Representation of Time in Digital Calendars

An Argument for a Unified, Continuous & Multi-Granular Calendar view

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Digital calendars have been heavily influenced by the design of the physical calendar and have invariably adopted their grid representation of days in the month. We argue that the alternative of a continuous list representation of successive days would offer several advantages such as faster calendar search, a more natural linear view of time, a scrollable and zoomable interface and better scalability for devices of different size. This prospect brings new design opportunities, especially for modern, touch-centric operating systems where a linear representation could benefit from the native support of scrolling and zooming.

We tested search performance and navigation with digital calendars in a comparison of grid and list representations by employing a remote, web-based method. On their personal computers, participants performed a series of search tasks in a fictitious calendar. The results show that calendar search is faster in list view when searching for dates, between month breaks and in the next month (with and without navigation). Searching for days is faster in grid view, however, with highlighted days in list view the difference in search times becomes insignificant. The results indicate substantial promise for the list view digital calendar and we describe a high fidelity rendering of the user interface for a digital calendar with a list view.

Keywords: digital calendars; time management; usability; interaction techniques; interface design

1. INTRODUCTION

Current generation digital calendars typically provide an essentially static viewport with navigation by discontinuously advancing through a sequence of consecutive screens (week to week, for example), or by discontinuously switching to a different representational format at a different temporal scale (days to months, etc). In addition, the daily, weekly and monthly views all utilise a different layout, leading to a loss of context and orientation (see section 2.2). In this paper we suggest a unified, continuous and multi-granular representation of time by means of a list-based view and the possibility of dynamic manipulation by scrolling and zooming. Such an interface would be unified because it combines the daily, weekly and monthly views, it would be continuous as it displays any arbitrary time interval and it would be multi-granular as it displays different temporal resolutions on different zoom levels. In section 2 we explore the advantages of such a representation but also discuss a resulting design challenge: In a grid it is easy to scan for certain days such as weekends but a list view needs to introduce additional cues to accomplish this (e.g. a higher order visual structure implemented through colour coding). Section 3 and 4 present a web-based study in which participants performed calendar search and navigation using both a grid and a list view calendar. Besides task execution times as a measure of efficiency, the reactions of participants towards both layouts were recorded with a questionnaire. In the following section we look at current digital calendars, calendar usability and the origin of the Gregorian calendar.

1.1 Origin

Digital calendars have mostly replicated rather than re-invented the paper calendar and to better appreciate this fact we should briefly remind ourselves of the origin, form and cultural significance of our calendar. The calendar owes its structure to astronomical cycles: its division into days and years reflects the movement of the earth around the sun, whilst months and weeks are determined by the lunar constellation (Kuhn & Koupelis, 2004; Steel, 2000; Boiy, 2004). All systems for describing and measuring time have attempted, with greater or lesser success, to synchronise with natural events including the seasons and moon phases (Richards, 1999; Rüpke, 1995, 2006). The Julian calendar (introduced by Julius Caesar in 45 BC) had an annual cycle some 11 minutes longer than the average solar year (Blackburn & Holford-Strevens, 1999). The Gregorian calendar we know today was first introduced in 1582 by Pope Gregory XIII (Feeney, 2007) and only needs an annual adjustment in the order of seconds (Nelson et al, 2001).

The consistency of the Gregorian calendar with the solar year is important to us in at least a general sense, but its lunar-centric features are probably not. An alternative decimal system would have several obvious attractions and such a system was used in China until 1645 (Yabuuti, 1963) and in France for a year following the French Revolution (Zerubavel, 1977); in 1998, the watchmaker Swatch attempted briefly to revive interest in a decimal system (Lee & Liebenau, 2000). However, the Gregorian calendar remains the de facto international standard and shows every sign of enduring in exactly the form it has now. In contrast, the way in which the calendrical system is represented has not reached an evolutionary end point and instead the scope for innovation is increasing with advances in the media for interacting with calendars and the variety of settings in which people will use them.

1.2 Layouts

Many different calendar layouts can be found and more will emerge. A large, shared wall calendar for the office or the whole family to use will likely use a different representation to one used in a personal organizer on a mobile device. The most familiar layouts are either a grid or a list view, examples of each appear in Figure 1.

Fig. 1. Grid and list view calendars.

The list view is the oldest known format for calendars and was used in ancient Egypt where calendars were written on rolls of papyrus. The physical scrolling involved in reading a papyrus document lends itself well to a linear representation of calendars (Rüpke, 2011). Yet a list layout can also be found in old roman calendars, which often were written on large tablets of stone (Rüpke, 1995, 2006).

It is not known when and why the grid view emerged but it was likely a response to new tasks and to changes in physical media. For example, perpetual calendars required computation of the days of the week for a particular year, for which a matrix of dates and weekdays is best suited; in the "Kalendarium Gregorianum perpetuum" (Catholic Church, 1582) can be found tables that come close to today's two dimensional grid layout. By the 19th century perpetual calendars appeared in the form of a table exactly resembling today's grid view (Choate, 1848). But it is also likely that the grid view was created as a compact layout for multi-paged calendars. If your medium consists of discrete pages rather than a continuous surface, you have to define a break point for each page and the calendrical structure with 12 months already offers these break points. Especially for large, shared calendars, the grid layout shows advantages as the cells become a large enough surface to annotate with information about appointments while maintaining a suitable aspect ratio of 7:4 (weekdays : week numbers) which approximately fits standard paper sizes. For this reason the grid view is also a popular layout for wall calendars today.

Comparison of the grid and list layouts in terms of their efficiency must take account of both the medium and the task. We will examine the characteristics of the list and grid view on electronic devices, focusing on search and navigation. Search and navigation are recurring, primary tasks within a multitude of calendar related activities such as planning and coordinating events, recording events or recalling events.

