Radial Calendar of Consumption

Catarina Maçãs, Penousal Machado
CISUC - Department of Informatics Engineering
University of Coimbra
Coimbra, Portugal
{cmacas, machado}@dei.uc.pt

***Abstract*—In the analysis of time-series, it is common to focus on the identification of changing behaviours and patterns that repeat over time. In this article, we propose a visualisation model based on a radial calendar to analyse the Portuguese's consumption data. The model is intended to assist the analysts within a Portuguese Retail Company in the identification of periodic patterns and deviations from the normal consumption values. Our main contributions are: (i) the representation and characterisation of the Portuguese's consumption behaviour over time; (ii) a radial visualisation model to identify consumption patterns and their deviations; and (iii) a user case study to compare this visualisation model to a regular calendar layout. Our model has as main requirement the representation of the maximum amount of data in one single space. As such, it is ideal for analysts without prior knowledge of the data, since it provides an effective and efficient qualitative overview of the Portuguese's consumption.**

***Keywords*-time-series; information visualisation; radial calendar; consumption**

I. INTRODUCTION

Time-series can be understood as a sequence of data points indexed over equal or unequal periods of time. This type of data is widely used, and its representation of great interest both for domain experts and for the majority of the audiences [1] [2]. In a business environment, analysts require tools to understand complex time-series data. They aim at understanding the impact of their sales and the inherent consumption behaviours. To help the analysts in these tasks, expressive visualisations can be used, to enable the navigation in the data and the recognition of recurring patterns and disruptions that influence the business performance [3].

The main purpose of our visualisation model is to aid the analysts in SONAE, a Portuguese retail company, to understand how the consumption values evolve through time. These analysts are not experts in the area of visualisation but need to visually perceive how the consumption patterns change through the different weeks of the month to improve their promotions. Hence, our visualisation must comply with one main requirement: represent all data in an efficient way, enabling the rapid identification of patterns and deviations, while requiring less interaction to understand the data.

In this work, we propose, implement, and validate a radial calendar to visualise the evolution of patterns of consumption in hundreds of Portuguese retail stores. The use of a radial model is due to its compact layout, enabling us to place selectable data within easy reach for the user [4]. The main goals of our visualisation are: (i) identification of patterns and periodic behaviours in different departments of the SONAE's product hierarchy; (ii) comparison of weekly consumption values in a month and between months; (iii) identification of deviations from the normal consumption values; and (iv) comparison between the two years of data.

This paper is structured as follows. In II, we review and discuss earlier radial visualisation models. In III, we present our visualisation model and divide this section in the following subsections: (i) III-A, we describe the visualisation's tasks; (ii) III-B, we describe the data and its parsing; (iii) III-C, we discuss our design process; and (iv) III-D, we present the web-application and its functionalities. In IV, we present a user study to compare our radial calendar with a regular calendar in terms of efficiency and aesthetics. In the last section, we present the conclusions and future work.

II. RELATED WORK

To understand the evolution of data attributes over time, one can apply several visualisation models. These models can be divided into two groups: linear and radial. In the present work, we will focus mainly on the state-of-the-art of radial visualisations, as it is the basis of our visualisation model. We choose a radial layout instead of a linear one because it fits better to our main requirements for the visualisation: to represent periodical patterns, and to use efficiently the visualisation space [4] [5] [6] [7]. Moreover, Draper et al. [4] states that the radial models are able to provide valuable insights from the data, using space efficiently and easing the comprehension and interaction of the user. Diehl et al. [8], also states that radial visualisations can be more appropriate for focusing on a particular dimension, which is aligned with our intent to represent uni-variate data (the growth and decline of consumption values).

Radial visualisations can be defined as the positioning of visual data points along a circle, ellipse, or spiral [7]. Some of the most commonly used radial models are pie charts [9], [10], radial bar charts [11] [12] [13], and radar plots [4], [14]. William Playfair's *Statistical Breviary* of 1801 [15] and the rose diagram of Florence Nightingale [16] are an early example of the use of radial models. The use of a radial calendar can also be seen in the early work of William Farr's *Temperature and mortality of London* [17], which shows the evolution of temperature and mortality in London in every week, from 1840 to 1850. Each year is represented by a circle equally divided in the 52 weeks of the year, and through colour, one can identify the number of deaths and temperature values [18].

