Attention, stimulus and Augmented Reality for urban daily-life education in a social peripheral setting: the *Streets that tell stories* AR app.

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Abstract. This paper aims to identify which design strategies can be considered when exploring different levels of stimulation of cognition and attention of the user in the development of educational location-based applications used in public urban space. We proposed the Stimulus Level Framework, divided into linear, circular and spiral stimuli, based on a theoretical reflection. It is a tool to help designers to think about educational and contextual digital experiences. Afterwards, we made a practical reflection about the proposed framework in a real context. An Augmented Reality project integrated with urban furniture of a historical street in the city of Fortaleza, Brazil, was proposed. Thinking about the design decisions based on the levels of the framework, helped in the process of data collection. It also helped in the proposition of elements that could stimulate the user's attention in different levels, having the technology as an element that unifies the whole experience.

Keywords: Activity Theory; Design for attention; location-based Augmented Reality; urban technology; Augmented Reality; educative technology, interaction design.

1. Introduction

In our contemporary reality, the use of interactive digital technology has found ways of being increasingly present in the most diverse spaces of daily life. This increasing possibility of constant computation technology everywhere was predicted by Mark Weiser around 1988, which made him coin the concept of Ubiquitous Computing [1, 2]. With the growing presence of technology in several aspects of life, a broadening amount of information must operate on the periphery of human attention. The field of Interaction Design has an essential role in conceiving such interfaces with adequate attention not to overlap proliferating layers of information and overload individuals with an excess of data and contents [3–5].

The expanding use of educational location-based applications is one of the potentials pointed out by technological ubiquity. Such devices have the potential to increase the reach of education, accessing the learning that is inside the apprentice's daily-life context. Informal education is the one that occurs outside the curriculum. Integrating moments of informal learning with artifacts and environments of our daily life can be a way of bringing education out of the walls of institutions. Digital technologies, such as Augmented Reality (AR), can be very beneficial to museums and schools by integrating their contents into the public space, for example, so that users can have access, if they want, to relevant and interactive data in specific contexts of their city. This becomes even more necessary regarding the realities of low-income areas, such as those found in Brazil, where this article's practical design was applied, in which about 70% of the population never went to a museum or cultural center[1].

We understand that technology-associated informal education can make learning more available and accessible to the largest possible number of people. This positive scenario, however, leads to some challenges that must be considered when designing such interfaces. Thus, this article seeks to discuss the following fundamental question: **which design strategies can be considered when one explores the distinct levels of user-directed cognitive and attentional stimulus when developing educational location-based applications applied to the urban public space?**

We discuss this subject in two parts. In the first one, we conducted the categorization of the Stimulus Level Framework based on theoretical lines. Through this model, we discuss techniques to approach, in the design of educational applications, various stimulus degrees in specific contexts. Following, in the second phase, we report the application of this framework in a real project of an AR application integrated into a public space for informal teaching of the daily-life history of the inhabitants of the low-income region in Brazil.

2. Theoretical Background

This work aims to address important authors and theories for the development of design strategies indicated in the previously mentioned fundamental question. To explore the distinct levels of the cognitive and attentional stimuli of the users, we address the concept of Calm Technology to approach the relationship with informal education through Activity Theory and correlated concepts. In the end, we present a diagram that summarizes the approached subjects to serve as a basis for the creation of the Stimulus Level Framework.

2.1 Technology, daily life, and augmentability

The constant presence of technology in ubiquitous computing results in distraction and information overload. Practical applications of the digital in our daily life must be

[1] According to a study by Ipea (Institute for Applied Economic Research) conducted in November 2010 [34].

considered with adequate care not to overlap the increasing layers of content and data excess. Inspired by this topic, Mark Weiser also coined, together with John Seely Brown, the concept of Calm Technology in the article *Designing Calm Technology* [2]. The word "calm" shows that technology should help us focus on what is really important to everyone instead of generating stimulus overload. This occurs through the act of thinking not only on the central part of the user's attention but also on the peripheries. According to Saskia Bakker in her thesis *Design for Peripheral Interaction* [3], few works invest in understanding the role of design in stimulating and projecting toward the non-focused attention. How can designers, therefore, project the use of technology for it to be part of a user's life without it being a distraction?

Amber Case presents in her book *Calm Technology: Principles and Patterns for Non-Intrusive Design* [5] some practical strategies to help in the process of gently capturing a user's attention whenever necessary. Supported by the studies of Weiser and Brown, Case proposes that, to be successful in the current world, interfaces tend to become minimalist and simple. This design decision broadens the information capacity of the artifacts when it is stimulated by the interest and motivation of the users themselves. An ideal version of an app, or technology in general, becomes invisible in its operation and shows its utility without taking excessive attention to itself.

