Appropriate Interface Designs for Mobile End-User Devices— Up Close and Personalized Executive Information Systems as an Example

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Abstract

This article develops interface designs for increasingly important mobile end-user devices. Such interfaces make „up close and personalized" executive information systems possible. Based on a multidimensional literature review, we propose ten design guidelines for „analyst"- and „consumer"-type executives and the different devices they use. Then, we validate the guidelines with an expert focus group and demonstrate their utility with a first instantiation.

1. Introduction

The higher managers are positioned within the organization, the more idiosyncratic they become—and the more complex their information system (IS) support is. This holds particularly true for senior managers, hereafter referred to as *executives*.

IT-based IS meant to help such managers are known as *executive information systems* (EIS). Designed as executives' central, hands-on, day-to-day information source, such IS share three characteristics [1]. First, their overall aim is to help an organization carefully monitor its current status and its progress toward achieving its goals. Second, they should enable users to navigate through information culled from both internal and external databases. And, third, even senior executives should be able to operate such IS themselves.

The present moment seems favorable for redesigning EIS. On the one hand, a new generation of executives more *comfortable with IS* is populating organizations' management [2, 3]. On the other hand, significant *technical progress* has been made, as EIS evolved from single IS to integrated applications on top of a corporate business intelligence (BI) architecture [4].

End-user devices and user interfaces are highly visible components and, thus, important levers for EIS acceptance [5]. We focus on *mobile* end-user devices such as notebooks, tablets, and smartphones as they provide a new freedom to consume information beyond the stationary desktop PC. They gain more and more importance as their worldwide sales totals 1.6 billion units in 2010, a 31.8 percent increase from 2009 [6].

Appropriate *user interfaces* simplify EIS handling, but most publications focus solely on layouts for desktop PCs [7]. As a consequence IS engineers will need to pursue more designs for mobile devices that attract and captivate executives [8].

In comparison to stationary usage, user-interface design for mobile devices is subject to more *limiting factors,* such as smaller screens, electronic (rather than tactile) keyboards, reduced processing power, and restricted connectivity. Thus, specific design guidelines for appropriate software components are needed. These fall into three areas [9]: quality of *information presentation,* intuitive *dialog control,* and *analytical functions* that executives can operate by themselves.

The objective of this article is to develop guidelines for designing (user) interfaces on mobile end-user devices to make „up close and personalized" EIS possible. We cover software components for „analyst-" and „consumer"-type executives (hereafter referred to as consumer and analyst executives).

Since we propose design guidelines, this article follows the tenants of *design science research* [10, 11]. The guidelines to be developed [12] contribute to Hevners et al. [10] artifacts such as constructs, models, methods, and instantiations.

Emphasizing „build" and „evaluate" activities, we apply Peffers et al.'s process model [13]. We begin this article by discussing current gaps in EIS acceptance and suggest appropriate interface designs for end-user devices to address them. After revisiting foundations (Sec. 2), we lay out our research model. Based on a multidimensional literature review, we derive ten design guidelines (Sec. 3). Then, we validate our arguments with an expert focus group (Sec. 4.1). Finally, we demonstrate the utility of our approach with a first instantiation (Sec. 4.2). The article concludes with a summary and discusses future research (Sec. 5).

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2. User interfaces for mobile end-user devices

According to ISO 9241-110 [14], EIS are a combination of software and hardware components that receive input from executives and communicate output to support them in performing their corporate management task. *User interfaces*, the software perspective of EIS, „[…] are what executives see and work with to use a product" [15, p.1]. Often, they apply web technology („web frontends") that simplifies EIS handling.

End-user devices are the physical part of IS worked with by the user [16]. Today, a variety of mobile devices are available, and new products are constantly entering the market that blur the boundaries of former system classes. For example, Apple's iPad and Android 3.0 products, such as the Motorola Xoom and Dell Streak, combine a letter-sized screen (9.7 inch resolution) and easy system handling to claim a niche between notebooks and smartphones.

Requirements are prerequisites, conditions, or capabilities needed by the users of a software system [17, p.62]. *Design guidelines* go beyond requirements to serve as predefined actions specifying how EIS are brought to life [18]. We consider them as not yet empirically tested, but they provide a first direction for forthcoming, more mature design principles.

User preferences describe the differences in how individuals use IS. By providing a non-functional perspective, they reveal requirements for how IS provide functions and services [19].

As early as 1979, Zmud [20, p. 975] echoes several authors by claiming that „individual differences do exert a major force in determining MSS success." A few years later, however, Huber [21] took the wind out of the sails of this approach for many years to come. He claimed that accommodating user preferences requires EIS designers to consider too many characteristics, that better educating users is a preferable solution, and that EIS might be configurable by users in the future anyway. The last 20 years invalidate Huber's line of argument. The technology acceptance model [22] and IS success models [23] prove that user perception plays a predominant role in IS success.

Moreover, user preferences, their associated EIS requirements and design guidelines become more and more important as digital natives populate organizations' management. They take their place alongside digital immigrants, some of whom become heavy users over the years, while others do not [3]. The varied needs of these groups mean one-size-fits-all EIS is no longer adequate.

