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Fostering a Patient-led Culture of Care Through Data Physicalization: A Design Approach to Create Awareness and Promote Data Collection on Antimicrobial Resistance

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Fostering a patient-led culture of care through data physicalization: A design approach to create awareness and promote data collection on antimicrobial resistance

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Abstract: The paradigm shift in healthcare delivery models is leading to individuals assuming greater responsibilities and control, as the agency is moving from doctor-centric to patient-centric. To foster a patient-led culture of care, health and data literacy are essential, especially in the context of global challenges, where citizen awareness is fundamental to play actively in co-creating knowledge. This paper outlines a methodological approach and the outcomes of a design research project focused on promoting engagement and literacy to facilitate citizen and patient participation in addressing the antimicrobial resistance threat. The approach is tested in the format of an experimental workshop, inspired by the procedure of the antibiogram. Data physicalization modalities are considered to promote literacy in healthcare and involve citizens in data collection practices to explain the scientific phenomenon of AMR, engage non-experts in understanding antibiotic functionalities and share personal information related to consumption behaviours.

Keywords: data physicalization; citizen engagement; data literacy; antimicrobial resistance.

1. Introduction

Global healthcare challenges, such as COVID-19, have highlighted the importance of onboarding the population to define and implement solutions through data collection and digital tools (Drew et al., 2020). People's participation in healthcare research and innovation contributes to actualising the parading shift that considers individuals taking more responsibilities and control, as the agency is moving from doctor-centric to patient-centric. Patient-centric design is an emergent definition of design that refers to the application of co-design or human-centred design principles within healthcare (Meskó & deBronkart, 2022). In recent years, more and more approaches are seeking to broaden this definition by focusing on collaboration between non-experts and healthcare professionals, bringing grassroots insights into the equation. In this direction, the "People-Powered Health" approach emphasises co-design and co-production with communities as integral components of healthcare innovation (Nesta, 2023). In the realm of public engagement with science and health, participatory practices are also increasingly recognized as essential for developing new models of co-creating knowledge. These models consider citizens active stakeholders deeply involved in the research process, rather than passive recipients of biased or overly structured engagement strategies (Chilvers & Kearnes, 2019). In this direction, a real onboarding of citizens and patients can be achieved by raising awareness through the development of key skill sets that, in the realm of digital health, should include data literacy, considered as the ability to track, collect and make sense of data.

As part of a four-year design research based in Switzerland, this contribution aims to address the challenge of AMR by specifically asking: How can hands-on data-driven strategies create awareness of AMR and engage citizens in data collection? To answer this question, a series of experiential workshops involving different experts in the fields of science, communication, and technology have been designed. These workshops consider treatment habits, attitudes, and personal stories to activate discussion, increase knowledge and provide information for scientists to frame the problem of resistance. This paper presents the methodological framework adopted for the workshop “Visualizing the Resistance”, which considers data physicalization to promote literacy and activate data collection. This contribution is supposed to provide an example of a creative approach employing data as material for engagement, discussion and knowledge to involve non-experts in scientific challenges. The paper provides a reflection on physicalization modalities representing personal healthcare data to foster awareness and engagement in healthcare. Additionally, the framework offers a strategy for microbiologists to facilitate access to their discipline and promote interdisciplinary collaboration.

2. The threat of resistance

Antimicrobial resistance (AMR) is the ability of microorganisms to become resistant to antimicrobials to which they were previously susceptible. This occurs when microorganisms change in response to the use of drugs. Known as the silent pandemic, it is one of the current biggest public health concerns (ECDC & WHO, 2022), estimated to cause 10 million deaths by 2050 and overtake cancer’s mortality rate (The Review of Antimicrobial Resistance, 2016). The problem of AMR is especially urgent regarding bacteria resistant to antibiotics (AB), which are a specific form of antimicrobials. Limiting the consumption of antibiotics has been highlighted as a prime policy concern in the fight against resistance (Adda, 2020). In fact, the more antibiotics are used, the more resistant microbes become; on the contrary, reducing consumption preserves the effectiveness of the existing drugs. In this direction, optimising antibiotic consumption is possible by considering proper diagnosis and consequent appropriate use of drugs (ECDC & WHO, 2022) therefore, making citizens and clinicians aware of correct practices and behaviours is essential to tackle this issue (WHO, 2017; The Review of Antimicrobial Resistance, 2016). Solutions to improve antibiotic stewardship include practitioners taking responsibility for prescribing, increasing the role of caregivers in diagnosing and improving communication with patients (Blaser et al., 2020). On the other hand, patients must avoid buying medicines over the counter without a prescription and demanding antibiotics from doctors without a real need.