Finding ways to provide information without overloading the user's attention is one of the contemporary challenges, which is aggravated even more when we relate it to the subject of education integrated with AR devices. AR is a tool that shows great potential when it is merged into the user's daily routine, because it shows the virtual's possibility of integrating to both physical space and analogical objects. The AR technology overlays a virtual object in the real world. This enables the user to have a simultaneous experience of the virtual integrated to the analogical, instead of completely replacing the real environment, as in virtual reality [6].

Regarding the way of linking digital and analogic, the concept of AR has different definitions. Some authors, for example, argue that AR adds digital virtual objects to real scenes [7]. Others state that AR allows interaction with virtual objects in two dimensions, and three dimensions in a real environment [8]. And there are also those who define AR as a projection of virtual elements on real objects [9]. Sommerauer, however, argues that AR is not limited to the visual sense, and consists, by definition, of the act of augmenting the reality of other senses as well, such as hearing, touching and smelling [10, 11]. While making a more contemporary review of the subject in his article *The Most Important Challenge Facing Augmented Reality* [12], Ronald Azuma[2] says that AR will only be relevant if it is contextual. According to him, convincing experiences must be powerful enough to give the user a different perspective of something, whether of an educational, cultural, historical, social, or political character, among others. To understand better the role of the experience's context in education, we will approach the subject of Activity Theory on the next item.

[2] Fundamental author that coined the term *Augmented Reality* when performing one of the first surveys on this subject in 1997 [6].

2.2 Motivation and activity

Interactive Design is often responsible for attracting the individuals' attention, motivating them to participate in the experience. According to Csikszentmihalyi and Hemanson [13], human actions are motivated by rewards of two natures: extrinsic and intrinsic. Extrinsic motivation occurs when there is an anticipation of the reward coming from outside the activity, e.g., avoiding punishment, receiving a good grade, etc. Intrinsic motivation exists when the reward comes from the activity itself, with the interest coming from the individuals themselves [13]. Sports, games, and artistic activities naturally have an intrinsic motivation basis, as people are doing something spontaneously [14]. The educational location-based applications, since they are often outside curricular institutions and linked to casual, contextual, and daily activities, must be intrinsically motivational to the users' informal learning. For this purpose, it is necessary to deepen the studies of the activity in its different levels to understand its motivations, goals, and contextual conditions.

Activity Theory (AT) conceptually summarizes the relationship between education, space, conscience, and motivation. These elements are essential to consider the design of location-based applications integrated into the urban space. AT is based on the thinking of Lev Vygotsky, a Russian researcher that produced his most important works in the 1920s and 1930s. His work consisted of understanding the interaction between mind and world, and how they changed through this mutual interaction. His original interests tried to understand ways to support the learning and development of higher psychological processes such as memory, consciousness, perception, attention, speech, thought, desire, concept formation, and emotion [15]. His ideas were developed in several directions, especially from the works of his followers Leont'ev and Luriia [16, 17]. In his turn, Leont'ev explored the relationship between consciousness and activity, which originates AT. This approach is currently spread, for example, by the works of the Finnish researcher Yrjö Engeström [18].

AT provides a broad and flexible model to think about how to describe human activities and what influences them. It offers a robust vocabulary of theoretical bases to deal with the complexity involved in the relationship of tools, tasks, and users [19]. It also shows great effectiveness and potential to be applied in methods of analysis of Human-Computer Interaction (HCI) for the study of complex activities in its context [20, 21]. A common line between the several applications of this theoretical axis is the focus on learning as development through social, contextual, and spatial interaction.

According to AT, it is important to clearly define the expectations related to the user's activities and the applied tools. The inter-relationships established between central and peripheral parts of human consciousness is something that can contribute to the integration of Interface Design and the concept of Calm Technology. About consciousness, Leont'ev defines three increasingly hierarchical levels of activity: operation, action, and activity [16]. Nevertheless, this division does not intend to segment the concept of activity into smaller parts. The main objective is to point out degrees of control and conscience in increasing levels, which have different guiding elements.

The lowest level is *operation*. It refers to the most concrete and objective steps of executing something. It is characterized by automated and non-conscious acts, such as moving the knife to cut meat, for example. Leont'ev states that the operation is directed to the situation's immediate *ambient conditions*. Kuuti defines this level as "well-defined habitual routines used as answers to conditions faced during the performing of the action" [22, p. 31]. The operations, since they occur outside the attention's focus, are characterized as an automatic response to the context itself. Therefore, it is an important level when one intends to relate attention and design.

The medium hierarchical level is that of *action*, which is directed to the *goals*. These concepts refer to conscious processes aiming to generate a short-term specific result. As an example, cutting meat is an action directed toward the goal of having enough food for dinner. It is different from *operation* because the act of sizing the cut pieces to the number of people that will eat demands a conscious cognitive process, even if it is momentaneous and short in duration.