1.3 Digital calendars

In this paper we propose a dynamic, scrollable and zoomable list view as means to a unified, continuous and multi-granular calendar layout. Our survey of contemporary digital calendars found no such representation being used (amongst others we looked at the calendars included with Windows, OS X, Ubuntu, Debian, Fedora, OpenSuSe, iOS, Android, Windows Phone, Bada, MeeGo, QNX, Web OS, Blackberry OS, Symbian, Microsoft Office, Open Office, Google Docs, Oracle Enterprise products, SAP, VMware Zimbra, Yahoo Mail, AOL Mail, Mozilla Sunbird & Lightning, Windows Live and Facebook). This observation applies equally to early digital calendars such as those featured in the Casio SF-4000 (released in 1988), the Atari Portfolio (released in 1989) or in early Windows and Mac operating systems. In his influential study of calendar usage, Payne (1993) examines the grid view calendar, stating that it was representative for that time.

For the early graphical user interface, the choice of a grid view calendar made a lot of sense. Even at the time of Payne‘s study the mouse wheel had not yet been invented (Atwood, 2007) and scrolling was a more restricted interaction idiom, a fairly indirect manipulation involving pointing at widgets in a scroll bar. Tabs and pop-ups were highly favoured interface elements within a book-like metaphor in which pre-defined content areas (‘pages’) were successively displayed. In contrast, today's touch centric interfaces rely heavily on scrolling and with the introduction of multi-touch to PC operating systems it is migrating into the desktop interface. Furthermore, web 2.0 designs radically increase the amount of scrolling on web pages. Where once it was good practice to distribute content over multiple pages to keep loading times short, modern web applications like Facebook or Twitter are now able to dynamically reload content as needed. Continuous scrolling is achieved as new contents appear automatically at the bottom of the display creating the illusion of a ”never ending” website. Lots of content can be aggregated because of the continuity in access afforded by scrolling and zooming with resistive touch technology. Curiously, these new touch-centric interaction techniques have not been exploited in digital calendars; there has been no re-examination of how best to represent time on electronic devices. Instead, the grid view has simply migrated from mouse-based to touch-centric interactions and a zoomable list view is nowhere in evidence.

While there are some list-based layouts being used in digital calendars they are very different from the list view that we propose in this paper. The most common examples are daily or weekly views that are usually presented as a list. However, instead of navigating by scrolling and zooming, the user usually has to switch between the different layouts and with the monthly view still being represented as a grid this inevitably leads to a loss of context and orientation each time (also see section 2.2). Another list-based layout is the so-called “agenda view” (see figure 2), which is commonly found on mobile operating systems. In contrast to the zoomable list view suggested here, the agenda view is a list of events and scheduled tasks, not a list of days. This is likely to have a substantial impact on usability: The canvas of a zoomable list view makes a strong connection between metric and temporal units. The proportionally spaced days and weeks help the user orientate in time. The agenda view however provides no such visual cues. For example, days with many appointments take up more screen space and days without appointments are not listed at all. This is even more alarming if we consider that it waives one of the major contributions of the Romans to time management: the standardization of the length of the month, visually and conceptually. Rüpke (2011) speaks of the “Strukturidentität” (identity through structure) of a month that provides a framework for orientation and planning. It is only then that concepts like “early May” or “at the end of the week” gain any meaning. The agenda view does not represent the Strukturidentität of any calendrical unit such as a day, week or month, making the view hard to read and reason with. While it has been an acceptable solution to overcome some of the limitations of the grid view on mobile devices (see figure 4) it cannot compare to a zoomable list view in terms of features and usability.

One of the reasons that, despite its apparent advantages, such a view has to date not been used in digital calendars is that it requires an excessive amount of resources to produce if compared with a standard digital calendar. A zoomable interface capable of displaying different granularities of time needs complex clustering algorithms, similar to those that are used in map applications.

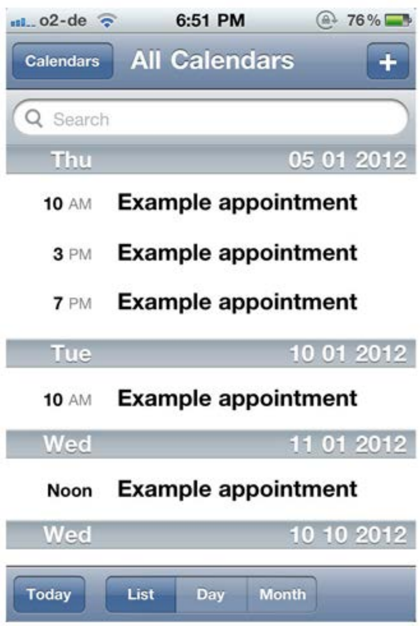

Fig. 2. Agenda view in iOS (called “List”).

Keeping this in mind, it is not surprising that the only example of a zoomable list view we could find is a ‘thought piece’ from Microsoft, a video envisioning the office of 2019 (Microsoft, 2009). Clearly visible in the video are electronic calendars using the list view on touch screen interfaces; however no prototype was built and the actors interact only with sheets of green cardboard that were then rendered in post-production as interactive interfaces. The status of this future concept within Microsoft is not certain but in any case and despite the technical challenges, we should not have to wait seven more years for a list view calendar. Multi touch interfaces are widely used and analysts project an annual growth rate of up to 66% for tablet devices (Gallagher, 2010). Therefore, this paper will explore the potential of an electronic list view calendar and ask whether it is sensible to invest in the development of such a UI.

1.4 Calendar usability

While there has been a good amount of research into calendar use and the implications for calendar design at a macro level (e.g. concerning groupware calendars, Palen 1999, forcasting algorithms, Tullio & Mynatt 2007, perceived busyness, Leshed & Sengers 2011, the use of shared calendars in relationships and families, Thayer et al. 2012, Neustaedter et al. 2009, calendars as memory aids, Wu et al. 2010, or the integration of data from social networks, Lovett et al. 2010), there has been relatively little research into calendar layout and most of it has examined only the grid-view. White (1989) noted how little attention has been paid to the layout of calendars and reported a comparative study of the effect of calendar layout on time to search for a stored event. The formats were different versions of the grid view, varying the first day of the week (Sunday or Monday) and the orientation of the grid (weeks configured as columns or rows). His results indicate that search is faster for horizontally arranged weeks and that the first day of the week does not affect search times.

