Understanding People's Interaction with Neural Sci-Art

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ABSTRACT

Recent studies in cognitive neuroscience have discovered a complex neural network that activates when not performing a task. Every time the mind wanders and an inner conversation takes place, a series of brain regions work together to achieve some very important mental processes. These regions conform the **default mode network** (DMN), and its study has become critical for understanding how consciousness operates. With the intention to introduce this novel scientific finding to a non-expert audience and motivated by related works that combine science and art, we designed and implemented *Default Stories*: a work in progress of an interactive and immersive experience on the web. Using features of web interactive documentaries (*i-docs)*, we present the main characteristics and relevance of the DMN in a language that can be understood by almost anyone. This website was published and available online for a month, where we collected navigation data (n=98) and analyzed the interaction between users and the interface. After this study, we were able to detect patterns on the interactions and intersect the findings with how the audience perceives and understands the presented subject. This work will serve as a starting point for new projects that present complex scientific research to non-expert public, by using interactive web experiences.

Keywords: Immersive and Virtual Environments, Sci-Art, user interface, i-doc, neuroscience, Default Mode Network

1 INTRODUCTION

Before the year 2000, neuroscience had focused on studying how the brain reacts when stimulated by external means, which brain regions activate when seeing, tasting, reading, moving, etc. Many of these previous studies, assumed that the neural activity that took place before and after a task, had no relevance to research. But a few years ago, neuroscientists discovered that some brain regions decreased their activity when commanded to complete a task [3]. Opposed to what they thought, the amount of oxygen consumed by the brain while resting was surprisingly high compared to the consumption while performing a task [19]. Further research lead to the discovery of a complex neural network conformed by regions that work permanently when we are not engaged in some external task, in other words, by default. In 2001, they gave this discovery the name of default mode network.

This network can be described as mind-wandering, i.e. using past experiences to plan for the future, navigate social interactions, and maximize the utility of moments when we are not otherwise engaged by the external world [3]. Now we know that in order to understand how the brain works depends critically on the study of its intrinsic activity and how it gets us closer to the understanding of consciousness [19].

Everyone has experienced some kind of mind wandering, but not all of them are aware that it corresponds to a specific neural network. The later, arises the possibility to collaborate between design, art and science to engage the public with these complex and novel scientific research, thus exploring new ways to see and acquire knowledge.

In this paper, we present *Default Stories*, a work-in-progress interactive documentary that aims to engage the non-expert public with the phenomenon of the default mode network. This online platform invites the user to explore day-to-day situations where this neural network is active. It is composed of seven videos, divided into three questions that every user has to answer. Without necessarily triggering the activation of the default mode in the users, our goal is to make the public feel identified with the answers while they understand the main characteristics of this neuroscientific topic of research.

The selection of the alternative videos defines a sequence of a unique story for each user, which we will observe by collecting the data generated in the platform. With this information, we intend to find patterns in the reconstructed stories. Will it be possible to identify different types of behavior when navigating this project? Is there a relationship between the chosen sequence of videos and the understanding of the theory? How the perception of the default mode network relates to the path the user chooses?

2 RELATED WORK

Our work mainly relates to interdisciplinary projects between art and science and the pursuit for new digital means to tell real stories, like the growing industry of interactive documentaries.

In the last decades, Sci-Art has been situated in the interaction between arts, sciences and technologies, including new media, digital art and interactive art [24]. This alliance has made possible to bring knowledge to non-expert citizens, offering a unique contribution to engaging the public with complex scientific issues [10]. New ways of establishing connections between scientific knowledge and those forms of 'human' and 'subjective experience', that lie outside the domain of scientific investigation, are being explored. Under the concept of Sci-Art, a new approach has been developing to engage broad audiences with complex scientific knowledge, by exploring a new language that emerges from intimate, sensory, persona, human-scale narratives, metaphors and aesthetics [5,11]. These novel ways of seeing and new ways of knowing [5] have reached various subjects such as genetics, neuroscience, climate change, astronomy, and so on, and have emerged from the traditional performance arts, interactive installations, sound art, data visualization, among others [22,10,18,5,9,13]. On the other hand, new technologies have given way to a new field where design, HCI, coding and documentary meet. Aston and Gaudenzi define this field as *i-docs*; a form of nonfiction narrative that uses action and choice, immersion and enacted perception as ways to construct the real, rather than represent it [2].