In turn, the highest level is that of the *activity* itself. This is the real reason for the performed process, the real *motive* of the previous levels (both *operation* and *action*). The motive is the moving force that seeks to fulfill the subject's *needs* and corresponds to long-term projects for a person or group [16, 22, 23]. The example of preparing dinner occurs due to the motive of having dinner, either to fulfill a basic need for food or a social need for interacting with friends, for example.

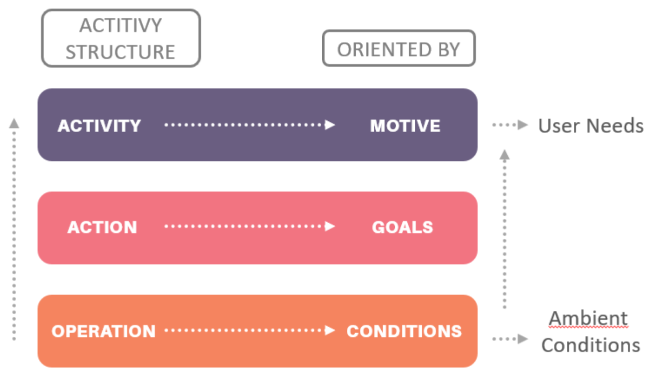

Fig. 1. Three hierarchical levels of activity: *operation*, *action*, and *activity*.
Source: Elaborated by the authors.

In a correlated way, by addressing the automation of human actions, the authors Donald Norman and Tim Shallice indicate automation as an action that can be performed without conscious control or using attention resources [24]. However, it can be modulated to a conscious deliberation whenever necessary. Two complementary mind processes are suggested by them: one simple, automatic, and unconscious, consisting of learned acts; and another that consciously modulates the performance. We can understand, therefore, that the long-term experience modeled by activity is linked to the motives and needs that originated it, being something conscious. On the other hand, the momentary and unconscious experiences are modeled by automated operations that are determined by the objective conditions of the context [24].

Understanding these various ways of classifying the user's actions is a fruitful way of glimpsing how design decisions can affect the process of learning with an interface.

We believe that educational location-based applications can benefit widely from projects that explore scalable methods of stimulus to the user. In sequence, we will present different authors that also approach hierarchical levels of consciousness, relating this theoretical approach with more practical aspects of interaction and design.

2.3 Levels of attention on the interaction

As well as AT, many theories that relate the cognitive aspect and human action approach a categorization into hierarchical levels. In many cases, such classifications consist of an increase between levels of automatic (unconscious), intermediate and conscious reaction. Below, we refer to some of these authors to address their particularities and similarities. Presenting these concepts is relevant to support the development of design strategies, regarding the type of stimulus targeted by the designer, aiming to help in the process of creating location-based applications.

In general, the categories addressed here move between two ends: the *world* at the lowest point, and the *self* (or *user*) at the highest point. Donald Norman [25], in his *Gulfs of Evaluation and Execution*, and also Marc Hassenzahl [26], proposed that the direction between these two poles determines many human decisions. These can be directed to emotion, attention, interaction, or projects deliberations, just to mention a few examples. Thinking of design proposals in the *bottom-up* direction leads to a greater focus on the *world* toward the *self*. This turns to the stimuli in a more motor level and can trigger extrinsic motivation, i.e., external to the subject. Decisions with a *top-down* direction, in turn, focus on the intrinsic motivations because they start from the *self* toward the *world*. They are directed toward stimuli in the individual's consciousness and reflection. A design does not necessarily have to choose only one direction between *top-down* or *bottom-up*. Both can be useful in the various moments of the development process.

From the perspective of human attention, the researcher Claudia Roda, in the article *Human Attention and its Implications for Human-Computer Interaction* [27], states that selective attention also occurs in both directions. This phenomenon is called *exogenous* and *endogenous* attention. The first is fast and inconsistent, allowing various parallel stimuli, such as multitasking, for example. Because they are external to the individual, these stimuli are often caused by changes in the environment: noise, notifications, light, color, sound, temperature, etc. This attention mode is directed by the salience of a stimulus. In turn, the *endogenous* attention works as a gear that voluntarily directs the perception and the cognitive processes. One example is the act of consciously reading a text. It is a sequential action that is hardly performed alongside other endogenous actions [27].

In their Self-Regulation Theory, Carver and Scheier differentiate the human goals when performing a task by addressing the relationship between affection, emotions, and behavior. The authors created the following categories: *motor-goals*, *do-goals*, and *be-goals* [28]. For example, if someone wishes to make a call, the *motor-goal* is the act of dialing. It is the mechanical act through which the action is performed. According to Hassenzahl [26], this related to the "*how?*" of the user's experience. Through the motor operation, one reaches the next level, the *do-goal*, which, in turn, is a concrete goal that the subject wants to reach. Dialing is a motor act to reach the goal of "making a call to that person". It is, according to Hassenzahl, the "*what?*" of the experience [26]. The *be-goal*, in turn, is the highest level. It is the instance of being that the goal of performing the call causes. For example: "being more communicative with distant friends" or "being closer to my mother", are activities that change the users and take them to another state. According to Hassenzahl, it is a layer more connected to the "*why?*" of the experience [26]. Understanding this classification can help both design and evaluate the effectiveness of a digital tool, as it supports the designer's understanding of the real motives of the interaction proposed.