While White's study was oriented towards the layout of wall calendars, later research has examined digital calendars and their interactions. Furnas (1986, 1991) observed that the monthly view shows context well but obscures the details of calendar entries, while the converse is true of the weekly or daily view. His solution is a grid layout with a fish-eye view where cells occupy different space depending on the distribution of their contents.

Another fisheye calendar interface has been described by Bederson et al. (2004) who looked at calendar use on mobile devices. On a small screen, the grid view can only indicate appointments (e.g. by colour coding) but not reveal its contents. Re-sizing a selected cell to re-size the contents and make them visible would be one solution. However, the fisheye concept destroys the essential symmetry and visual simplicity that is the major advantage of the grid view and it has not appeared in commercial products.

Neither Furnas nor Bederson et al. considered the alternative of the list view calendar even though it could resolve the issue of finding a good mixture of context and detail and the issue of displaying a calendar on a small screen. This will be discussed in more detail in section 2.2 and 2.4. A study by Mackinlay et al. (1994) did consider alternative layouts but only to propose complex 3D visualisations, which have neither materialized in a distributed form.

As well as its representations and interaction techniques, use of the calendar in time management has been investigated in relation to setting up appointments, managing recurring events or handling alerts. Payne (1993) interviewed 20 IBM staff to understand their apparent preference for paper calendars and concluded that paper calendars are easier to browse and offer a better spatial representation of time. He also notes that electronic calendars typically do not allow users to make entries for arbitrary time windows but only for particular days or hours. More recently Tungare et al. (2008) found a majority of the users they studied were using physical calendars for similar reasons to those reported by Payne.

2. UNDERSTANDING THE LIST VIEW

To better understand the list view layout we can examine its advantages both generally and in comparison with the grid view; we can consider these benefits in relation to two core interactions with digital calendars: search and navigation. We will assume that the digital calendar is presented on a multi touch interface supporting scrolling and zooming.

2.1 A linear visualisation of time

The linear visualisation of time in the list view brings several benefits. First, it reflects the linear way we tend to view time; external representations should map directly to our mental representations (Scaife and Rogers, 1996). Culturally stereotyped concepts of time have been widely investigated and have usually reported "that time is a unidirectional line, that the position of the speaker marks the position of the present and that the future and the past lie on opposite sides of the speaker" (Mitchell & Sommers 2007, p.226). An intriguing exception is the Aymara tribes people in South America whose spatial construction of time treats the future as lying behind their backs rather than in front of them (Nunez & Sweetser, 2006). While most insights about our mental model of time come from studying spoken language, the same principles have been found in sign language where time is presented as a linear structure extending from the front of a speaker to the back (Frishberg & Gough, 1973).

Second, the linear visualisation should enable a faster search for dates because users are able to more accurately predict the position of a particular date spatially within its ordered sequence. Consider, for example, where you should look for a date three weeks ahead in the list view, contrasted with where to look in the grid view for the 19th of the month if the first of the month happens to be, say, a Wednesday. Usually it would be faster to perform a progressive visual search through all items than to attempt to predict the location of the correct cell in the matrix. Our expectation of a better overall performance in the list view when searching for a date was tested and the results are reported in section 3.

Third, the primary spatial dimension of the list view naturally encourages standardization in layout. By contrast, the grid view encourages variation in spite of an international standard covering the format of date and time (ISO 8601, 1988). Variations are found in the first day of the week (Sunday or Monday) and the orientation of the grid (horizontally or vertically arranged weeks) (White, 1989; Mitchell, 2004).

2.2 Compatibility with the touch-centric interface

The list view is particularly suited to touch-centric interfaces and for several reasons. First, it provides a better fit with the “endless-page” metaphor of touch centric interfaces. Gestural interaction with a moveable and resizable canvas, for example in map applications, has transformed the user’s experience of interacting with this new genre of interface.

Second, the list view allows customization. Existing electronic calendars typically offer the alternatives of monthly, weekly or daily views. Continuous zooming on a calendar interface would allow users to continuously vary the granularity in the view, for example depending on how many appointments were on different days. While some grid-based calendars have experimented with scrolling, zooming a grid leads to either a fish-eye view or a loss of context. With a list view however, the combination of scrolling and zooming would allow the user to freely manipulate and adjust the displayed time span. Figure 3 presents a design for the list view at high scale and low granularity, showing that when zoomed-out, the view is able to provide orientation and navigation across periods of many months. Similarly, using one of the now common gestures for zooming such as a two-finger pinch or a double tap, the user could choose a view that shows only a couple of hours, but in high detail.

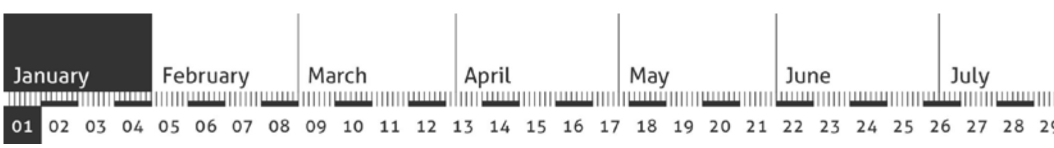

Fig. 3. A low-granularity list view variant showing more than 200 days / 28 weeks

Third, scrolling and zooming are efficient ways to interact with digital calendars. They eliminate the pointing at buttons that adds significantly to the user costs of interacting with graphical user interfaces (e.g. MacKenzie, 1992; Wobbrock et al. 2008). Scrolling and zooming can be performed anywhere on a multi touch surface. The hypothesis that scrolling is more efficient than clicking to skip to a different month will be tested empirically in section 3. Removing buttons also has the benefit of reducing visual clutter, consistent with standard guidelines such as ”eliminate what can be eliminated” (Microsoft, 2010, p.22) and ”an uncluttered user interface is essential” (Apple, 2011(2), p.37) and recommended for user interfaces for different devices (Rossen, 1989; Swain, 2008, Apple, 2011).

