Sánchez, J. (2018) Editor. Nuevas Ideas en Informática Educativa, Volumen 14, p. 249 - 259. Santiago de Chile.

Reading as a Collaborative Construction: supporting the design of physico-virtual environments

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ABSTRACT

Collaborative reading and hypertext allow readers to have an active role through their points of view and interests in the text. The active interaction in the reading of these texts brings cognitive advantages, since it changes interpretation of its contents. Although we find literature research on this type of reading, we do not find forms of hypertexts created to favor collaborative reading in richer interaction. Thus, this work proposes a framework for the construction of systems with the concept of Collaborative Reading in the Physico-Virtual environment (CRPV). This framework is based on Organizational Semiotics artifacts, the structure of hypertexts and the concept of enaction. In this work, text structures of this model and corresponding multimodal interfaces were created. The CRPV scenarios implement the interactions with contemporary technologies, including augmented reality, seeking to achieve the concept of an enactive and socio-enactive system. One of these scenarios has already been tested and the initial experiment showed engagement and high motivation of participants in the activity. This research has the potential to contribute to the creation of new spaces and reading processes through multimodal interfaces studies, offering highly dynamic interactions in environments that can be built at low cost.

Author Keywords

Enactive System; Socio-Enactive System; Reading; Framework; Human-Computer Interaction; Physico-Virtual Environment; Collaborative Reading; Hypertext.

ACM Classification Keywords

H.5.2 User Interfaces (D.2.2, H.1.2, I.3.6)

INTRODUCTION

Reading is one of the most important human social tools. It is important in every aspect of our lives, especially when we consider a society based on information. Among reading practices, collaborative reading is defined by the Brazilian National Curricular Parameters - PCNs [6] - as an activity that allows meshing up individual reading processes with group reading, mediated by teachers inside classrooms to develop critical thinking. Each reader interprets texts differently, not only using information provided by the text, but also by each one's social context and experiences.

In the enaction theory, cognition is not only within our heads but spread across the environment and the body [43]. The enactive approach in texts can produce a new type of multimodal hypermedia. This kind of media is a variation of traditional hypertexts. Hypertexts have links to other texts, making a chain of information that readers can explore according to their interest. According to Dias [14], these characteristics of hypertexts have pedagogical advantages. In terms of cognitive processes, memory works based on non-sequential structures and on different inputs, being closer to the reading experience of hypertexts and hypermedia than sequential traditional reading [14].

In this paper, we propose a new concept that aims to unify reading, technology and enaction: a framework to create enactive systems for collaborative reading. In this article, we present concepts of this framework and a pilot system that uses it.

The paper is organized as follows: first, we discuss our research context and then our theoretical references to make the framework. Then, we present the text models and its interaction and how it can be used to create enactive systems.

RESEARCH CONTEXT

The background context of this work involves educational qualities, text formats, technological aspects, and works related to reading in virtual environments.

Educational aspects

Reading is usually an individual activity. This practice is much more than simply decoding letters and other symbols;

but a process to make sense using our surrounding and experiences [24]. In that sense, the whole world - people, cultures and values - can influence the reading of a single person. However, there are more direct forms to make reading a group activity, for example, collaborative reading.

Collaborative reading is more common in informal environments and in polemic texts, because divergence is one of the most important factors to develop critical thinking [30]. It is also usually not applied to fictional texts, because they are more propense to not favoring a discussion [11]. When an author composes a text with a fixed storyline, their intentionality can make it harder for the reader to have new interpretations.

However, some texts are less linear, having more than one ending or collaboratively written by readers. This dynamic relationship between reading and writing in collaborative form require effort and complex text structures. For this reason, it can be hard for teachers to compose these texts to use them in classrooms for collaborative reading. Still, new languages and reading models with small number of rules can be easily learnt [17], suggesting that well defined and smaller text structures that are derived from non-linear texts are more appropriate for use in general classes.

In this paper, we work with collaborative reading due to its potential for collaborative learning mediated through computer-supported activities. Collaboration is an activity that differs drastically from cooperation. While collaborative activities seek a shared construction, cooperative activities build a collective result from well divided individual sub-tasks [36].

