AR and Public Participation in Maputo City: An Exploratory Study

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Abstract

This study examines the potential of using Augmented Reality to increase urban participation to deal with identified problems in Maputo city, Mozambique, southern Africa. The study's aim is twofold; first, it seeks to add to the nascent literature on Augmented Reality (AR) in Africa; second, to experiment with AR for public participation in urban Maputo to explore the affordances of AR and examine the possibility and limitations of deploying the technology for such purposes. The study concludes that AR can enhance public participation and engagement with public spaces in Maputo city. However, technical and economic limitations must be considered when designing projects to deploy AR technologies in the city.

1. Introduction

Cities worldwide are increasingly seeking to promote urban citizens' participation in urban planning, development, and management to grapple with the severe challenges they face [Elinoff 2014]; [UN-Habitat 2019]. That movement results from the neoliberalisation process that seeks to bring the private, and civil society sectors and citizens into urban governance. In that movement, different actors defend the idea that technology can further improve urban governance and, important to this study, public participation. One such technology that has been employed to open-up urban spaces for public engagement is augmented reality (henceforth, AR). This study constitutes an exploratory approach to examining the potential of using AR to increase urban participation and address identified problems in Maputo city, Mozambique, southern Africa. The study seeks to contribute to burgeoning scholarship that focuses on how technologies could enhance public participation and improve urban governance and service delivery with the material from the global south. Specifically, the study intervenes in the scholarship that has taken the name of AR graffiti and AR Activism and examines how AR could be used to engage in politics around urban spaces, urban citizenry, urban arts, and other domains [Geroimenko 2014]; [Gwilt and Wilde 2022]; [Kondlo et al. 2020].

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AR is a recent technology that is part of mixed reality (XR) technologies. Mixed Realities technologies include Augmented Virtuality, Virtual Reality and Reduced Reality [Kwok and Koh 2021]; [Milgram and Kishino 1994]. Those designations have to do with how technologies intervene in the real-world and situate the user in the continuum between the virtual and the real-world. Jonathan Linowes and Krystian Babilinski define AR as "a technology and, more importantly, a new medium whose purpose is to improve human experiences, whether they be directed tasks, learning, communication, or entertainment" [Linowes and Babinlinski 2017, 10]. According to Ronald Azuma, AR systems present the following features: "Combines real and virtual; Interactive in real-time; and registered in three dimensions (3-D)" [Azuma 1997, 2]. AR does so by relaying computer-generated graphs in the real-world using a smartphone or tablet.

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Seeking to explore the affordances of AR, this study looks at AR as more than a technological apparatus that enables the relaying of computer graphics on real-world. Instead, the study frames AR as a form of intervention in the real-world and the perception of the user — in other words, AR creates new phenomenological experiences on the users while also intervening in the real-world [Chevalier and Kiefer 2020]; [Gwilt and Wilde 2022]. This approach is inspired by AR artist Thiel Tamiko (see [Thiel et al. 2017]) and the scholarly work of Vladmir Geroimenko [Geroimenko 2014]. Following that approach, then AR is best conceptualized as "real-time computationally mediated perception" [Chevalier and Kiefer 2020].

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As the literature review on this study will show, the few existing studies on AR and public participation (including artistic) have occurred mostly in the context of the global north. Studies on that topic are limited in the global south and nearly nonexistent in contexts like Mozambique, a Portuguese-speaking country characterised by digital, socio-economic, and "ruled and the rulers" divides that need to be addressed [Roque, Mucavele, and Noronha 2020]; [Tvedten et al. 2018]; [Tvedten, Picardo, and Bertelsen 2021].

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This study was conducted in Maputo city, the capital of Mozambique. Highlighting the city's histories and present predicaments is crucial as a way of contextualizing the affordances that AR can provide — enhancing public participation. Maputo city was constructed during the colonial period by the Portuguese colonial settlers[1]. It was elevated to a city on 10 November 1887. It was then constructed for the white settlers. Most black people were moved to the periphery of the city that constitutes today's shanty areas. That racial and spatial segregation is best captured by what locals called the city: they referred to the city as *xilunguine*, meaning the land of the whites. Mozambique became independent in 1975, after an armed struggle[2]. However, the colonial debris (racial and spatial segregation policies) still shapes the city's

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current life. Those colonial legacies intersect with today's challenges including over-population, overburdened urban infrastructures, poor solid waste management service, climate change impacts, and related to this work, a sense of gaping divide between the government and the citizens. In the survey circulated among fifty-seven residents of the city as part of this project most respondents mentioned that the divide between the municipality and them as being one of their main concerns. The responses also highlighted that solid waste management was one of the most pressing issues in the city that, according to them, negatively affected their quality of life and perception of the city.