The use of spirals to represent time-series data is also a well-known technique. In 1998, John V. Carlis and Joseph A. Konstan [6] introduced a spiral visualisation to highlight serial data attributes along the spiral axis and periodic attributes along the radii. In 2001, Weber et al. [7] applied a spiral to compare data elements, both in a neighbourhood and between cycles, and to identify patterns and periodic behaviours. In 2008, Tominski et al. [19] implemented a two-tone colouring in a spiral visualisation to allow users to read the data values more precisely. In 2013, Xiaoji Chen [20] used a spiral model to represent the evolution of air quality in the major Chinese cities. Spirals have also been used in data aesthetics, with the intent to explore the ability of a swarm system to represent consumption data [21].

Other radial visualisations can be applied to improve the visualisation of periodic behaviours [7]. In 2004, Keim et al. developed *Circle View* with the goal of comparing continuous data through time [22]. In 2012, Clever Franke, divided equally a circle in twelve months with the aim to represent the relationship between real weather data and the social media reactions to it [23]. In the work of Paolo Buono et al. [11], the daily routine of work team members is represented in a radial model where each ring represents a 24h work day of one team member. In *KronoMiner* [12] Jian Zhao et al. focus on non-intrinsically-periodic linear sequences of ordered time points.

Non-radial time-series visualisations based on calendar metaphors can also be found. In the work of van Wijk et al. [24] the calendar disposition is used to represent trends in different time levels: days, week, years. They apply clustering techniques to aggregate similar days and represent visually those clusters by colouring the calendar slots. In the work of Fernanda Viégas et al. [25] a calendar is used to represent the exchanged emails of a specific user and enable the users to explore their own email patterns. This visualisation shows the busiest days, through size, and how personal a day of emails is, through a coloured heat map. In the work by Maçãs et al. a calendar is used in a preliminary study for the representation of deviations in consumption values [26]. In these examples, the use of a calendar in a grid disposition makes it necessary to use more space, comparing to the same amount of data in a radial calendar. Besides, they represent only one year in each calendar—and we aim to represent more than one year.

All the above visualisation models are efficient in representing time-series. Nonetheless, we intend to overcome some specificities of their approaches. In the case of the *Circle View*, they use small multiples to represent different groups, and we aim to represent two years of data in a single visualisation, enabling a faster comparison between values. In the work of Paolo Buono et al. [11], as the team grows, the visualisation model has also to grow in size, making it difficult to compare all team members in one visualisation, and not complying with the above-mentioned requirement. In *KronoMiner* [12], the option to use different charts also requires more screen usage and might split the user's visual attention. While the use of spirals to represent time-series can be advantageous to identify cyclical patterns, they do not fit one of our tasks to discern the weekly patterns. For this task, we benefit if each week of the month is aligned, facilitating their comparison. By using a spiral, this would only be obtained if we defined its period (one lap) as week. With this project, we argue that other radial visualisations besides spirals can be equally efficient to represent cyclical patterns, and, at the same time, use less space.

With the state of the art, we could perceive that it is difficult to visualise several years in one visualisation without grew the model in size, use small multiples or get a too cluttered visualisation and that most of the visualisation models do not align the weekdays, making it difficult to compare the weekly consumption. In this project, we intend to explore these constraints and create a visualisation based on a radial calendar that enables: (i) the detailed comparison between different weeks of consumption; and (ii) the identification of yearly periodic behaviours in the same visualisation.

III. CALENDAR OF CONSUMPTION

Our radial calendar aims at assisting the SONAE's analysts to search for information about the sales values and how they change over time, the impact of a certain sales promotion, and the most relevant department in the business. The SONAE's analysts require an overview of the data which can be rapidly learned and easily passed within the team. Thus, the visualisation must be compact and simple, representing in a single image the whole time span and, at the same time, showing details about each specific day.