3. Research model

Two approaches to model artifacts exist: a bottom-up approach that reuses reference models and fragments, and a top-down approach that utilizes analytic argumentation [24]. While the first ensures consistency with the body of knowledge, the second is often better suited to innovative artifact design. We combine both approaches as follows. A multidisciplinary framework with findings from requirements engineering (RE), enterprise engineering (EE), and human-computer interaction (HCI) structures our literature review (Sec. 3.1). We then describe the search strategy we employ (Sec. 3.2). Based on the findings, we specify artifact requirements (Sec. 3.3). The result is a hypothesized design for user interfaces derived by analytical argumentation (Sec. 3.4).

3.1 Multidimensional EIS design framework

A single-discipline approach by Carlsson et al. [25] that uses the competing values model [26] to design IS is currently under discussion. We argue that designing EIS to accommodate increasing user-group characteristics requires a *multidisciplinary approach*. Figure 1 illustrates our framework (based on [28], p. 296).

Based on Mayer et al. [27], we start with a review of HCI publications. The *user model* covers user-group segmentation (A.1) and their characterizations (A.2). We continue with EE, which breaks up the IS design process into two stages. The *black-box model* describes the user perspective, covering users' functional requirements and guidelines (B.3). The *white-box model*, in turn, considers the engineering perspective on EIS design and covers constructional requirements (C.1) and guidelines (C.2). Next, we use RE to detail the functional requirements into domain-specific requirements (B.1), which cover the purpose of IS design, and cross-domain requirements (B.2), which cover more formal aspects of IS as they fulfill their function. Finally, we detail EIS adaptation in terms of how user interface designs present information on mobile end-user devices. In other words, we apply *situational artifact design* (SAC, [28]).

3.2 Search strategy

Based on the Webster and Watson [29] approach to literature review, our search strategy followed v. Brocke et al.'s method [30]. We selected ten journals based on the catalog provided by the LSE [31]. We consider this catalog as appropriate for our purposes, since it incorporates not only mainstream, but also social studies of IS.[1] Furthermore, we supplemented our list with proceedings from the two „A"-ranked conferences: the International and European Conferences on IS. To expand our journal base towards the discipline of engineering, we looked at publications

[1] We choose five journals of each set: MIS Quarterly, Information Systems Research, Information & Management, Journal of Management Information Systems, and Decision Support Systems in the first case and the European Journal of Information Systems, Information & Organization, Information Systems Journal, Journal of Organizational and End-User Computing, and Journal of Information Technology in the second.

covering systems and software engineering.[2] Finally, our search covered important HCI journals.[3]

To access the journals, we chose EBSCOhost, Science Direct, and ProQuest covering issues from the last 20 years. In a third step, we executed a keyword search of titles and abstracts.[4] A total of 466 hits resulted, of which we found 20 to be relevant. To identify further articles, we performed a backward search, which led to a total of 44 articles examining user-group characteristics and their implications on EIS.

3.3 Results

Figure 1 presents the publications identified as relevant. The following citations are based on findings from our prior work [28]. Studies relating to more than one cluster of the framework appear more than once. Publications from the journals with the highest impact factors are highlighted in gray and briefly described below to provide a sense of our design phases A-D.

Phase A. User model

A first group of publications are rooted in psychology and cover user-group segmentation (A.1). They deal with individual cognitive style—in other words, the way in which individuals tend to grasp information (e.g., quantitatively vs. qualitatively) and apply this information when making decisions (e.g., logical argumentation vs. intuition).

Huysmans [34] measures decision styles in two ways. Individuals with an *analytical* style seek causal relationships to identify a solution to a problem. Usually, they tend to ignore factors that cannot be quantified. In contrast, individuals with a *heuristic* style include qualitative factors, such as past experience, intuition, and unqualified feelings, in their models.

A second set of publications covers user-group characterization (A.2). Either these studies differentiate characteristics that have an impact on EIS (e.g., women vs. men [35]) or they develop IS profiles for a certain user group. For example, Tractinsky and Meyer [36] claim that an EIS user is not only in a *receiving*, but also a *presenting* role. Consequently, they demonstrate that a managers' objective—such as facilitating decision making or maintaining an impression—has an impact on his or her preferred user interface design. In a current study with executives from companies listed in the FT „Europe 500," Mayer and Stock [3] report four working styles among C-level managers: *analytical power users, opportunistic analysts, all-around basic users,* and *de facto non-users*.

In summary, a number of authors provide methods for differentiating individual cognitive styles (A.1), while even more discuss characterizing user groups (A.2) and the resulting preferences for IS usage. This convinced us that the influence of individual user-group preferences should be considered seriously in EIS design. Thus, in our research model we summarize all the variables we researched related to executives' individual user preferences—such as gender, age, temperament, self-efficacy, level of expertise, prior IS experience, and past device usage patterns—under the first EIS use factor, *working style*.

Phase B. Black-box model

None of the researched publications consider connections between domain-specific requirements, user preferences, and EIS design (B.1). One reason could be that the homo oeconomicus theory, rejecting individual user preferences, has dominated management research in recent years, including IS research.