Against that backdrop, the study's aim is twofold; first, it seeks to add to the incipient literature on Augmented Reality and public participation in public urban spaces; second, to experiment with AR for public participation in urban Maputo to explore the affordances of AR and examine the possibility and limitations of deploying the technology to address the issue of solid waste management in the city. The study does so by creating an AR art object called the Trash Snail that the study participants could deploy in the city to make the issues of solid waste management visible using their mobile devices. 6

The next section reviews both the scholarly and grey literature on AR and Virtual Reality (henceforth, VR) with a special focus on Africa, where similar conditions of the deployment of AR are found. Section three is the methodology section where the surveys and design of the AR experience Trash Snail are explained. Section four is the analysis and results section that examines the responses of the survey participants and shows how the issue of solid waste management is foregrounded in their responses. By drawing on AR arts practices, the study examines the experiments of deploying the Trash Snail App on urban Maputo to make the issue of solid waste management visible. Finally, the discussion and conclusion identifies the main findings of the experiments of deploying AR for public participation in Maputo city and the relevance of the experiments in similar contexts. 7

2. Related Work

In this section, the study reviews some of the literature and projects done in AR and Virtual Reality on the African continent. The choice of focusing on both technologies and limiting the geographical emphasis to Africa has to do with the fact that while both technologies are burgeoning in the global north, few studies and projects exist exploring them in the global south. While Virtual Reality presupposes a total immersion of the user into a virtual environment using Gadgets or glasses, AR enhances the user's reality [Milgram and Kishino 1994]. This review seeks to foreground the potential of the AR technology as a catalyst of change in the African continent. 8

One field in which AR technology has gained traction is tourism. In South Africa, scholars and practitioners have proposed using AR to enhance the tourism experience and deal with the existing shortages in the sector. For example, Aphile Kondlo and colleagues observed the need for more tourist guides in the Cape Flats Nature Reserve, situated in the Western Cape, South Africa. The Reserve provides guided tours only once a day. The authors argue that that shortage could be mitigated using AR self-guided tours. That would mean that more self-guided tours could happen and, in the process, generate more income for the reserve [Kondlo et al. 2020]. 9

Because tourism is a large industry in Africa, the International Finance Corporation (visit https://www.ifc.org/wps/wcm/connect/corp_ext_content/ifc_external_corporate_site/home) estimated that in 2019 tourism accounted for approximately 7% of Africa's overall GDP and contributed $169bn to its economy. Hence, it is no surprise that in 2021, DPVR, a Shanghai-based company, announced a partnership with Travel Africa Network (TAN), a South African satellite travel TV channel, to provide VR solutions to promote tourism on the continent [Sprigg 2021]. 10

Other sectors that VR and AR have seen growing interest in are museums and storytelling. For example, Electric South and the Goethe-Institut presented a vibrant exhibition of African VR named "New Dimensions - Virtual Reality Africa", which showcases artworks from artists from Kenya, Senegal, and Ghana on their website [Oyelude 2018]. In South Africa, the museum Origins Centre at Witwatersrand University created a virtual reality exhibition of African fossils, art, and artefacts that enable visitors to interact with the past [Oyelude 2018]. Also in South Africa, Africarare became the first metaverse to seek to showcase African creativity and modes of living (visit https://www.africarare.io/). The platform enables artists to sell their work. In Nigeria, multiple projects, and forums for discussion about the importance of the digitisation of cultural heritage, have also produced encouraging results. Also in South Africa, Makhulu Media recorded a 360° video of a young man that decided to know his virological situation (visit https://unicrio.org.br/na-africa-do-sul-programa-da-onu-lanca-videos-em-realidade-virtual-sobre-teste-de-hiv/). The UN-AIDS organization financed the video and sought to explore the potential of the "empathy machine" [Kummer et al. 2012] — a name that Virtual Reality is also known for due to its ability to make the user experience the life or world of another person phenomenologically through the mediation of a VR headset — to encourage young people to be tested and understand the plight of the people infected by the HIV-AIDS virus. 11

Education is another sector where the use of VR and AR to enhance the sector and deal with its shortcomings has increased. However, most work in this sector is still in the exploratory phase. For example, David Lockwood prepared a pilot study of the use of VR in education in Uganda and South Africa that UNESCO commissioned. The author concluded that students and teachers found using VR in the classroom satisfactory and enjoyable [Lockwood and Kruger 2008]. The African Leadership University (ALU), known for its innovative and business-oriented education model, has embraced VR in classrooms as an educational tool (visit https://www.alueducation.com/virtual-reality-african-education/); however, little information exists about the project's status. Equally, Angelina Misso and colleagues explored the potential of using VR in education in Tanzania [Misso et al. 2019]. They found that respondents were aware of the technology and believed it could enhance the learning experience in the country. Similar exploratory works of AR and VR in education were done in South Africa [Abdul- 12

Razak 2020]. Also, the University of Witwatersrand in Johannesburg, South Africa, has started a pilot study of VR to teach students in STEM disciplines that they expect to replicate in other schools and universities in the country. However, much like with the explorations in Uganda and South Africa described above not much is known about those projects in the present, which limits the understanding of their long-term impacts in the locales where they were implemented.