There are some tools that can be used to promote collaborative reading more easily. Meyer [25] uses three charts: Burning Questions Chart (questions about text's semantic level), Wondering Wall Chart (wonderings about pragmatics in information of the text) and Clever Connections Chart (intertextual relations). These artifacts help to create a visualization of the mental process of groups in their reading experience, making the results of collaborative reading more concrete.

Text format aspects

Linear reading is the most common text reading model, since it is the way we learn since childhood: with rigid and clear literacy practices to define the protocol between reader and text. Overall, in linear texts, readers receive information about the text, unlike when reading hypertexts [14]. Reading in a linear model does not happen only in books, and magazines: it extends to television, cinema, series, music and a variety of media that we consume every day. Information diffusion in those communication media is unilateral [13].

Non-linear reading is the way we comprehend the world: serial and parallel information pieces are received all the time. Non-sequential texts started their ascension along with transformations in digital technology. It is a reading model in which information does not have a fixed position in a reading chain, changing the position of these text pieces according to different factors. In hypertexts, there's no fine line between readers and writers [13].

Tolhurst [42] defines hypertexts with characteristics related to 2 main segments: functional and semantic. Functionally, they are texts which have relations to other texts and that can be explored through links. Those links can be pictures or words that allow navigation between them. Semantically, they are non-linear texts that have information nodes that connect to each other.

Hypertext is not a new concept of information technology. There were other elements that allowed linking texts such as indexes, footnotes and references in books, which can bring the reader out of linear reading. The use of technology, however, changed drastically the speed at which these structures can be built and rebuilt by the reader. Nowadays, an extensive hypertext network can be available with a single click.

Hypermedia is the concept of hypertext applied to different media. Interactive media fits this category [28]. Differently from hypertext, hypermedia is strictly dependent on technology and started to get attention in the 1980s. A good example of this model of hypermedia is electronic gaming.

Non-linear reading presents two important characteristics:

- The possibility for a text to be read more than once and in different ways, which are guided by the interests of the reader [28];
- Giving an active role to the reader in the comprehension of what they read.

This second property is particularly important in the pedagogical domain, because every concrete comprehension is active [47]. This property combined with hypertexts' structure, which is closer to our working memory, can create a type of text with potential benefits for education.

Technological aspects

In our current society, technology is increasingly becoming mixed with our everyday life. Some of them work with our visual perception of reality, such as augmented reality (AR) and virtual reality (VR). AR is present when we represent virtual elements in a model of our physical world. In a broad definition, it is an "augmenting natural feedback to the operator with simulated cues" [26, p. 283]. Steuer defines VR in terms of experience as "a real or simulated environment in which a perceiver experiences telepresence" [39, pp. 76-77]. Telepresence is the user sensation of living and interacting with the environment as if it was real [39]. In a more technical point of view, virtual reality is a technology that needs projection of images created by a computer, which create an environment where interaction and vision happens in first-person [34]. Whereas augmented reality can be used subliminally, VR requests all the user's attention [32].

One of the types of systems that use VR in a highly interactive way are interactive dramas and games, applications that were foreseen by Ryan since 2001 [31, apud 12]. The reading model of this project is technically in between games and dramas, due to, respectively, intense interaction and interest in the underlying narrative.

Current smartphones are capable of rendering both AR and VR. A variety of products have been developed in the last years for this purpose, such as Google Cardboard (https://vr.google.com/cardboard) and Microsoft Hololens (https://www.microsoft.com/en-us/hololens), both for virtual reality. Mobile applications which use augmented reality have also been growing: Pokémon Go was a record-breaking mobile game in popularity, with more than 20 million users active daily and more than 100 million downloads [15]. Other companies, such as Snapchat, also bet on the use of AR to create fun interactions. Besides entertainment, these technologies are used in other areas such as education.

Aiming to improve education, Solak & Cakir [35] used augmented reality to create courseware for studies in English language, having positive results in motivating students. The overlap of information over the physical world can help comprehension of content with quick feedback and there are several works using that fact [1]. There are kits to create AR or VR content without the need for direct coding, and they have been used by Di Serio et al. [33] to create multimodal content with AR for Art classes.

