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A method and advisor tool for multimedia user interface design

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Abstract

This paper describes a multimedia user interface design method and a design assistant tool which supports the method. The method covers specification of user requirements and information architecture, selection of appropriate media to represent the information content, design for directing attention to important information and interaction design to enhance user engagement. Guidelines for media selection and design for attractiveness, i.e. usability and user experience, are given. The method was evaluated in a case study design of a crowd control simulation training system, which demonstrated the method was usable and gave good solutions against an expert gold standard design. The tool provides advice on media selection and attention effects that match specification of the information content expressed as information types and communication goals. A usability evaluation was carried out to measure the usefulness and effectiveness of the tool in comparison to the method, and the results showed that the tool has a positive impact on multimedia design.

Keywords: Multimedia; Design method; Guidelines; Advisor tool; Aesthetics

1. Introduction

Nielsen (2000) noted that multimedia provides more design options but also requires design discipline. He argued that ad hoc use of multimedia confuses users and makes it harder for them to understand information. For instance, unnecessary use of animation or video clips can distract users' attention, so the users may not be able to find the important information. Design guidance to avoid such pitfalls exists (ISO, 1998, 2000); however, the guidelines have not been synthesized into a method or supported by tools. Furthermore, the effectiveness of such guidance in delivering usable and attractive interfaces has not been put to the test. This forms one of the motivations for the research we report in this paper. We aim to provide computer-based design guidance for multimedia designers (both novice and experienced) to carry out a formative evaluation of the effectiveness of the method and tool.

While there is some evidence that HCI guidelines are used in industrial applications (Bevan, 1997), the extent of direct use in the design process is open to debate (Gray and Salzman, 1998). Some suggest that design advice is effective once it is reasoned about as trade-offs, rather than being used directly as "cook book" knowledge (Carroll, 2000). HCI methods which have been integrated with software engineering processes and object-oriented design (Rosson and Carroll, 1995) may be a conduit for making guidelines easier to apply by providing a context for their application. However, methods without support tools have a poor track record of use (Van der Donckt, 1999) and even if users want to use the paper-based manuals, they may not be able to find relevant information (Nielsen, 1993).

In our previous research (Faraday and Sutcliffe, 1999) we developed a multimedia design advisor with an integrated sketching and scripting environment as a standalone development tool. However, such tools have a poor prospect of becoming integrated into commercial development practice. Rather than duplicate the interactive storyboarding and scripting facilities of commercial tools we decided to develop a design advisor that would

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complement multimedia development environments as a helper wizard to provide guidelines on demand and in context. The tool is motivated by the premise that media selection for multimedia presentations should be based on the information types and communication goals. With help from the multimedia advisor tool, multimedia designers could select appropriate media types for different types of information and communication goals. Our intention was to target novice users who would benefit from such advice rather than expert users who have already probably internalized considerable multimedia design knowledge.

In the remainder of this paper, Section 2 describes related work in the area, while Section 3 describes the revised method for multimedia design. It is followed by an evaluation of the method in Section 4. The conceptual architecture and scenario of use of the tool are described in Section 5. The evaluation of the tool and results are reported in Section 6. Section 7 discusses the findings and the contributions of the research and related work.

2. Related work

Frameworks for multimedia design guidelines have been proposed in the modality theory (Bernsen, 1994) which classified media into dimensions of visual, audio and haptic modalities; and dimensions that describe the properties of media, such as dynamic (continuous) or static, and analogue/discrete/linguistic representations. The modality theory also proposed mapping rules for selecting modality dimensions for different types of information content, although these were based on an informal analysis of the information content. Another framework proposed by Heller et al. (2001) classified multimedia along three axes: media types (e.g. text, sound, graphics and motion); context or qualities, such as aesthetics, interactivity and usefulness; and expression, which conflated qualities with abstraction in representation. Heller et al. also proposed guidelines that mapped from information types (concrete, abstract, spatial temporal, quantitative and covariant-relationship) to media types. However, the main purpose of their taxonomy seems to be an evaluative framework for educational multimedia rather than a design method. Design principles, similar to the concept of Nielsen's (1993) heuristics, were proposed for multimodal communication by Reeves et al. (2004). These drew attention to cognitive limitations of human information processing such as the need to avoid conflicting messages on the same modality (i.e. audio, visual communication channel), and advised on choice of modalities for input controls as well as computer output media. The importance of interaction for promoting comprehension in multimedia has been demonstrated by Narayanan and Hegarty (2002), who showed that multimedia applications which were designed to provide users with appropriate knowledge, interactive simulations and quizzes outperformed multimedia designs with animations but no interaction. Narayanan and Hegarty proposed design guidelines that focus on the link between the information content, interactivity and media representations; however, they were primarily concerned with causal explanations and did not address a wider range of information content. In our previous work (Sutcliffe, 1999, 2000, 2003) we proposed a taxonomy of information types that drew the distinction between dynamic (changing) and static facts, and information on physical aspects of the real world versus conceptual information. This taxonomy was employed to select appropriate media, and supplemented with attention-directing design guidelines.