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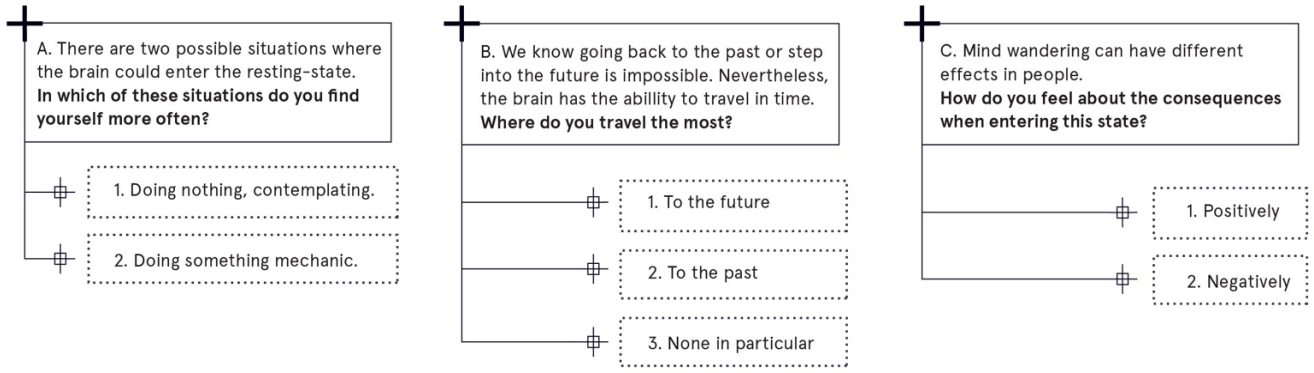

Figure 1. Concept map of questions and alternative answers.

There is also a relationship between *i-docs* and the well known *interactive narratives*, which are a "type of narrative form that allows someone other than the author to affect, choose or change the plot" [14]. Interactive narratives have been present since the late 1970s and have been specially used to design interactive fiction computer games, either text-based, such as the *Colossal Cave Adventure* (1976) and *Zork* (1977), or multimedia-based, such as *Myst* (1993) [16]. However, there is also a clear distinction which makes us choose *i-docs* as the conceptual framework for our platform rather than interactive narrative. As Bonino explains [4], *i-docs* deal with non-fiction and "…have the opportunity to actually impact on the way the viewer/player perceive reality." With our work, we aim at introducing the user to a scientific concept in neuroscience, the default mode network, which understanding can eventually impact how user perceives reality.

Generally, *i-docs* are designed as databases of content fragments, often found on the web and accessed through a digital interface which modes of interaction allow audiences to play with the content [17]. *I-docs* can be defined as a relational object that requires the agency and interactivity of the audience [7]. Agency is understood as the satisfying power to take meaningful action and see the results of our decisions and choices [16]. The possibility of the user to make their own decisions over a narrative, are the ones that allow a story to be configured as a personal sequence of the content fragments organized in the digital interface. These nonlinear narratives, are usually designed as open, evolving and processual [17]. Therefore, the user has an active role in the construction of his/her own story. *Default Stories* is built upon some features from *i-docs*, but rather than construct 'a real world' [2], we designed a narrative that connects us with a concept from neuroscience, the default mode network. Our aim is making people aware and engaged of recent discoveries of this network of neurons which activate specially when we are in a state of mind-wandering, and help people relate with their own experience.

Lately, *i-docs* have been focused on building realities from social, political or historical subjects [12, 20, 15], but it seems that it has not been used to present complex scientific knowledge. With this investigation, we intend to explore whether the *i-doc* language is suitable to engage the public with novel neuroscientific findings.

3 Default Mode Network

Since the discovery of the network is very recent (2001), there are few accurate findings of the functions of the default mode network and the information available is sometimes speculative. What we know for sure, is how to distinguish the difference between the brain activity that corresponds to the default mode and which one corresponds to other neural networks. Either you are completing a task interacting with the exterior, or you are doing 'nothing'. This nothingness is random thought made out of anything that concerns you in that precise moment. It can make you travel in time to the past, the future or no time at all. So far, any kind of mind wandering is associated with this neural network and its outcomes are fundamental for further understanding of the brain, and every task induced activity turns off the default mode. With this in mind, it is possible to distinguish any neural activity into two main states of mind: rest and attention. It is also relevant for this project to highlight the fact that the function of the default mode is entirely personal. Internal thought is not shared among others, only happens between you and your mind.