Fourth, the need for re-orientation after discontinuous changes of views is eliminated with scrolling and zooming within the list view. Studies clearly show that user interfaces benefit from continuous transitions because users do not need to re-orientate; animations help to maintain a mental map of spatial information, even if not all of the information is displayed on the screen at all times (Bederson & Boltman, 1998; Shanmugasundaram et al. 2007). The benefits of interface animation are well summarized by Chang and Ungar (1993): ”By making it easier for the user to track objects and understand what is changing on the screen, animation offloads some of the cognitive burden associated with deciphering what is going on in the interface from higher cognitive centres to the periphery of the nervous system” (p. 14).

Fifth, by eliminating the grid view’s visual discontinuities between months, users can more easily work with events that cross month boundaries. Within the list view, those events can be shown completely. The hypothesis that events, which fall in between two months, can be handled faster in the list view will be tested empirically in section 3.

2.3 “Today” is at the top

Another advantage of the list view is that it allows the current day to be displayed at the top as a default position. This is helpful when opening the calendar for a number of reasons: dates in the near future are consulted more often; placing them at the top makes them easy to find and signals their importance. Additionally, as a linear layout allows for different sized cells, ‘today’ and ‘tomorrow’ could be given more space with the granularity of events varying into the future. In their research about different time granularities, Maria Kutar et al. (2001) note that ”if today is Monday, and our meeting is arranged for next week, Thursday, at 10am for one hour, we might initially consider our meeting to be over a week away. At this stage the finer granularities are of no real significance to when the meeting is with reference to today. [...] On Thursday itself, we would think of the meeting as being today, at 10am, or perhaps, an hour away [...]. By now, the coarser granularities do not convey the information about the time of our meeting in a form that is easily understood” (p.56). So with the possibility of varying the granularity of the display into the future, the list view can reflect the same user’s mental model.

Possibly the most significant advantage of displaying the current day at the top is that users are able to look several weeks ahead. The number of upcoming visible days depends on the zoom factor but can easily exceed 30 days even on devices with small screens such as phones. Contrast this with the grid view where on average only 15 upcoming days are visible and sometimes far fewer. And even though it is only a secondary requirement for a calendar the user can always scroll back in time to view past events. We tested the hypothesis that the permanent visibility of the upcoming weeks leads to faster calendar search and present the results in section 3 and 4.

2.4 Flexible layout

The list view offers a more flexible layout in a number of respects. First, cells can expand easily, for example when selected by the user to reveal more details. The limitations of the fisheyed grid view have already been noted.

Second, the list view offers a more useful annotation surface. While the grid layout consists of square-like cells, the list view has cells with a much wider aspect ratio in which significantly more characters can be fitted because of the saving in line breaks needed. We have tried to quantify this advantage using a standard screen resolution of 1024x768 and average word lengths and found the list view to be able to display over 30% more characters.

Third, while in grid view the second dimension is taken up by the days of the week, in list view it is available to encode further information. For example, a second axis could indicate at which time an appointment takes place. Alternatively, the second axis could be used to indicate separate columns for separate types of appointments such as private and business calendar entries, public holidays or birthdays. Calendars from different sources like Facebook, Google Docs or LinkedIn could be displayed on the same screen but in different columns. Furthermore, the second dimension could be used for easy calendar sharing and project management. The calendars of multiple persons could be displayed side by side in different columns, for example to provide an overview of who is free on certain days.

Fourth, the list view offers a better scalability. It can be used one-to-one on small screens and mobile devices. Today's digital calendars have to make extreme trade-offs on small screens as the grid view shrinks content to an unreadable size (see figure 4).

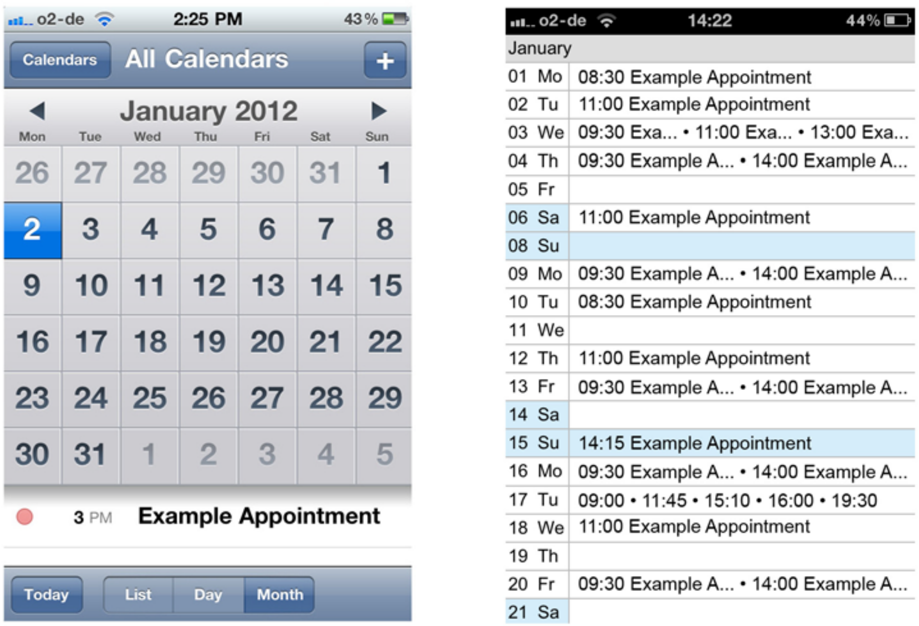

Fig. 4. Standard iOS calendar and a list view prototype with scroll and zoom.

Appointments therefore have to be indicated by an icon or non-symbolic means such as colour coding. Calendar entries can only be viewed in a small area below the grid after the respective day has been selected. In contrast, the list view can display the appointments for a whole month on a 3.5-inch screen in a readable font size. Choosing a more comfortable font size there is still room for more than three weeks. A list view calendar for smartphones and larger touch screen devices like tablet PCs could not only provide a superior usability but also a consistent cross-platform user experience.

2.5 Limitations of the list view

The advantages of the list view layout are extensive and compelling but some limitations are apparent nevertheless.

