9-1-2010

# Simplicity, consistency, universality, flexibility and familiarity: the SCUFF principles for developing user interfaces for ambient computer systems

Rich Picking
*Glyndwr University, Wrexham*, r.picking@glyndwr.ac.uk

Vic Grout
*Glyndwr University*, v.grout@glyndwr.ac.uk

John McGinn
*Glyndwr University*, j.mcginn@glyndwr.ac.uk

Jodie Crisp
*Glyndwr University*

Helen Grout
*Glyndwr University*



## Recommended Citation

Picking, R., Grout, V., McGinn, J., Crisp, J. & Grout, H., "Simplicity, consistency, universality, flexibility and familiarity: the SCUFF principles for developing user interfaces for ambient computer systems", International Journal of Ambient Computing and Intelligence, July-September 2010, Vol. 2, Issue 3, pp40-49.

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**Abstract**
This paper describes the user interface design, and subsequent usability evaluation of the EU FP6 funded Easyline+ project, which involved the development of ambient assistive technology to support elderly and disabled people in their interaction with kitchen appliances. During this process, established usability design guidelines and principles were considered. The authors' analysis of the applicability of these has led to the development of a new set of principles, specifically for the design of ambient computer systems. This set of principles is referred to as SCUFF, an acronym for simplicity, consistency, universality, flexibility and familiarity. These evaluations suggest that adoption of the SCUFF principles was successful for the Easyline+ project, and that they can be used for other ambient technology projects, either as complementary to, or as an alternative to more generic and partially relevant principles.

**Keywords**
Easyline+ project, assistive technology, support elderly, support disabled, kitchen appliances, computer systems

**Disciplines**
Computer and Systems Architecture | Computer Engineering | Digital Communications and Networking | Hardware Systems | Systems and Communications

**Comments**


The Easyline+ website is located at http://www.easylineplus.com/

# International Journal of Ambient Computing and Intelligence

July-September 2010, Vol. 2, No. 3


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# Simplicity, Consistency, Universality, Flexibility and Familiarity:

## The SCUFF Principles for Developing User Interfaces for Ambient Computer Systems

*Rich Picking, Glyndwr University, UK*

*Vic Grout, Glyndwr University, UK*

*John McGinn, Glyndwr University, UK*

*Jodi Crisp, Glyndwr University, UK*

*Helen Grout, Glyndwr University, UK*

## ABSTRACT

*This paper describes the user interface design, and subsequent usability evaluation of the EU FP6 funded Easyline+ project, which involved the development of ambient assistive technology to support elderly and disabled people in their interaction with kitchen appliances. During this process, established usability design guidelines and principles were considered. The authors' analysis of the applicability of these has led to the development of a new set of principles, specifically for the design of ambient computer systems. This set of principles is referred to as SCUFF, an acronym for simplicity, consistency, universality, flexibility and familiarity. These evaluations suggest that adoption of the SCUFF principles was successful for the Easyline+ project, and that they can be used for other ambient technology projects, either as complementary to, or as an alternative to more generic and partially relevant principles.*

*Keywords:* *Ambient Design Principles, Assisted Living, Evaluation, SCUFF, Usability*

## 1. INTRODUCTION AND MOTIVATION FOR RESEARCH

We have developed user interfaces situated in modified familiar home devices, specifically television sets, mobile devices and interactive digital photographic frames, as part of the EU FP6 IST Easyline+ project (Low Cost Advanced White Goods for a Longer Independent Life of Elderly People).

Sensors using radio frequency identification (RFID), ZigBee, powerline communication

DOI: 10.4018/jaci.2010070103

and infra-red technologies enable the Easyline+ system to interact with the home environment. Human activity is monitored by an intelligent server, which we call the *e-servant*. The e-servant recognizes and adapts to changing needs as the user grows less able over time.