The activity of the default mode, often compared to a stream of consciousness, can be made out of limitless amount of varied contents. This kind of thoughts appear spontaneously in your mind and they can skip rapidly into other thoughts, even other times and spaces, and end it up somewhere unexpected. This makes the default mode network a nonlinear system, where small changes at the beginning can amplify in the process and cause enormous changes at the end [21].

In order to simplify this scientific research for the project, we took into account the main contents across related neuroscientific articles and also those which could be easier to identify by a non-expert public. After discarding the most complex topics we selected seven day-to-day situations where the DMN could be active such as, merely contemplating, walking while thinking in something else, planning the future, remembering the past or just random thoughts.

Finally, we arranged these topics into three aspects to understand: (1) when does the network activates, (2) what kind of thoughts are produced and (3) the outcomes of lingering in the state. Each of these aspects were then transformed into a question to guide the user into selecting the answer that made him/her feel identified. Therefore, each topic was transformed into an alternative answer. With these we built a workflow that would allow the user to explore freely, without any determined path through the presented videos (Fig. 1).

4 Design Goals

In order to provide new approaches to neuroscience we transferred the main concepts behind the DMN research into a digital space for engaging with the non-expert public. We found these alternatives in the Sci-Art scene, where the narratives are designed to engage the citizen on an emotional level in order to bring into play their rational, cognitive and intuitive thinking [8]. Therefore, we propose three design goals:

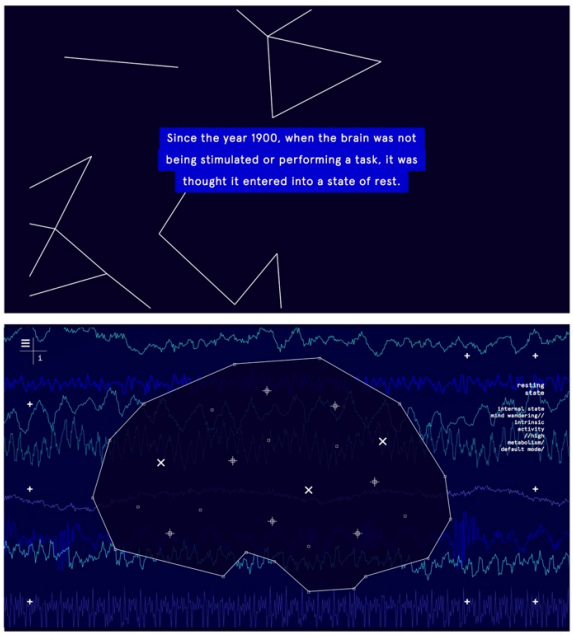

Figure 2. Top: Introduction animated text. Bottom: main interface. Visit: http://historias.xdefault.cl/en

Engage the public through enticing aesthetics

We will design the experience to provide an immersive space for the user to explore and engage with the presented narratives. The creation of this space consists on a soundtrack created specially for this project that will attract the user attention into the developing of the narrative. Together with the graphics, the sound will respond to the user activity by reacting to his/her clicks. In this way, we will provide an interactive and immersive space through the whole experience to increase the user interest and make sure they don't abandon the web before the end.

Provide the user with content fragments to build a personal story

In order to engage the public with the narrative, we transformed each topic into an answer to a question as described earlier. Instead of presenting the stories in a linear narrative or randomly, the user will have to choose which story to watch based on his/her answer to the questions. In this manner, we will make sure that the information provided makes sense to each user and their own previous experience. To follow this goal, we chose the personal computer as the mean to explore the platform to ensure a personal and private experience.

Produce awareness of the network

The default mode network can be found in every human brain, so it is almost impossible to find someone that has never had an inner conversation with themselves. The fact is, many of them don't know that there is an actual neural network dedicated exclusively to these moments. *Default Stories* requires the attention of the user so that the information is transferred as clear as possible. We intend to communicate and share this recent research by engaging the public in a meaningful experience, so that the next time they find themselves wandering, they can consciously recognize that this activity isn't purposeless. On the contrary, it plays a fundamental role for certain mental processes.