In 2014 a global systematic review of the results of quantitative and qualitative studies on the public's knowledge and beliefs about antibiotic resistance demonstrated that "the public has an incomplete understanding of and misperceptions about antibiotic resistance" (McCullough, 2014). The Swiss Federal Office of Public Health (FOPH, 2022) investigating knowledge of, attitudes towards, and use of antibiotics in Switzerland, revealed that 48% of people wrongly believe that antibiotics destroy viruses, more specifically, someone uses them against flu and cold. Almost one in four is still unaware of side effects, such as diarrhoea provoked by antibiotics, and 9% of respondents keep antibiotics to use for a future infection. Overall, the general figure reveals that only 44% of the survey's respondents follow the instructions of their GP or pharmacy when prescribed antibiotics.

Because of this common lack of knowledge, good practices of antibiotic consumption need to be transferred to people, engaging them in good practices to reduce AMR. With this purpose, data-driven strategies based on antibiotic functionalities are employed to explain the phenomenon of resistance to non-experts and promote a bottom-up collection of data aimed at promoting engagement and generating knowledge. Collecting people's experiences is indeed fundamental to investigating antimicrobial use and misuse and helping physicians define the best cure (Huang et al., 2022; The Review of Antimicrobial Resistance, 2016; WHO, 2022; Zhu, 2018). Increasing data availability and specificity facilitates the associations between symptoms and causes, allowing doctors to improve decision-making, identifying the best treatment and avoiding antibiotic misuse (Hummel & Braun, 2020).

3. Approach

To facilitate prevention and monitoring, instead of acute reactive (Huzooree et al., 2019), the agency needs to move from doctor-centric to patient-centric, confirming the paradigm shift that is happening in the healthcare delivery model, where roles are re-considered and individuals are asked for more responsibilities and control (Feng, 2021). To allow active participation and management of own care, health and data literacy are essential. On one hand, to make scientific knowledge accessible to non-experts, citizen science practices are suggested to increase the public's awareness and involvement (Edwards et al., 2018). Citizen science projects (Fritz et al., 2022) not only promote the acquisition of skills necessary for participation but also foster a deeper understanding of the scientific processes and knowledge involved (Roche et al., 2020). On the other hand, to increase the responsibility of participants, data literacy is also fundamental, especially in the growing context of data-driven medicine (Hummel & Braun, 2020; Terenghi, 2023). There are many definitions of data literacy (Yates, 2021; Inverarity et al., 2022), depending on the context of its application, but within this research, the emancipation acquired by people during the process is the most valuable aspect to consider. Literacy is meant to include a vision of the process that transforms data into information and then, information into knowledge, prioritising the importance of empowering people, instead of teaching them how to use tools (D'Ignazio, 2017). A human approach to data encourages intersectional research and facilitates participation, especially regarding sensitive and personal information (Almeida et al., 2020). In this view, being implicated in the action of collecting and organising the data promotes understanding and scales the perception, producing results that not only represent information but also entangle the presence of participants (Sadokierski et al., 2022). Because of people's general inexpertise in managing and interpreting numbers, and the relevance of qualitative information together with quantitative data related to consumption practices and experiences, alternative design methods appear particularly relevant to raise awareness (Blaser et al, 2020; Kosiyaporn H., et al., 2020) and promote literacy (D'Ignazio, 2018) in the field of this research.

3.1 Data physicalization in healthcare

Data physicalization modalities have been identified in order to explain antibiotic resistance and increment involvement and participation of non-experts in collecting data on consumption attitudes and practices. In physicalization, data can be viewed, touched and even handled, thanks to 2D support and 3D object fabrication (Lupton, 2015). Physicalizations are multisensory in nature, as they address not only the visual senses, but also the tactile, kinesthetic, and, in some cases, auditory perception (Hogan et al., 2020; Jansen et al., 2013), freeing expression and communication from cultural visual codes (Boy, 2014), technology and tools' limitations. It is indeed verified how new forms of interaction promote involvement in manipulating data (Rapp, 2015), which is especially effective in supporting conversation about tabooed topics (Almeida et al., 2020), such as personal, intimate or medical information (Lupton, 2017), but also feelings and reflections (Rapp, 2015) thanks to the possibility of encoding both quantitative and qualitative information (Bae et al., 2022; Lupi, 2017; van Koningsbruggen et al., 2022). Objects built out of data have the potential to enhance people's lived experiences, promoting individual and collective reflections (Karyda et al., 2020; Thudt et al., 2018), especially in the case of non-experts working with data (Thompson, 2020).