Several publications examine the implications of user-group preferences on cross-domain (functional) requirements (B.2). Walstrom and Wilson [37] define typical functionalities used by groups they identify as „converts," „pacesetters," and „analyzers." Converts use EIS to access *predefined reports*, sources outside the company, company news, and the latest updates on key performance indicators. Analyzers, in turn, use MSS primarily to perform *analysis* of data that was not previously available. Pacesetters use the functionalities employed by the other groups while also making extensive use of *communication capabilities*.

A third group of identified publications contributes to functional guidelines (B.3). Tractinsky and Meyer [36] derive functional guidelines based on the objectives of EIS users. If the reports in the EIS are used to aid decision making, the interface should be restricted to *2D bars and figures* so as to not distract from the content. For presentation, in turn, the interface should apply *3D bars and figures*. Based on their distinction between managers' working styles, Mayer and Stock [3] define functional guidelines in terms of EIS user interfaces and the analysis and corresponding data model for each type.

Eckerson and Hammond [38] distributed a questionnaire about user-interface characteristics and came up with a list of the most wanted *user interface features*, such as drillable charts or one-click access to metadata. To take account of the diverse working situations in which executives use EIS, we incorporate their *use case* into our research model.

[2] We used both the AIS ranking [32] and impact factor as described by Elsevier [33] to choose Information and Software Technology, Communication of the ACM, ACM Computing Surveys, Journal of Systems and Software, and the International Journal of Systems Science.

[3] We found Human-Computer Interaction, International Journal of Human-Computer Interaction, International Journal of Human-Computer Studies, and Computers in Human Behavior in the journal rankings [33], and added AIS Transaction on Human-Computer Interaction as an up-and-coming HCI Journal.

[4] Search string: ("decision making" OR "executive information system" OR "decision support system" OR "management information system" OR "data warehouse" OR "business intelligence") AND "use" OR "style" OR "pattern" OR "adoption" OR "acceptance" OR ("mobile ICT" OR "user interface" OR "user-interface characteristics").

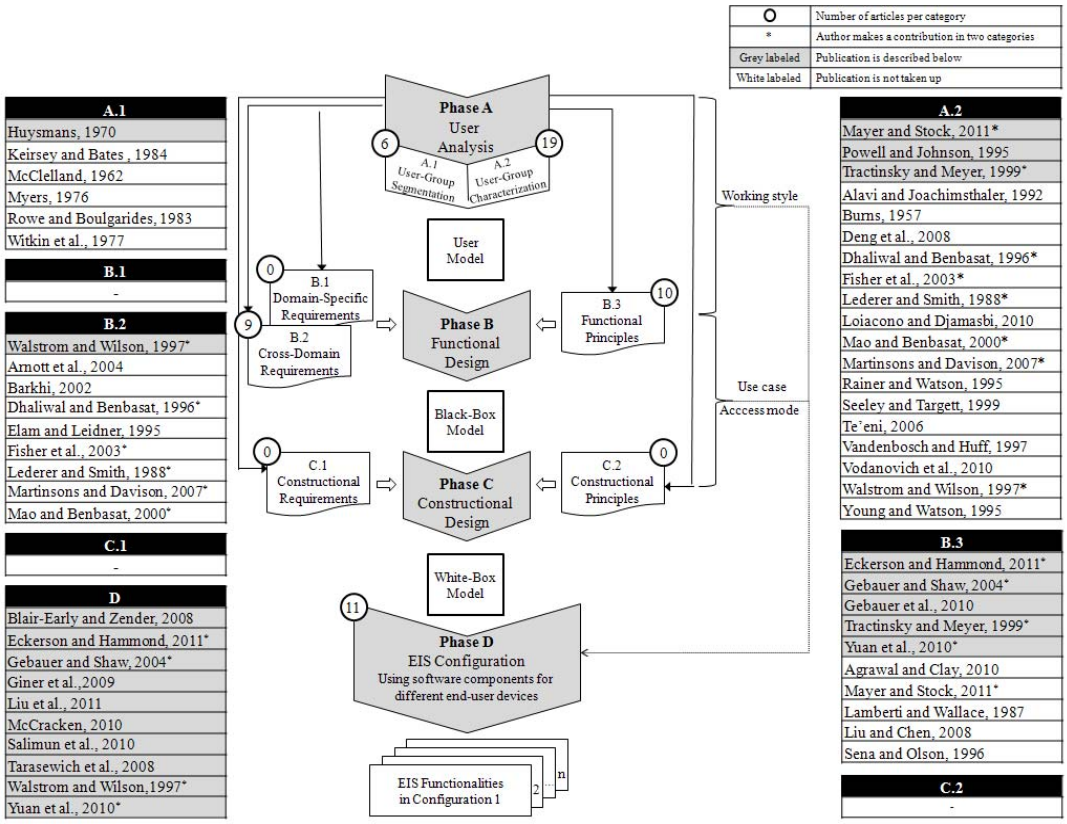

Figure 1: Relevant publications considering user-group characteristics within the EIS design process
Expanded illustration based on Mayer et al. [27], p. 296

Since organizations have become larger and more dispersed, Yuan et al. [39] examine the fit between mobile work and systems to support it along the dimensions of *mobility, location dependency,* and *time criticality*. Gebauer et al. [40] assume that a good fit between the managerial task, mobile IT, and mobile use context improves task performance. In their task-technology-fit model, Gebauer and Shaw [41] highlight *portability, operations and performance, usability,* and *network connectivity* as determinants of mobile-device appropriateness. In light of these findings, we incorporate EIS *access mode* into our research model.