Related works

There are some works that present collaborative reading tools based on software. However, most of them do not follow the same definition as the Brazilian PCNs propose [6]. They use reading with mediation or in group activities, but it doesn't have the criticism aspects which are present in the pedagogical practice.

Language learning and collaborative learning have already been explored by works such as MPAL by Lan, Sung & Chang [22]. However, the activity was much more restrictive, and it doesn't work in collaborative reading activities, were criticism and discussion aspects are the main goals.

Several works address narratives reading and writing through digital systems. Many times, they create a canvas that copies the same interaction present in paper materials. Mobile Stories [16] is one of the works that has a difference: it uses devices' position to tell the story. Still, the freedom presented in creating stories is not addressed. A work that bypasses the digital copy of paper artifacts is Yarner [20]. It is a rich web & mobile environment which uses animation and virtual reality to break the linearity of traditional stories for children inside schools. Results showed the importance of using physical material and interaction among students, which was lacking in the system. MagicBook [5] changes this notion by moving between reality (paper) and virtuality (handheld display) easily, creating a visually immersive experience, but it had neither much interaction among readers or content.

Even though enactive systems are still a few, enactive media has taken form in highly interactive systems, such as enactive cinema [41]. Its use is limited because the device used is not easily available in different contexts. Complex content production process and expensive equipment are some of the problems faced by enactive cinema. CRPV aims to cover these points as a framework to support the creation of educational socio-enactive systems.

THEORETICAL REFERENCES

Enaction and enactive systems

Enaction is a concept which is defined by different authors. One of the most important definitions related to education is made by Bruner [7, 8, 9, apud 46], defining knowledge representation. Each representation is transformed from one to another in this order: enactive, iconic and symbolic. Enactive knowledge is discovering through action; Iconic representation is about storing a direct representation of our senses, such as mapping the environment in our minds; symbolic representation is the final step, which symbols are used to make abstractions to represent the knowledge.

The enaction is more deeply studied by Varela et al. [43], where the idea of an enactive approach is that the process of cognition is part of coupling between the environment and auto-regulated organisms - such as cells, that modify itself and react to what they are exposed. Cognition is not enclosed to our heads; instead, all body and individual experiences are involved in the process. Thompson & Stapleton [40] highlight 4 main principles for this concept: adaptive autonomy in the environment (*sense making*), transparent embodiment relation, synchrony between body and mind as one, and integration of cognition and emotion. The enactive approach sees a relation between the world, environment and individual as something that each part doesn't make sense by its own, but only as a whole.

Enactive systems are the ones where there is a dynamic coupling of an embodiment of mind and technology [21]. Enactive media, such as Tikka et al. enactive cinema [41], which the content itself changes depending on physiological feedback from the viewer, uses the concept of enactive system. We use the same approach to develop the CRPV system.

The socio-enactive systems concept [2] is based on enactive systems, with social factors added to the coupling and embodiment. It creates a new relation between environment, group and individual, permeated by technology. The biggest difference that socio-enaction has in relation to enaction is the explicit concern about the people involved and attention not only in the individual enaction, but also "collective enactive" cycle. Here, in more practical terms, we expect from this kind of system:

1. To have a physico-motor input and output, both individually and in group;
2. To have a transparent interface between users and environment.

Multimodality and reading

Multimodality is defined as an interaction from multiple channels without the segmentation of experience, respecting a coordination between time, order and presentation in each medium [27]. Most forms of reading are restricted to a single medium: physical (books made of paper) or virtual (websites, blogs, e-books). One of the exceptions to this rule are the augmented documents [44], such as hybrid books, that represent multimodal interfaces. In this type of document, there are some kind of tag (barcodes, images or RFID). Each of them has different characteristics related to their robustness, use and impact on the final product's affordance.

To better understand multimodality, lets define a virtual environment. When we have a digital representation of our physical world, we have a virtual world. This virtual world can contain also symbols and figures that exist only in the virtual representation. We create a virtual environment when we create a virtual world in an interactive medium [34].