While data visualization in healthcare is broadly adopted, especially to accelerate the process of understanding and interpreting patients' data, detect abnormalities (Morales-Botello et al., 2021), and explain phenomena for non-experts, the role of physicality has not been yet completely explored. Emerging tools and technologies supporting physicalization in healthcare mainly allow for recreating patients' data and body conditions (Traynor et al., 2022; Ang et al., 2019; Hadeed et al., 2018). For this purpose, 3-D printed models reproduce patient-specific anatomy to increase understanding, and consequent trust, improving compliance. Differently, physicalizations can be considered to make patients communicate their feelings related to the disease. An emerging trend in this direction takes advantage of qualities enhanced by physical artefacts and the action of working with materials to promote self-awareness and reflection (Abtahi et al., 2020; Thudt et al., 2018) in order to improve self-empowerment and healthcare management (Thompson, 2020; Freeman et al., 2023), but also provide doctors with additional information for decision-making (Keefe et al., 2021; Li & Bernhaupt, 2023). In general, physicality appears to facilitate communication among people with different backgrounds and experiences, enabling empathy and facilitating co-design or participatory sessions involving physicians and people affected by specific diseases (Garde et al., 2018; Heiss & Kokshagina, 2021). As physicalization is particularly suitable for encoding qualitative data, this practice fits the attempt to represent pain and other similar variables whose values are far from universal (Lane & Roussos in Gwilt 2022). Additionally, these objects, and the actions required for their creation, not only help in making data tangible but also contribute to creating public awareness and sensitivity to the disease (Barrass in Gwilt, 2022).

To explain antibiotic functionalities and resistance, engaging the public with the topic through personal data and experiences, this research considers physicality to facilitate data contextualisation by situating and embedding information in real living experiences, as operated by autographic visualization (Perovich and Offenhuber in Gwilt, 2022). In this view, connections between data and sites emphasise their implication (Perovich & Offenhuber, 2022) and materiality is considered to "co-respond" data, underling the strict relationship between data and bodies (Thompson, 2020). Not only does physicalization represent data but becomes data itself, making the qualities and features of the material identify the dataset (Offenhuber, 2020).

4. Proposal and method

This paper presents the method and the results of the experiential workshop titled "Visualizing the Resistance". Based on data physicalization, the activity is meant to create awareness of resistance development and foster data literacy skills, encouraging participants to play an active role in promoting correct antibiotic consumption practices and behaviours specifically related to urinary tract infections (UTIs). UTIs, such as cystitis, have been selected because one of the main causes leading to resistance development (Huang et al., 2022). The choice of narrowing down the focus of the activity to UTIs is to facilitate discussion among participants based on similar experiences and encourage the exchange of practices which are related to the specific disease. In this direction, the workshop activities are simultaneously employed to 1) explain antibiotic working action and 2) involve participants in the process of data collection related to their personal experiences. The understanding of the phenomenon of resistance is, in fact, implicitly acquired through the action that people are asked to perform to collect and share personal information.

4.1 “Visualizing the resistance”: An experiential workshop based on autographic physicalization to explain resistance

Inspired by the procedure of testing antibiotic susceptibilities operated by scientists, this workshop format considers explaining the resistance development to non-experts through the natural reaction of microbes to antibiotics. More specifically, the activity refers to the diffusion susceptibility method, known as Kirby-Bauer test. The purpose of this test is to determine the sensitivity or resistance of a specific bacterium to various antimicrobials in order to assist a physician in selecting treatment options for their patients (Gajic et al., 2022).

To test susceptibilities, filter paper disks impregnated with a specific concentration of an antimicrobial mixture are positioned into a Petri, which is a transparent lidded dish previously inoculated with a suspension of the bacteria to test. For this purpose, a swab is dipped into the liquid suspension containing bacteria and meticulously spread on the plate surface. After 24 hours of incubation, bacteria grow and the inhibition area becomes visible. These zones of inhibition appear as circles and correspond to areas where the antibiotic blocks bacteria from growing. If no zone of inhibition is present, it means that the drug is not effective on bacteria which grow close to the disk. Generally, the higher the antibiotic efficacy, the fewer bacteria grow close to the antibiotic, leaving empty space around the disk; on the other hand, the smaller that area, the higher the resistance development of microbes, as not affected by the antibiotic (Fig. 1).