Phase C. White-box model

In the field of constructional guidelines (C.2), it is researchers in software engineering who deal with styles of IS architecture, such as a service-oriented architecture [19]. However, none of the articles consider the implications of user-group characteristics on constructional requirements or guidelines.

3.4 Developing design guidelines

Now that we have specified the relationship among user group characteristics and EIS design, we hypothesize about user-interfaces and their most important software components on mobile devices. We therefore incorporate literature on EIS adaptation (Phase D., figure 1) as laid out in Sec. 1: quality of information presentation, dialog control, and analytical functions to be handled by executives themselves.

Information presentation

Executives need to enter the EIS at a clear and interesting starting point. Giner et al. [8] identify an information overview on the first screen as an important factor of perceived usefulness. Gebauer and Shaw [41] state that mobile business applications are often used to handle emergency situations. End-user devices therefore need to present the required information quickly. Applying the distinction between exception reporting and a corporate overview using symbols to represent the most important reports, we can propose a first design guideline as P1:

P1. *Executives want the most important messages at a glance, with exception reporting consisting of a picture, headline, and teaser followed by a „read more" function.*

Blair-Early and Zender [42] stress content visualization to encourage executive interaction with the IS.

Salimun et al. [43] add that aesthetics can improve attitude towards EIS usage. Intuitive visualization of information is important, especially for novice IS users. We differentiate between a primarily graphical visualization, a textual one, and a combination of both. The fact that text and tables of numbers are harder to read on smaller screens leads to a second proposition.

P2. *The smaller end-user devices are, the more executives ask for graphs and portfolios instead of tables with text and numbers.*

Specifying different graph types, Eckerson and Hammond [38] show that bar charts are still the most preferred way to present information, followed by line graphs and pie charts. Furthermore, they suggest that a high-contrast presentation is the best way to show deviations. Two design guideline propositions follow:

P3*. Bar charts (e.g., for deviation analysis) are the most important type of graphs for presenting information.*

P4. *The smaller end-user devices are, the more important high-contrast presentation becomes.*

Gebauer and Shaw [41] find evidence that executives will first use mobile applications for notification and communication purposes rather than to process data. In light of smaller screens, the following design guideline proposition seems straightforward.

P5. *The smaller the devices, the fewer analysis steps users are accepted.*

Dialog control

After entering the EIS, executives should be able to navigate within the IS by themselves. To do so, non-technical executives in particular need intuitive dialog control [43]. We offer executives both interactive navigation with filters, drills, sorting, etc., and a more static, predefined page-by-page mode [37].

P6. *Analysts prefer a more interactive navigation style, whereas consumer analysts prefer a predefined flow of charts with a few deep-dive options.*

Advanced navigation elements, such as breadcrumbs, can also be identified [43]. Other examples include „blend out/gray out" of unneeded functions, avoiding overlapping windows (window insight technique), or using tabs instead of pull-down menus.

P7. *Since analyst executives make use of more interactive navigation, advanced navigation components matter more to them than they do to consumers.*

McCracken [44] states that end-user devices can be classified in terms of their control philosophy, differentiating among operation by hand, keyboard and mouse, or gesture. Tarasewich et al. [45] identify several special issues for mobile IS, including limited user attention during usage, users' occupied hands, user mobility, and IS interaction while in motion. Smaller screen size means that the smaller mobile end-user devices are, the less they accommodate traditional navigation. Alternatives, such as natural language interfaces, are the focus of current research efforts. Nevertheless, predefined displays offer advantages for direct interaction, especially while in motion.

P8. *The smaller end-user devices are, the more preferable a predefined display becomes. Notebooks, in turn, allow more drillable charts.*

Analytical functions

Because they connect to networks easily, mobile end-user devices have an advantage in information access and follow-up communication capabilities [39].

P9. *Software components enabling quick access to „online" information and follow-up communication capabilities are more important on smartphones than on other devices.*

A trend toward smaller devices is evident for communication functionalities such as e-mails or instant messaging, while sophisticated information analysis with methods like regressions require still a larger screen. Gebauer and Shaw [41] suggest that users will first use mobile business applications for notification and communication purposes rather than for data processing. As a result, we propose a tenth and final design guideline.

P10. *Communication functionalities are more important on smaller devices, whereas more advanced analytical functions are dominant on larger ones.*

4. Validation

Validating our proposed design guidelines (Table 2) we worked with an expert focus group (Sec. 4.1). The section that follows covers a first instantiation evaluating the resulting approach. To avoid circular argumentation, no members of expert focus group took part in the post-pilot evaluation interviews.

4.1 Workshop with expert focus group

We evaluated our propositions in a three-hour workshop in November 2010 using an expert focus group, as that approach provides direct suggestions and feedback in a personal working atmosphere. The participants, 42 experts from 25 companies, belong to a working group examining trends in IS support since 2006. Table 1 summarizes their characteristics.