Nielsen (2000) has argued that "the web is an attention economy where the ultimate currency is the users' time". In our previous work we proposed attention-directing design guidelines for salience effects in different media (Sutcliffe, 2000, 2003), based on cognitive models of users' attention and information-processing abilities (Wickens, 1992; Teasdale and Barnard, 1993), and experimental analysis of multimedia interaction (Faraday and Sutcliffe, 1996, 1997, 1998b), including earlier work on media patterns for causal explanations by Narayanan and Hegarty (1998). However, more recent interest in banner adverts in web user interfaces, and eye-tracking studies, have shown that high salience effects, such as animation, are not necessarily effective. For instance Bayles (2002) found that animation in banner adverts was not effective in promoting memorability, while Guan and Zhang (2004) and Diaper and Waelend (2000) found that although attention was directed towards animated adverts in terms of eye-tracking fixations, users did not comprehend or remember the information. Hornof and Halverson (2003) have demonstrated that even fixations on animated adverts are not reliable indicators of attention, let alone comprehension of content. Many of the guidelines we proposed (Sutcliffe and Faraday, 1994; Faraday and Sutcliffe 1997, 1998a; Sutcliffe, 1999), with recommendations from other sources (e.g. Bernsen, 1994; Heller and Martin, 1995), were incorporated in the ISO multimedia user interface design standard, ISO 14915, parts 1–3 (ISO, 1998, 2000). However, these standards do not cover design concepts relating to the new usability of user engagement and aesthetics. Hallnas and Redstrom (2002) and Norman (2004) point out that user engagement and affective responses to interfaces influence user satisfaction as well as the classic sense of operational usability. Lavie and Tractinsky (2004) developed questionnaires to evaluate aesthetics with components of "classical aesthetics" such as clean and symmetrical design, "expressive aesthetics", e.g. creative and fascinating design, and usability. Tractinsky et al. (2000) also demonstrated that although aesthetic judgement is culturally dependent it does influence the overall attractiveness of user interfaces across cultures.

Commercial multimedia design tools have provided support for authoring interactive scripting of applications (e.g. Director, Authorware); in contrast, research prototypes have focused more on the creative design process with support for storyboarding, linking media sequences (e.g. SILK: Landay and Myers, 2001), and semi-automatic generation of applications from storyboarding design with a visual design language for specifying interaction and synchronization (DEMAIS: Bailey et al., 2001). However, no multimedia design tools have provided design advice as well as prototyping support.

3. Designing attractive and usable multimedia systems

The ISO 14915 standard defines a *medium* as different specific forms of presenting information to the human user, such as text, video, graphics, animation, audio; and *multimedia* as the combinations of static and/or dynamic media which can be interactively controlled and simultaneously presented in an application. Static media do not change over time whereas dynamic media do. In this paper we follow the ISO definition which emphasizes that media are a form of representation rather than a modality as a means of receiving information or interacting (Oviatt, 2003). Multimedia design has to address the problems inherent in the design of any user interface, viz. defining user requirements, tasks, dialogue design; however, there are three issues that concern multimedia specifically:

- *Matching the media to the message,* by selecting and integrating media so the user comprehends the information content effectively.
- *Managing users' attention* so key items in the content are noticed and understood, and the user follows the message thread across several media.
- *Navigation and interaction* so the user can access, play and interact with media in an engaging and predictable manner.

Fig. 1 gives an overview of the design process we propose in order to address these issues.

The design process starts with requirements and information analysis to establish the necessary content and communication goals of the application. Concurrently the domain and user characteristics are analysed to establish a profile of the user and the system environment. User characteristics specify user abilities, preferences, and existing knowledge, which inform the choice of content so that information builds on the user's existing knowledge; and media choice takes user preferences and the system context into account. The output from these stages feeds into media selection and integration which matches the logical specification of the content to available media resources. Design then progresses to thematic integration of the user's reading/viewing sequence and interaction design. The method can be tailored to fit within different development approaches. For instance, in rapid applications development, storyboards, prototypes and iterative build-and-evaluate cycles would be used. On the other hand, in a more systematic, software engineering approach, more detailed specifications, e.g. UML class and activity sequence diagrams, and scripts, will be produced before design commences. Even though the process is described as a sequence, in practice the stages are interleaved and iterated; however, requirements, information modelling and media selection are carried out, even if they are not complete, before the media and attentional design stages commence.

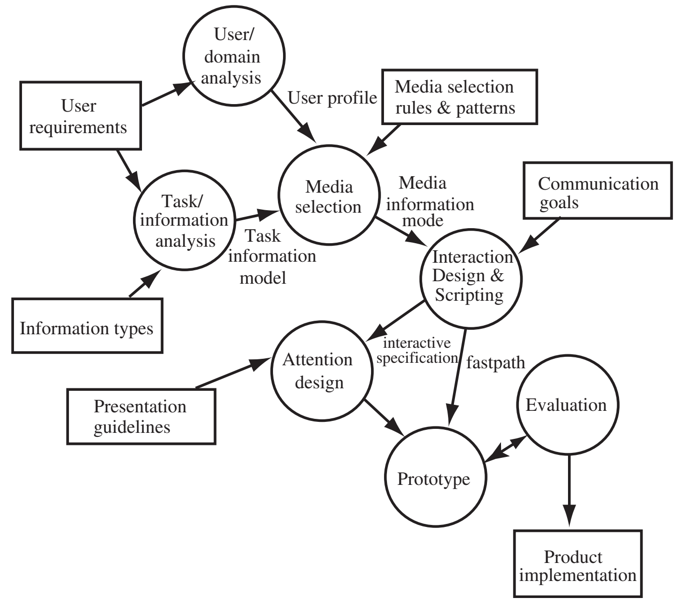


Fig. 1. Overview of the multimedia design process expressed as a data flow diagram.