One of the famous theories that deal with a systematization of human consciousness in progressive levels is that of Donald Norman in his book *Emotional Design* [29]. The author also suggests a division into three levels, which is similar to Leont'ev's classification in the AT. His reflections come close to the debate about form and function, raising questions regarding the artifacts' usability and beauty. Norman addresses the human emotions when they interact with objects and interfaces, classifying them as: *visceral, behavioral*, and *reflective* [29].

The *visceral* level is the first reaction in the interaction. It is a more automatic, fast, and direct layer, as it does not demand a cognitive load of interpretation. At this level, the emotion is very quick and directed toward what one considers pleasant or unpleasant in greater percentages of the population, such as beauty, sweet taste, symmetry, saturated colors (and their opposites). Even if one does not have particular favoritism in these characteristics, most of the population tends to see them as more pleasant at first. According to Norman, it happens due to the inheritance from the animal instinct of survival and coevolution in nature. The second one is the *behavioral* level, which affects our usability more directly by interacting with the artifacts. It is directed toward the pleasure of the effectiveness of use, and consists of brain processes that work with the successful (or unsuccessful) daily use of something. At this level, the function comes together with questions such as: "what does a product do? How does it work?" [29].

According to Norman [29], the *reflective* level is not only the highest one, but also the closest to the self. This concept relates more closely to the rational aspect of cognition. It consists of an emotional layer directed toward personal preference. The *reflective* level can include many aspects, as it depends on some factors such as cultural context, history, past and heritage. Norman gives the example of "crowded, busy spaces, or noisy ones, and discordant, non-harmonic music, sometimes with irregular beats: all things that are viscerally negative but that can be which can be reflectively positive", because they require more reflective work of interpretation [29, p. 67]. The *reflective* level, therefore, is linked to objects that tell the user a story, that represent something, that are related to specific personal interests. To Norman, a design project will always present these three characteristics at some level. They are always entangled and can, of course, vary in intensity according to the decisions of design or use [29].

With Norman's contributions, it is possible to make direct links with authors that bring similar classifications regarding attention. One example is the researcher John N.A. Brown, who neurologically classifies human attention according to the typologies of responses to stimuli [30]. The author states that many human decisions are not taken rationally but intuitively. In general, we understand that we take a certain decision when we notice their resulting action, be it positive or negative. For the author, understanding the level of consciousness and intuition in the interaction with an interface goes through analyzing the brain process of central and peripheral information processing. For this, J. Brown presents three types of classification of interaction in terms of human attention: *reflexive, reactive,* and *reflective* [30].

One example of *reflexive* interaction is the patellar reflex test, also known as the knee-jerk test, in which the movement is an unconscious response to a stimulus produced by the hammer. The reflexes are automatically activated, and one reacts to them without thinking. The processes occur in the nerves and coordinate responses which are sent to the spinal cord. This is one of the most primitive and fast of our systems of perception, processing, and response to stimuli. According to the author, the *reactive* interaction is part of the comparative adaptation between different situations, which occurs in the same brain region where our emotions are processed. The action of riding a bicycle, for example, is the combination of different reflexes. While we keep our balance, we also consciously perceive the way and adapt our path to obstacles that may appear. The patterns are built from comparisons with what we are familiar with in our pathway and its changes. Thus, we can quickly adapt to the new experiences that may appear. Regarding the last level, the brain resources can do more than only compare and recognize. When there is an analysis and new ideas are formed, this is characterized by J. Brown as a *reflective,* or attentive interaction [30]. Such an interaction is associated with more rational and conscious behavior of our cognition, as also stated by Norman [29].

These cited classifications demonstrate, through several authors, the different degrees of consciousness and attention to internal and external stimuli. They also indicate the different levels of control over decisions. As a result, one can notice that unconscious and non-rational actions are much more common in a person's daily routine. Sneezing or hiccoughing consciously, for example, may even be possible but is not natural, although it can be learned. When a toddler is learning to walk, the start is difficult, but it gradually goes from something attentive (*reflective*) to pre-attentive (*reactive*), and gradually becomes an automatic (*reflexive*) response [30]. The inter-relationship between these categories, and those of AT presented previously, are summarized on the table below. These concepts guided the process of elaborating the Stimulus Level Framework, which will be presented in the next item**.**

Table 1. Summary table of the theoretical lines previously covered. Source: elaborated by the authors.