A simple example of an Easyline+ interaction is the scenario of a cooker hob being left on either with no pan on it or after a pan has been removed. The message *Hob left on with no* pan is conveyed to the user (wherever they may be in the home). The precise nature of the interaction and the range of options available to the user are adaptive, flexible and dependent on their level of ability, which can be assessed on a number of scales. However, the essence of the dialogue in this case would be that the user could turn off the hob remotely or respond: *Yes, I know; leave it on* (if they are permitted to according to their profile). Other scenarios include: *Food has expired in the fridge*, *The washing cycle has finished*, *This food cannot be microwaved*, and so forth. Additionally, a standalone RFID reader advises the user what to do with an item of food or clothing, an innovation particularly useful for visually impaired people. To support the international dimension, a range of European languages is also supported. The system is also adaptive in that it can modify the user interface for changing physical and cognitive abilities.

During the project's development, a number of user-centred exercises and events were undertaken to tune the design requirements, including workshops, focus groups, interviews, and evaluation sessions (Picking et al., 2009). We also employed personas (Cooper, 2004; Blythe & Dearden, 2009) to help us stay focused on the expectations of the end users. Summative testing of the ranges of devices and interface designs took place in a purposely developed usability laboratory, which simulated an elderly/disabled person's living space.

Satisfying the user and functional requirements are of course critical in any computer system development project, and good design augments these by referencing design principles relevant to the domain of enquiry. This paper describes the rationale for how we framed our user interface design decisions, and how this framing provided us with a structure which we propose here as a set of principles specifically for user interface design practice in the domain of ambient computer systems.

## 2. USER INTERFACE DESIGN GUIDELINES AND PRINCIPLES

The process of user interface design can be highly complex, as typically there are many competing variables involved. We could describe those variables as the *who* (the user population), the *where* (the environment the proposed system will be used in), the *how* (the style of user interaction, and the design of the tasks), and the *what* (the technological nature of the devices as well as the software/hardware constraints). Most user interface designers champion the *who* as the most important of the four variables, and consequently advocate a user-centred approach to their work.

To support designers in their consideration of users, a number of guidelines have been published over many years. Such guidelines aim to steer designers by keeping them on the track of developing quality, consistent user interfaces that conform to the standards expected by the *owners* of the guidelines. Examples of these include Apple's I-phone Human Interface Guidelines (Apple Inc., 2010) and Microsoft's Inductive User Interface Guidelines (Microsoft Corporation, 2001). As they tend to be for specific styles of interaction, for known types of devices, and for tasks that take place in typical environments (in other words the *how's*, *what's* and *where's* are predictable), such guidelines are always highly detailed.

At a further level of abstraction, design principles seek to cover a wide range of applications and application domains. Most sets of design principles are relatively short, comprising typically between six and ten individual principles. A well-known example is Shneiderman's eight golden rules of design (Shneiderman, 1999), summarized in Table 1.

During our initial consideration of user interface design guidelines and principles for ambient computing systems, we quickly determined that detailed guidelines were not applicable as they are too specific for the wide range of ambient computing applications, their users, and their environments. However, such guidelines may be developed for individual projects or platforms.

Rather, our concern centred on whether design principles, such as those of Shneiderman's, could easily be mapped onto the ambient subset of generic interactive computing applications. In order to do this, we looked at two further well-known sets of principles (Constantine & Lockwood, 1999; Nielsen, 2005) to determine their common features, possible differences, and whether any of them were appropriate for an ambient computing project. These are summarized in Table 2 and Table 3.

## 3. COMPARISON AND SYNTHESIS OF PRINCIPLES

We now move on to consider how the aforementioned usability principles apply to user interfaces for ambient computer systems. Each principle has been given a unique code in this paper for ease of cross referencing and discussion. Shneiderman's set is defined as {**S1...S8**}, Constantine and Lockwood as {**C1…C6**}, and Nielsen as {**N1...N10**}.