The guidelines and recommendations in the method in the following parts of this section are the result of an eclectic synthesis from several theories as well as experimental studies. For instance, media combination rules can be inferred from cognitive resource limitations (processing visual, audio, speech, input, etc.) specified in Interactive Cognitive Sub-Systems (Teasdale and Barnard, 1993). Wickens' multiple resource theory (2002) specifies conflicting cognitive resources in multiple task processing/media input but also gives more insight into problems of selective attention (see Section 3.4). Norman's (1988) description of attentional errors was also used as a source for Section 3.4. Theories of emotion (Ortony et al., 1988) and arousal provide sources for recommendations about affective use of media, while the computer as a social actor theory (Reeves and Nass, 1996) is used extensively for advice on aesthetic, persuasive and emotive use of media. Existing compilations of HCI guidelines (Gardiner and Christie, 1987) and human factors (Bailey, 1982) have also provided advice on media usage.

3.1. Task and information analysis

Task analysis follows conventional HCI approaches such as Hierarchical Task Analysis (HTA) (Annett, 1996) or Task Knowledge Structures (Johnson et al., 1988) or may adopt use cases from object oriented and software engineering approaches (Cockburn, 2001). Task models are developed and then annotated with information requirements for each sub-goal. The influence of the task varies between applications; in some cases information analysis is more important and the task is simply to explain or provide information, and in these cases information structure models are created. In training applications the task becomes to explain and instruct, possibly about another external task. Alternatively, applications may have a prime task focus (e.g. multimedia for process control: Alty, 1997).

Information content is modelled following standard approaches to create entities, objects or groups of thematically related information. Information groups are then assigned types. Information types are amodal, conceptual descriptions of information components that elaborate the content definition. Information types specify the message to be delivered in a multimedia application by mapping rules that select appropriate media resources.

The information types are used in "walkthroughs" in which the analyst progresses through the task/scenario/use case asking questions about information needs. The type definitions, based on the Task-based Information Analysis Method (Sutcliffe, 1997) and ISO 14915, part 3, (ISO, 2000), categorize the information in objects and their attributes using the decision tree shown in Fig. 2. The first question is whether information represents concrete facts about the real world, or is more abstract, conceptual information; this is followed by questions that relate to

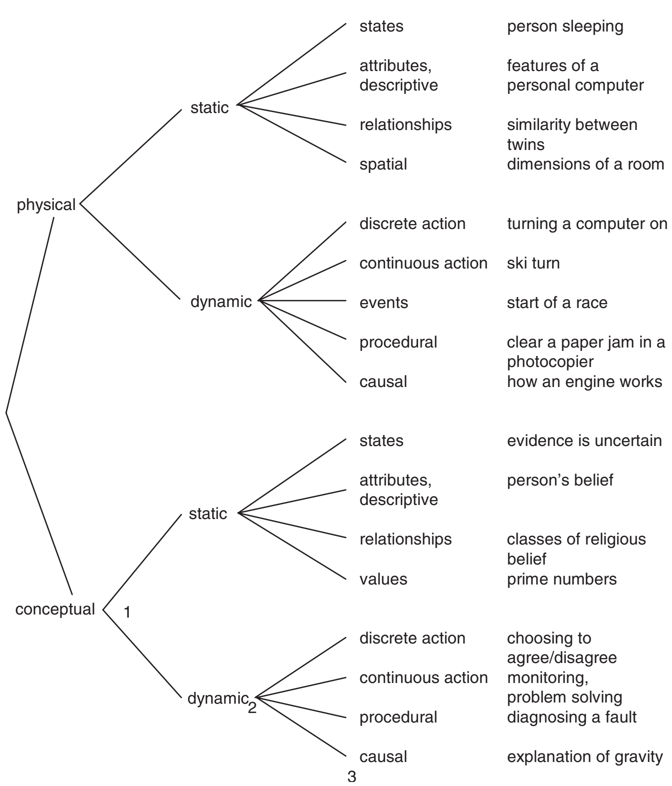


Fig. 2. Decision tree for classifying information types. The first decision point reflects abstraction from the real world, the second points to change in time and the third categorizes content.

information which changes in the world or describes permanent states. Finally, the decision tree gives a set of ontological categories to classify information based on type definitions commonly found in software engineering specifications. The classification is a compromise between more complex ontologies (e.g. Mann and Thompson, 1988; Arens et al., 1993), and ease of use. A finer-grained classification enables more finely tuned media selection decisions, but at the cost of more analysis effort.

3.2. Selecting and integrating media

Task and user characteristics influence media choice; for instance, verbal media are more appropriate to language-based and logical reasoning tasks; visual media are suitable for spatial tasks involving moving, positioning and orienting objects. Some users may prefer visual media, while image is of little use for blind users. To guide media selection and interaction design, a set of communication goals are provided. These are "generalised tasks" that commonly occur in multimedia applications which are associated with design advice on information architecture, media selection and interaction in a pattern-like format. The task model is assessed to select one or more communication goals; for instance in applications without an obvious task the goals are more likely to be Explain, Persuade or Attract. In task-oriented applications the goals can be used to augment the task model.

Explain (Casner, 1991; Maybury, 1999)

- Introduce topic (signposting), provide explanation, summarize explanation.
- Provide a clear information structure, with topic, sub-topics hierarchy, with matching access controls and a search facility for direct access in large structures.
- To explain causal arguments, provide background knowledge first, illustrate the causal sequence by images for each step, followed by animations to integrate the sequence, then summarize steps and principles using bullet points or numbered lists.
- Create interactive simulations with controls so users can experiment with parameters and observe effects (Narayanan and Hegarty, 1998).