Gulfs of Evaluation and Execution [25]	**Selective Attention** [27]	**Activity Theory** [16, 23]	**Self-Regulation Theory** [28]	**Emotional Design** [29]	**Typologies of responses to stimuli** [30]
Self (User)	Endogenous Attention	Activity	Be-goals	Reflective	Reflective
		Action	Do-goals	Behavioral	Reactive
World	Exogenous Attention	Operation	Motor goals	Visceral	Reflexive

2.4 Overview - Stimulus Level framework

Based on the theoretical discussions presented above, we summarize a framework that aims to unite the reflections of the several levels shown. It is worth highlighting that, in this model, the addressed theoretical lines are not considered equal in definition, but with sufficient similarities that justify an alignment. This model graphically organizes the characteristics of each level to facilitate the process of design decisions that may work at different stimulus levels in educational location-based applications. We suggest this graphic and conceptual organization to contribute to the planning of digital interfaces integrated into the user's daily life in the urban space. Another possible contribution is to assist in the process of analyzing the constraints of the project's context, facilitating decision-making. Thus, we divide the Stimulus Level Framework according to the possible stimulus typologies, going from the *world* to the *self* layer, in the *bottom-up* or *top-down* direction [31].

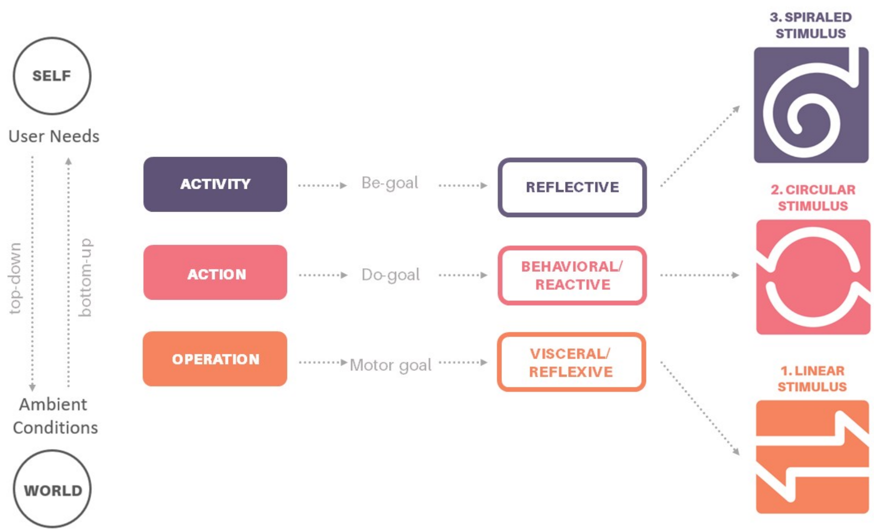

Fig. 2. Overview of the theories for the Stimulus Level Framework. Source: Elaborated by the authors.

Finally, we reach a three-layered synthetic organization of the previously addressed concepts. The first is the lowest level, which deals with *linear stimulus*. This layer is closer to the *world*, to the ambient and conditional context in which the project and the user are inserted. It normally has a short duration and is closer to the motor decisions, to the designs' tactile, manual, and physical aspects. It is connected to the level of *operation* – in the AT bias – and is dedicated to supporting the subject's peripheral and non-focused attention. Since this level is the closest to the user's automatic reactions and reflexes, the design's proposals should guide the subject to use the system, application, or artifact in a natural, direct and intuitive way. For these reasons, the stimuli at this level are represented graphically in a linear way.

The second and intermediate level deals with *circular stimulus*. In the AT bias, this level consists of the user's *actions*, which are directed to specific goals, either individual or collective ones. It deals with project decisions that stimulate practices coming from the users themselves, generating feedback that promote the doing – the *do-goal*. These practices are not self-ended, but cause positive feedback either by cooperation, sharing, or individual acts in the short term. Because of these characteristics, we decided to adopt the icon of a circular design. When concerning attention, this level focuses on *reactive* aspects and, therefore, is linked to emotional issues. Artistic and participatory aspects, such as the use of color, graphic and esthetic elements, are interesting to be explored at this level.

The third level, that of *spiraled stimulus,* is the highest point and gets closer to the *self*. It represents the complete composition of the activity. It is the optimal motive of the experience. It is directed toward the *be-goal*, the individual's existence, and must approach a wider layer of the user's greatest and long-term needs. It assumes a spiral form because it aims to stimulate the user in activities that trigger reflective, more rational, and attentive aspects. Such activities cause thoughts that extend beyond that specific experience, in a constantly increasing and evolutionary way. Approaching identity, narrative aspect, inserting the person in the interaction can be fruitful ways of engaging and triggering new activities associated with this third level.