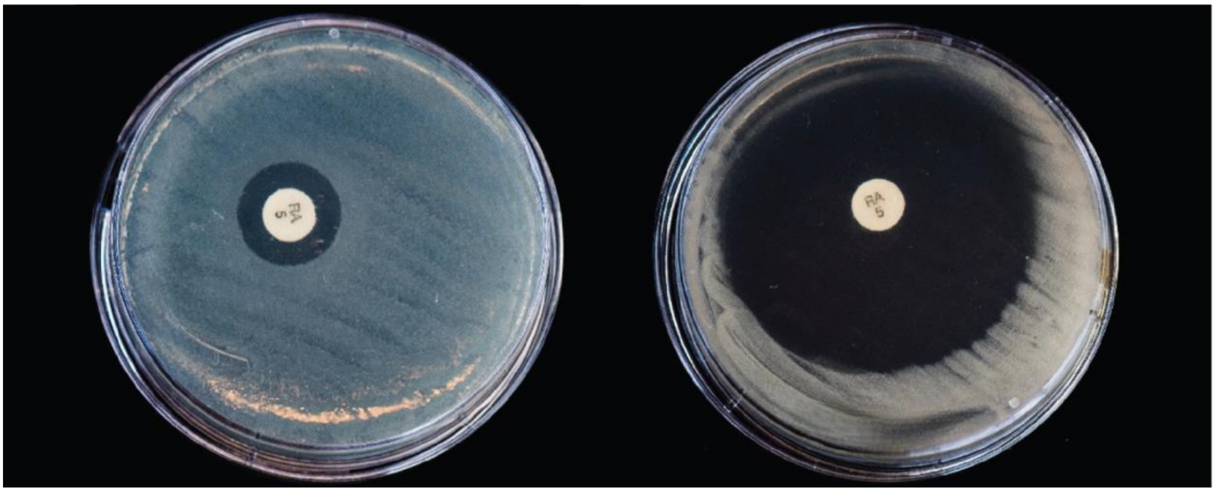

Figure 1 The image represents the inhibitory effect of the same antibiotic (RA5) tested on two different bacteria (gram-negative on the left and gram-positive on the right). The inhibitory effect is low in the image on the left, as the bacteria have grown near the antibiotic pill. On the opposite, in the right image, the inhibitory area around the pill demonstrates a low inhibitory effect.

During the activity, participants operate the same procedure as scientists but with a different purpose, as they are asked to choose antibiotic pills based on the expected inhibition area to answer some questions related to their relationship with antibiotics. The larger the area of inhibition associated with the answer, the more participants' behaviour helps in preserving the antibiotic inhibitory effect, specifically by reducing antibiotic consumption over time and focusing the treatments on only essential cases.

4.2 Creating Petri dishes as data portraits

The workshop format considers the limit of 10 participants for each session. This is mainly because of the laboratory dimension and the activity. At the time of this paper, four sessions have been run, involving 32 participants in total. The Instagram page of the project (MAKEAWARE!, 2022), printed posters and word of mouth were adopted to recruit participants. The other two sessions were organised for students of the bachelor course in nursing care. The call for participation was open to everyone interested and available to reach the University campus, where the workshops took place. Because of safety concerns, people with deficiencies in the normal function of the immune system were suggested not to take part.