Persuade (Reeves and Nass, 1996)

- Structure arguments to present proposals, provide evidence for a choice then motivate a particular option.
- Present arguments with praise for the client/user, congratulate the user on appropriate choice.
- Be polite in introducing the argument.
- Use video or photographic images of people with speech to engage the user and present arguments.

Warn (Bailey, 1982; Pezdek and Maki, 1988)

- Alert users with audio tones and visual highlighting to draw attention to key information supplemented with speech.

- Present users with information to understand the hazard in text, with maps and diagrams to show the location.
- Present suggestions for responses in context, with maps, diagrams and/or sequence of photographs to illustrate action (Wickens, 1992; Alty, 1997).
- When users are known, use voice of family member to speak warning message.

Excite and Attract (Reeves and Nass, 1996).

- Introduce content with dynamic media (video, animation, audio, speech) to attract attention.
- Design interactive worlds, simulations or games to engage the user, provide the user with an identity (self-presence) in the interactive world.
- Plan animation and action sequences with unexpected events.
- Use exceptions in visual design, e.g. oddity, unusual images, white space, to invoke curiosity.
- When appropriate, use aesthetic design guidelines (see Section 3.3) to attract users.

The suggested mappings from information types to media resources are given in Appendix A. Information types are mapped to a simple categorization of media as static non-streaming media; still image, text, diagrams, graphs and dynamic media; audio: natural sounds, speech, music and designed sounds; video and animation. Several media map to each type, although the preferred choice is shown in italics. Since most components in the information architecture will have multiple information types and each information type maps to several media, the selection process encourages multimedia integration. For example, when a procedure for explaining a physical task is required, first a series of realistic images will be selected, followed by video and speech to integrate the steps, then text to summarize the key points. The mappings are supplemented by the following heuristics:

- To convey detail use static media, e.g. text for language-based content, diagrams for models, or still image for physical detail of objects (Booher, 1975; Faraday and Sutcliffe, 1998b).
- To engage the user and draw attention use dynamic media, e.g. video for physical information, animation or speech.
- For spatial information use diagrams, maps, with photographic images to illustrate detail, animations to indicate pathways (Bieger and Glock, 1984; May and Barnard, 1995).
- For values and quantitative information use charts and graphs for overviews and trends, supplemented by tables for detail (Bertin, 1983; Tufte, 1997).
- Abstract concepts, relationships and models should be illustrated with diagrams explained by text captions and speech to give supplementary information.
- Complex actions and procedures should be illustrated as a slideshow of images for each step followed by a video of the whole sequence to integrate the steps. Text captions on the still images and speech commentary provide supplementary information (Hegarty and Just, 1993). Text and bullet points summarise steps at the end, so choice trade-offs may be constrained by cost and quality considerations.

Media selection and integration guidelines have to be interpreted according to the users' task and design goal. If information provision is the main design goal, e.g. a tourist kiosk information system, then persistence of information and drawing attention to specific items is not necessarily as critical as in tutorial applications. Media resources may be available for selection, or have to be purchased from elsewhere. If existing media can be edited and reused this is usually preferable to creating new media from scratch. Graphical images can be particularly expensive to draw, whereas capture of images by scanning is usually quick and cheap.

The method does not give detailed advice about sequencing presentations and design of interactive multimedia. However, the designer is advised to follow one or more of the following strategies, depending on the application.

- *Task sequencing*: the presentation sequence follows the task model, with appropriate navigation controls. This strategy would be appropriate for multimedia displays for process control applications with sequences to support monitoring, control, and hazard diagnosis tasks.
- *Interactive metaphors*: interaction is planned using a domain model to create a graphical multimedia world and metaphor for interaction. An example might be an educational game in which image and diagram media are used to show a world inhabited by animals with a compass metaphor enabling the user to assume the character of one of the animals and thereby move through the world. The event response dialogue and information requirements are driven by the domain model, such as ecology of the animal, good and bad foraging choices, etc.
- *Navigation-based scripting*: more suitable for information intensive multimedia without a strong task model. The access dialogue is determined by the information architecture and the needs for user support, e.g. facilities such as interactive visit lists, selectable maps of the information space, etc.

Media integration needs to consider continuity between interactive sequences, particularly in task-driven or interactive metaphor type applications.

3.3. Aesthetics and attractiveness

Media selection can also be motivated by aesthetic choice. Aesthetic considerations may contradict some of the task-motivated guidelines because the design objective is to please the user and capture the attention rather than deliver information effectively. Design guidelines for aesthetics are difficult to formalize since judgement of aesthetic quality suffers from considerable individual differences. A person's reaction to a design is a function of their motivation (Brave and Nass, 2002), individual preferences, knowledge of the domain and exposure to similar examples, to say nothing of peer opinion and "fashion". Aesthetic considerations will affect design and choice of media as well as design of the visual aspects of the user interface. Aesthetic design is important for e-commerce applications with high-value brand-conscious products, when presenting organizations where style and image are important or when addressing audiences who have high expectations of aesthetic style. The following guidelines, which need to be interpreted in the context of the application and user audience, were synthesized from several sources on graphical, visual and interaction design (Kristof and Satran, 1995; Mullet and Sano, 1995; Reeves and Nass, 1996; Macdonald, 2003).