3. Application in a case study

In this item, we apply a description of the practical use of the stimulus-level framework in a real design context[3]. It refers to the design of an AR interface integrated into urban spaces of a historical street, named Padre Justino, in the city of Fortaleza, Brazil. Seeking to highlight the historical layer of the street, we decided to address the following question: **how to make an urban furniture, at the same time, meet its functions and tell the story of its inhabitants, stimulating new forms of interaction to the users?**

3.1 Data collection and context analysis

To collect data on the circumstances of the project's location, we initially performed a series of semi-structured interviews [32]. We also applied playful activities with the residents to collect information about urban legends and stories of oral culture. The dynamics carried out were based on Hanington and Martin theoretical notes on design methods [33]. The investigation revealed a strong sense of community in the population and a well-structured use of the public space for social interaction. Empirically, we observed that the periods of most intense use were early in the morning and in the

[3]This project arose from a call for proposals launched by the Iracema Institute in partnership with the Fortaleza City Hall, capital of the state of Ceará in Brazil.

evening, when the solar incidence was lower, and the city's temperature milder. Subsequently, we conducted a comparison with the historical and academic data reported by researchers about the region. This information enabled us to start the development of narrative content that integrated the AR app experience.

As we observed, Fortaleza´s history is still little appreciated by its inhabitants and public policies. Padre Justino Street is located in an area with important heritage and memories of the region's ancient history. Fortaleza is a tourist and coastal city in Brazil's northeast. It has a hot and humid climate, with a strong solar incidence across the year. Considering the high temperatures during many hours of the day, we decided to develop a set of urban furniture that could stimulate the use of the street even during hotter periods. With this premise, we proposed to integrate the narrative and historical aspects to such furnishings, adopting digital technologies. We used the Stimulus Level Framework as the basis for the development of the design ideas by the linear, circular, and spiraled layers.

Fig. 3. Padre Justino Street with free movement of residents in the shaded area after the implementation of the project. Source: Elaborated by the authors.

3.2 Conceptual aspects

We used the Stimulus Level Framework to align the design decisions to each desired level in the design process. The following sections report the decisions based on each of the three levels of the model.

As previously pointed out, the *linear stimulus* can be directed toward most motor and operation aspects of the local context. As a result, we decided to explore, at this level, analogic elements to meet the user's most basic and automatic needs. Initially, to provide shade and a sensation of security, we devised a cover for an area of 8 x 36m consisting of shading cloth bands twisted in different directions and attached to a mixed structure of eucalyptus pillars and metallic lattice beams. Additionally, considering that the project's area also includes residences, shops, and inns, we stacked concrete modules to fulfill the needs of several circumstances. The modules can be configured to become benches, bins, flowerbeds, community gardens, canvases, and notice boards. Their positioning was determined by the needs of the owners close to each unit, allowing their participation in the project.

Fig. 4. Three Stimulus Level Framework. Source: Elaborated by the authors.

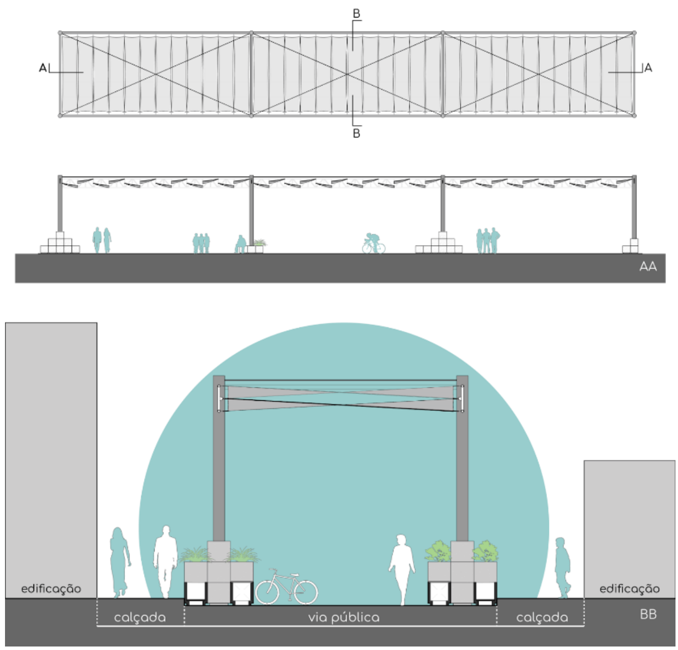

Fig. 5. Design of the floor-plan and sections. Source: Elaborated by the authors.

For the decisions directed toward the *circular stimulus,* we decided to develop more cooperative activities with the street's residents. We conducted drawing workshops and observational visits to understand the local habits and routines [33]. These data confirmed that this was a very united community, where the residents knew each other their entire lives and had a strong connection with the place. As circular design strategies we created cooperative murals and paintings where both residents and interested artists could contribute with periodically changeable works of art. To facilitate the inhabitants' creation and development process, we proposed a basic color palette, as well as geometric figures that could be freely explored by the users. Again, we performed a series of cooperative painting activities in the space and in its physical elements with the participation of the local residents[4].