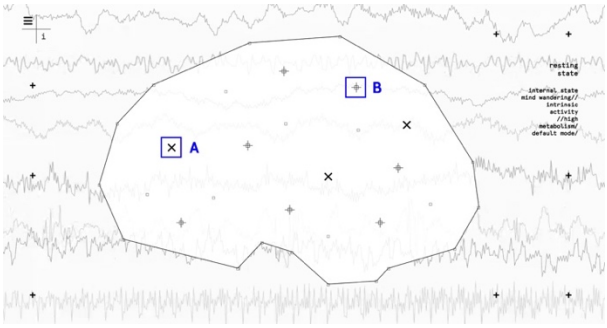

Figure 3. Diagram of the elements shown on the main screen.

5 Default Stories

In the following section, we will describe the navigation flow through this first prototype, divided into three main instances: preface, main body and closure.

5.1 Preface

The first thing the visitor will see when entering the website, is a short introduction of the theme to orientate the audience towards what they are about to watch. The introduction consists on a small text divided into four paragraphs that tell the story of how the default mode network was discovered (Fig. 2). The last phrase connects the introduction text with the title of the project, concluding that "the brain constantly tells stories to itself, and it does so by default". The texts on the screen will appear on top of an animated background of lines forming an unfinished network that completes in a brain silhouette by the end of the introduction. This brain shape, will help the audience contextualize the project with neuroscience.

5.2 Main Body

After the introductory animation, the name of the project is revealed with the recommendation to use headphones, in order to truly engage with the story. When entering the main view, the user will find the same brain shape silhouette from the beginning, but now filled with crosses inside and outside the shape.

This graphic interface is designed to encourage the exploration of two different interactions. The main one occurs inside the brain that contains the seven stories. The user will find two kinds of crosses on the screen (Fig. 3). Crosses A, are the biggest ones, following their importance to the platform. When the user clicks on cross A, a question will be prompted and lines will connect to crosses B, which hold an alternative answer. The user will answer the question by selecting the alternative that suits him/her the most. When an answer is clicked, a related video to the answer will load full screen and played automatically.

Every story had to be built in order to reach a large audience. Engaging with the audience will depend on how general the stories can be so that more users could feel identified and recognize themselves as they explore the website. Each of them is a monologue that goes through both states, mostly in default mode but interrupted by something that triggers the attention mode. Through this monologue we pursue the simulation of an inner speech, so the text is recorded with a narration that is altered and mixed with the audio of the website to evoke an inner conversation inside your brain.

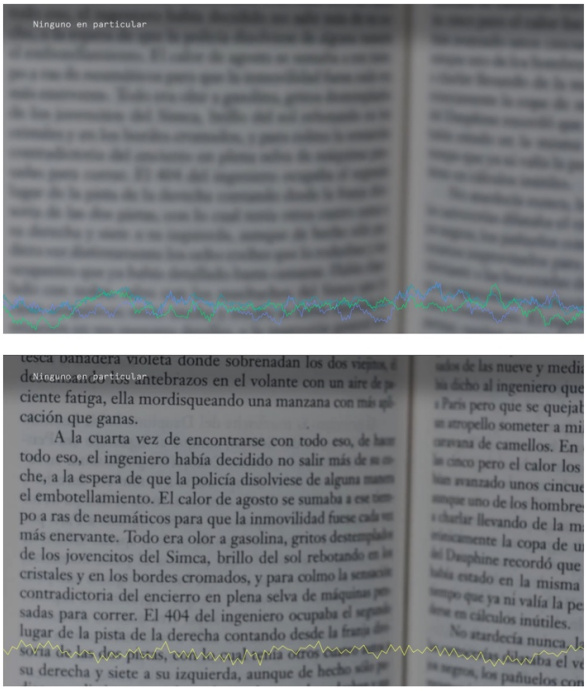

Figure 4. Screenshot of a story. Top: blurred image. Bottom: sharp and clear vision

The images playing along with the narration are blurred views of an exterior scenario that the narrator is in. Therefore, we filmed videos of real scenes for each story that were shot from the point of the view of a person. To imitate the eyes of the narrator, we used a subjective camera and kept natural movements of the head for each video. When the narration is in default mode, the video is blurred, representing the restricted attention to external objects while the mind is wandering. But when some external stimulus disrupts the wandering, the blurriness is rapidly transformed into a clear and sharp image of the exterior scene. This doesn't last very long, since the mind is easily brought back to wandering and the scene slowly blurs back (Fig. 4).