- *Judicious use of colour*: colour use should be balanced and low saturation pastel colours should be used for backgrounds. Designs should not use more than 2–3 fully saturated intense colours (Mullet and Sano, 1995).
- *Symmetry*: visual layout should be symmetrical, e.g. bilateral, radial organization that can be folded over to show the symmetrical match (Kristof and Satran, 1995).
- *Shape*: use of curved shapes conveys an interesting visual style which attracts by being different from the conventional box/rectangle layout.
- *Space*: use of white space or empty background to surround information; use of space in an irregular format. More space makes the screen less cluttered, irregular forms interest users by being different (Mullet and Sano, 1995).
- *Structured and consistent layout*: use of grids to structure image components and portray a consistent order; grids need to be composed of rectangles which do not exceed a 5:3 height to width ratio.
- *Depth of field*: layers in an image stimulate interest and can be attractive through promoting curiosity. Use of background image with low saturated colour provides depth for foreground components.
- *Use of dynamic media to attract attention*: video, animation, speech and audio all have an arousing effect and increase attention and improve the attractiveness of presentations. However, animation must be used with care as gratuitous video which cannot be turned off quickly offends (Spool et al., 1999; Nielsen, 2000).
- *Match mood to audience*: use of content, visual style and media to set an appropriate feel of mood, e.g. light or dark colours to set serious/light-hearted mood. *Media content* can affect users' mood. For example background images of natural scenes provide a restful setting whereas images of technology and unusual objects have an arousing effect (Reeves and Nass, 1996). *Natural sounds* such as running water, wind in trees, bird song and waves on a sea shore have restful properties. Backgrounds in half shades and low saturation colour provide more depth and interest in an image (Mullet and Sano, 1995).
- *Use of personality in media to attract and persuade*: static human image, photographs and speech can help to attract users and persuade them to buy goods by being polite and praising their choices (Reeves and Nass, 1996). Interactive animations of people, e.g. talking heads or full body avatars, have an attractive effect since we ascribe human properties to computers when interfaces give human-like visual cues. An example of a site which uses static human image for attraction effectively is illustrated in Fig. 3.
- *Design of unusual or challenging images* that stimulate the users' imagination and increase attraction: unusual images often disobey normal laws of form and perspective.
- *Speech* engages attention because we naturally listen to conversation. Choice of voice depends on the application: female voices for more restful and information effects, male voices to suggest authority and respect (Reeves and Nass, 1996).
- *Music* has an important emotive appeal, but it needs to be used with care. Classical music may be counterproductive for a younger audience, while older listeners may not find pop music attractive.

The effectiveness of media representing people depends on the characters' appearance and voice. In human–human conversation, we modify our reactions according to our knowledge, or assumptions about, the other person's role, group identification, culture and intention (Clark, 1996). Use of human-like forms is feasible with pre-recorded video and photographs; however, the need depends on the application and the rules of human conversation apply

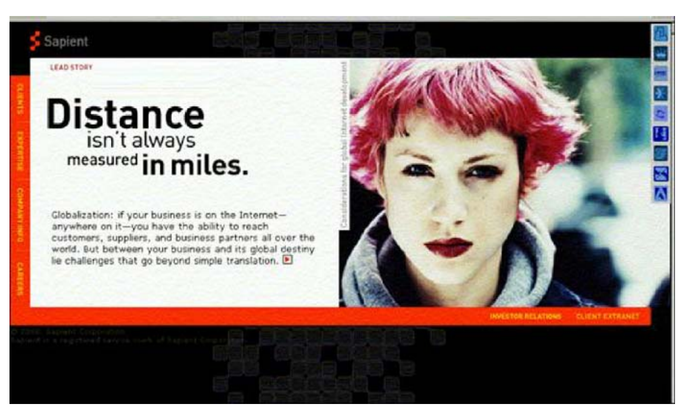


Fig. 3. Effective use of human image for attraction. The picture attracts by the direction of gaze to the user as well as by the appearance of the individual. Reproduced with permission of Sapient Ltd.

Table 1
Attention-directing techniques for different media

	Attention-directing techniques in approximate order of power	Sources and notes
Still image (designed and natural)	Movement or change in the shape/size/colour of an object, outline or boundary, colour, shape, size or texture to distinguish important objects. Object marked with a symbol (e.g. arrow) or icon	Some effects may compromise natural images because they overlay the background image with new components (e.g. arrows, arcs, icons). (Gardiner and Christie, 1987)
Moving image	Freeze frame followed by applying a still image highlight. Zoom, close-up shot of the object. Cuts, wipes and dissolve effects	Animation overlays and annotation on video can be effective for highlighting objects (Hochberg, 1986)
Text	Bold, font size, type, colour or underlining. To direct attention to larger segments of text use formatting, headings/titles, bullet points, sub-sections, indentation	Formatting using indents and hierarchical nesting is useful to show structure (Levie and Lentz, 1982; Mullet and Sano, 1995)
Speech/sound	Alarm sounds (police sirens), familiar voice (relative), silence followed by onset of sound, change in speaker's voice, prosody (tonality), amplitude (loudness), change and variations in pitch (frequency), voice rate or source direction	Discourse markers "next", "because", "so", etc. draw attention to subsequent phrases (Patterson, 1982)

(Grice, 1975), so generated dialogue needs to be relevant, succinct, unambiguous and cooperative.

3.4. Attention-directing techniques

Design for attention is particularly important if vital information is present in parts of an image which may not be obvious to the user. Users' attention to time-varying media is determined by the medium itself, i.e. we have little choice but to listen to speech or to view animations in the order in which they are presented. However, viewing order in images is unpredictable unless the design specifically selects the user's attention.