The analysed data is concerned with the consumption values gathered in a period of two years. Each product is placed within a product hierarchy of 6 levels. However, for this project, we aggregated all data by the first two levels of the hierarchy—namely the Department and BizUnit—as a proof of concept and to conduct a preliminary study of how our model facilitated the understanding of the data. Notwithstanding, our visualisation can represent any other level of the product hierarchy (our system represents each level independently). Besides, our model can be used by any other dataset, given that it is time-varying and uni-variate.

Our visualisation model can represent the Portuguese's consumption behaviour in the different weeks of the month, emphasising the repetition of such behaviours through the years. The use of radial calendars has a long tradition, especially in the representation of astrological data, such as the calendars from Oronce Finé in 1549. We wanted to reinterpret this calendar model in the new media to further explore this positioning of time and to emphasise weekly and seasonal behaviours and detect patterns over time.

A. *Tasks*

To represent the data, we explore a set of alternatives to augment the perception of periodic behaviours. Our model allows the understanding of how the consumption values vary in time within a specific Department, what is the most relevant Department in the business, and which month has the higher consumption values. To fulfil these requirements, we defined a set of tasks to which our visualisation model must respond: [**T1**] detect the overall yearly, monthly and weekly patterns; [**T2**] identify the behaviours within the first two levels of the product's hierarchy; [**T3**] detect the differences between weeks of a specific month or set of months; [**T4**] compare the consumption values between the two years of data; [**T5**] compare different Departments/BizUnits; [**T6**] detect the deviations in the consumption's behaviours.

B. *Data*

The data used for this project consists of the consumption values in 729 Portuguese supermarkets and hypermarkets of the SONAE's chains. When shopping in these retail stores, the customers tend to use their client cards to accumulate discounts and other benefits, enabling the association between customer and purchase. We analysed all the transactions made in these stores from May 2012 to April 2014. Each transaction corresponds to one product bought and has attributes such as price, date, and time of purchase.

We aggregated all purchases by BizUnit or Department, and by day. This decision was based on a preliminary analysis of the data, where it was perceptible a recurrent daily periodic behaviour through all Departments and BizUnits—at the beginning of the day the consumption values are low, they grow during lunch time and have their peak before dinner time. With the daily aggregation, we can overview all purchases in the different years without unnecessary clutter.

We also calculated the normal consumption value and its deviations. Our preliminary analysis of the data revealed that different days of the week tend to have different consumption values—being Friday, Saturday and Sunday the days with the highest consumption values, and Monday and Thursday the lowest consumption days. Hence, we decided to define this "normal" consumption value for each day of the week separately. Additionally, we calculated the "normal" week of consumption by month. This decision took into consideration the overall variation of consumption values within a given year. For instance, in December the consumption values are higher than in May, and a yearly normal week would be influenced by it, not representing

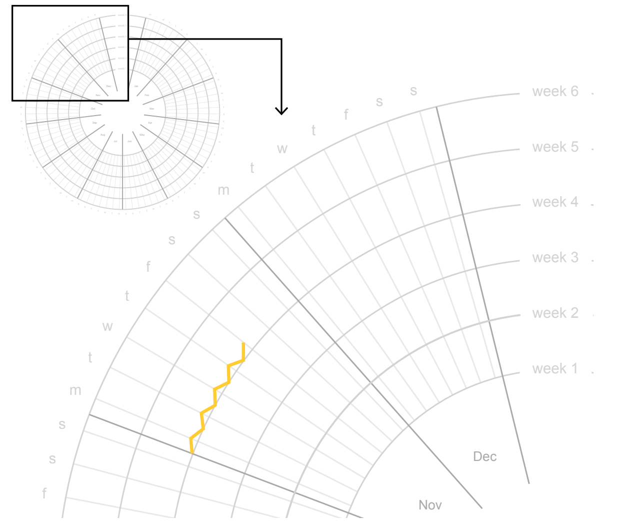

Figure 1. Structure of the radial calendar and respective labels positioning: month, in the inner part of the smallest circle for each wedge; day of the week, in the outer part of the biggest circle; and the number of the week, in the first wedge in the upper part of each circle. A yellowish zigzagging line will be positioned on the calendar to mark special events.

accurately the consumption values for each month. As such, to calculate the "normal" consumption value, we summed all values on each specific day of the week and month and divided it by that number of days. For the deviations, we calculated the difference between a specific consumption value and the previously calculated "normal" consumption according to its day of the week and month.