In order to provide common ground for discussion, the user-interface components were made available within an EIS implementation, the Corporate Navigator [46]. We then asked the participants to vote on them, using the example of an individual performing an *analysis* (use case) *offline* on a plane (access mode).

Following findings from Mayer and Stock [3] on executive working styles (Sec 2), *analyst executives* accessed the EIS on a notebook (Lenovo T 410s), a tablet (Apple iPad 1), and a smartphone (iPhone). Because *consumer executives* replied that they use paper-based reports rather than smartphones in the offline access mode, their comments refer to printouts modus instead of smartphones (Table 2).

All participants voted using the format: 1) strongly disagree, 2) disagree, 3) neither agree nor disagree, 4) agree, and 5) strongly agree. To evaluate our guidelines, we calculate *means (μ)* and *standard deviations (σ)* for the responses to multiple-choice questions (Table 2). Furthermore, we performed a *two-sided t-test* to determine the significance of differences in mean. Aggregating the responses leads to the following findings, which are summarized in Table 2.

We could not find significant evidence for *design guideline 1*. In terms of the mean, exception reporting appears most important for analysts using a tablet, but the value is not significantly higher than for other devices (p=.605). On smartphones and notebooks, analyst executives prefer to enter the EIS via a corporate overview with symbols for reports (p=.742 and p=.442). Consumer executives, in turn, show an insignificant preference (p>.225) for exception reporting on all end-user devices: tablet, notebook, and paper-based reports.

With respect to *design guideline 2*, analyst executives rank graphical presentation on smartphones significantly (p•.01) higher than a textual one or combined dashboards. On notebooks and tablets, a dashboard is the most preferred solution, although this preference is only significant for notebooks (p•.05). For consumer executives, dashboards on notebooks are the most preferred solution; the preferences for graphical presentation on tablets and textual presentation in paper-based reports are not significant (p>.225).

In terms of graph type, *design guideline 3*, we found that analyst executives value bar charts less as the devices decrease in size, with mean ratings significantly lower for smartphones than for notebooks or tablets (p•.01). In terms of mean scores, line charts are preferred on notebooks and bar charts on tablets and smartphones. Consumers, in turn, preferred bar charts to an insignificant extent on notebooks and tablets, and considered line charts important in paper-based reports. On tablets, they prefer bar charts to line charts (p•.1).

Regarding *design guideline 4*, analyst executives rank screens with high-contrast resolution significantly higher for smartphones than for notebooks (p•.05). Consumer executives share this preference, but to an insignificant extent. Views employing high-contrast resolution were ranked highest on tablets.

Validation reveals *design guideline 5* to be the strongest. While no significant differences were apparent concerning analysts' preferences on a notebook (p>.59), they significantly prefer 1-3 clicks (p•.001) on smartphones. On tablets, the difference between 1-3 and more than 5 clicks is significant (p•.01). The preference for consumers is more pronounced: on all devices, they accept only 1-3 clicks for any analysis (p•.05).

Responses to *design guideline 6* showed clear differences between the two working styles. Analysts prefer interactive navigation on notebooks (p•.001) and showed a slight preference for it on tablets (p=.267). On smartphones, surprisingly, the opposite was true (p•.001). Consumers, in turn, prefer predefined navigation on all devices (p•.001).

In terms of advanced navigation components, only some evidence for *design guideline 7* emerged. Analyst executives value all advanced navigation components higher on notebooks and tablets than consumers. Of the 7 cases in which the mean differs (Table 2), five are significant (p•.05). Analyst executives consider a transfer function on laptops to be important (p•0.001). Strong evidence exists for *design guideline 8*. The larger the screen, the more highly analysts valued all components. The differences between notebooks and smartphones and between tablets and smartphones

Table 1: Sample characteristics

Position	**No.**	**%**	**Sector**	**No.**	**%**
Executives	13	31	Industrial	12	49
Team lead business department	23	55	Financial Services	3	11
Director IT/BI department	6	14	Other Services	10	40
Total	42	100	Total	25	100
Age			**Market capitalization [bn USD]**		
•40	12	28	•30	12	48
40-45	4	10	30-90	10	40
46-50	22	52	90-120	2	8
>50	4	10	> 120	1	4
Total	42	100	Total	25	100
Working Style			**Frequency of EIS use**		
Analyst	21	50	Permanent	8	19
Consumer	21	50	Multiple times a day	14	34
Sum	42	100	Once every day	6	14
Gender			2-3 times a week	8	19
Female	10	24	Once a week	6	14
Male	32	76	Total	42	100
Total	42	100			

were highly significant (p•.001), while those between notebooks and tablets were only significant in two of four cases (p•.05). Consumers disliked drillable charts and gave them low ratings in general.

When it comes to analytical functions, we found no evidence exists regarding information access (*design guideline 9*). While analysts rate the push function highest for smartphones, other functions, such as live tickers, comments, and topic monitoring, rank higher as device size increases. Consumers, in turn, show the same results, but rank the comment function significantly higher on notebooks (p•.05).