First, the days and weeks matrix of the monthly grid view makes it easy to identify and think about recurring weekly events. But recurring events are probably less common than one-time events and are often scheduled using a weekly view rather than a monthly view. The weekly view of a grid calendar is effectively equivalent to the zoomed-in list view calendar. A more common situation triggering the search for days of the week is a suggestion like "we should meet on the first or second Tuesday next month". A grid-view calendar user could respond to this by first finding the column for Tuesday and then scanning down. In list view one would have to search for the first and second Tuesdays separately unless some mechanism were provided to identify the succession of Tuesdays. Both the hypothesis that grid view is faster when searching for a day of the week and that this advantage decreases or is even removed completely when the days of the week are highlighted in list view will be tested empirically in section 3.

Second, using the grid view a whole month can be displayed in a very compact form. This format does leave no room for calendar entries but is often used as a simple date picker, e.g. when selecting flight dates on an online booking site. However, this advantage really only applies to ultra-compact formats and not to digital calendar applications which are the focus of this paper. As soon as calendar entries have to be displayed the list view offers advantages such as a more efficient text layout as discussed in section 2.4.

The study we report was to verify our conjectures about these limitations and also to attempt to assess the user experience of the list layout, taking account of the great familiarity users have of working with the grid layout.

3. METHOD

Many advantages of the list view layout became apparent during our examination of the layout, particularly when considered against the grid view layout and in relation to search and navigation interactions. Overall we believe that the list view offers faster calendar search in most situations with the notable exception of search for a day of the week. The following scenarios and hypotheses represent key and representative advantages we have identified. They were each tested in the study that we report. The individual tasks were constructed based on existing research (White, 1989) as well as observations of calendar users and their typical scheduling routine.

A: Search for dates
(Participants search for a date, e.g. the 21st of January.)
H1: Faster in list view, see section 2.1

B: Search for days, no highlights in list view
(Participants search for a day, e.g. the third Sunday in January)
H1: Faster in grid view, see section 2.5

C: Search for days, days highlighted in list view
(Same as scenario B but e.g. with all Sundays highlighted)
H1: Less difference than in scenario B, see section 2.5

D: Search between month breaks
(Participants search for a time span between two months)
H1: Faster in list view, see section 2.2

E: Navigation: Search in next month
(Participants search for an appointment in the next month)
H1: Faster in list view, see section 2.2

F: Outlook: Search in next month, no navigation needed in list view
(Same as scenario E but with the current day in the scenario being the 15th of the current month. Therefore, in list view the 15th is at the top and part of the next month is visible without navigation)
H1: Faster in list view, see section 2.3

3.1 Participants

62 people participated in the study remotely by interacting with a web server on which the experiment was running. The records of 51 participants were fully complete and therefore

used for the analysis. 26 of those participants told us they were males, the median age was 25 (min = 22; max = 64). Participants were recruited via an invitation posted to a Facebook Group for UCL (University College London) students, with some of those students further promoting the study among their Facebook contacts by “liking” or reposting the original request (see section 5.2 for a discussion of the sampling method). Consequently, 76% of the participants told us they were students at the time of the study. All but 4 participants stated they were regular calendar users with 32 participants utilising electronic calendars. However, most participants estimated the frequency of their calendar use to be low or average with only 8 participants having to schedule 3 or more appointments on a usual day. It took the participants about 10 minutes to complete the study and they received no payment as a reward.

3.2 Design

A within subject design was chosen with each participant performing calendar search tasks with both grid view and list view calendars. The time to complete the search tasks and the error rate were recorded. Multiple measures have been performed for the different scenarios (A to F) of calendar search listed above.

3.3 Materials

Web pages were created for the online experiment to present instructions and questions to the participants and a list view and a grid view calendar. The web site was built using HTML, CSS and Javascript on the client side and PHP and MySQL on the server side. It was decided to measure response time at the client system using Javascript so that the data would not be affected by internet connection speeds and latency.

Several pre-tests were carried out to ensure cross-browser compatibility. Microsoft‘s Internet Explorer was found not to display the calendar designs correctly and was excluded from the experiment; Internet Explorer users were asked to instead complete the experiment with a different browser.

All participants stated that they were using either a mouse or a touchpad as an input device. This is backed up by the collected statistics on participants’ browsers, operating systems and hardware-settings, indicating that only standard desktop or notebook computers and no touchscreen devices were used to complete the study. Implications of this are discussed in section 5.2

3.4 Procedure

Participants were asked to follow a link that took them to the home page of the web-based study, which explained the general procedure and asked them for demographic details. Participants were then asked to take the role of two different students, one using a grid view calendar, the other a list view calendar. They were asked to perform 9 search tasks for each view consisting of three practice trials followed by 6 test trials where their search was recorded. For each of the 6 test scenarios, two similar tasks had to be developed (e.g. ”What day of the week is the 17th / 23rd of February?”, the complete list of questions can be found in the appendix). While the order of the tasks was fixed it was randomised as to whether the participants saw the grid view or the list view calendar first.

Fig. 5. Experimental procedure: the 3 different pages of a search task.

Each search task consisted of three different pages (see Figure 5). On the first page participants were presented with a question. Participants were also informed that while they should respond as quickly as possible it was equally important to answer a question accurately. On the second page participants saw the (fictitious) calendar of one of the students. On the third page participants could answer the question in a multiple-choice format. This three-step process was intended to remove the confounding effect of the time needed to read the question or to answer it. The time recorded was the time that participants spent on the second page of each search task. The "onLoad" Javascript command was used to start the timer as soon as the second page had loaded. The timer was stopped when participants clicked on the link to switch to the third page.

At the end of the experiment users were asked to complete a questionnaire in which they rated both types of layouts and gave additional comments in a free answer format. Participants were also asked which layout they would prefer in a forced-choice format. These results are discussed separately in section 4.3.

4. RESULTS

4.1 Pre-Analysis

The first step of the analysis was the calculation of the error rate. It was consistently low (under 5%) for all 12 test trials and no different for the two calendar layouts. Therefore the error rate will not be discussed in more detail. All false responses have been excluded from the data set before the search times were analysed. The second step of analysis determined if any of the demographic variables and data about the used technical equipment had a significant impact on search times. No significant effects were found.