One of the areas where VR is prospering in Africa beyond the exploratory phase is the gaming industry. For example, In Morocco, Funsoft produced a VR puzzle game called Rangi that draws on African art, music, folklore, and culture to create its world (visit https://www.oculus.com/blog/explore-african-culture-and-solve-puzzles-in-rangi-now-available-on-rift/). In South Africa, the V&A Waterfront in Cape Town got the world's first permanent arcades to enable gamers to use the newest VR headsets in an old-school arcade environment (visit https://mygaming.co.za/news/entertainment/101152-south-africa-is-getting-one-of-the-worlds-first-vr-arcades. The use of AR and VR for gaming is one people associate the technologies with most. In the case of this study's respondents, one of them, when asked whether he knew what AR was, responded that "yes, in Gaming," but 52 (out of 57) responded that they had not heard about AR.

VR and AR have also found their way into the industrial and small enterprise sectors. In South Africa, the high incidence of accidents in the mining industry has made it so that the South African government has been trying to teach mine workers about safety protocols to reduce accidents. In 2001, CSIR Miningtek developed a PC-based VR hazard awareness training simulator to train miners [Squelch 2001]. Only a little information exists in the present about its status. In Kenya, Black Rhino, a company created in 2015 focusing on producing documentaries and stories, recently embraced VR in its business after Facebook acquired Oculus for 2 billion dollars. Their work includes immersive documentaries, news format content, education, marketing, advertising, and AR (visit https://www.blackrhinovr.com/services/). In South Africa, VR360.oc.za started operating in VR in the late 1990s and produced street view maps using 360 degrees videos. The company works in virtual tours, virtual reality, and creative industries (visit https://vr360.co.za/about-vr360/). Still, in South Africa, bizAR Reality started operations in 2015, working on immersive technologies. They produce AR for their client's websites, social media, smart glasses, and apps and games (https://www.bizarreality.co.za/ar/). One leading organisation in AR and VR in Nigeria is Imisi3D which seeks to build a community of VR and AR enthusiasts in the continent (visit https://imisi3d.com/). Moreover, the Start-up list Africa identified start-ups from more than 25 countries that have embraced VR in their business model (visit https://startuplist.africa/industry/virtual-reality). The growth of start-ups in this area shows that VR and AR are increasingly gaining popularity on the continent.

Another area that is closer to the interest of this study is the use of AR for public participation in public spaces. The use of VR and AR in public spaces is the least explored element on the continent. Speaking of the affordances of VR and AR, Virpi Oksman and Mika Raunio argued that "[…] these tools can be used to increase transparency and inclusive engagement in city planning" [Oksman et al. 2018, 249] and explored the potential of their use in Keetmanshoop, Namibia. An exploratory study on the potential of AR and VR to enhance public participation in urban planning is a report created in 2019, with the title *Mixed Reality for Public Participation in Urban and Public Space Design: Towards a new way of Crowdsourcing more Inclusive Smart Cities* containing a pilot study in South Africa. The UN-Habitat organization commissioned the study. Much like Oksman and Raunio's study, the UN-Habitat's report highlighted that MR could enhance the participation of multiple stakeholders such as "municipalities' urban planning departments, architect firms, engineering companies, and game developers" [UN-Habitat 2019, 48]. In other words, AR had the potential to enhance collaboration and public participation on issues related to the governance, planning and development of public spaces.

2.1. Limitations and opportunities of VR and AR in Africa

The brief survey of VR and AR use in Africa highlighted above underscore some of the most exciting prospects of the emerging VR and AR technologies in the continent but also their pitfalls. As seen above, most work in those fields is still exploratory, and few studies exist detailing the successes and failures of the different pilot projects conducted in the sectors of education, tourism, museums and storytelling, business and industry, gaming industry, and relevant to this study, public participation in urban public spaces. For example, not much is known about the long-standing impacts of the deployment of AR in those sectors, hence their ability to be sustainable.

The cases reviewed above show that the inexistence of proper infrastructures, the prohibitive prices of internet data bundles, and the shortage of reliable funding hinder the public's use of AR and VR in Africa beyond the early adopters and technology enthusiasts on the continent. However, some international organisations are starting to set up funding agencies, collaborating with African agencies and organisations to set up funding for AR and VR interventions in the continent. For example, Africa No Filter (ANF) and Meta have recently established a program named "Future Africa: telling Stories, Building Worlds" that aims to increase the use of VR in Africa. The program grants African storytellers up to USD30000 to produce digital media stories (visit https://africanofilter.org/future-africa-telling-stories-building-worlds). The other example mentioned above is the DPVR, a Shanghai-based VR headset manufacturer, and Travel Africa Network (TAN), a cable network broadcaster from South Africa, partnership agreement to explore the potential of tourism in Africa using VR and AR. In 2022, Meta organised a continent-wide Hackathon for VR and AR in Africa, bringing enthusiasts and field specialists to explore the continent's technologies. Those embryonic experiments show that VR and AR have a place in the continent and can play a role in solving the continent's challenges.