For *design guideline 10*, strong evidence regarding information analysis exists. Analysts rated analysis capabilities significantly higher on notebooks and tablets (p•.05) and consider these functions to be more or less unimportant on smartphones. Consumers, in turn, rate analysis as more or less unimportant on all devices. For communication functionalities, participants evaluated e-mail, instant messaging, and internal firm blogs. Analysts significantly prefer blogs on notebooks (p<.01), and rate instant messaging and e-mail equally on all devices. For consumers, instant messaging and blogs are unimportant on all devices. E-mailing is rated higher on notebooks than on tablets (p=.125).

4.2 Synthesis

To demonstrate utility, our findings were applied from January 2011 to May 2011 at a large automotive supplier (market capitalization: USD 32 bn.; about 150,000 employees). Interviews with an analyst and consumer executive show the impact of user-interface design on mobile devices.

Analyst executive: Analyst executives prefer to enter the EIS on smartphones and notebooks via an aggregated overview employing symbols ([3], Table 2, design guideline 1). Therefore, a corporate overview should use graphical icons (design guideline 2) to represent the most important reports available (Figure 2, top). Thanks to comments provided directly on the KPIs, analyst executives can continue with self-service analysis, which increases in depth along with the size of the device in line with design guideline 5. On the notebook, a full OLAP analysis is available.

Evaluation: Coming to our first instantiation, one of the first digital natives at the C level in Europe, he is the CFO of the automotive supplier. Since 2006, he has used the EIS to an equal extent for his own analysis and in working meetings, accessing information predominantly from his office (80%) and in a mobile context (20%). He was equipped with a desktop PC, a smartphone for telephone calls and e-mailing, a notebook, and a tablet. Although he is outfitted in line with the model of Mayer and Stock [3] for his profile, he claimed that having three mobile devices is too much. Thus, we propose replacing the notebook and tablet with a tablet PC for performing analysis, while maintaining his smartphone for calls and short e-mails.

Consumer executive: As described in design guideline 1, consumer executives prefer to enter the EIS via exception reports with a picture, headline, and teaser followed by a „read more" function (Table 2). In our example, this reporting is a corporate portfolio showing the performance of each division in graphic form (design guideline 2). Comments on the portfolio serve as teasers and highlight deviations or other important issues require an immediate response. On a notebook or a tablet (guideline 4), the first navigation step leads to a one-page corporate dashboard summarizing the most important KPIs of the division selected from the corporate portfolio. Bearing in mind design guideline 5, executives can switch to the dashboard view with a single click on the division they want to analyze.

Consumer executives prefer receiving just the most important information, aligned in a predefined analysis track (design guideline 6) with easy-to-handle step-by-step navigation (guideline 7). Functions beyond this main track are blended out. Instead, they prefer page-by-page navigation (Figure 2) handled on the tablet with a „wipe" function and on the notebook by pushing the „return" bottom. Consumer executives do not value drillable charts, so we propose just a few predefined reports and financial management analyses (Figure 2). Regarding guideline 10, we propose making information available to consumer executives in the form of an *„e-book",* a PDF file delivered on demand to their e-mail inbox. This allows them to launch their analysis by just clicking on the PDF attachment and navigate page by page instead of using the flexible navigation that analyst executives prefer. Just some links allow consumers to navigate to predefined analyses provided in a „read more" appendix.

Evaluation: In our first instantiation, this EIS configuration was designed for the human resource director. He does not like IS, as (in his words) his tasks most often require face-to-face meetings. But to prepare for meetings when „on the road," he asked for an easy-to-use mobile device. Before our implementation, he was equipped with a desktop PC and an ordinary mobile phone. Analysis and e-mails were given to him as handouts. Because he did not want a bulky notebook, we provided him with a *tablet* with the software components listed above. In general, he now is more satisfied with his EIS—primarily as a way to begin reducing his paper-based reports.