Our methodology uses a simple form of theme analysis, where we identify the common

*Table 1. Shneiderman's eight golden rules of interface design*

| Principle | Description |
|---|---|
| **S1. Strive for consistency** | Consistent sequences of actions should be required in similar situations; identical terminology should be used; consistent commands should be employed. |
| **S2. Enable frequent users to use shortcuts** | As the frequency of use increases, so do the user's desires to reduce the number of interactions and to increase the pace of interaction. Abbreviations, function keys, hidden commands, and macro facilities are very helpful to an expert user. |
| **S3. Offer informative feedback** | For every operator action, there should be some system feedback. |
| **S4. Design dialog to yield closure** | Sequences of actions should be organized into groups with a beginning, middle, and end. |
| **S5. Offer simple error handling** | As much as possible, design the system so the user cannot make a serious error. If an error is made, the system should be able to detect the error and offer simple, comprehensible mechanisms for handling the error. |
| **S6. Permit easy reversal of actions** | This feature relieves anxiety, since the user knows that errors can be undone; it thus encourages exploration of unfamiliar options. |
| **S7. Support internal locus of control** | Experienced operators strongly desire the sense that they are in charge of the system and that the system responds to their actions. Design the system to make users the initiators of actions rather than the responders. |
| **S8. Reduce short-term memory load** | The limitation of human information processing in short-term memory requires that displays be kept simple, multiple page displays be consolidated, window-motion frequency be reduced, and sufficient training time be allotted for codes, mnemonics, and sequences of actions. |

*Table 2. Constantine and Lockwood's user interface design principles*

| Principle | Description |
|---|---|
| **C1. The structure principle** | Your design should organize the user interface purposefully, in meaningful and useful ways based on clear, consistent models that are apparent and recognizable to users, putting related things together and separating unrelated things. The structure principle is concerned with your overall user interface architecture. |
| **C2. The simplicity principle** | Your design should make simple, common tasks simple to do, communicating clearly and simply in the user's own language, and providing good shortcuts that are meaningfully related to longer procedures. |
| **C3. The visibility principle** | Your design should keep all needed options and materials for a given task visible without distracting the user with extraneous or redundant information. |
| **C4. The feedback principle** | Your design should keep users informed of actions or interpretations, changes of state or condition, and errors or exceptions. |
| **C5. The tolerance principle** | Your design should be flexible and tolerant, reducing the cost of mistakes and misuse by allowing undoing and redoing, while also preventing errors wherever possible. |
| **C6. The reuse principle** | Your design should reuse internal and external components and behaviors, maintaining consistency with purpose rather than merely arbitrary consistency, thus reducing the need for users to rethink and remember. |

themes that run through each of the sets, and then assess that theme's applicability to the domain of ambient systems. We then synthesize them to propose our own set of principles for this domain.

Shneiderman's first principle **S1 Strive for consistency** marks clearly the theme of *consistency*, which is repeated in C1, C6 and N4. Ambient computer systems are no different from any other in this respect. The user interfaces should always be consistent.

The principle of *simplicity* is also evident throughout, specifically in Constantine and Lockwood's second principle **C2 The simplicity principle**. This principle is also evident in the descriptions of S8, N6 and N8, where advice is given of not overwhelming users' cognitive abilities by over-complication of the interface. Maximizing the system's visibility is also highlighted in C3 and N1. This is clearly a fundamental principle for most interactive computer systems, yet one might argue that for ambient systems, where the computer system often *disappears*, this might cause some confusion. The user interface itself is the one thing that may remain visible, but not always. For example, in a smart home environment, the interface may be embedded within a room's familiar fixtures and fittings, and the system status is evident in the environment, not in the interface. The same argument applies to the principles of feedback and closure, which are highlighted by S3, S4 and C4. We are not arguing here that visibility, feedback and closure are not important. Rather, for the specific domain of ambient computer systems where the environment itself is often the *output device* for want of a better term, these principles become less prominent. Consequently, we propose that they can be absorbed into the overall principle of *simplicity*.