In some cases a common topic may be sufficient for directing the user's reading/viewing sequence; however, when a theme is important or hard to follow, designed effects for attention, or contact points, are necessary to aid the user's perception. The term "contact point" refers to a reference from one medium to another (Hegarty and Just, 1993); and reinforcing the links between information in different media has been shown to improve comprehension (Scaife and Rogers, 1996; Narayanan and Hegarty, 1998).

Multiple contact points may be organized in a logical order to follow the theme and connect a thread of topics (Faraday and Sutcliffe, 1998a, 1999). For instance, in a biology tutorial, the explanation of parts of a cell is organized by interleaving speech segments and a diagram describing the cell's components. Highlighting techniques locate each component in turn, following the order of the spoken explanation.

The design problem is how to direct the user's attention to the appropriate information at the correct level of detail. Initially, users will tend to extract information from images at the scene level, i.e. major objects will be identified but with little descriptive detail (Treisman, 1988). Windows or frames can be set to control which parts of an image are viewed. Larger window frames will be attended to before smaller areas. A list of the key components that the user needs to focus on and thematically related information are specified, then attention-directing techniques are applied in the relevant medium either to make the information item salient or to design a contact point between related items and thematic sequences. Attention-directing techniques for each media type, organized in approximate power of their effect, are summarized in Table 1.

Adding contact points and attention-directing effects completes the design process. Design approaches in multimedia tend to be interactive and user-centred. *Storyboards* are a well-known means of informal modelling in multimedia design (Nielsen, 1995; Sutcliffe, 1999). Translated to software, storyboards depict key stages in interaction and are used for conducting walkthroughs to explain what happens at each stage. Allowing the users to edit storyboards and giving them a construction kit to build their own encourages active participation (Bailey et al., 2001). Storyboards are followed by building concept demonstrators using multimedia authoring tools (e.g. Macromedia Director, Toolbook) to rapidly develop early prototypes. *Concept demonstrators* are active simulations that follow a scenario script of interaction. Several variations can be run to support comparison; however, the user experience is mainly passive. In contrast, users can test *interactive prototypes* by running different commands or functions. The degree of interactivity depends on the implementation cost which increases as prototypes converge with a fully functional product.

The tool described in Section 4 provides guidelines as a help function which can be accessed from standard multimedia development environments.

4. Evaluation of the method

The method was evaluated through a case study of how designers, who were given a design brief, used the guidelines and the method to create storyboards. The application domain was a crowd control simulation-training system for the police. The design brief required a multimedia design for training officers to control crowds while evacuating public stadia (e.g. football grounds) in emergencies.

4.1. Subjects

Nineteen students (18 male, one female; age range 20–32, mean 23) took part in the evaluation. All were third year undergraduates in the School of Informatics, University of Manchester who had taken the advanced HCI class during which the method had been taught. Even though there is a gender imbalance in the subject pool, a closer observation does not reveal a radical difference between the female and the male subjects.

4.2. Experimental procedures

For the evaluation the subjects were given complete paper-based documentation of the method and asked to read it for 30 min before attempting the storyboard design. The subjects worked at their own pace and no time limit was given for completion of the design. The evaluation task was to apply the method and produce a task plus information content analysis, select appropriate media and create storyboard designs, and then give written explanations of the interaction and dialogue. In addition the subjects had to explain which design guidelines they used and why, with a critique of the comprehensibility and utility of the guidelines. The subjects filled in a questionnaire rating the effectiveness of the design principles and guidelines on a 1–7 scale. Most subjects completed the task in three hours although some required longer to complete the storyboards.

4.3. Scoring procedures

The designs produced by the subjects were assessed against a "gold standard" expert solution produced by the evaluators in collaboration with an independent expert designer. The major design features which the method should have suggested were:

- Design of an interactive simulation to promote user engagement; the simulation could be augmented with a quiz or games concepts.
- Design of a simulation using diagrams or drawings of the stadium (spatial information) to represent crowd behaviour, possibly augmented with photographs and videos for realistic detail.
- Use of video and audio of crowd scenes to provide realistic sensation during training.
- Evacuation procedure as text checklist, augmented with photographs and/or diagrams to illustrate each step, possibly with video to show the complete sequence; summary of sequence and principles at the end.
- Lists or tables of officers available, training, status, etc.

The storyboards needed to explain the interactive simulation, controls and the user system dialogue and media used.

4.4. Results

The performance scores, which cover the major areas of the methods guidance—information analysis, media mapping, design guidelines for aesthetics and attention—are given in Table 2. Assessment of the method and effectiveness of the guidelines were judged from the critique provided by the subjects, while the overall quality of the solution was judged from the storyboards, and the accompanying explanations which were compared with the expert solution. Two aspects of the method, task analysis and media integration, were not covered explicitly by guidelines. Task analysis had been explained in depth to the subjects using HTA (Annett, 1996), but media integration required use of communication goals, media selection guidelines (see Appendix A) and aesthetic guidelines. Media integration was assessed as a solution quality reflecting how well the subjects interleaved static and dynamic media concurrently when appropriate, and avoided either standalone media in separate windows or media overload with too many concurrently running video or audio tracks.