Table 2: Results

		Proposed design guidelines	Evidence	Category	Analyst executives: Notebook μ	Analyst executives: Notebook σ	Analyst executives: Tablet μ	Analyst executives: Tablet σ	Analyst executives: Smartphone μ	Analyst executives: Smartphone σ	Consumer executives: Notebook μ	Consumer executives: Notebook σ	Consumer executives: Tablet μ	Consumer executives: Tablet σ	Consumer executives: Paper μ	Consumer executives: Paper σ	Findings (μ: mean; σ: standard deviation; ns: not significant)
Information presentation																	
EIS entry	**P1**	Executives want the most important messages at a glance, with exception reporting consisting of a picture, headline, and teaser followed by a "read more" function.	Yes	Headlines and teasers	3.29	1.65	3.62	1.28	3.38	1.40	3.71	1.38	3.86	1.42	3.05	1.61	**Analyst executive:** Slight preference towards entry by symbols on smartphone and notebook (ns) **Consumer executive:** Preference for exception reporting by picture, headline, and teaser with a "read more function" on all devices (ns)
				Symbols	3.48	1.40	3.43	1.21	3.76	1.41	3.38	1.47	3.25	1.55	2.65	1.76	
Visualization	**P2**	The smaller end-user devices are, the more executives ask for graphs and portfolios instead of tables with text and numbers.	Yes	Graphical	3.58	0.96	3.85	1.04	4.15	0.81	3.67	1.06	3.57	1.08	3.48	1.33	**Analyst executive:** Primarily graphical presentation preferred on smartphone ($p<.01$); dashboards on tablet (ns); on notebook ($p<.05$) **Consumer executive:** Dashboard preferred on notebook (ns), primarily graphical presentation on tablet (ns), primarily textual (ns)
				Textual	4.00	0.88	3.30	0.92	2.75	1.37	3.71	1.10	3.33	1.28	3.95	1.19	
				Both (dashboard)	4.60	0.75	4.19	1.03	2.45	1.15	3.76	1.00	3.52	1.12	3.62	1.32	
Graph type	**P3**	Bar charts (e.g., for deviation analysis) are the most important type of graphs for presenting information.	No	Line	4.33	0.86	4.00	1.08	2.90	1.30	4.24	0.94	4.00	1.22	4.33	0.73	**Analyst executive:** Prefer bar charts for basic analysis **Consumer executive:** Prefer bar charts for basic analysis
				Bar	4.29	0.78	4.05	1.07	3.29	1.27	4.29	1.01	4.14	1.15	4.24	0.89	
				Pie	3.80	1.20	3.70	1.17	3.05	1.19	4.10	0.94	3.90	1.14	4.05	0.92	
High-lighting	**P4**	The smaller end-user devices are, the more important high-contrast presentation becomes.	Yes.	Contrast	3.55	1.37	3.64	1.29	4.09	1.45	3.55	1.28	3.76	1.26	3.17	1.32	**Analyst executive:** Screens with high contrast is most important on smartphone (ns) **Consumer executive:** No difference in means between notebook and tablet detected
				Bold/italic	3.95	1.32	4.05	1.13	3.74	1.48	3.75	1.21	3.70	1.38	3.84	1.42	
				Hyperlinks	4.43	0.68	4.20	1.11	3.85	1.31	3.19	1.03	3.10	1.34	1.94	1.44	
				Traffic light coding	4.43	0.93	4.33	1.15	4.35	0.88	3.55	1.28	3.76	1.26	3.17	1.65	
No. of clicks	**P5**	The smaller the devices, the fewer analysis steps users are accepted.	Yes	1-3 clicks	3.76	1.26	3.90	1.18	3.90	1.25	4.19	1.44	4.14	1.42	-	-	**Analyst executive:** Preference for just a few clicks on smartphone ($p<.001$); no difference on notebook **Consumer executive:** High preference for few clicks on all devices ($p<.05$)
				3-5 clicks	3.90	1.04	3.43	1.25	2.43	0.98	2.19	1.17	2.00	1.14	-	-	
				> 5 clicks	3.76	1.51	2.86	1.28	1.67	1.02	1.62	1.12	1.43	0.81	-	-	
Dialog control																	
Basic navigation	**P6**	Analysts prefer a more interactive navigation style, whereas consumer analysts prefer a predefined flow of charts with a few deep-dive options.	Yes	Predefined navigation	3.10	1.34	3.57	1.25	4.29	1.23	4.38	0.74	4.24	1.04	-	-	**Analyst executive:** Interactive navigation preferred on notebook ($p<.001$) and tablet (ns). Smartphone is preferred with a predefined navigation ($p<.001$) **Consumer executive:** Prefers predefined storyline on all devices ($p<.001$)
				Interactive navigation	4.57	0.75	3.86	1.11	2.48	1.33	2.48	1.25	2.29	1.23	-	-	
Advanced navigation	**P7**	Since analyst executives make use of more interactive navigation, advanced navigation components matter more to them than they do to consumers.	Yes.	Breadcrumbs	4.35	0.97	3.85	1.27	2.95	1.47	3.20	1.24	3.15	1.39	-	-	**Analyst executive:** 5 out of 7 advanced navigation components are higher ranked ($p<.05$) **Consumer executive**: Just a wipe function or an easy-to-handle navigation
				Blend/grey out	4.10	1.20	3.62	1.53	2.90	1.65	3.52	1.40	3.57	1.50	-	-	
				Window inside	4.00	1.00	3.05	1.20	1.71	1.27	3.62	1.20	3.48	1.50	-	-	
				Transfer function	4.67	0.67	3.29	1.23	2.05	1.24	2.52	1.60	2.14	1.46	-	-	
				Bookmarks	4.24	0.66	4.00	1.30	3.71	1.35	3.52	1.44	3.38	1.56	-	-	
				Mind-note	4.10	1.09	4.24	1.18	3.90	1.48	3.57	1.36	3.29	1.52	-	-	
				Library	4.48	0.93	4.00	1.17	2.35	1.35	3.19	1.44	2.90	1.48	-	-	
Drillable charts	**P8**	The smaller end-user devices are, the more preferable a predefined display becomes. Notebooks, in turn, allow more drillable charts.	Yes	Do more function	4.57	0.75	4.05	1.02	2.43	1.47	2.95	1.32	2.71	1.45	-	-	**Analyst executive:** Drillable chart functions preferred on the notebook compared to smartphone ($p<.001$) **Consumer executive:** Low valuation for all drillable chart functions
				Sliders	4.20	1.01	3.80	0.95	2.30	1.45	2.62	1.36	2.29	1.35	-	-	
				Direct links	4.55	0.60	3.48	1.29	1.86	1.20	2.60	1.31	2.30	1.30	-	-	
				External news	4.38	0.74	4.05	0.97	3.00	1.48	3.43	1.16	3.24	1.30	-	-	
Analytical functions																	
Information access	**P9**	Software components enabling quick access to "online" information and follow-up communication capabilities are more important on smartphones than on other devices.	No	Push function	4.00	1.14	4.38	1.02	4.50	1.05	3.71	1.31	4.10	1.22	-	-	**Analyst executive:** Comment function lower valuated on smartphone ($p<.001$); push function highest on smartphone **Consumer executive:** No difference between notebook and tablet detected
				Live ticker	3.81	1.29	3.90	1.22	3.81	1.44	3.48	1.36	3.48	1.33	-	-	
				Topic monitoring	4.05	1.05	3.85	1.09	2.95	1.02	3.45	1.32	3.38	1.32	3.38	1.56	
				Comment	4.71	0.56	4.05	1.07	2.38	1.53	3.52	1.54	3.19	1.54	4.17	0.99	
Communication and analytics	**P10**	Communication functionalities are more important on smaller devices, whereas more advanced analytical functions are dominant on larger ones.	Yes	Email	4.62	1.07	4.30	1.08	4.35	1.15	4.19	1.25	3.71	1.38	-	-	**Analyst executive:** Information analysis functions preferred on notebooks ($p<.05$) and not important on a smartphone; communication equally important **Consumer executive:** Analysis function nearly unimportant; email more important on a notebook
				Instant messaging.	3.38	1.40	3.24	1.30	3.57	1.40	2.24	1.51	1.95	1.24	-	-	
				Firm intern blog	3.76	1.37	3.00	1.45	2.57	1.33	2.38	1.36	2.14	1.20	-	-	
				Statistic functions	4.19	0.98	3.35	1.42	2.00	1.10	2.75	1.52	2.35	1.39	-	-	
				Semantic search	3.95	1.12	3.43	1.16	2.52	1.17	2.71	1.31	2.38	1.12	-	-	
				Ad-hoc analysis	4.52	0.60	3.65	1.04	1.95	1.12	2.33	1.59	2.00	1.45	-	-	