The examples reviewed above show that AR has indeed a potential for transforming social relations on multiple domains including education, tourism, GLAMS, industry, city planning and others. AR has the potential to elicit public participation. However, most studies reviewed showed that the use of the technology is still in its infancy and mostly exploratory. Little is known about their operations in the present and

their long-term impacts. That is the limitation that this study seeks to address.

3. Methodology

This study resulted from qualitative approach to gathering, analysing, and communicating data. The study emerged out of trial and error, technological and economic constraints, and COVID-19 restrictions on mobility that the researcher had to navigate to implement the study. |19|

The specific site for the AR experience was Maputo City. Maputo's choice was due to its being the country's largest city. It is also where the political and economic elite of the country is based. Those conditions make it so that the city has more reliable mobile phone coverage, and many young people living in the city own a smartphone[3]. It is crucial to note that AR experiences have restrictive requirements and this significantly reduced the number of participants in this study. The study will discuss those limitations in the analysis and results chapter. |20|

Additionally, the choice of Maputo was because it is the capital city where most opportunities exist. The more people live in a city, the more solid waste is produced, and a timelier response from the municipalities is required. Those material conditions made it so that an experience of AR in Maputo was likely to yield a more significant impact on urban dwellers. |21|

3.1. Data collection methods

The study employed a participatory approach, meaning that the participants' voices and opinions were central and informed the design of the Trash Snail. Participants actively engaged in downloading and deploying the Trash Snail on their smartphones. However, it is crucial to highlight that the ongoing COVID-19 pandemic constrained such a participatory approach and that the study was conducted from Sweden, where I currently live. The study engaged with the city and the participants by resorting to technology, like the cloud-based program Survey&Report and phone calls. |22|

One of the affordances of AR is that physical borders and space do not constrain it. Hence, designing an experience that anyone with the app worldwide could engage in was possible. At first, there was a plan to produce a geolocated AR experience that would be placed at Maputo City Hall, where the municipality is housed; however, because GPS is not reliable in Maputo and that experience was more centralising (meaning more people would be concentrated in one area during COVID 19), then it was decided that the used plane detection technology in Vuforia Unity Engine would be better because it enabled each user to place the snail in a specific locale of their choice. |23|

For this specific project, using Vuforia Unity Engine, an interactive AR application named Lix.AR Maputo was produced through which participants could display a Trash Snail on public locales with solid waste that needed to be properly managed. The app and Trash Snail was inspired by the study participants' responses to a survey conducted during the first and second weeks of February 2022. |24|

The study collected the participants' responses using an online questionnaire created via Survey & Report. A link was shared to the survey on social media networks, such as WhatsApp and Facebook (Meta). Respondents who resided in Maputo or were in Maputo two weeks before the survey were asked to respond and share the survey on their social media handles. |25|

The survey was conducted in Portuguese, the official language of Mozambique, and consisted of 18 questions. The first six questions were structured and asked about gender, age, profession, physical condition, residence, and workplace location and aimed at producing a demographic and spatial profile of the participants. |26|

The next five questions were also structured and asked about the study participants' use of Maputo public spaces, frequency, reason for the visit, and means of transport to and from the public spaces. This set of questions sought to get data about the different uses of the public spaces or lack thereof that could be connected to the issues of public spaces and access in Maputo city. Finally, the last six questions were unstructured and asked about the city study participants' perceptions of the public spaces regarding what they liked and did not like. Some of the responses to those questions were used in the epigraphs of this study, and they were also fundamental in selecting waste as the main problem in public spaces that needed to be addressed. |27|

Regarding the opinion of the participants about the challenges of the public spaces, apart from the lack of inclusion in public spaces design and management, they reported that waste ("lixo"), sanitation ("limpeza"), lack ("falta"), and spaces ("espaços"), noise ("barulho"), maintenance ("manutenção") and safety ("segurança") as being the main issues plaguing public urban spaces in the city (see figure below). |28|

Figure 1. QSR NVivo word cloud with 50 most common words highlighting the main issues in public urban spaces.

Altogether, the survey enabled the study to gather the participants' profiles, their uses of public spaces, and the challenges around the public spaces, namely, solid waste, as the word cloud above suggests. Then the study used the participants' answers to design an AR experience Lix.AR Maputo, following the AR art practice [Gwilt and Wilde 2022].

In Unity Vuforia Engine Asset Store, the AR Shadow (AR Foundation: Arkit/ARCore: Plane Detection Template with AR Shader) that provided a template to build the canvas, shade, and plane detection was acquired. Then the 3D Trash Snail was created using the open-access online platform Monster Mash and the software Blender to save the file in an FBX (Filmbox) format that could be used in Unity Vuforia Engine. The Trash Snail was created by randomly cutting an image that was extracted from a 2020 news article from Radio Moçambique [Radio Moçambique 2020], with the title " Maputo municipal council reinforces garbage collection means" (see figure 2 below).