C. *Visualisation Model*

For the implementation and design of our visualisation, we divided the radial model into 12 equal wedges—representing the 12 months. As we wanted to represent and enhance the perception of weekly consumption behaviours and their repetition through different months, we opted to further divide each month wedge into seven parts—corresponding to the seven days of the week. Each week of the month is defined by a circle with a different radius. The first week is placed in the circle with the smallest radius, and the succeeding weeks are placed in the following circles (Fig. 1). With this positioning, we can compare the evolution of the consumption values among every week of every month, and easily perceive the weekly patterns [**T1**][**T3**]. We added labels to increase the readability of the calendar's values. These labels refer to the month represented in each wedge, the days of the week, and the number of the week (Fig. 1). We decided to separate the representation of the consumption values with the label of the week number, to increase the distinction between the end and beginning of the year. In our first analysis of the data, we perceived a substantial difference in the consumption values between December and January. With this visual gap, we aim to

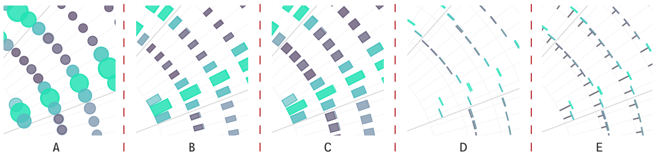

Figure 2. Different marks to represent the consumption values: (A) circles; (B) rectangles with width and height according to the consumption value; (C) rectangles with only the height representing the consumption value; (D) parallel lines; (E) parallel and perpendicular lines.

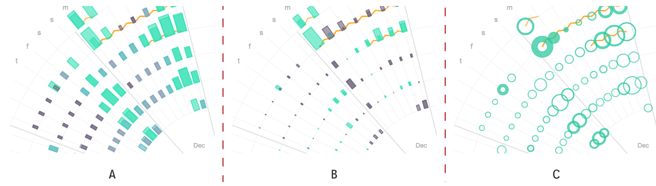

Figure 3. Three different visualisations: (A) the consumption values aggregated by day; (B) the deviations (size represents the deviation length and colour if it is negative or positive); and (C) the differences between years (the thicker the doughnut, the higher the difference).

emphasise this consumption difference and, at the same time, facilitate the identification of each week number.

The value of each day of consumption is represented through size. Yet, as the size of a mark can be difficult to analyse [27], leading to misinterpretations of the data and wrong comparisons, we decided to use colour to emphasise the differences in consumption. As the consumption values can comprehend a large range of values (millions), and subtle differences in colour would also be imperceptible for the user, we opted to restrict the colour palette to four possibilities. This colour palette is defined through the calculation of the quartiles of the consumption values, which divide the dataset into four equal groups. Low values get a darker purple tone, and high values get a green bright tone [ ].

For the representation of each consumption day, we explored the use of three different marks: circles, rectangles, and lines (Fig. 2). From these approaches, we promptly discarded the line marks as they were more difficult to read. It is difficult to compare the distances of the lines to the "baseline". Even with the perpendicular line to aid in that task, it is still difficult to read as the area that these marks occupy is reduced. In the case of the rectangle and circle marks, we concluded that the creation of gaps and clutter with the marks emphasise the consumption values and aid in the detection of higher consumption days (more clutter) and lower consumption days (more gaps between days). Both represent the consumption value with their size, but, as the circles are harder to compare, we opted to define the rectangles as our marks for the visualisation. To emphasise the differences in consumption values, we opted to use the rectangle marks where the length and width of the rectangle alter according to the consumption value.

The deviations are also represented by a rectangle, with a size corresponding to the absolute deviation value and coloured in green, if positive, or grey, if negative [**T6**]. Additionally, we defined another functionality to our visualisation model where we apply the circles to emphasise the yearly differences in consumption [**T4**]. We created a doughnut mark where the outer circle represents the maximum value of consumption, the internal circle represents the minimum value, and the area between them represents the difference in consumption. The thicker the doughnut, the larger the difference between consumption values (Fig. 3).