All subjects performed well, apart from three who made little attempt to use the method; the quality of their solutions was also poor. The scores were in the mid-range of the 10-point assessment scale, indicating reasonable comprehension and use of the guidelines. Overall solution quality and scores for use of the method were significantly positive for all components ($p<0.01$ Spearman rank order correlation, $n = 19$), although the correlations were marginal for task analysis ($p<0.05$), so most method components appear to have contributed to the quality of the overall solution. Of the method components, media selection guidelines scored highest, and even the three

Table 2
Effectiveness of the subjects' use of method components and design solutions

Performance measure	Mean	Range
Use of information types, information analysis	5.1	0–9
Task analysis	5.1	0–7
Media selection	6.4	3–9
Communication goals and interaction	5.4	1–8
Aesthetics and attractiveness	4.4	0–9
Attention-direction	5.2	1–8
Media integration quality	5.2	0–9
Overall solution quality	6.3	3–8

poor solution-quality subjects achieved scores in the 3–5 range. However, media integration and other aspects of solution quality were much worse for the three poor-performing subjects, thus providing evidence for the positive effect of the guidelines. The other method components received similar average scores in the 5.1–5.4 range apart from use of aesthetics (4.4) which several subjects considered, not unreasonably, to be less relevant to the application domain. The three method components with lower averages (aesthetics, media integration and information types) also, not surprisingly, had a higher incidence of poor scores with the below-average subjects. Overall the solution quality scores were higher than method usage; however, some parts of the solution could be attributed to individual creative reasoning and the task analysis which was not explicitly covered in the method. Three interpretations are possible: first, even imperfect understanding produced better solution quality; second, the evidence of understanding and use reported by the subjects did not reflect their actual understanding; or third, solution quality was not influenced by the guidelines. Given the positive correlations between quality and guideline understanding we argue that one of the first two explanations is more likely.

The subjects' own ratings of the comprehensibility and usefulness of the design principles and guidelines are given in Table 3. These mirror the assessment of the understanding and usage of the method components based on the subjects' written rationale and critique; in particular media integration received the lowest score in both measures. Information types were rated positively but less favourably than other components. The aesthetic guidelines were rated highly for understanding and usefulness, even though some subjects commented on their low relevance to the application; this may explain the lower scores these guidelines received in the method/usage assessment.

In the information analysis, the concept that caused most confusion was the distinction between physical and conceptual information, since, as several subjects remarked, in many cases information could have both aspects. For example evacuation procedures consisted of a set of logical, conceptual instructions but detailed instructions could also contain physical elements which may become clear when sequential interaction is planned.

Table 3
Subjects' ratings of comprehensibility and usefulness of the goals and heuristics

Method	Comprehension		Usefulness	
	Mean	Range	Mean	Range
Information types	4.6	3–6	5.0	4–7
Media selection	6.0	5–7	5.8	5–7
Goals	5.7	4–7	5.7	4–7
Aesthetics	5.8	4–7	5.7	5–7
Attention	5.3	3–7	5.1	3–7
Media integration	3.6	2–6	3.7	0–7

4.5. Subjects' comments on guidelines and heuristics

The communication goals Excite and Attract (six individuals), followed by Warn (five subjects) and Persuade (four), received favourable comment and explanation on how the goals influenced their design. However, Persuade and Warn confused another two subjects. Interactive simulations formed part of the solution for 12 subjects while ten added a quiz to test the effects of training. Three subjects designed a scripted character to guide the user through the application. Use of dynamic media to interest and engage the user was commented on favourably by six subjects, while five noted that they used images of people to engage or persuade users. Problems with distinguishing between physical and conceptual information, particularly in evacuation instructions, received adverse comments from two subjects, and another three commented that the information types and mappings were not useful, although they did approve of the media type taxonomy. Two subjects commented that they did not use the guidelines directly but felt the information provided acted as a *gestalt* to inform design. Of the aesthetic and attractiveness guidelines, use of colour and consistency were the most favourably received and frequently used (52%, 56%); setting mood was commented on by five subjects although three of them stated that more comprehensive guidelines were needed, e.g. how to set somber and serious moods. Difficulties were noted for interpreting depth of field (one subject), symmetry (three subjects), use of space (three subjects), while two subjects discussed the conflict between some of the guidelines (e.g. consistency, use of space, symmetry). One aspect of the application that caused confusion was the distinction between communication modalities (e.g. video and radio/speech links that might be required in the operational task) and media to represent information in the training application. Since operation communication modalities could form part of the content of the training application, two subjects suggested that modalities should be explicitly distinguished in the method.

4.6. Evaluation in tutorials

The method was presented at three tutorials at the ACM CHI conference in consecutive years as well as tutorials at INTERACT and HCI International conferences. Space precludes presentation of the feedback assessments; however, audience reaction was always positive. The main lessons learned when presenting the method and using it with a medical training case study were that the information types gave some of the participants' problems, particularly with the conceptual/physical distinction; media types and mapping rules were well received but more advice on media integration was requested. Communication goals were easy to understand and apply; however, more advice on interaction and dialogue design was necessary. The aesthetic design guidelines attracted a bipolar reaction: participants with a graphics or visual design background rejected them as naïve and not appropriate, whereas participants who were novice designers or designers with a software engineering background liked them, although some guidelines were considered difficult to interpret (symmetry, use of space, depth of field and mood).

5. Multimedia design advisor tool

The Multimedia Design Advisor tool was developed to support all aspects of the method apart from the aesthetics and attractiveness guidelines, which were not implemented because the rationale of tool operation was to search for guidelines based on the user's specification of information type requirements. Aesthetics and attractiveness guidelines did not fit into this operational scenario. The media design advisor was intended to act as a help wizard-style application, running concurrently as an advice window when the designers used media authoring tools such as Director or Stagecraft. The Multimedia Design Advisor was developed using Visual Basic (v.6) to provide advice on communication goals, media selection and attention effects. The main functions of the tool are explained in more detail in the following sections.