Constantine and Lockwood's sixth principle **C6 The reuse principle** is interesting to discuss from an ambient perspective. As

*Table 3. Nielsen's usability heuristics*

| Principle | Description |
|---|---|
| **N1. Visibility of system status** | The system should always keep users informed about what is going on, through appropriate feedback within reasonable time. |
| **N2. Match between system and the real world** | The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order. |
| **N3. User control and freedom** | Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo. |
| **N4. Consistency and standards** | Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions. |
| **N5. Error prevention** | Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action. |
| **N6. Recognition rather than recall** | Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate. |
| **N7. Flexibility and efficiency of use** | Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions. |
| **N8. Aesthetic and minimalist design** | Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility. |
| **N9. Help users recognize, diagnose, and recover from errors** | Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution. |
| **N10. Help and documentation** | Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large. |

ambient systems interact with humans in their environments, it is highly likely that more than one instance of a user interface will exist. For example, there may be a user interface in several rooms in a smart home or workplace, and there may be mobile interfaces owned by each person within that environment. This principle of reuse not only applies to the internal components of a user interface, but should also be adhered to for alternative user interfaces and their platforms. In other words, the user interface should be universally the same (as far as possible) for all platforms and all devices. We term this principle of external consistency *universality*, and we regard it to be specifically important for ambient systems.

The nature of the disappearing computer in ambient computer systems leads us next to concentrate on Nielsen's second principle **N2 Match between system and the real world**. Clearly, ambient systems are very closely linked with the *real world*, and so particular attention on this principle is warranted. To this end, user interface metaphors have been successfully applied in ambient user interface design (Adam et al., 2008). Many ambient user interfaces are embedded within the environment, and often in familiar devices (appliances, televisions for example). Also, their users expect their interaction with the ambient computer system to be natural and familiar, and in some cases the interaction itself is invisible to the user (for example, where lights are switched on when a room is entered). We term this principle *familiarity*.

Nielsen's seventh principle **N7 Flexibility and efficiency of use** reminds us of the requirement that ambient computer systems should be personalizable. This principle is also referred to in S2, where frequent or expert users should be provided with faster ways to achieve their goals. Ambient systems are also often adaptive and intelligent enough to know who their user is, so this principle of *flexibility* is clearly fundamental to this domain.

A number of the previously published principles focus on error handling, and error recovery (S5, C5, N5, N9, S6, C5, N3). These principles are of course crucial for all typical interactive systems. For ambient systems with typical user interfaces, the same applies, although we argue that for an interface to be truly ambient, errors should be either avoided at all costs, or if not then not critical, and easily rectified by a user's subsequent action. In other words, the environment would behave in a manner familiar to the user as if they were not actually using a computer system. In the same respect, the concept of *undo* is unnatural, conflicting with the principle of *familiarity*.

Two further established principles recommend that the user should feel in control and be the initiator of dialogues (S7, N3). This is clearly true for traditional computer applications, but in ambient systems, the system itself often initiates a dialogue, and also often controls that dialogue by responding to human behavior and environmental situations.

The only principle not yet discussed is Nielsen's tenth **N10 Help and documentation**. We agree with Nielsen that it is better that a system can be used without help or documentation. Ambient systems especially should be intuitive and encourage natural behaviour. Whilst all systems will be supported by some form of documentation, we consider this principle to be peripheral to the fundamental principles of user interfaces for ambient computer systems.

Now that all the published principles have been discussed, we can reflect on the themes identified. This analysis has provided us with five principles, derived from those themes: Simplicity, Consistency, Universality, Flexibility, and Familiarity – re-arranged now to give us the SCUFF acronym.

In the following section, we describe how we applied the SCUFF principles to a real ambient system design project and the subsequent evaluation of its user interface.

## 4. APPLICATION AND EVALUATION OF THE SCUFF PRINCIPLES

Interface devices implemented in the Easyline+ project include the television, interactive digital photo frames (DPFs) and hand-held (or worn) mobile devices (MDs). The television was selected as the central point of control in the home, an observation corroborated by initial user surveys and the narrative workshops. This *simplicity* and *familiarity* of the user interface device conforms to the SCUFF principles, and is also supported by research into elderly users' views of interaction with technology (Davidoff et al., 2005; Nygard, 2008).