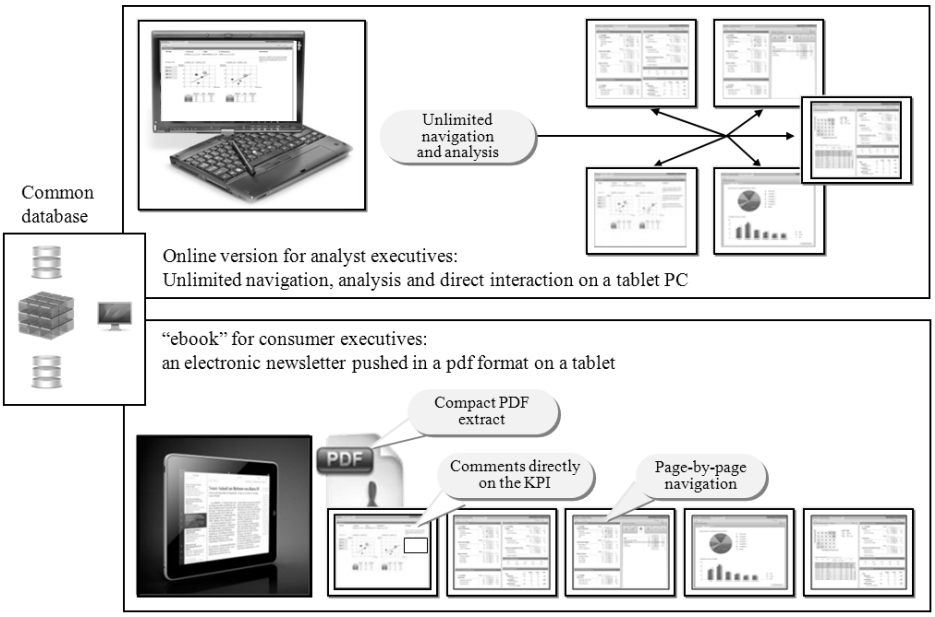

Figure 2: A combination of user-interface software components on mobile devices for analyst and consumer executives (navigation schema based on screenshots from the first instantiation)

5. Outlook and future research

Executives are not an appealing subject for many researchers because they are often unfamiliar with IS and not eager to use them. This paper argues that the present moment seems favorable for an IS redesign. To do so, we revisited previous EIS work, focusing on user preferences and how newer end-user devices and their user-interface software components can accommodate them. We end up with ten guidelines for designing „up close and personalized" EIS.

Tablets are the fastest growing class of end-user devices, even for business use. While notebooks continue to be the primary end-user device for most analyst executives [3], we argue for integrating *tablet functionality* in smaller notebooks leading to a newer class of end-user devices, tablet PCs. For consumer executives, „classic" *tablets* could be their first device ever—primarily to begin reducing their paper-based reports.

For future research, our user-interface designs should be applied in more EIS projects. To do so, situations in which executives access EIS content „on the road" should be researched in greater detail. In addition, the implications of the increasing number of end-user devices on system administration should be surveyed to determine IS architectures and policies that support governance, application development, and maintenance in a more heterogeneous IS world.

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