Barros [4] says that texts are always product of multimodality, with written text being one of them. In fact, in the proposed framework, texts are considered in different channels, using iconic, textual, sensorial and spatial perception to interpret them.

Organizational Semiotics

Organizational Semiotics (OS) is an area that studies organization of information systems to reflect a social reality. The design process can use it, analyzing the context which goes from informal systems to formal systems (bureaucracy) and then technical systems. This organization is represented by the Semiotic Framework [38].

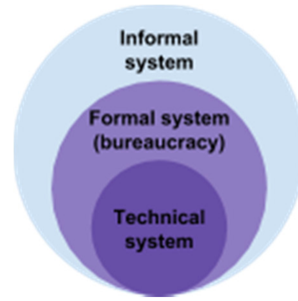

Figure 1. Semiotic Framework [38].

Social and cultural values are represented by the informal level of this framework (Figure 1), being extremely important to design interactions that make sense to people. The Socially Aware Design - SAC [3] - helps in this by providing tools to consider a sociocultural scenario from different stakeholders' perspective.

OS provides artifacts to consider the human aspect and context, which is useful for designing the CRPV system, but mostly, the CRPV framework. Other artifacts were used to structure the framework, such as Semiotic Ladder [37], dividing important concepts for reading practice as a social activity and socio-enactive systems as a technical system. To consider the socio factor in socio-enactive, OS is especially important.

THE PROPOSED READING MODEL

This paper proposes a reading model developed to be used in collaborative reading practices that use technology in an enactive approach to potentialize characteristics such as collective sense, debate, different individual points of view and mediation. This framework defines some ways to create systems to support Collaborative Reading in the Physico-Virtual environment (CRPV).

Collaborative Reading in the Physico-Virtual environment

CRPV is defined as an extension of collaborative reading practices with the use of immersive technologies and sensors, where depending on how each reader interacts in a physico-virtual environment, the content been read changes [19]. The CRPV framework has norms for both reading practices and interactions in the system.

The framework has 2 main parts: text construction and multimodal socio-enactive interface development. This framework is intended to be extensible and to be used in different works besides this one, using a theoretical and practical base to design systems that are socio-enactive. Some examples of its use are presented later.

Text structures and interaction

To have a collaborative reading activity, texts or reading objects are essential, because individual reading is required to accomplish the collaborative version of the interpretation. We assume here that texts are information structured in some language, no matter how they are presented (iconic, verbal etc.). In the CRPV case, texts are hypermedia (hypertexts with extensive use of media) made in the physico-virtual environment. Text structure defines a large part of how the interaction will proceed. Even though we are used to read non-sequential materials, our writing process is, in most cases, linear. The most common way to write hypertexts is creating the main line of the text and then create branches related to each part.

Figure 2 shows the types of text structures that were studied. Each node shown in the figure represents a meaningful information piece in the text. These models in the figure help us clarify the text goals and intentions that are present in each case of the CRPV.

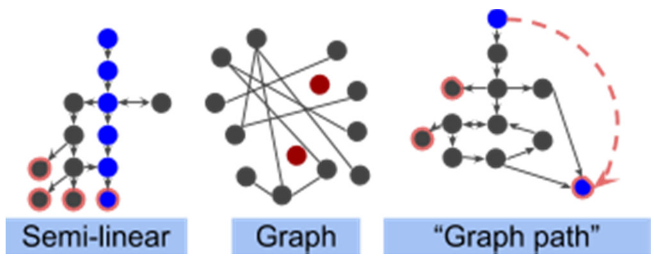

Figure 2. Text models studied in the creation of CRPV.

Semi-linear text

We denominate semi-linear structured text the ones where the hypertext creation was originated by a sequential text. In Figure 2, the blue path represents the main sequence. This is the easiest type to create because is very similar to the method that we are used to: after creating the central plot of the narrative, new branches are created upon this structure. The interactions in the system using this type of text follow a time-guided sequence of actions, making it easier to create all the possible system's states.