Figure 2. Empty waste containers in Maputo are surrounded by waste. [Radio Moçambique 2020]

What was compelling about the image was the fact that it showed empty containers surrounded by solid waste on the ground. That waste on the ground could be because the municipality only emptied the overflowing containers and did not clean the waste, or urban dwellers did not put the waste into the waste containers. Judging by this photo, it was hard to immediately find "who was to blame" for the current condition in

the locale and other similar conditions in the city. As some of the respondents mentioned, the municipality had to do a better job managing solid waste, but the residents also needed to be educated ("sensibilizar") on how to use public spaces and deal with solid waste.

Hence the image was good to think with [De Ruijter 1982]. The image also depicted a mix of organic and inorganic waste, reflecting the city's general treatment of solid waste or lack thereof. The study participants also found similar situations in other locales, which will later be described in the analysis and results chapter. Then, animations were added to the Trash Snail that resembled the movements of a snail to give the impression of a living creature — living waste. The gruesome movements served as entry points to showcasing how solid waste was itself a matter with social life, despite it been portrayed as a "matter out of place" that elicits urban dwellers' and municipality's responses to get rid of it [Douglas 1996]. Even though it moved the trash snail never left the locale. It is a though it was stuck in a place. That quality of being stuck represents the respondents' feelings of solid waste not being properly moved out of the public spaces and lingering in their urban spaces.

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After creating the Trash Snail, people who resided or had been in Maputo two weeks before the study were invited to test the application. The invitation was sent via social media. Seven people accepted the invitation to use and provide their feedback on the AR experiences in two interviews: the first before using the application and the second after using the application. However, only three participants could utilise the app due to the technical limitations and the fact that the study was conducted remotely in the context of the COVID-19 pandemic.

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The study allowed the participants to respond anonymously to protect their identities. However, the study participants were asked to take a screenshot with their smartphones of the Trash Snail placed in the real world if they were willing to. The study also used those screenshots to draw the analysis and visualise the uses of the AR experience in Maputo city. The study also used that data to communicate the study to a wider audience via social media to draw a wider audience.

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4. Analysis and results

The initial study survey gathered responses from fifty-seven urban participants, of which 66,7% responded as being male and 33.3% as female. The data could be biased toward male perspectives about public spaces. Regarding age, 12 respondents were 18-29, and 45 were in the age range of 30-59, meaning that young and adult perspectives were mostly gathered in this study, leaving outside older adults and children. This high number of young participants might be the effect of children and older adults' limited access to mobile phones and the internet.

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The most revealing part was the residences ("bairros") of the respondents, which showed quite an interesting mix. 9 out of the 57 respondents resided in Maxaquene, a peri-urban neighborhood where the author of this study was born. The prevalence of respondents from Maxaquene is likely connected to the fact that the questionnaire was shared via this study's author's social media handles with "friends," some of whom the author lived and grew up with. Only five respondents were from the city centre, namely Alto Make (2), Bairro Central (1), and Coop (2), which means 52 respondents lived outside of Maputo city but had engaged with public spaces in the city.

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In terms of public spaces that the participants used in the past three months (December- February), 68,2% responded that they used municipal markets ("mercados municipais"), 54,5% reported that they visited beaches ("praias") in the city, 50% responded that used plazas ("praças"), and 43,2% and 29,5% visited gardens ("jardins") and parks ("parques").

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When asked about what activities they performed in public spaces, 65% responded leisure activities ("lazer"), 41,3% responded meeting with friends, partners, relatives, etc. ("encontro com amigos, familiars, parceiros", etc.), and 23,9% reported that they used the space for physical activities ("actividade física"). Of the seven respondents that answered other (*outra*), six stated shopping, and one respondent studied.

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4.1. Residents' views of the city

When asked about their opinions on Maputo city public spaces, a study respondent reported a "[l]ack of adequate sanitation and hygiene. Lack of garbage bins for waste. And cars occupy sidewalks because there are no available parking spaces." Another respondent reported that the spaces are characterised by "badly managed waste, little safety, and no maintenance [of the spaces]." However, respondents also mentioned that the waste problem was due to the municipality's incapability to keep public spaces clean and stop city dwellers' from littering them. Hence, they stated the need for "raising the urban dwellers' awareness" (in Portuguese "sensibilizar") about keeping public spaces clean.

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The study respondents addressed the need to raise awareness in the following terms: "I think that the municipality, through its city councilors overseeing a certain area, should mobilise funds for that end (cleaning public spaces) and add human resources. Also, they should sensibilise the residents and teach them not to litter." Using the respondents' opinions about the main challenges the city faced, the study designed the Trash Snail experience that participants could engage with using their android smartphones or tablets as a form of participation in making the issues of "matter out of place" visible [Douglas 1996].