DPFs can be positioned in any room of the home for immediate notification (when not in use, they display conventional photos) and MDs can be used for emergencies and other forms of mobile interaction – in the garden, for example. It could be argued that MDs are not popular with the current generation of elderly people; however, this is changing quickly as such devices become more ubiquitous. All devices present an identical display, to provide external consistency of use (the *universality* principle).

The *consistency* principle is assured throughout the interface design with consistent presentation of the display layout, placement of menus, use of colour, text, graphics and icons. Dialogue with users was also designed to be consistent and appropriate for the user.

*Flexibility* was enabled as this dialogue could be adapted for the user's individual needs. We employed three levels of cognitive adaption, three levels of visual adaption, and three of aural adaption. The latter two physical factors are also adaptable by providing users with larger and louder physical display devices. Blind users are supported as the interface is usable in aural display only. However, a suitable tactile input device is required for these users.

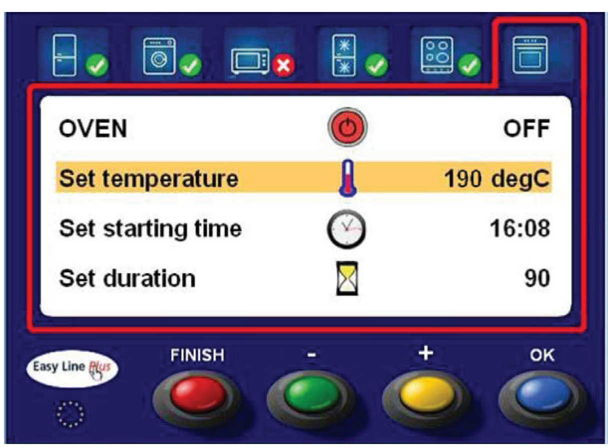
The *familiarity* principle informed our selection of remote input devices for the TV, based on the four-colour (red, green, yellow and blue) buttons of a typical television remote-control. This four-colour menu style of interaction was also employed on devices not associated with the TV such as DPFs and MDs, allowing for complete *universality* of device appearance and operation.

An example of the final interface design, maintaining adherence to the SCUFF principles, is given in Figure 1.

## 5. USABILITY EVALUATION

To test our designs, and indirectly the value of the SCUFF principles, we conducted between-groups laboratory-based usability studies with heterogeneous groups of users, including elderly and disabled users, people with learning difficulties, as well as with 'healthy' adults. We were interested in evaluating the latter group for two reasons. Firstly, it has been documented that elderly and vulnerable participants in usability studies may react differently than they normally would, for example by being over-positive due to their involvement in the study (Park & Schwartz, 2000; Eisma et al., 2004). Comparing their results with what might be termed a control group would potentially identify issues of this nature. Secondly, our earlier evaluations suggested that the product might be suitable for time-impoverished people (for example, stressed parents with babies in the home), not just elderly and disabled people (Picking et al., 2009).

*Figure 1. Interface design screen example*



We selected a total of 27 participants for this evaluation exercise, comprising nine elderly users, nine with learning difficulties, and nine from the 'control' group. Each group was given a set of scenarios to follow (for example loading the refrigerator, baking food, and doing laundry), which involved interaction with the kitchen appliances and the user interface, which for this study was provided on a television screen and an MD. Participants' activities were recorded in the laboratory, and were subsequently analyzed. They were also asked to complete a usability experience questionnaire comprising 20 semantically-rated questions, which were categorized according to usability, design and layout, functionality, user satisfaction, and expected future use.

The aggregated results for every category and for all groups indicated a positive outcome for the usability experience questionnaire. An Analysis of Variance (ANOVA) revealed that there were no significant differences in the responses provided by the three groups ($F = 1.52; p < 0.05$), apart from one question which asked whether they felt embarrassment at using the system - some members of the learning difficulties group were uncomfortable with it from this point of view. The control group performed expectedly better in general, and the only observed usability issues involved elderly users' difficulty in using a standard remote control handset and the small-screened MD, both of which were easily rectified by selecting alternative input and output devices.