In the third level, the *spiraled stimulus* representation denotes something that can be connected to the users' *self*. For this level we chose to explore the proposal's narrative potential by developing something that could connect to the local history through interaction and digital technology. We promoted a series of workshops using techniques for the development of cooperative comics. The inhabitants suggested how the stories of their past could be told, and a screening of these testimonies and drawings was condensed on a single script. In the end, we prepared a set of comics on panels attached to the furniture, which pays homage to some former residents who are relevant to Padre Justino Street. The user can access part of the story with the AR application, which was named *Streets that tell stories* AR app. This technological device is being incorporated by the authors of this paper to other historical heritages of the city of Fortaleza, and is part of future studies on educational location-based applications that are currently under development.

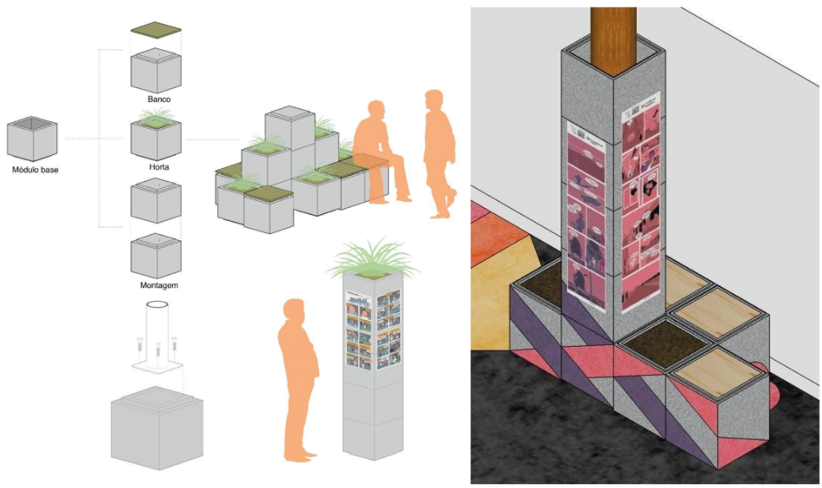

Fig. 6 and 7. Perspectives of the stacked concrete modules, with the application of paint and fixation of the comics. Source: Elaborated by the authors.

[4] Fragments of these activities can be watched in video: https://youtu.be/DCW_1RfVao8

The main character of the comic's narrative is a 10-year-old boy named *Joãozinho*, diagnosed on the autism spectrum. He actively participated in all the proposed workshops and lives in one of the houses on Padre Justino street. The narrative is constructed after *Joãozinho* finds a magic hourglass with which he can travel through seven distinct chapters of the street's past. This way he meets the memorable characters and participates in moments that were collected during the interviews and workshops[5]. After the script and drawings were finished, the comics were printed and attached to the space's pillars in an integrated manner.

The user experience with the narrative in the *spiraled level* occurs at first analogically, with the reading of the comic's seven chapters. By installing the app on a smartphone, the user can direct their camera to the panels. By doing so they can watch the drawings moving, with the story flowing in real time as in a short-film. The application was developed using the plugin named *Vuforia* for the software *Unity Engine*. At the end of the experience, in the last panel, the interaction shows a virtual 3D sculpture of one of the story's past characters, *Dona Maria de Mel*. As it is a 3D model, the users can take pictures beside the sculpture and share them on social media. The sculpture was modeled in Virtual Reality using the software *Quill,* and later imported to *Unity Engine*.

Fig. 8. Panels with comics telling the stories of Padre Justino Street installed on the pillars of the urban furniture.

[5] The full comic can be read by accessing the link: https://issuu.com/leonardoverasarq/docs/00_-_altamira-completo_1_

Fig. 9 and 10. Images from the use of the location-based app. On the right, there is a picture of the user manipulating the system, and on the left, there is a printout of the smartphone screen where the animation can be seen in real time.