An example of this structure of text would be an adaptation of an existing story. Suppose we would create a text in a system which uses CRPV for the story *Alice in Wonderland* [10]. To keep the storyline present, the easiest way to write the hypermedia would be to imagine new things that could happen inside the world described by Lewis Carroll and connect these branches with the original narrative. In terms of interaction design, this would result in a reading experience not too far away from the linear reading, but with new aspects that could change interpretation.

The potential differences in reading in this model are smaller than in the others and it is possible to perceive more strongly the "path to be followed" intended by the author. The result of the collaborative reading activity in this case would be a more complete understanding of a fragmented text.

Graph text

In this case, we have a collection of nodes with text information that are connected with no clear time order. This type of text construction is easier to be made by non-fictional texts from newspaper, magazines, publications and other linear texts to be used as each node. The graph represents the theme of the collection of texts. In analogy with a debate, each node can be considered a point of view, which may or may not agree with others, creating relationships with each other. Collaborative reading activities of this model needs to have clear objectives so that they do not end up becoming the same practice of reading multiple sequential texts.

Interactions in this text model have to consider a large number of different scenarios. The physico-virtual environment cannot have many dependencies between actions, so that the flow of the reading is not plastered. When long chains begin to form to access certain information, the graph may degenerate into a semi-linear text structure, as in the example in Figure 3.

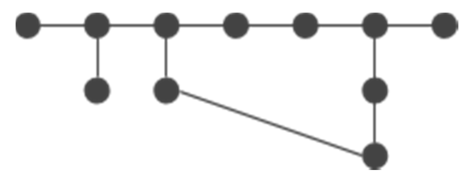

Figure 3. Graph text that becomes a semi-linear text structure.

"Graph path" text

The "graph path" texts have similarities with the other two. They have a general structure closer to the graph because elements are created that do not have a direct temporal relation, but the intention of the author is that the reading starts at one node and walks towards another, as in a path in a graph. In Figure 2, this is shown by the blue nodes as initial and final, in the direction indicated by the red arrow.

Writing this type of text is centered in the beginning and end of it, defining later the way the story is developed. Robert Lawrence Stine, author of American children's literature, cites this mindset in his Masterclass propaganda (https://www.masterclass.com/classes/rl-stine-teaches-writing-for-young-audiences) as the way he creates his stories.

Using this structure, it is easier to think of fictions that have the type of interaction similar to the graph while maintaining an intentionality of the work close to the semi-linear text (there is an expectation that the reader will "go through" a certain path).

Discussion

Each presented text structure model has different characteristics, possibilities of reading and interactions in the system. Table 1 summarizes some of these key points; it was constructed based on the proximity of the text format of other genres regarding its linearity, correlation between information, possibility of divergence of opinions and in the works of O'Brien [30] and Daniels [11], mentioned before.

Characteristic	Semi-linear	Graph	"G. path"
Use in fiction	Easy	Hard	Medium
Use in non-fiction	Hard	Easy	Depends
Expected reading path	Yes	No	No
Narrative	Yes	No	Yes
Different points of view	Low/Mid	High	Mid/High

Table 1. Characteristics of different text models in CRPV.

The characteristics of Table 1 represent:

- Use in fiction / non-fiction: refers to the ease of being able to create text of that type with the model;
- Expected read path: is the author's expectation that a sequence of actions be performed by the readers;
- Narrative: defines if it is possible to insert the structure of a narrative in the reading (a storyline with beginning, middle and end);
- Conflicts of vision: frequency with which conflicting points may appear in the text.

Thus, it cannot be said that there is the "best" text model to be used in CRPV, but definitely there are different models that are more suitable for some uses depending on the context.

CRPV IN PRACTICE

We will discuss in this section some applications of the CRPV system and its technical functioning, presenting the characteristics of its multimodal interface.

Multimodal interaction in CRPV

In order to present the characteristics of a socio-enactive system, the CRPV needs, in technical terms, a form of reading which uses the physical environment and the relations between the readers and the system.

Systems that use this concept as a base have 5 steps (not necessarily in this order) to reach a socio-enactive system:

1. Interaction in the physico-virtual environment;
2. Enactive data input;
3. Collaborative-individual interaction;
4. Enactive data output (closed enactive cycle);
5. Feedback cycle from the system to the individual-group relation (closed socio-enactive cycle).