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4.2. Enter AR in Maputo

The Trash Snail was an attempt to allow the participants to reflect on solid waste issues in urban spaces. Hence, rather than overlaying information in public spaces, the purpose was to create an AR experience that would invite the participants to reflect on the solid waste that

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shapes urban life, politics, citizens' understanding of well-being, and the environment in Maputo, much in line with the work of AR art or activism [Gwilt and Wilde 2022].

After the Trash Snail was built, people with an android mobile phone were asked to volunteer to download and use the app on their mobile android smart devices. The invitation was sent via social media platforms. Seven people showed interest in participating in the study and filled out a survey before using the app to gather their profiles and experience with AR. Then a link was sent to download the APK file with those volunteers.

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However, when installing the app, the volunteers needed some help. First, the AR experience required Google Play AR services; some volunteers' phones did not support that service. Second, the APK gave a warning sign of possible phone damage due to the APK size. Altogether those aspects made four volunteers give up.
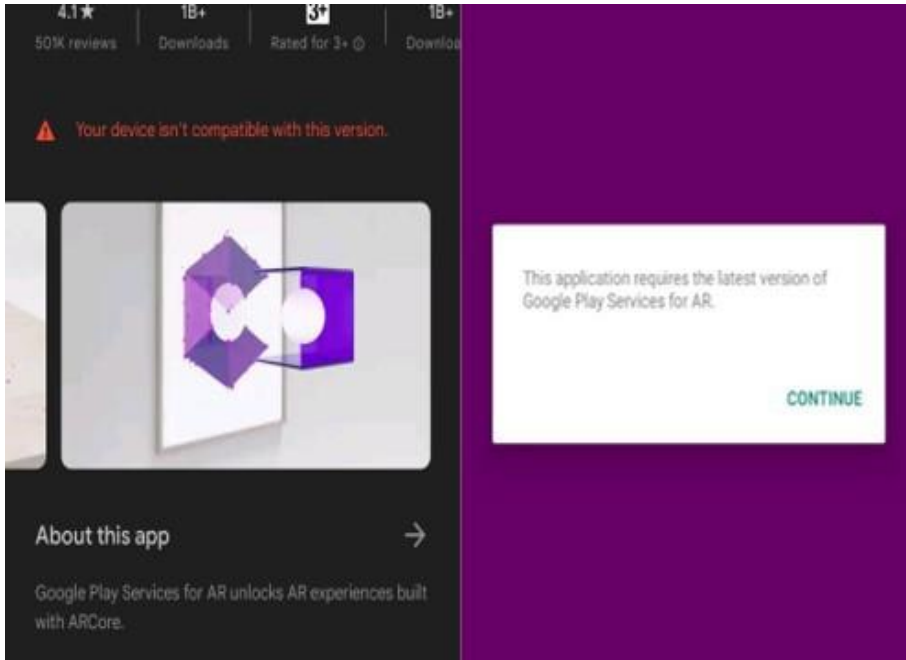
43

Figure 3. Screenshots showing Google Pay Store notifications about device incompatibility with AR.

Then, the application was listed as an ABB (Android App Bundle) on the Google Play store to ensure that people trusted the application and downloaded it on their phones. The study understood the implications of using Google Play Services in terms of Google extracting data from their users, as discussed by Trzaskowski [Trzaskowski 2022] and Zuboff [Zubiff 2019]; however, this was not an issue that could easily be mitigated around in this study nor was it within the study's scope.

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Listing the app on Google Play Service helped the study gain the remaining three volunteers' trust in the app. However, it added another challenge. The app could only work with android devices from android 7 (Marshmallow) and above. Furthermore, such devices are also required to have Google Play AR Services. Google Play Store listed only around 514 phone models as being able to use the app worldwide. Many residents of Maputo could not afford those models. None of the three study participants' models were on that list.

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Hence, as suggested by this study's supervisor, those participants were asked to find one device that could work following Google Play Service's stated requirements. The participants managed to find a Samsung A70 device listed on Google's list of recommended mobile models. After using the app, the three participants were asked to respond to a survey before and after using it, take screenshots of their experiences with the app and send them to this study's author's personal WhatsApp number.

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The participants were all male, aged between 18 and 29, and all lived in the same neighborhood in Maputo called Malanga. Two of them were students, and the other was unemployed. They all learned about AR after the study. The study participants used the app on the 7th of April 2022. It was a public holiday in Mozambique. The participants were instructed to take a screenshot of waste that was not properly managed and then add the specific name and date after taking the screenshot and sharing a pre-written message with me, saying, "Lixo que precisa ser retirado" [waste that needs to be removed].

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One fascinating aspect of the results of such screenshots was that the participants chose to start from their neighborhood, which is a place they knew best. They knew they were very likely to find waste — in this case, in Malanga. That observation highlights the major concerns raised by the study participants about their perception of public spaces. In the first survey, participants reported waste and insecurity as the major problems around public spaces in Maputo (see Figure 1).

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4.2.3. Screenshots: Making solid waste visible

This screenshot (Figure 4) shows the Trash Snail alongside a waste container overflowing with waste. The container is in the Malanga neighborhood at Fajardo Street, Trabalho Avenue.