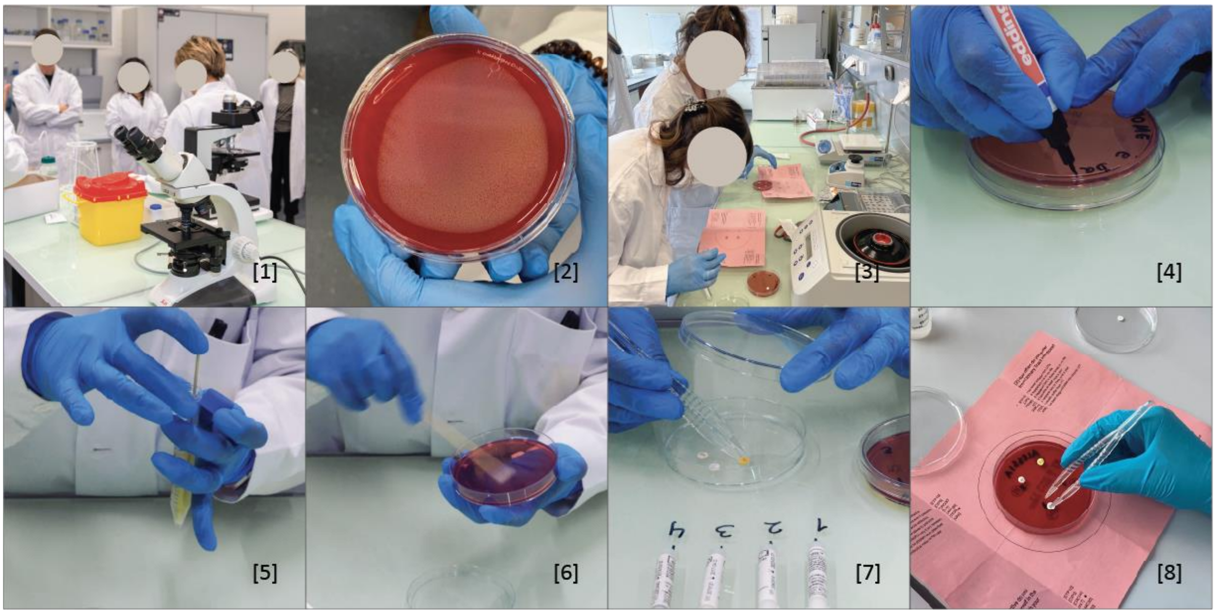

Figure 2 Workshop activity step-by-step. Every step is further explained in the text below.

After a first introduction to the project, participants are welcomed into the Microbiology Lab of the University. The material to perform the activity is distributed to each participant, together with the personal protective equipment (PPE), such as dedicated lab coats, gloves, and eye protection. Then (as from Fig. 2), a microbiologist introduces antibiotic working actions and functionalities, supported by four working stations with microscopes available for participants to observe different bacteria in slides previously prepared [1]. At this point, participants receive a Petri dish [2] and a printed guide with questions and instructions. Each of them is assigned a space on a table [3] and, as the lab procedure requires, writes the name and the date on the Petri dish [4]. A team of two designers is supposed to facilitate the activity. First, participants are invited to use a swab to inoculate the microorganism to the agar plate surface, also known as the growing medium. In order to do so, participants have to dive the swab into a test tube containing the liquid suspension of bacteria [5]. The first bacterium used is Enterococcus faecium (E. faecium) which is widely distributed in the intestines of humans and other animals. To ensure uniformity of the inoculum, the action needs to be performed three times, in different directions and taking care not to break the growing medium, which is fragile [6]. Then, driven by the guide previously distributed, participants are invited to answer one question per time, selecting the answer based on their personal experience and moving to the antibiotic station where a table is specifically predisposed to display all the options available. The questions regard personal attitudes and experiences with antibiotic consumption and urinary tract infections (UTIs), which are one of the main causes of antibiotic consumption (1. How do you feel about taking antibiotics? 2. How often do you suffer from urinary tract infections? 3. When did you take antibiotics last time? 4. How active do you consider yourself in the relationship with your doctor?). A team member distributes antibiotic disks based on the requests. Participants collect all the disks needed to answer the four questions and come back to the table to position antibiotics into their Petri dishes [7]. The printed guide helps in positioning the pills correctly based on the questions. Each antibiotic corresponding to an answer is positioned in one of the quadrants of the Petri dish [8]. Disks are gently pressed into the growing medium, to avoid moving, and then, the Petri dish is covered with a lid. All inoculated plates must be taped with parafilm before incubation to ensure they cannot be opened accidentally. The inoculated Petri dishes are then incubated at 37°C degrees upside down to prevent the condensation that occurs on the lid from dripping onto the culture.

The procedure is then repeated with Escherichia coli (E. coli), which is a different bacterium normally present in the intestinal flora but also the cause of intestinal and extraintestinal illness in humans (Bennet et al., 2016). This microbe is in fact among the most common ones causing urinary tract infections (UTIs). Participants are invited to inoculate a new Petri dish with the different bacterium and position new disks of the same antibiotics previously used. The purpose of repeating the procedure is to demonstrate the different effects of the same antibiotic on different bacteria, highlighting the importance of antibiotic selection. This second Petri dish is also then covered, sealed with parafilm and incubated at 37°C, to recreate the human-body conditions which allow bacteria to grow.