To improve the understanding of the consumption behaviours, we opted to give additional context about the data and marked on the calendar some of the principal festivities, e.g. Christmas and *São João* (one of the Portuguese traditional festivities). With the understanding that too much visual clutter may harm the legibility of the visualisation, we opted to represent the periods in which the festivities occur with a yellowish zigzagging line (Fig. 1). This line is intended to be visible but, at the same time, to not to draw too much attention to it. Therefore, it is drawn in a light colour and positioned behind the consumption marks. This representation is an effort to aid the user to create possible correlations between consumption and external factors.

D. Graphic User Interface

We implemented a web-application in *javascript* with a set of functions to enable the user to further explore the visualisation and get an overall understanding of the dataset. A video of the web-application can be assessed through https://vimeo.com/270077090.

The graphic interface is divided into two main areas: (i) the interaction area, placed on the left side of the page; and (ii) the visualisation area, placed on the right side (see Fig. 4). In the first, the user has access to the title of the visualisation, to a set of buttons that manipulate the visualisation, and to an index with all Departments and respective BizUnits. The title of the visualisation changes according to the Department or BizUnit that is being represented (e.g. "Analysis of Grocery").

Below the title, we positioned a set of buttons that enable the user to: (i) see the deviations from the normal consumption value [**T6**]; (ii) see the total consumption value by day [**T1**, **T2**, **T3**]; (iii) see the mean consumption of the two years that occur on the same slot of the calendar [**T1**]; and (iv) see the difference between the higher and lower consumption value [**T4**] (Fig. 3). The third functionality can be used in conjunction with the deviation and total consumption value visualisations.

Also in the left area, the user can explore the product hierarchy through an index. In the beginning, the user only sees "All Departments", which means that, currently, the visualisation is representing the values aggregated only by