In our case, CRPV systems were planned to be implemented as follows: the system is based on smartphones (to use their mobility, processing capacity and sensors), mixed reality and data entry via mobile accelerometer, environment sensors and wearable devices to measure heart rate, representing the reader's emotional and spatial data.

Steps 4 and 5 have not yet been tested in the implementation of a pilot system. For step 4, we plan to use scattered devices in an Internet of Things (IoT) physical environment. For step 5, the interaction of step 3 will be partially transposed to the virtual environment and linked to the enactive information of the system, coming from step 2.

Pilot scenario in a museum

The first prototype that adopts the CRPV was created for the scenario of an interactive museum [19]. In a web-based system using smartphone, cellphone accelerometer and a physical scene with QR codes, participants were able to explore a reading experience in the museum. The scenario had low production cost, using materials available at home (batteries, decorations, paper folding) with QR codes attached to them. The collaborative reading was of a "graph path" fictional text, where the story told that "energies" invaded objects in a museum. In groups of 4 people, the participants had to explore the environment and try to find out what had happened in the museum.

The pilot experiment was executed in the InterHad research group, with 4 readers and 8 observers, specialists in HCI. A room was created to simulate the space of the museum and the story was segmented into physical objects and virtual objects that were tied to QR codes. Scanning them with the application allowed a 3D representation of the "energy" contained in the object, which took the form of some item related to the story (Figure 4). Each representation, shown with augmented reality, was accompanied by written texts. The combination of simultaneous scanning of different objects generated new bits of information and interactions in the story.

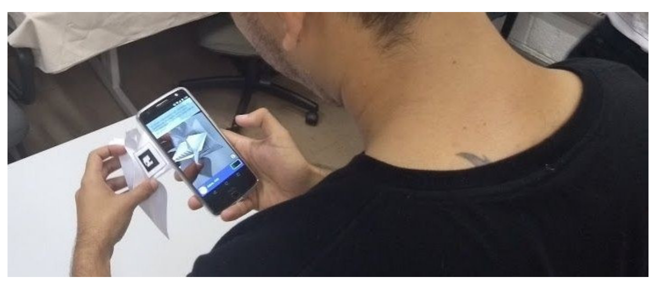

Figure 4. Application scanning a QR code and showing it's text and virtual 3D object representation in the pilot experiment.

Augmented reality was used as a first step to bind the physical and virtual environment with both technology and content. Also, it is an easy way to use and visualize spatial information of QR codes.

The experiment was based on the game genre Escape Room [45]. The multimodality of this type of game, presence of moderator and hypermedia text structure were compatible with the objectives of CRPV. To represent the pressure that is put on players of this genre, participants had a time limit determined by a virtual battery in the application. The passage of time discharged the battery, while moving (information captured by the accelerometer of the smartphone) recharged the battery.

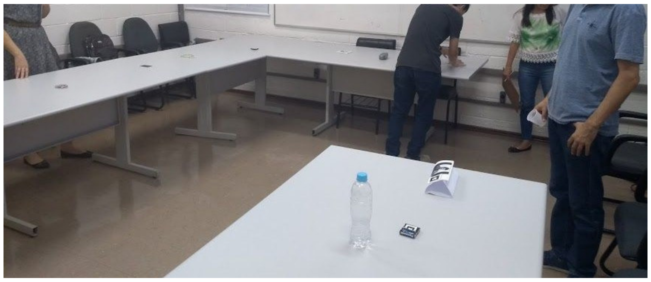

Figure 5. Physical environment of the pilot experiment.

The setting of the scenario can be seen in Figure 5. The multimodality here is quite remarkable, because there were many channels of information and interaction of the participants:

- Physical objects;
- Texts and information linked to objects;
- Movement in the scene;
- Graphical representation of objects in the application;
- Relation between different objects in the context of the story;
- Group discussion to find out what happened in the museum.