At this point, participants leave the microbiology lab and move into a room where the expected outcomes of their experimentation are displayed on a screen. This is because, as previously introduced, bacteria require 24 to 48 hours to grow. Pictures will be taken of the results, and sent to participants two days after the workshop. For the purpose of providing tangible feedback on the activity, images depicting results from other participants of previous activities are shown and discussed to trigger a conversation based on consumption modalities and practices. Participants are asked to share their experiences, especially regarding their attitudes and their relationship with the doctor during consultation. In order to do so, physical cards are distributed for participants to fill in. Some questions guide the activity but, for the purpose of encouraging new insights to emerge, answers are intentionally left open.

Cards are then collected and participants are asked to spontaneously share their stories. The table (Tab.1) summarises all the steps mentioned.

Table 1   Workshop steps' modalities, locations and scopes.

Step	Modality	Location	Scope
Project and topic (AMR/AB) intro	Screen presentation and microscope exploration	Room with seats arranged in a circle	Familiarise with the topic and lab environment/tools
Lab access	Safety rules and PPE distribution	Lab	Intro to the lab environment and work modalities
Activity and tools intro	Material distribution	Lab	Provide participants with sources for the activity
Question answering	Printed guide to answer questions	Lab	Collect data
Petri dish portrait creation (I)	Manual activities (inoculation, collecting and positioning AB)	Lab	Experience the protocol
Petri dish portrait creation (II)	Repeat the previous action	Lab	Memorise the protocol
Results' preview	Screen presentation	Room	Provide immediate feedback on the action performed
Discussion	Physical cards	Room	Collect stories and share insights
Assessment	Poster with stickers	Room	Collect feedback on the method
Results	Via email (1/2 days later)	Virtual	Provide images of the Petri dish portraits

5. Results and discussion

64 personalised Petri dishes have been created based on the format of this workshop. Participants' answers are anonymised and organised into a table (Fig.3) to better classify information.

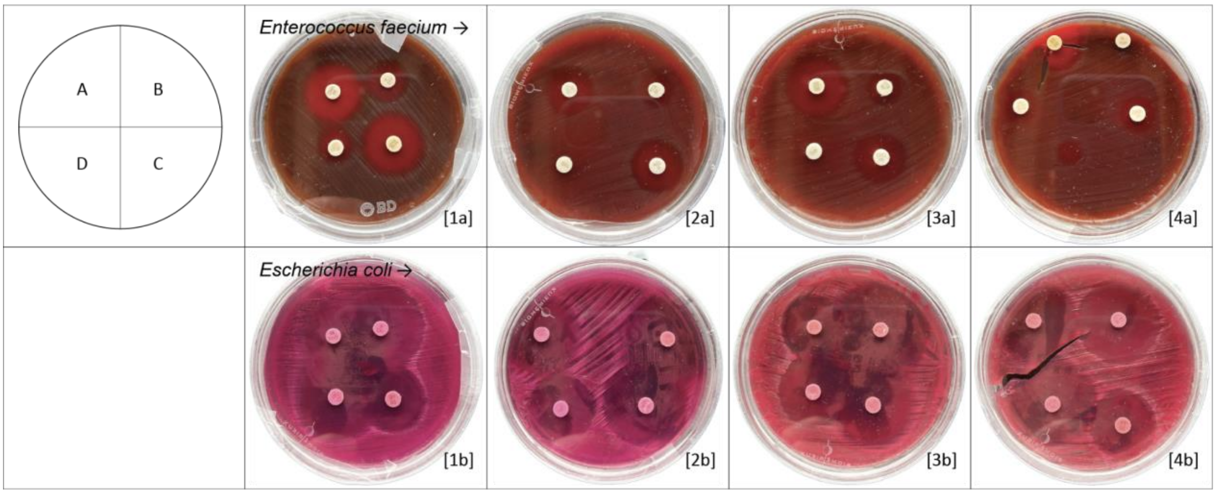

Figure 3 A selection of Petri dishes created by participants during the workshop. The first row is based on the effects of the pills on Enterococcus feacium. The second row demonstrates the different effects of the same antibiotics on a different bacterium (Escherichia coli). Each column reports results from the same participants. Four participants' Petri dishes from different workshop sessions have been selected to show results.