The secondary interaction on the website intends to represent the two different mental states described previously; attention and resting. As a metaphor, the click in the outside of the brain symbolizes an external stimulus that triggers the change of state. This interaction will modify the waveform animation and the sound will abruptly transform into a high pitched, clean and continuous tone. Also the outline of the brain shape will fade out and disappear from the screen allowing external stimulus to 'permeate' into the mind. When the user clicks back somewhere inside the brain, the animation will go back to its initial state as well as the sound (Fig. 5)

5.3 Closure

Every time the user visits a story, the line that connects the question to the answer remains in its place. This feature guides the user navigation so by the end of the experience, the brain shaped becomes a network. Although the user can visit as many stories as he/she wants, answering the three questions will conclude the navigation. A final text will tell about who and when the DMN was discovered.

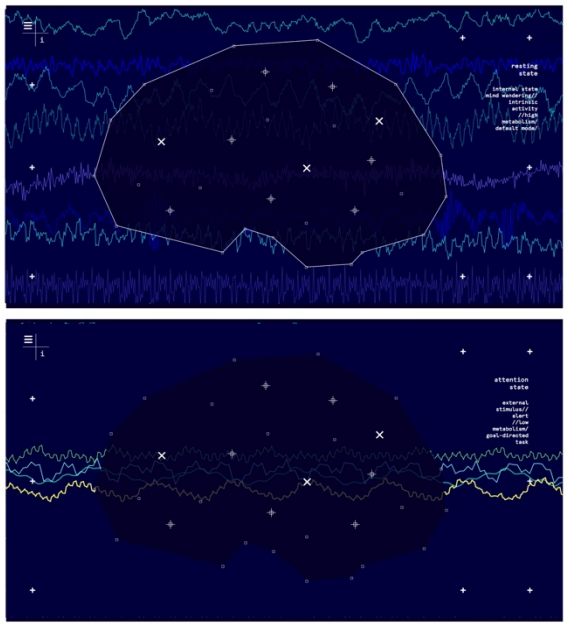

Figure 5. Secondary interaction. Top: click inside the brain. Bottom: click outside the brain.

Also it argues that the discovery of this network changed the idea that the brain is only active when completing a task and that the moments in which there are no clear goals, could be the most lucid and creative ones. After the text appears, the user is given the option to go back and watch more videos. If the user decides to finish the experience, a form with more questions will be prompted, allowing us to collect additional information from he/she.

6 Evaluation

On a first evaluation stage of *Default Stories* we were interested in gathering navigation data in order to analyze the interaction between the users and the interface and how they perceive and understand the default mode network. In the following section we will describe how we collected and studied this data from each user.

6.1 Data collection

During each user session, every click is being logged. Additionally, by the end of the experience, the user will be asked supplementary questions in a form. When accepting to share their information, the clicks registered and the questions on the form will be saved in our server.

From the total of clicks logged, we were able to identify the user answers to each questions asked on the main interface. Although the user can click on all of the answers and watch every story, only the first three selected answers were taken into account. This allowed us to to observe the sequence each user chose.

Secondly, the form will collect information about the user's perceptions in two more questions; 'Could you explain the default mode network to someone else?' (yes or no) and 'Select from the following list, which elements describe better your personal experience of the DMN? (list: voices, images, sound, emotions, people, concepts). Additionally, the form registers demographic data such as age, sex and location.

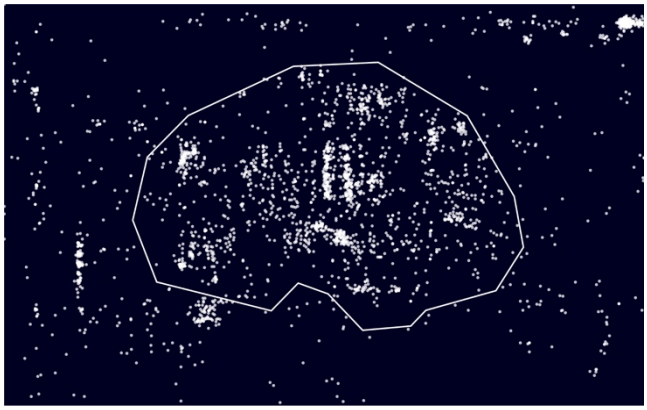

Figure 6. Map of every click action logged upon the screen, contextualized with the brain silhouette of the interface.