Adapting Meyer's charts in collaborative reading workshops [25], we have as a result of CRPV scenario a text created from the charts that synthesize the collaborative vision. Physical and virtual channels blend together, and data entry is given by physical, spatial, and motor elements. These elements were combined with a simple architecture application, requiring only one web page and use of the AR.js library (https://github.com/jeromeetienne/AR.js).

From the experiment, data were obtained by observers in the environment, taking notes, taking photos and filming. The participants adopted the Think Aloud protocol, where they speak out loud what they are thinking at all times [29], and evaluated the experience using an adaptation of AttrakDiff, a questionnaire that uses scales of opposing pre-defined word pairs to evaluate the experience of the user [18]. The AttrakDiff goes on a scale of -3 to 3, these extremes being the representation of each adjective that describes the experience. Some of the pairs of adjectives are: human / technical, pleasant / unpleasant, and ugly / attractive. In total, 20 pairs of words were used.

The first experiment results showed 5 consolidated adjectives, being placed at maximum intensity ("3" by all participants) in the AttrakDiff questionnaire: pleasant, inviting, creative, captivating and motivating. This is a very positive experience. Other adjectives that stood out, having an average value of 2.75, were: practical, integrative, good, innovative, challenging and new. Participants became interested in the story and wanted to repeat the experiment to explore the whole narrative.

A prospective scenario in classrooms

This was one of the scenarios that motivated the project. The application of the system in classrooms was planned to be a possible scenario for different educational contexts, such as public and private schools.

Teachers can apply the system with students in regular classrooms. Each student must have access to a mobile device that should communicate with the smartphones of other students in the same group using some form of wireless, local (Bluetooth) or Internet (Wi-Fi) communication. After the activities with the CRPV system, the teacher and the students can discuss the content, consolidating the results informally or formally, by writing texts to represent the collective and individual visions of the story. This formalization can be done physically or digitally. Figure 6 details how the interactions between students, their groups, teacher, and the system would occur.

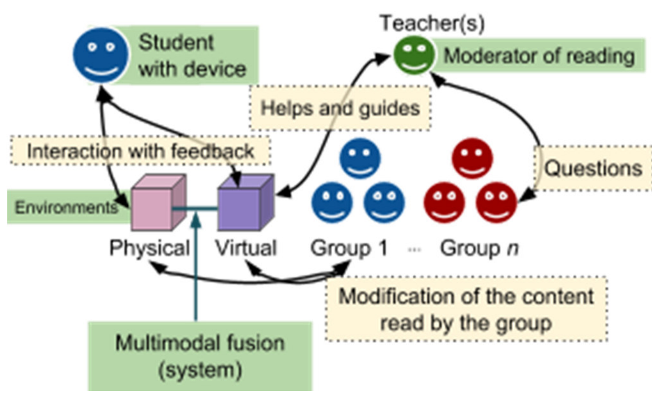

Figure 6. Scenario of use of CRPV inside the classroom.

Students are the protagonists of this scenario. Every interaction is centered on them. They can interact in different ways with their own group, but they will need to act in the physico-virtual environment of the system. The exploration of the environment must be done autonomously by the student, but he can rely on the guidance of the teacher if he feels the need.

The groups are independent units during the activity. Segmentation of groups helps to increase the difference in interpretation among students, allowing a better discussion at the end of the activity.

The orientation of specific points of the activity is given by the teacher(s). Each teacher will be a mediator of reading and will have access to a tool that allows, to a certain extent, to modify the virtual scenario. In this way, if the student gets blocked by not understanding the reading or the process, the mediator can intercede for him and help him understand what is happening. The teacher is also available for group discussions and questioning. Teacher's main purpose should be to encourage students to think in different ways, helping to build a critical, collaborative reading environment.

The system needs to accommodate the physical environment, the virtual environment and multimodal fusion. The types of data collected depend on the type of virtual interaction that the mobile phone offers. For this scenario, we will consider the use of mixed reality with possibility of exchange between augmented and virtual reality, an idea close to adding social and enactive interactions and tangible artifacts to the MagicBook reading design [5].