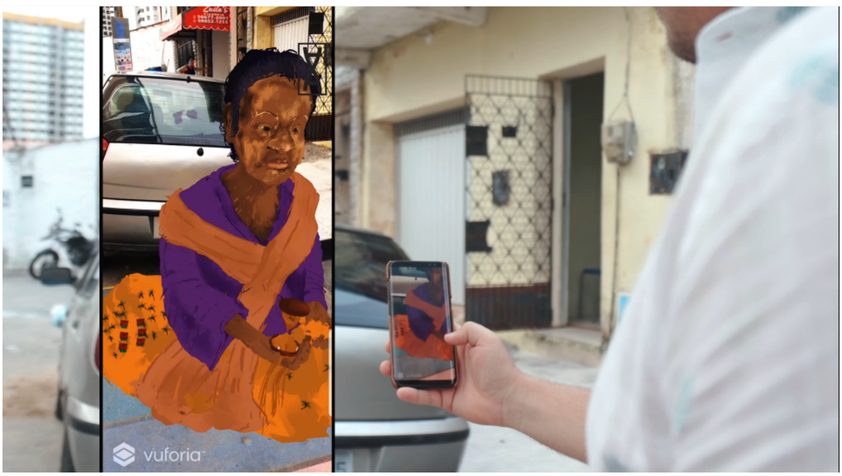

Fig. 11 and 12. On the right, there is a picture of the user interacting with the sculpture visualization feature of the app. On the left, there is a printout of the smartphone screen where the sculpture can be seen integrated with the street context.

According to Azuma, AR will only be relevant if it is contextual [12]. Convincing experiences must be powerful enough to give the user a different perspective about something, be it of a cultural, historical, social, or political character, among others. The author defines three strategic approaches for projects in AR contexts: *reinforcing strategies*, e.g., telling a historical fact at the exact place where it happened; *reskinning strategies*, when, *a priori*, there is nothing special about a place and one remakes, reinterprets, and redefines history based on reality; and *remembering strategies*, when the digital is integrated to the real to remember personal stories [6, 12]. In the *Streets that tell stories* app we sought to integrate Reinforcing Strategies with Remembering Strategies to create a story that is based on real events that happened at that place.

4. Conclusion

This paper aimed to understand which design strategies can be considered when one explores the distinct levels of user-directed cognitive and attentional stimulus when developing educational location-based applications applied to the urban public space. First of all, we presented a theoretical approach based on Activity Theory (AT) and correlated perspectives addressing human attention and the progressive process of consciousness in the interaction with artifacts. Based on this discussion, we organized the Stimulus Level Framework, which was divided into linear, circular, and spiraled stimuli. Finally, this model was applied in a real project to develop urban furniture integrated with an AR comic storytelling application.

In the Stimulus Level Framework, we summarized the theoretical categorizations into clear graphic elements that can be used by designers to help in the conceptual development of stimuli offered to the users. These stimuli can support complementary aspects of the experience to intrinsically motivate the passers-by to participate in an educational urban action, without necessarily overwhelming them with excessive lights, images, and sounds.

Regarding the first level, the *linear stimuli*, we can see that working the motor and physical aspects to meet the basic contextual needs, proved to be very effective when applied to the public urban space. We noticed that there was a notable increase in the use of the shaded area in the hotter period of the day due to the furniture proposed. Offering comfort proved to be a good strategy to make the passer-by feel open to perceive the other levels. The flowerbeds were effectively adopted by the users, generating engagement, interchange actions, and collaboration between the street's residents.

In the second level, that of *circular stimuli*, the proposal of using the space as an art gallery that is constantly changed by the residents, proved to be effective in the initial cooperative sense. Many residents helped in the process of elaboration and painting of both furniture and floors. However, the projected expectation of it being a circular action, with constant interventions, did not obtain the expected engagement. We believe that increased publicity with artists and contributors still can make the space more open to these free interventions. The intervention's conclusion overlapped, in part, with the period of the Covid-19 pandemic, which hindered the maturity of more ephemeral and cooperative actions in public urban space.

The third and highest level, corresponding to the *spiraled stimuli*, is certainly more challenging to be reached. Fostering the reflective aspect involves providing a number of different stimuli for passersby in order to give them the opportunity to bond personally and intrinsically by the experience, making it expand beyond that instant. The use of comics associated with the AR application was a way to propose a diversity of connected stimuli, consisting of visual elements that could be smoothly integrated into the landscape without being excessively conspicuous. This strategy proved to be effective in the engagement of the residents. However, the need for downloading the application to take part in the digital experience was a bottleneck that we noticed very clearly. Many users preferred to read the comics without using the app, even if it provided additional visualization experiences. A way to bypass this issue in future educational location-based applications is giving priority to the use of webAR - the use of the internet to show the virtual elements of the experience. Nevertheless, this will only be possible after 5G mobile connection is effectively used in the city.

By the end of this exercise, it is valid to assume that the Stimulus Level Framework was very beneficial for our design process. Thinking of design decisions based on these three levels helped us in the process of data collection. It also supported the proposition of elements that could stimulate the user's attention at different levels, adopting digital technology as an element that unifies and crowns the experience. The undertaken action can contribute to other similar projects to be conducted elsewhere.

As future steps we are developing systematic applications of the Stimulus Level Framework in other practical projects of educational location-based applications. We are looking for means of passing audio-visual information and animations *in loco* through the web, which does not require the user to download any application. Concerning the AR technology, we intend to perform usability and satisfaction tests through semi-structured interviews with the users to obtain deeper qualitative feedback of the after-use of these digital tools.

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