6.2 Participants

When the website was published and online, we made an open invitation to a broad public to visit the project. After a month, we were able to collect 98 users that completed the experience and submitted their data. Of the total users, 49 are females and 49 are males. The majority (59 people) belong to the second age group, from 21 to 27 years. The rest distributed evenly in the remaining four age groups; ten from 14 to 20 years, ten from 28 to 34 years, ten from 35 to 42 years and nine had 43 years or more. Since this first version of the website is available only in Spanish, every participant has domain of the Spanish language.

7 Results

We conducted two different analyses in order to understand user interaction with the platform, described in the next two subsections: click-log analysis –to understand sequences of actions– and frequent itemsets –to find a relation between sequences of actions and how people perceive the default mode network.

7.1 User interaction analysis

A map of every click action logged upon the screen is shown in Fig. 6. We can conclude that users explored freely around the screen, both inside and outside of the brain shape, experiencing both interactions described in section 5.2. However, a more intense activity is recognized inside the brain shape.

Taken the first three selected answers, and discarding every non-relevant click for this analysis, we looked for the most frequent sequences of stories. Given that there are 3 questions with 2, 3 and 2 alternative answers respectively, there are 12 possible sequences. The first step in this investigation was analyzing the frequency of each possible sequence.

As observed in Fig. 7, only 10 out of the 12 sequences appear in the data. This means that no one answered 2 out of the 12 potential combination of stories. Also, we can rapidly distinguish 4 preferred sequences over the remaining 10. In this plot, each bar includes the amount of yes or no answers when asked if they are capable of explaining the DMN to someone else. Although the rates of negative answers are similar between the 4 preferred, sequence 1-1-1 has a larger percentage of yes than the others. After identifying these four sequences, hereinafter we called "1" the sequence of answer 1-2-1, as "2" the sequence 1-1-1, then 2-2-1 the sequence "3" and finally 2-1-1 as "4".

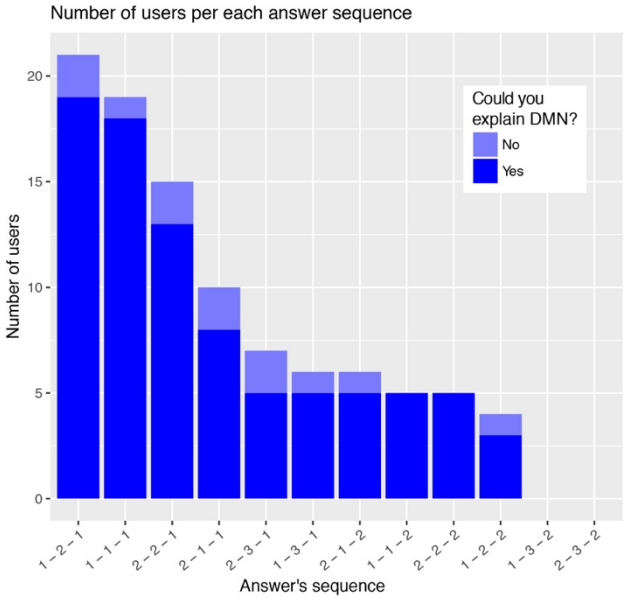

Figure 7. Number of users per each answer sequence, sort by frequency.

These sequences are the following in terms of their answers to questions Q1, Q2, Q3:

1-2-1: Q1. Doing nothing, contemplating | Q2. Future | Q3. Positive
1-1-1: Q1. Doing nothing, contemplating | Q2. Past | Q3. Positive
2-2-1: Q1. Doing something mechanic | Q2. Future | Q3. Positive
2-1-1: Q1. Doing something mechanic | Q2. Past | Q3. Positive

Interestingly, with respect to the third question (Q3), all people answered that they felt 'positive' about the consequences of entering to this state. Moreover, in Fig. 7 we can observe that the top 6 sequences had a positive answer. Another interesting pattern is that in this top 4 sequences there was no answer "None in particular" to the second question (Q2). Finally, we see both possible answers in question 1 (Q1), asking about "In which situation do you find yourself more often", implying that the people understand that the default mode network can be triggered as a consequence of different mental states.

7.2 How do people experience the DMN?

The last question in the final survey was from the following list, which elements describe better your personal experience of the DMN? (multiple-answer options: voices, images, sound, emotions, people, concepts). In order to understand the pattern of experiences as reported by the users and to relate them with the sequences (stories), we conducted an analysis of frequent itemsets using the Apriori algorithm [1]. We conducted this analysis with the R package *arules*[1] and the results are shown in table (Fig. 8).

