstehen: Konzepte, Methoden, Werkzeuge*. Konstanz, Germany, pp. 159–175.

Mayring, P. (2015) *Qualitative Inhaltsanalyse: Grundlagen und Techniken*. 12th edn. Weinheim, Germany.

Mayring, P. (2019) *Qualitative content analysis: Demarcation, varieties, developments*. Available at: https:// www.qualitative-research.net / index.php/ fqs/ article/ download/ 3343/ 4558/ 0.

Myers, M. D. and Newman, M. (2007) ‘The qualitative interview in IS research: Examining the craft’, *Information and Organization*, 17(1), pp. 2–26. doi: 10.1016/j.infoandorg.2006.11.001.

Rejeb, A. et al. (2021) ‘The potentials of augmented reality in supply chain management: a state-of-the-art review’, *Management Review Quarterly*, 71(4), pp. 819–856. doi: 10.1007/s11301-020-00201-w.

Scaravetti, D. and Doroszewski, D. (2019) 'Augmented Reality experiment in higher education, for complex system appropriation in mechanical design', *Procedia CIRP*, 84, pp. 197–202. doi: 10.1016/j.procir.2019.04.284.

Stamerjohanns, C. and Stubbe, A. (2024) *Logistikumsatz und Beschäftigung*. Available at: https:// www.bvl.de / service/ zahlen- daten- fakten/ umsatz- und-beschaeftigung (Accessed: 14 January 2025).

Steffen, J. H. et al. (2019) 'Framework of affordances for virtual reality and augmented reality', *Journal of Management Information Systems*. doi: 10.1080/07421222.2019.1628877.

Stendal, K., Thapa, D. and Lanamaki, A. (2016) 'Analyzing the Concept of Affordances in Information Systems', *2016 49th Hawaii International Conference on System Sciences (HICSS):* IEEE, pp. 5270–5277. doi: 10.1109/hicss.2016.651

Wang, W. et al. (2020) 'Application of Augmented Reality (AR) Technologies in inhouse Logistics', *E3S Web of Conferences*, 145(1), p. 2018. doi: 10.1051/e3sconf/202014502018

Wu, H.-K. et al. (2013) 'Current status, opportunities and challenges of augmented reality in education', *Computers & Education*, 62, pp. 41–49. doi: 10.1016/j.compedu.2012.10.024