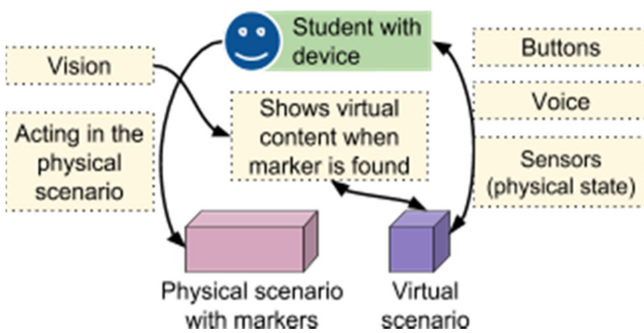

Figure 7. Students interaction within CRPV system.

Figure 7 illustrates how interactions occur, with different modalities occurring simultaneously. There is stimulation of touch, physical space, the student's physical state (heartbeat, movement and, when using a mixed reality glasses, head's position), buttons on the device (virtual or physical) and voice. The feedback loop is present both with virtual data entry and physical data input, but the output in both cases is still virtual. A more complex scenario can be built with output in the physical environment with the use of Arduino-based electronic devices.

This educational scenario presents all the characteristics desired for CRPV: collaborative reading in order to construct a critical debate while valuing individual and collaborative actions and multimodal technology in a non-linear narrative. In addition, the scenario can be built at a low cost. Many contemporary technologies that work with multimodal interactions are expensive. Published works by Want with augmented physical objects in the virtual environment showed costs between US$10,000 and US$35,000 (1999). Even today, Microsoft Hololens, for example, costs US$3,000 in its cheapest version (https://www.microsoft.com/en-us/hololens/buy). The scenario presented can be built with QR codes, mixed reality glasses using cardboard with biconvex lenses, like Google Cardboard, and smartphones with Internet access. Access to these phones is widespread and the cost of QR codes with mixed reality glasses costs less than US$10.

Even with a complex and rich multimodal interface, this CRPV scenario presents the possibility of being applied in a wide variety of different contexts due to its ease of physical and virtual assembly and cost. Evaluation of the model will include experiments in different scenarios and versions of the CRPV system, looking for interaction design, text format and computational aspects. This scenario which is inside schools is planned to be applied in an Educational Space for Children (CECI Partial) inside our university campus.

Other scenarios

CRPV may be suitable for application when the context involves a group of people discussing subjects that allow divergence of opinions, the presence of a moderator who understands the subject of reading, and a physico-virtual scenario that materializes the structure of fiction.

CRPV can be used to create fictional scenarios with highly interactive and enactive media. Although being in a fictional story context, the enactive experience allows what is happening to be "credible", aided by the process of cognition involved in the reader's relationship with the physico-virtual scenario. This can make the reading model suitable for experimenting with prototypes that are part of the plot, making it a tool to be used with design fiction. Some important characteristics for the design fiction are complex and involve socio-technological relations [23], both existent in CRPV.

CONCLUSION

By reading we understand and transform the world. The reading process is being transformed over time, coupled with the novelties of the digital era, especially the web environments. The Collaborative Reading in the Physico-Virtual environment, as proposed in this work, represents a further step in approaching the experience of reading in a embodied way.

CRPV systems can be used for different purposes and scenarios. It is a new concept of media and system that consider beyond the content and presentation of the text, but also an entire enactive environment. The pilot experiment showed the potential for a positive, motivating and engaging interaction experience. The models of text created so far take into account mainly the division of the categories of fictional and nonfictional texts, but the texts of CRPV can still be studied in other perspectives, both in terms of their writing and the type of interaction made possible.

Although the construction of this type of text can be done with low cost scenarios, they are still difficult to create because of the extensive configuration between devices and scattered textual elements. However, this can be solved with systems that help developing other CRPV systems; future work in this direction is promising.

ACKNOWLEDGEMENTS

Thanks to the research group InterHad for all project support, both with observers and volunteer participants. Thanks also to the institutions and research funding agencies that supported this research: CNPq (process #306272/2017-2), FAPESP (processes #2017/23023-7 and #2015/16528-0); Institute of Computing of State University of Campinas (UNICAMP) and Alumni Scholarship from IC / UNICAMP.

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