In detail, the effects of the following variables on overall calendar search time have been examined with a one-way ANOVA: The input device used (mouse, touchpad, other, $F(1,48)=.58$, $p>.05$); the way of scrolling (on-screen scrollbars, mousewheel or touchpad gesture, $F(1,48)=1.91$, $p>.05$); the level of expertise with a computer (novice, advanced, expert, $F(2,48)=3.53$, $p>.05$); the kind of calendar regularly used (paper, electronic, both, none, $F(3,48)=.97$, $p>.05$); the preferred time range for a calendar (daily view, weekly view, monthly view, varying views, $F(3,48)=1.99$, $p>.05$); the number of appointments on a usual day ($F(3,48)=.12$, $p>.05$); the gender ($F(1,48)=1.84$, $p>.05$); the first language ($F(1,48)=.09$, $p>.05$) and the age ($F(14,48)=1.64$, $p>.05$). While it was expected that at least the preferred way of scrolling should have an effect on the search time, this can be explained by the unevenly distributed preferences: only 10 people stated that they were using on-screen scrollbars for navigation, the rest used either a mousewheel or a touchpad gesture (which should be significantly faster). In combination with a small effect size ($f=.06$) this leads to a low power of only $1-b=.07$, calculated according to Cohen (1992).

Apart from this aspect the non-significant results can be considered as an affirmation of the validity of the study. For example it allows for the conclusion that the interface was easy enough to use for computer experts as well as for novices. It also shows that non-native speakers had no trouble understanding the instructions.

4.2 Comparison of calendar search and navigation performance

The search and navigation performance for the two different calendar layouts was compared for each pair of test trials (see Figure 6). Table 1 shows the detailed results of the repeated measures ANOVA. Calendar search in list view was faster in the scenarios A, D, E, and F. Calendar search was faster in grid view in scenario B. In scenario C there was no significant difference in search times. This confirms our expectation that calendar search in list view is generally faster except for the search of days of the week.

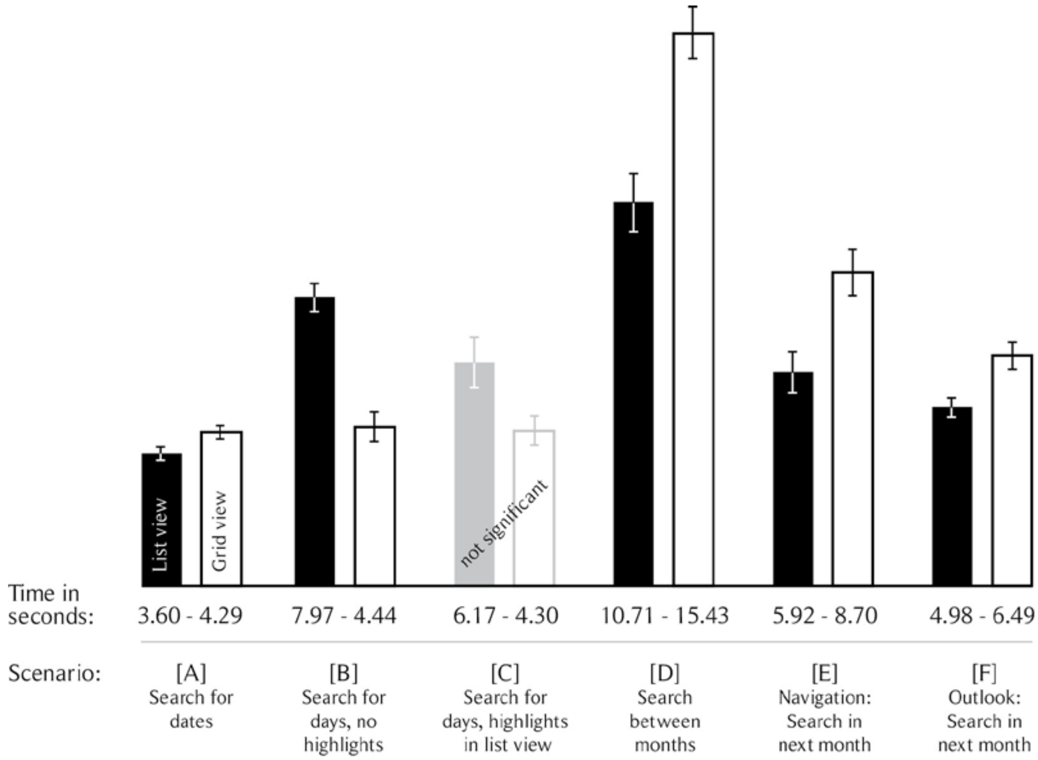

Fig. 6. Differences in search and navigation performance.

The results of scenario C indicate that highlighting corresponding days can decrease this limitation of the list view, an observation that is supported by a comparison of the list view search times for scenario B and C. A paired sample t-test shows a significant difference between both conditions, $t(49)=4.54$, $p<.001$. Furthermore, the standard errors displayed in figure 6 reveal a higher than expected variance for list view search times in scenario C (relative to scenario B). For some participants, the highlights used in this scenario might not have been immediately clear, an issue that would become obsolete with more regular use of the list view.

The effect sizes have been calculated according to Cohen (1992). The measured time difference has an effect size of $f=.36$ in scenario A, $f=.96$ in scenario B, $f=.64$ in scenario D, $f=.33$ in scenario E and $f=.45$ in scenario F. Cohen classifies an effect size of $f=.35$ as large.

Table 1: Repeated measures ANOVA – Calendar search and navigation performance

Source of Variance	Scenario	Sum of Squares	dF	F	Significance
Calendar Layout	A	1.07E+10	1	6.136	.017*
	B	3.13E+11	1	44.958	.000**
	C	1.48E+10	1	3.480	.068
	D	6.68E+11	1	19.826	.000**
	E	1.90E+11	1	5.371	.025*
	F	6.18E+10	1	9.635	.003**

N = 50. **p<.01; *p<.05.