Figure 4. Trash Snail placed at Fajardo Street, Trabalho Avenue, Malanga, Maputo.

The Trash Snail reaches for a tire on the ground circled by organic waste, including onions and tomatoes sold in the vicinity, mostly plastic inorganic waste.

The screenshot in Figure 5 depicts an empty waste container at Rio Tembe Avenue in the Malanga neighborhood.

Figure 5. Trash Snail placed at Rio Tembe Avenue, Malanga, Maputo.

A "barraca" (barrack) in red sells food and beverages behind the container. Behind the barrack, there is a secondary school. While the waste container is empty, it is possible to see waste on the floor. That waste includes vegetables, cardboard boxes, plastic bags, and glass bottles. The Trash Snail hovers over the road facing the waste on the ground. Underneath the Trash Snail and closer to the container, we can see vestiges of urine on the ground since there are no public toilets available in public spaces, as the residents' opinions on Maputo public spaces survey respondents also reported. One can almost sense the smell of urine in the image. Behind the container, a male figure can be seen looking inside the waste container. At the bottom of the picture, a finger can be seen.

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The screenshot below (Figure 6) also depicts an empty waste container in a residential area. The empty container is surrounded by waste on the ground, including plastic bags, cardboard boxes, and glass bottles. In this screenshot, the Trash Snail is facing the camera. We can see a pile of sand, waste, and vestiges of urine behind the waste container to the left.

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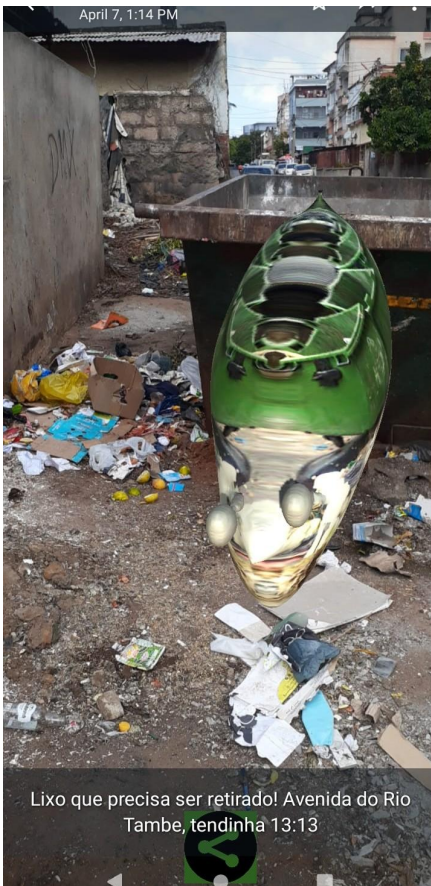
Figure 6. Trash Snail placed at Rio Tembe Avenue, (Tendinha), Malanga, Maputo.

Figure 7 depicts the Trash Snail hovering close to one waste can occur in a residential area at Zambia Avenue, Alto Maé, a neighbourhood close to Malanga.

Figure 7. Trash Snail placed at Zambia Avenue, Alto Maé, Maputo

The Trash Snail is facing the Ecolife logo with its mouth wide open. Eco-Life is a private company responsible for public waste management in Maputo, which was implemented after the municipality realised it could not manage waste in the city. Next to the container, there is a small bundle of waste consisting of food and plastic bags.

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In this picture, different from other areas, the floor is cleaner, and not much vestige of urine can be seen. That could be because the waste containers are in residential areas that are often very well-policed and maintained instead of places close to municipal markets with many dwellers and poorly lit.

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The container in Figure 8 is at Commander Moura Bráz street in Malanga.

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Figure 8. Trash Snail placed at Commte. Moura Bráz street, Malanga, Maputo.

In this picture, we can see the body of the Trash Snail hovering close to a waste container. The Trash Snail's head is out of the frame. We can see plastic bags, clothes, cardboard boxes, and paper on the ground underneath the Trash Snail. There is also an exercise book. It is impossible to tell whether the container is full or empty; however, like other containers depicted above, waste can be seen on the ground around the waste container.

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5. Discussion and conclusion

This study sought to add to the incipient literature on AR and VR in Africa and explore how AR could enhance participants' engagement with public spaces and solid waste issues in urban Maputo, Mozambique. The study was inspired by the previous research and projects in the field that showed that AR has the potential to enhance public engagement and transformation on different domains [Geroimenko 2014]; [Kondlo et al. 2020]; [Thiel et al. 2017]. However, to be able to reap those benefits one needs to carefully consider the material conditions in which the technology will be deployed.

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After receiving around 57 responses from Maputo urban dwellers it was possible to note that one of the main issues that they faced was the poor management of solid waste that according to them resulted in their experienced negative perception of the city as well as the gaping divide between them and the municipality. To provide an outlet in which the participants could engage in showcasing their concerns, this

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study created the Trash Snail following the work of AR artists and scholars. That construction was inspired by the fact that AR was "real-time computationally mediated perception" [Chevalier and Kiefer 2020]. In other words, it intervened both in the user and the public space by intermediating their interaction.