For each of the top 4 sequences, we present the 10 most frequent responses and their respective support, i.e., the proportion of users within the same sequence who actually replied with that option. For instance, the top item in the sequence 1-2-1 is 'Voices' with a support of 0.85, which means that 85% of all the people which followed the sequence 1-2-1 marked 'Voices' as one of her answers.

[1] https://CRAN.R-project.org/package=arules

#	**Seq 1:** 1 - 2 - 1		**Seq 2:** 1 - 1 - 1		**Seq 3:** 2 - 2 - 1		**Seq 4:** 2 - 1 - 1	
	ITEM	SUPPORT	ITEM	SUPPORT	ITEM	SUPPORT	ITEM	SUPPORT
1	Voices	0.86	Emotions	0.74	Voices	0.88	Images	0.8
2	Images	0.86	Images	0.74	Emotions	0.69	Voices	0.7
3	**Concepts**	0.76	Voices	0.63	Images	0.63	Emotions	0.7
4	Images, Voices	0.76	**Concepts**	0.63	Emotions, Voices	0.63	Emotions, Images	0.7
5	Emotions	0.67	**Concepts**, Emotions	0.53	Images, Voices	0.56	Images, Voices	0.6
6	**Concepts**, Images	0.67	Emotions, Images	0.53	**Concepts**	0.50	Emotions, Voices	0.5
7	**Concepts**, Voices	0.62	Images,Voices	0.47	Emotions,Images	0.50	Emotions, Images, Voices	0.5
8	Emotions, Voices	0.57	**Concepts**, Images	0.47	People	0.44	Sonidos	0.3
9	Emotions, Images	0.57	People	0.42	Emotions, People	0.44	**Concepts**	0.3
10	**Concepts**, Images, Voices	0.57	Emotions, Voices	0.42	People, Voices	0.44	People	0.3

Figure 8. Table presenting frequent item sets of how people perceived DMN concepts.

From the table we find two interesting patterns both supporting differences especially in terms of how people answered question 1 (In which situation you find yourself when entering a resting-state):

a. Only in sequences 1 and 2 the item "Concepts" is among the top 5 and with a support over 60%, and also on itemsets of size 2 and 3. On the other 2 sequences, "Concepts" is between the 6th and 9th position with a rather smaller support between 30% and 50%. Since in sequences 1 and 2 people reported that when entering a resting-state they are more likely doing no physical activity, this pattern reveals that these people are more likely to get close to abstraction when activating the default mode network. On the other side, people who report entering in a resting-state while doing some mechanical activity are more likely to think of Images, Voices and Emotions.

b. The differences in support between item sets ranked between 1-5 and 6-10 shows a significant change in sequences 1 and 2 versus sequences 3 and 4. While sequences 1 and 2 shows a rather small difference in support between those 2 groups, sequences 3-4 present a strong decay. This might signify that people who activate the default mode network while "doing nothing, contemplating" are more likely to get a large diversity of ways to manifest it. Meanwhile, people who activate the DMN doing a mechanical activity have a smaller set of items by which it is manifested with more frequency.

8 Conclusions

In this work, we have introduced *Default Stories*, a work in progress interactive documentary with the purpose to engage non-expert public with a scientific concept –the default mode network– by means of interacting with an aesthetic experience. In this first stage of our work, we were interested in recognizing types of user behavior when navigating this project; identify the chosen sequence of videos and how they relate with perceptions about the default mode network. Therefore, we collected interaction data (click logs) and analyzed it in combination with answers to a survey, unveiling different patterns which will guide further stages of the project. For future work, we will make use of the interactions pattern to design a more personalized experience for this Sci-Art project. In terms of research, we base our effort in the paradigm of Design-Based Research [6], a methodology used in educational practices aimed to improve, through iterative analysis, design, development, and implementation, leading to contextually-sensitive design principles and theories. In our case, we aim at incorporating this methodology for the Sci-Art domain, an area where we expect to engage people into novel research theories and concepts. In a second phase of the analysis we pursue to explore whether the i-doc language is suitable to engage the public with scientific research. This evaluation should benefit from qualitative methods that allow us to get to know the participant perceptions with unguided discussions.

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