The tasks of the presented study share characteristics with those of reaction time experiments and Usability research – both of which generate data that is positively skewed (Whelan, 2008; Sauro & Lewis, 2010). Consequently, the distributions of calendar search times are skewed as well (Scenario [list, grid]; A [.459, .439]; B [.880, .595]; C [.940, 1.005]; D [.585, .851]; E[1.653, 1.261]; F [1.200, .925]; SE=.337). While the ANOVA is often seen as robust against type I errors (Wilcox 1998; Schmider et al. 2010) the analysis was repeated with log transformed data that satisfied the criteria for normality, resulting in the same statistical significance patterns (Scenario A: [$F(1,48)=5.85$ $p<.05$]; B: [$F(1,48)=58.97$ $p<.01$]; C: [$F(1,48)=3.55$ $p>.05$]; D: [$F(1,48)=14.35$ $p<.01$]; E: [$F(1,48)=10.32$ $p<.01$]; F: [$F(1,48)=19.63$ $p<.01$]). The non-parametric Kruskal-Wallis-Test also showed significant differences between groups for the Scenarios A, B, D, E and F (Scenario A: [$H(1)=20.39$ $p<.01$]; B: [$H(1)=34.13$ $p<.01$]; C: [$H(1)=3.80$ $p>.05$]; D: [$H(1)=14.79$ $p<.01$]; E: [$H(1)=5.46$ $p<.05$]; F: [$H(1)=12.65$ $p<.01$]).

4.3 Questionnaire data

The follow-up questionnaire was answered by 41 participants. Participants were asked for their opinion on which of the two layouts was faster; 16 believed the grid view was faster and 25 the list view. Participants were also asked to rate the ease of use (2.46 grid view / 2.29 list view) and the visual appearance (2.6 grid view / 2.5 list view) of the two calendar layouts on a scale from 1 to 6 with 1 being ”very good” and 6 being ”bad”. While the list view has been rated slightly better, the difference is not significant ($t(40)=.73$, $p>.05$ for ease of use, $t(40)=.42$, $p>.05$ for visual appearance). Participants were then asked which of the two layouts they would prefer; the grid view was preferred by 20, the list view by 21 participants.

Asked the reason for their choice in a free answer format, participants who preferred the grid view stated that it provides a better overview (7x) and faster search for days of the week (3x), that there is no need for a scrollbar (1x) and that they were familiar with that format (3x). Those who preferred the list view stated that it provides a better overview (8x), faster search in general (6x) and especially for dates (3x), faster search between months (1x), a customizable view (1x) and easier navigation, presenting all content on a single, scrollable page (4x).

At the end of the questionnaire participants were given the opportunity to give additional comments and nine made suggestions about how to improve the list view, including a better grouping, another column for additional content and a better visual structure to distinguish between appointments on a single day.

5. DISCUSSION

5.1 Implications

The study supports our claims about the list view calendar, which was shown to be significantly faster for most of the tasks we studied. The disadvantage when searching for days of the week can be compensated by placing a higher order visual structure on top of the list view. The large effect sizes found in our study suggest that the benefits of the list view will likely transfer well from the laboratory into real use settings.

Calendars support routine but often cognitively complex scheduling tasks. Our study used a set of stereotypical search and navigation tasks involved in those longer and higher level processes. More complex tasks (e.g. scheduling a meeting that depends on the availability of a handful of persons) would have created differences in search time arising from individual differences in working memory capacity and reasoning and not the different calendar layouts. While another study regarding calendar search (White, 1989) opted for even simpler questions resulting in answer times of 1 to 2 seconds, the tasks used in our study (3 to 16 seconds) can be seen as a good compromise between internal and external validity. Furthermore it can be argued that any more complex task inevitably has to be an aggregation of the basic tasks (e.g. search for dates or days) discussed in this study.

Apart from the measured time differences in calendar search, the questionnaire data provided helpful insights on how the participants themselves perceived the two layouts.

A majority (25 out of 41) thought that the list layout provides faster calendar search but only 21 out of 41 would choose the list view in its current form over the grid view. The difference can be explained by participants who stated that they preferred the grid layout because they were used to it. A design implication would be to offer users the opportunity to switch between the grid and the list view so that they can easily try out the new layout and gain familiarity with it.

This still leaves 16 participants who believe the grid view is faster to use. ”A better overview” was the most stated reason participants gave for this assumed speed advantage; however this was the same reason given by the 25 participants who thought that the list view was faster. This indicates a considerable individual variance in the perception of the grid and the list view. While most participants felt that the list layout offers a more structured layout, others felt the same for the grid view. An explanation for this phenomenon could be the so-called ‘mere exposure effect’. Zajonc (1968) states that ”mere repeated exposure of the individual to a stimulus is a sufficient condition for the enhancement of his attitude toward it” (p. 1). While some of the participants described the effect themselves when they stated that they were used to the grid layout it is reasonable to assume that others have been affected unknowingly, resulting in a better rating for the grid view. This means that while the ratings for the list view are certainly satisfactory for a new concept, the ratings might further improve in a long-term study.

5.2 Limitations

The study used a combination of convenience and snowball sampling and therefore cannot make population level claims. However, differences in the recorded demographic variables did not result in different search times, suggesting low demographic influences on the effect (see section 4.1). The same is true for technical knowledge as well as calendar usage and experience. However, the group of calendar “power-users” was small and further studies are needed to conclude if the concept of a digital list view calendar would be suitable for such users as well. More importantly, all of the study’s tasks revolved around student affairs – results might differ with a more cluttered business calendar.

The remote, web-based method used for this study has its obvious charms for researchers (e.g. participants do not have to be interviewed personally and can participate in the study at a time and place of their choice) but implies less control over the conditions if compared to a lab setting (e.g. some participants might listen to music while completing the tasks or screen sizes might differ). To minimize the effects of such external factors each participant completed both conditions of the study in randomized order. With this experimental design it also becomes obsolete to counterbalance any demographic or other attributes between groups.