## 6. CONCLUSION

It is very well-documented that we are experiencing an increase in the number of elderly people and a reduction of younger people to care for them as they lose their independence in later years. Our evaluation of the Easyline+ project suggests that it has made a small but valuable contribution towards helping elderly and disabled people remain independently in their own homes for longer, something that is popular with those people, as well as potentially tempering future increases in elderly healthcare spending. The design of the user interfaces was informed not only by our close work with our user population, but also by the SCUFF principles we employed.

For future projects of this nature, where ambient technologies are embedded in human environments, adherence to the SCUFF principles should help designers focus on the unique factors that must be considered for user interface design in this domain.

## ACKNOWLEDGMENT

This research was supported through the European Union Framework Six (FP6) Information Society Technologies (IST) programme (No. 045515) EASYLINE+, 'Low Cost Advanced White Goods for a Longer Independent Life of Elderly People'.

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*Rich Picking is a Reader in Human-Computer Interaction and Deputy Director of the Centre for Applied Internet Research at Glyndwr University, Wrexham, Wales. He completed his doctoral thesis in 1996 in interactive hypermedia and multimedia design, under the supervision of Professor Cliff McKnight at Loughborough University. Currently, he specializes in user interface design and evaluation for assisted living, and is the lead designer and technical manager for the FP6 EU-funded programme: "Easyline+: Low Cost Advanced White Goods for a Longer Independent Life of Elderly People". Dr. Picking has extensive experience in both academia and industry, and has worked as a user interface design expert on many projects in a wide range of industries, such as engineering, logistics, security, production control, healthcare, and e-commerce. He has published widely on these topics.*

*Vic Grout was awarded the BSc(Hons) degree in Mathematics and Computing from the University of Exeter in 1984 and the PhD degree in Communication Engineering ("Optimisation Techniques for Telecommunication Networks") from Plymouth Polytechnic in 1988. He has worked in senior positions in both academia and industry for over twenty years and has published and presented over 200 research papers. He is currently Professor of Network Algorithms at Glyndwr University, Wales, where he leads the Centre for Applied Internet Research. His research interests span several areas of computational mathematics, particularly the application of heuristic principles to large-scale problems in Internet design, management and control. Professor Grout is a Chartered Engineer, Electrical Engineer, Scientist, Mathematician and IT Professional, a Fellow of the Institute of Mathematics and its Applications, British Computer Society and Institution of Engineering and Technology and a Senior Member of the Institute of Electrical and Electronics Engineers. He chairs the biennial international conference series on Internet Technologies and Applications (ITA 05, ITA 07, ITA 09 and ITA 11).*

*John McGinn graduated with first-class honours in Multimedia Computing from the North East Wales Institute of Higher Education (NEWI) in 2000. Since then he has worked as a lecturer,*

*senior lecturer and research fellow at NEWI and Glyndwr University and, most recently, as the lead developer for the FP6 EU-funded programme: "Easyline+: Low Cost Advanced White Goods for a Longer Independent Life of Elderly People". John's research interests include network protocols and standards and distributed collaboration and visualization. He has published and presented a number of technical papers on topics from information visualization to traffic filters and routing. He is a member of the British Computer Society and the Institution of Engineering and Technology.*

*Jodi Crisp obtained a BSc(Hons) in Computer Science from the University of Southampton in 2001 and an MSc in Human-Computer Interaction with Ergonomics from University College London in 2008. She has worked as a software engineer, integration engineer, senior test analyst and lexicographer before her role as a usability tester and developer on the EasyLine+ project at Glyndwr University. She has extensive experience of all aspects of the software development lifecycle, with a particular emphasis on usability.*

*Helen Grout graduated with honours in Environmental Studies from North East Wales Institute of Higher Education in 2004. After a brief period of working in industry she returned to academia, completing a PGCE at Glyndwr University in 2009. She then worked as a tester and developer on the EU funded Easyline+ project. From April 2010 Helen has been researching Phytophthora Pseudosyringea in Vaccinium myrtillus on Cannock Chase for a PhD at Staffordshire University. She is a Member of the Institute for Learning.*