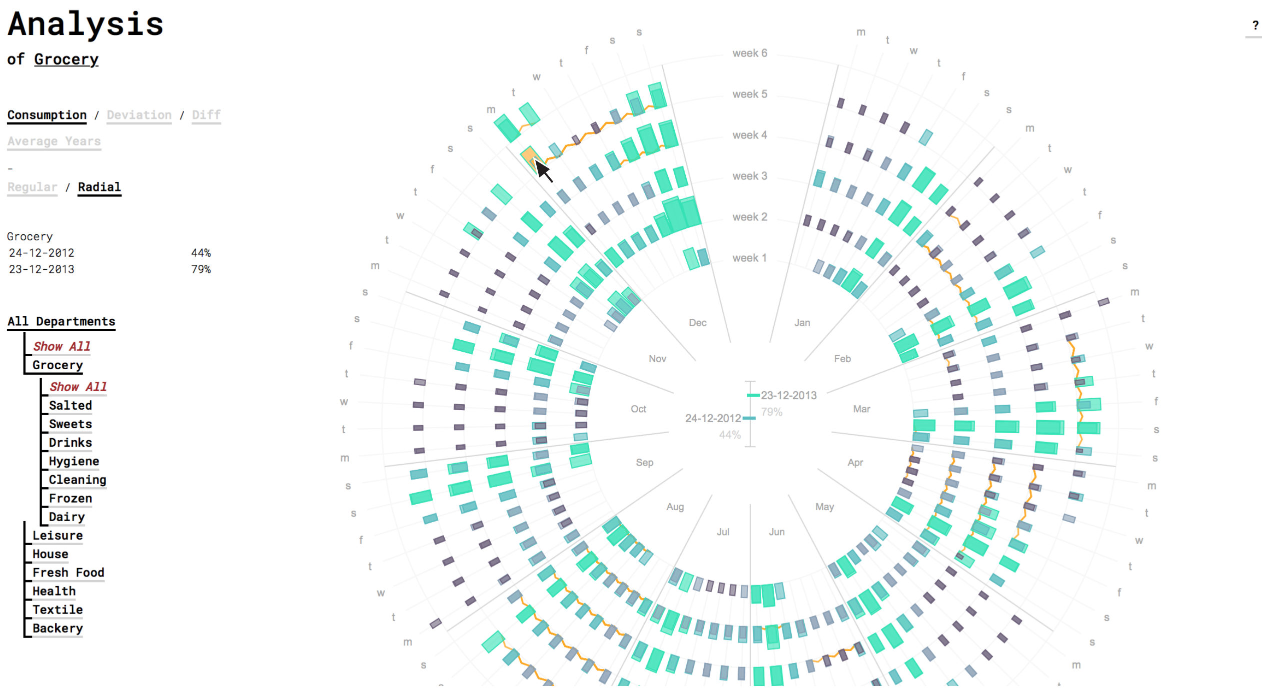

Figure 4. By hovering the mouse over the rectangles, the user can see the percentage of consumption on those specific dates. This information appears in two places: (i) in the centre of the calendar visualisation; and (ii) above the index of all Departments and BizUnits. A video of the web-application can be assessed through https://vimeo.com/270077090

date, not distinguishing Departments or BizUnits. As the user clicks on "All Departments", a list of all Departments will appear below. In addition to the Departments, we also added a button entitled "Show All". By clicking on it, the user will see the mean week of consumption in each month for every sub-level (Department or BizUnit) [**T5**]. To distinguish it from the other Departments/BizUnits, we used an italic font and coloured it in red.

When hovering each consumption mark, the user gets additional information about the data (Fig. 4). This information consists of the dates and percentages of the consumption values and appears: (i) in the left area, between the functions and the index; and (ii) inside the radial calendar, in a visual chart. This way, the user can analyse more precisely the differences in consumption on the same calendar's slot.

Finally, in the bottom right corner of the interface, there is a label, containing information about the used colours, the relation between size and consumption value, and the used representation for the festivities.

IV. USER STUDY

We conducted a user study to compare our radial calendar to a regular calendar layout. The objective of this study is to explore the intuitiveness and effectiveness of the radial layout in the representation of consumption data. For this study, 30 participants tested the two visualisation models in relation to performance (efficiency and accuracy) and visualisation quality (subjective evaluation of clearness, intuitiveness and general attitude toward a visualisation). The participants' age was between 21 and 47 with an average of 27, and, on average, ranked their expertise in visualisation has "some understanding of the visualisation domain". Each testing session took between 15 to 30 minutes.

A. Method

The study envisioned three different phases. In the first, we contextualised the used data, the visualisation interface (presented in III-D), and the two visualisation models. In the second phase, and to reduce user fatigue, the participants had to fulfil 6 tasks: [**Ta**] In which pair [month, week] the consumption tend to be higher?; [**Tb**] Is there any week with recurring higher consumption? (comparing to the others); [**Tc**] Which BizUnit has higher consumption averages during the year?; [**Td**] Is the consumption in the 1st Saturday of January higher than the 3rd Thursday of August?; [**Te**] Which pair [month, week] has higher deviations?; [**Tf**] Which pair [month, week] has higher differences between years?. Since our aim was to compare two alternative visualisations, instead of evaluating the interactive prototype itself, we used static images of the two visualisations along with the study task. In each test and for each task, we randomly used one visualisation model to represent the same dataset. All tests had a total of 3 tasks answered with the radial calendar and 3 with the regular one. The two

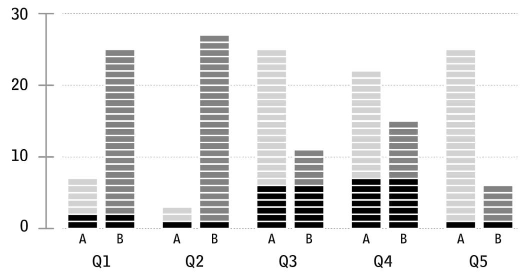

Figure 5. Distribution of answers to the questionnaire (each rectangle represents one answer). The lighter grey (columns A) represents the regular calendar, and the darker grey (columns B) represents the radial one. Black is used to indicate when a participant answered both models in a certain question.