Significantly, the study was not performed on touch screen devices for which the list view is particularly suited: some users were using scrollbars for navigation and it was not possible to zoom the interface either. While it might seem odd not to test the list view with a device it is best suited for, a careful consideration of the arguments made in section 2 revealed that a web-based study performed on traditional personal computers could already answer the majority of questions (including the most fundamental ones such as search performance in a list and people’s reactions to an unfamiliar digital calendar layout). One claim that could not be empirically validated however, and this is another limitation of the study, was that users do not need to re-orientate after zooming in or out. This has been demonstrated for other applications (see section 2.2) but is still something that should be tested with a high fidelity prototype. Such a prototype cannot be easily realised with web technologies and would require native code to be written for one of the available touch-centric operating systems. However, given the fact that the results presented in this paper provide very encouraging feedback it now seems reasonable to invest in a second phase of research, this time including a high fidelity prototype. This would also enable the testing of more detailed aspects of the interface (e.g. scrolling speed, the size of the scrollable canvas, temporal resolution at different zoom levels) and matters of long time user experience (e.g. how do people feel about their calendar having a different look on each day as the current day is always displayed at the top).

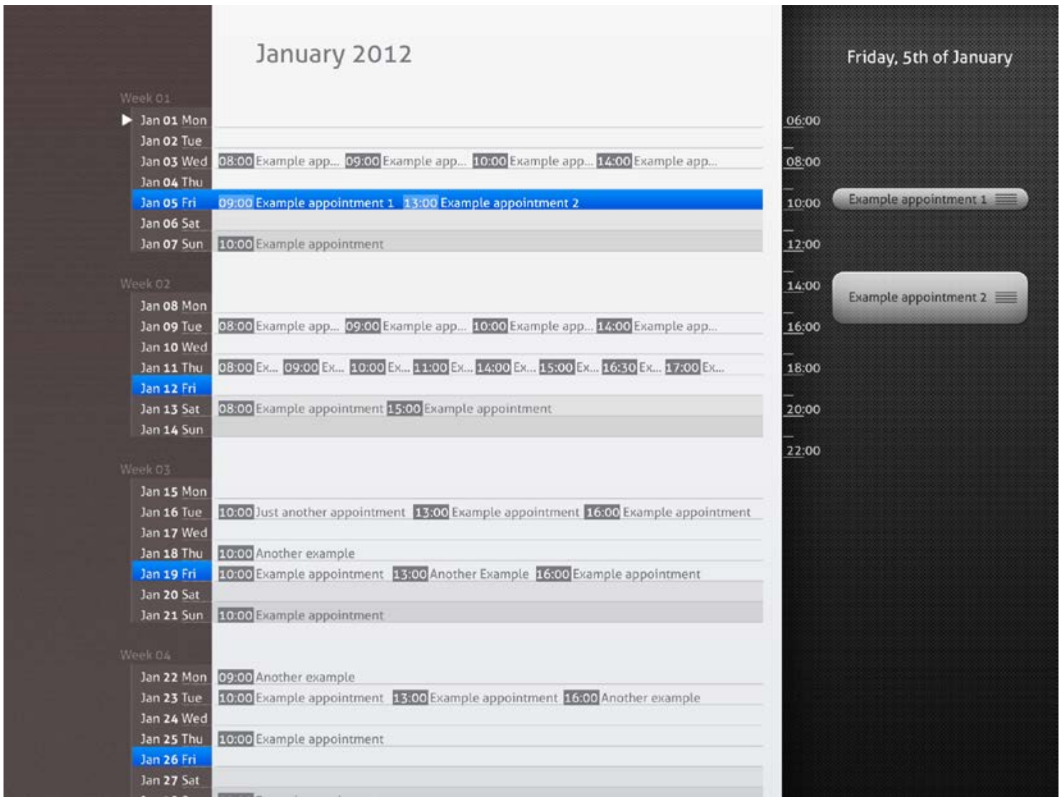

Fig. 7. High fidelity mockup of the list view calendar.

5.3 Outlook

A high fidelity prototype (figure 7) has already been tested in mockup form with participants in two small focus groups and has shown to evoke more discussions about detailed interface elements than was possible for the low fidelity prototype. During the creation of the mockup it became clear that a different calendar layout might stimulate advances in other areas as well. The different layout made the designer re-think conventional approaches (e.g. in the mockup the creation of appointments was moved to a third calendar column instead of being placed in a more traditional pop-up layer).

This innovation-led approach to the development of digital calendars contrasts with the prevailing design culture in industry, which in recognizing users' enduring attachment to the physical calendar, has attempted to re-produce it in digital form. For example the designers of Apple's iCal digital calendar have tried to create a digital emulation of physical surfaces rather than confront the issues underlying the apparent preference for the physical calendar. The result has been described as ”the ugly failure of the physical metaphor” or as ”a (damned) pseudo-calendar made of paper and leather” (Diaz, 2011).

With iOS 7 however, Apple has started to remove skeumorphic elements from the operating system, instead relying on a flat, “digitally native design” as already promoted by Microsoft and Google for their mobile operating systems. After updating the visuals to better fit a new generation of electronic devices, rethinking the interaction paradigms as well seems like a logical next step and might even lead to digital calendars that take advantage of the new scrollable and zoomable interface technology.

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APPENDIX

COMPLETE LIST OF SEARCH TASKS (The corresponding scenario is written in brackets):
01 What day of the week is the 17th of February? (Test)
02 On what date in January is the management presentation? (Test)
03 What day of the week is the 21st of January? (A)
04 When in January and February are you still free for a 7-day trip? (D)
05 How many Sundays are in January? (C)
06 On what date in February is your flight to Amsterdam? (E)
07 What is the date of the first Thursday in January on which you do NOT have an appointment? (B)
08 (Today is the15th) What day of the week is the 5th of February (Test)
09 (Today is the 15th) When in February is the Sydney PhD deadline? (F)
10 What day of the week is the 24th of February? (Test)
11 What day of the week is the 23rd of January? (A)
12 You fly to Spain at the end of January - how many FULL days do you have in Spain? (D)

13 On how many Sundays in January do you have appointments? (C)
14 On what date in February is Kathy's birthday? (E)
15 What is the date of the third Thursday in January? (B)
16 (Today is the 15th) What day of the week is the 9th of February? (Test)
17 (Today is the 15th) On what date in February is the Bayer Job Interview? (F)