Much like previous studies and projects that employed AR, this study concludes that AR has the potential to enhance public participation in urban Maputo. The study participants' engagement with the Augmented Reality showed that Maputo residents live with waste in public spaces. Much like The World Bank reported, some of that waste is "not managed in an environmentally [and socially] safe manner" [Kaza et al. 2018, 3]. More importantly, it showed that AR could mobilise public participation in urban Maputo city despite the many technical and economic challenges that such an endeavor entails. Using Vuforia Engine to build the AR app required more recent mobile phones (android 7 onwards) to support the application, which in turn limited the number of participants because most used older mobile phone versions.

The study respondents that were able to deploy the AR using their mobile devices reported that it was useful to make them think about solid waste in Maputo. Moreover, the screenshots generated could easily be shared on social media. Their sentiment connected to Geroimenko's idea that "AR is ideal as a social tool to generate conversations in and around the community. It is often experienced in public space at the site of a problem, creating an opportunity to engage people in conversation. AR can create experiences that make people laugh, cry, or think deeply" [Geroimenko 2014, 8]. This was also the case with the use of AR in education in which students reported that they felt that their learning experience was more fun and engaging [Misso et al. 2019]. Those findings are consistent with the ones in other contexts beyond Africa that also suggest how AR has improved classroom experiences and learning process [Chen et al. 2017].

Figure 9. Facebook post of the Trash Snail on my Facebook (Meta) stories.

Speaking about the possibility of AR enabling conversations beyond the immediate physical space, after posting one of the screenshots on a personal Facebook story, one of my Facebook "friends" asked me, "how did I know about the waste left in containers in public spaces?" He then stated, "it doesn't matter how; the waste has to be removed whatever it takes." The story had 141 views. The Trash Snail made those interactions possible. And more than individual experiences, those interactions could be shared with other people across space and time using new and traditional media [Geroimenko 2014]. This experience connects to Ian Gwilt's words, when he stated that AR enables us "to switch between a personal and shared experience of an artwork or urban space and to experience both digital and analogue versions of the same environment" [Gwilt and Wilde 2022, 227].

The application has a screenshot and sharing button that enables the participants to share their experiences. The screenshots depicted empty and full waste containers surrounded by waste and urine on the ground, mostly close to municipal markets and non-residential and poorly unlit areas. The urine on the ground reflected that those public spaces in Maputo lacked public toilets, a situation that respondents to

the residents' opinions on Maputo public spaces survey also reported.

The study's findings open room to creatively think the place of new technologies such as AR as being able to increase the much-needed participation of residents and actors on public matters. Similar findings were also presented in studies on education ([Chen et al. 2017]; [Lee et al. 2012]). This means that the policymakers, scientists, and practitioners of AR should carefully consider the affordances of using AR to enhance public participation and deal with today's severe challenges that cities and other contexts face. However, in the context of the global south certain limitations need to be considered. Those limitations include shortage of technical material, existence of old phone models that do not have the capacity to render AR experiences, the digital divide that characterise the country, poverty, and others. These findings open room to think about how the municipality itself could benefit from employing AR for urban governance and enhance citizens' participation in public spaces in postcolonial Maputo.

<div style="text-align:right">65</div>

The Trash Snail shows how AR could truly enable the empathy of the users and readers of the material by enabling the people to visually bear witness to challenges urban residents face in urban public spaces in postcolonial Maputo [Kummer et al. 2012]. AR emerges as a way of visually storying life in urban Maputo which opens the public space for multiple interpretations that challenge hegemonic modes of framing and visualizing the city. However, different from tourism examples, AR with the Trash Snail does not present a sanitized reality of space and the relationship between the viewer and the AR experience. Rather, the viewer is invited to visually engage with the issues of solid waste as "matter out of place" in which the discomfort, disgust, and other related sentiments are elicited in the user of the AR object. This differs significantly from the touristic sanitized modes of visually representing and engaging the public space [Douglas 1996].

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While the study successfully gathered Maputo residents' concerns over public spaces, it was limited in that it could not bring the perspectives of the municipality. Beyond that, the study could not follow the study participants as they tracked waste in public spaces and deployed the app and, in the process, making evident the littered spaces and their knowledge of the city due to COVID-19 travel restrictions. The other limitation has to do with the fact that the study participants were not selected randomly, but through snowballing effect which could generate bias in the study. However, this study was able to show that despite existing structural challenges, AR can be deployed in cities like Maputo to enhance public participation on public issues.

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Notes

[1] It was then called *Lourenço Marques* after a Portuguese trader.

[2] The armed struggle started in 1964 and ended in 1974, a year before independence.

[3] Since only a few people own an iPhone in Maputo, it was decided to develop an app for android smartphones.

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