visualisation models were well distributed, being used 15 times for each task. For each participant, the tasks and the visualisation model to accomplish it were randomly sorted. For each task, the participant had first to read the task in hand, and then choose from a multiple choice answer. The time between the reading of the task and the answer was counted. After answering to the task, we asked the participant to rate its difficulty. In the third phase, the participant was allowed to freely look at the prototype and interact with the visualisations. Then, he/she had 5 questions to compare the two visualisations: [**Q1**] Which visualisation was more aesthetically pleasing?; [**Q2**] Which one arouse more curiosity?; [**Q3**] Which one was easier to learn and to navigate?; [**Q4**] Which one you found more useful?; [**Q5**] Which one seemed more intuitive?. In the end, the participant could give subjective comments on the models.

B. Results

To analyse the results of the user testing, we used the statistical software SPSS version 24. To check if our data followed a normal distribution we applied the Kolmogorov-Smirnov test with a level of significance $\alpha = 0.05$. The test revealed that the data did not follow a normal distribution. Based on this, we applied a set of non-parametric tests. We used the non-parametric multivariate version of the ANOVA, at with a $\alpha = 0.05$. If we perform our analysis considering the Model variable only, the results revealed that in terms of time, the regular calendar model is statistically different from the radial model (p-value = 0.019). In what concerns accuracy, there are no significant statistical differences. Additionally, if we consider the Model and Task variables together we see no statistically meaningful differences. Looking at this results, we conclude that there is no superior model for answering all the questions. We also analysed the perceived difficulty of each Model and concluded that there is a small statistical difference between the models (p-value=0.047). The p-value is very close to the significance level, meaning that to confirm this significance we would need to perform more tests.

For the five final questions of the test, we used a $\chi - squared$ for categorical variables. We found that there are statistically meaningful differences in all the questions (p-value = 0.000). Figure 5 illustrates the distribution of votes per question. As one can perceive, the majority of participants found the radial visualisation model more aesthetically pleasing [**Q1**] and it was the model which arouse more curiosity to explore the data [**Q2**]. The fact that the regular calendar was assigned to the most intuitive [**Q5**], is related to the fact that this layout is more familiar, as we are accustomed to interacting with this type of calendars in a daily basis. This fact also explains the tendency to chose the regular calendar as the most useful and easier to learn [**Q3**][**Q4**]. However, there was a higher number of participants which chose both visualisations in [**Q3**][**Q4**], revealing their uncertainty from which to choose.

In the comments section, most participants stated that, after some interaction, the radial visualisation was easier to read. A participant also stated that as the radial visualisation condenses better the information, it brings more insights. Although all participants stated that there is an unavoidable familiarity with the regular calendar, the radial calendar aroused more curiosity in them. One participant also stated that once learned, it was impossible to not to prefer the radial visualisation. Some participants also gave particular insights: one stated that the doughnut visualisation of the differences was very intuitive, and another referred to the regular visualisation has a better alternative when comparing specific days of the month. To facilitate this last task, a user referred that interaction would improve the comparison of different days in the radial calendar.

With these results, we can conclude that the regular model is more intuitive at first, but as the user learn to navigate and read the radial, it can be a better choice to represent time-varying data.

V. CONCLUSIONS

In the present work, we explore a radial calendar visualisation to support the analysis of time-series and the detection of periodic behaviours. We present our design choices for the visualisation model as well as for the definition of the graphic interface and interaction functionalities. We apply our visualisation model to the Portuguese's consumption data, during the months of May 2012 to April 2014, but, this model can be used with any other time-series data. Our main contributions include: (i) the characterisation of the Portuguese's consumption behaviours; (ii) the identification of patterns and periodic behaviours throughout the years; (iii) the highlight of weekly behaviours; and (iv) a user study to compare a radial calendar layout to a regular calendar one.

As future work, we intend to: (i) allow further analysis of the lower levels of the product hierarchy; (ii) enable the user to know which product/category led to higher consumption values in the form of a visual hint; and (iii) implement a query system, so the user can search for specific products without having to resort to the interface buttons.

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