Based on this method, data collected are primarily quantitative, as from the choice of pills is possible to decode the specific answer assigned by the participants. However, responses are not meant to depict antibiotic consumption trends. By answering, participants take part in an exercise designed to facilitate comprehension and promote familiarity with data collection practices. Answers are collected on the Petri dishes in a visual form. They are then transferred to an Excel file, which allows results to be organised and compared to the personal experiences that emerged during the activity. These experiences refer to the stories that were collected at the end of the workshop through the printed cards, but also from conversations happening during the activity itself.

For example, the person who created the first Petri dish (Fig. 3), in the image above [1a], takes antibiotics only if very necessary [quadrant(q)A]; she/he suffered from UTI once [qB], consumed antibiotics in the last six months [qC] and is in habit of asking questions to the doctor [qD]. Different behaviour is shown by the second participant [1b], who feels antibiotics made her/him safer. This person suffered from UTI at least once a year and assumed antibiotics within the last 6 months, without having any conversation with the doctor.

5.1 Participants' attitudes and engagement

This activity is supposed to bring attention to a relevant topic (AMR), explain a scientific notion (antibiotic mechanism of action) and incentivise familiarity in collecting data. By taking part in the activity, participants actively share their relationship with antibiotics in the format of physical data portraits, collectively depicting the level of awareness of the group. Generally, everyone gains benefits from taking part, as everyone could be affected by AMR or encounter problems due to antibiotic prescription and/or intake. In this direction, the activity is supposed to sensitise people regarding consumption choices. Additionally, the conversation generated during the last part of the workshop allows participants to share opinions and suggestions based on personal experience, enriching the data collected through the physicalization method and providing further bottom-up information increasing collective knowledge on the topic. From a research perspective, the conversation also allows new trends to emerge, such as the impact of AMR on the psychological conditions of the patient and the trust in sharing detailed personal data.

The problem of AMR and antibiotic consumption is mainly addressed by scientists and collecting bottom-up information helps to identify new possible correlations and solutions from different perspectives. Furthermore, having nursing students among the participants helped introduce them to the problem of AMR from the very beginning of their careers, stimulating a professional approach that includes people's experience and perception of the disease in the decision-making during the choice of treatment.

Assessing the activity is difficult as medium/long-term changes should be observed in behaviour change. Considering the purpose of the workshop, an assessment focusing on the method is included in the design of the activity, specifically to evaluate the engagement generated on the topic and possible implementations. For this reason, feedback from participants was collected at the end of the activity for each of the four sessions, asking participants if the activity was useful in understanding AMR, if the activity helped to build confidence in promoting correct antibiotic consumption, and what step of the activity should be improved. Participants provided their feedback by positioning a sticker on a poster fixed on the wall.

Responses are overall positive. In general, participants expressed their enthusiasm for the activity. They especially expressed satisfaction with the experience, highlighting that having the chance to experiment with real material was engaging and raised their interest in the topic. This is also confirmed by the further questions that were asked to the expert. The majority of participants knew AMR at the time of the workshop but the experience raised their involvement by demonstrating tangible effects of the concern, which otherwise is perceived as abstract and far from every day and everybody's life. "I found the workshop very useful especially because of the way in which the subject can be understood through an engaging experience that is playful. The process is explained step by step so it is not complicated." (AL).

5.2 Benefit of physicality

The concept of autographic visualization (Offenhuber, 2020) appeared particularly suitable in the case of public engagement. The fact that antibiotic resistance reveals itself as becoming visible within the natural environment and situation facilitates the understanding of the phenomenon. Contextualising data is fundamental, especially for non-experts, who can not rely on their previous knowledge to recognize the meaning. This modality also allows utilising physical materials to support theoretical understanding, as representation exploits contents that participants need to learn or understand. The visible effects of the phenomenon become the rules of the activity and the instruction does not only lead to actions but also explanation of the resistance development. To perform the activity, participants are required with some effort. The request must be manageable but not taken for granted, so the engagement starts with the understanding of the task. Supporting material, such as guidelines, video tutorials, and cheat sheets is precious at this step. Linking the task to the topic facilitates the consequent understanding of the phenomenon itself. Through the creation of the personal Petri dishes, participants are introduced to the scientific method of measuring antibiotic susceptibility through the request to answer some questions. Associating parameters to specific meanings is meant to promote their ability to work with data, specifically to translate values into visual dimensions. In this direction, the experience is meant to promote a learning-by-doing process (Merzali Celikoglu & Timur Ogut, 2013) validated by the fact that, while at the beginning support was requested from someone to complete the task, the redundancy of the second part of the experiment helped participants to learn the procedure and act independently. The understanding of the phenomenon is also accentuated by the fact that Petri dishes are created based on personal data, generating a direct link between individuals' attitudes and the consequences of behaviour. Making people work on their situation and information facilitates understanding and fosters interest. Data being the issue, instead of describing it, is revealed to be effective in this context specifically. The participants' answers also provide different realities to explore, rather than investigating fictional situations. Furthermore, the activity is not relegated to the clusters of quantitative or qualitative data, on the opposite, this approach incentivises an interactive exchange of different levels of information. Quantitative data works as the access point to personal experiences, as specific questions are set to be easy to answer, providing inputs to deepen the interest and eventually the conversation. This might be valid for other projects treating sensitive topics, where icebreaking is suggested to activate engagement. Lastly, the activity does not include structuring the dialogue happening during the creation of the Petri dishes, but having the expert available demonstrate catalysing the participants' spirit of inquiry.

6. Limits and future Implementation

6.1 Limits of the activity

The first limit identified within this project concerns the location of the activity. Because of the biological materials involved and safety precautions and controlled operating procedures, the workshop can only take place in appropriate (BSL1 or BSL2) laboratories. In fact, even if being in a lab emphasises the experience, on the other hand, this limit restricts the scalability of the format in a context where there is no access to laboratories. To address this limitation, a solution is provided by working with alternative materials, such as food. Biohacking and science education communities have already considered this direction, as the idea of working with metaphor prevents every risk of infection and waste of medicines. Differently, technology provides a safe environment to work with bacteria and antibiotics, engaging users in interactive movements that aim to digitally recreate laboratory experimental practices. "DipLab - Digital Petri Laboratory" (Subet, 2023) is a console-based device developed in parallel to this workshop and intended to make the same contents available for young students without safety limits.

A different problem raised by the discipline of data physicalisation regards material waste. The material used in the workshop is biologically contaminated and waste management must be considered. All consumables that have come into contact with microorganisms (such as PPE, swabs, tweezers, and test tubes) must be autoclaved before being eliminated. Overall, the idea is that employing this material to make people aware produces more benefits than losses, especially in the long term, but unfortunately, due to the diverse nature of the parameters involved, a reliable cost-effect figure is difficult to predict.

6.2 Designing a guideline for future engagement on AMR

The protocol of the activity, together with all the material needed in order to perform it, is available on the project's repository (MAKEAWARE!, 2022) for others to replicate the format. Having nursing students involved helped in recruiting possible experts able to reproduce the format in different locations and occasions.

This workshop is one of the initiatives part of a wider project which focuses on citizen awareness and engagement in antibiotic consumption, and for this reason, other activities are designed with the same purpose. Findings and trends originating from this approach will be organised into guidelines for hands-on activities on microbiology topics addressing non-experts. In this direction, the activity promotes an interdisciplinarity approach which considers designers and microbiologists to work together and gain different benefits, as designers experimented with unusual and unexplored materials for communication purposes, while scientists were enthusiasts of employing alternative methods to bring scientific knowledge beyond other experts.

7. Conclusions

This research considers data physicalization modalities to promote literacy in healthcare and involve citizens in data collection practices, with the purpose of explaining the scientific phenomenon of AMR, engaging non-experts in understanding antibiotic functionalities, and sharing personal information related to consumption behaviours. The acquisition of skills is pointed to transforming data into information and then, information into knowledge, prioritising the importance of empowering people regarding antibiotic consumption.

Modalities of autographic and co-responding data physicalization are employed to explain antibiotic working action and collect data from participants related to their personal experiences. Individuals are supposed to benefit from this practice first, as acquiring knowledge regarding antibiotic functionalities helps in empowering their role and agency in taking care of their healthcare. During the workshop, people experiment with the antibiogram, are provided with correct consumption suggestions, and access to scientific notions by an expert.

Additionally, scientific research is also supposed to benefit from this activity as collecting personal experiences enriches knowledge regarding antibiotic consumption and people's attitudes. Data is missing in this sector and restricted to quantitative information. For this reason, personal stories and contextualising experiences are fundamental especially to identify symptoms and causes of antibiotic resistance.

Finally, this approach is tested within broader design research which focuses on citizens' and patients' collaboration in projects addressing global healthcare challenges. Data-driven methods of engagement are considered fundamental to nurturing a patient-led culture of care as this is a key pillar for resilient healthcare innovation and research.

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