5.1. Media selection advice

The tool was designed to give advice on media selection according to 17 information types and seven communication goals. The target media types with illustrative examples were realistic/non-realistic moving/still image, realistic/non-realistic audio, speech, text or language-based media. The communication goals used in the tool were an expanded version of the goals described in the method, as follows:

- *Persuade*: the goal is to persuade users about an issue when decision making is involved, e.g. e-commerce websites.
- *Explain*: the goal is to explain the information to users, e.g. encyclopedia, or reference sites, etc. This is the default communication goal for many non-task applications.
- *Demonstrate*: the goal is to demonstrate operational procedures or actions, e.g. exercise routines, do-it-yourself house repairs, etc.
- *Entertain*: the goal is to entertain users, e.g. games, quiz, films, music, etc.
- *Users' mood excite*: this goal is to interest users or excite them about the information by setting the mood, e.g. car racing sites, etc.
- *Users' mood calm*: the goal is to make users calm and restful, e.g. yoga, meditation.
- *Aesthetic appeal*: the goal is to appeal to users aesthetically, e.g. websites for art, artists, designers, e-commerce with high value goods, design brand image, etc.

Once the user selects an information type, the tool recommends appropriate media types with examples. The tool also displays any relevant communication goals for the selected information type; some communication goals are not relevant for particular information types, e.g. the conceptual value information type is rarely used for the entertainment communication goal. Communication goals, generally, have only weak implications for media types; however, some do have stronger implications, for instance, the Mood: Calm goal is associated with image and audio with natural world content. Once an information type and any relevant communication goals have been selected, the tool shows relevant media examples. The users can access media examples for each communication goal without selecting any information type or for information types without selecting any communication goals. The library of media examples can also be browsed independently as shown in Fig. 4.

The mapping rules in the tool are based on media selection guidelines for the information types and/or communication goals. Some illustrations of the format of the rules for media selection, with examples, are as follows:

- *IF* ⟨Information Type = 'Physical state'⟩ *THEN* recommend ⟨Media Type = 'realistic still image; text'⟩ *AND* show ⟨Media Example = 'image of people sleeping'⟩
- *IF* ⟨Communication Goal = 'Persuasion'⟩ *THEN* recommend ⟨Media Type = 'realistic moving image; non-realistic moving image; speech'⟩ *AND* show ⟨Media Example = 'an animated image of human face gazing at users'⟩
- *IF* ⟨Information Type = 'Physical spatial'⟩ *AND* ⟨Communication Goal = 'Demonstration'⟩ *THEN* recommend ⟨Media Type = 'realistic moving image'⟩ *AND* show ⟨Media Example = 'a video clip showing different viewpoints in panoramic images'⟩

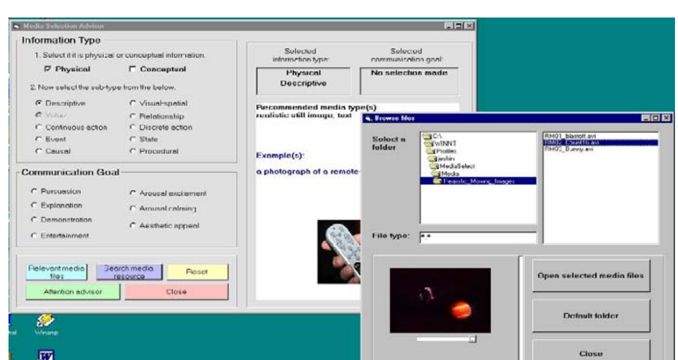


Fig. 4. Screenshot of Multimedia Design Advisor (main window with media browser).

The media examples are retrieved from a media resources library using a simple keyword search; for example, a video index viewpoint on museum exhibits would be retrieved for the last rule. Alternatively, specific examples can be entered for each rule.

5.2. Attention effects advice

The Advisor provides guidelines and examples on how to direct users' attention so they will find important information within each medium and on implementing contact points between thematically related pieces of information. The guidelines are ordered in approximate force of their effect so the design can match the guidelines to the importance of the information, while being aware of the trade-off that overuse of attention-directing effects will reduce their effectiveness and annoy the user, as demonstrated by the excessive use of animated banner adverts (Nielsen, 2000).

The following attention-directing guidelines were provided, with examples:

- *Text*: flash text, reveal caption bold, underline, change font.
- *Text structure*: indentation to format, bullet point, discourse markers.
- *Image*: move, highlight, point to, mark.
- *Audio*: warning tone, change speaker voice, increase amplitude, frequency change, direct command (speech with text/speech only).
- *Video*: zoom, freeze frame, close up, wipe, dissolve, cut.
- *Image layout*: centred, enlarged, symmetric, asymmetric, regular, irregular, space around the image.

The user selects one of the six media types and then the desired guidelines; see Fig. 5. The tool can also be set to show attention-directing effects directly linked to media types that were selected from specification of information type and communication goals. The tool shows an example of the attention guideline in the appropriate medium, and for contact points in appropriate source and destination media, e.g. visual highlight with audio (i.e. speech and sound) effects (Sutcliffe, 1999). For example, to illustrate the attention guideline "Highlight" in image, the drawing of a car is shown highlighting the wheels with salient colour; while for video freeze-frame a video sequence of a moving car is halted to draw attention to an overtaking action, with a close-up zoomed in to show a view of the road ahead being clear, etc.

6. Tool evaluation

This section reports two sessions of user evaluations that were conducted as a formative investigation of the effectiveness of the method and its support by the developed tool.

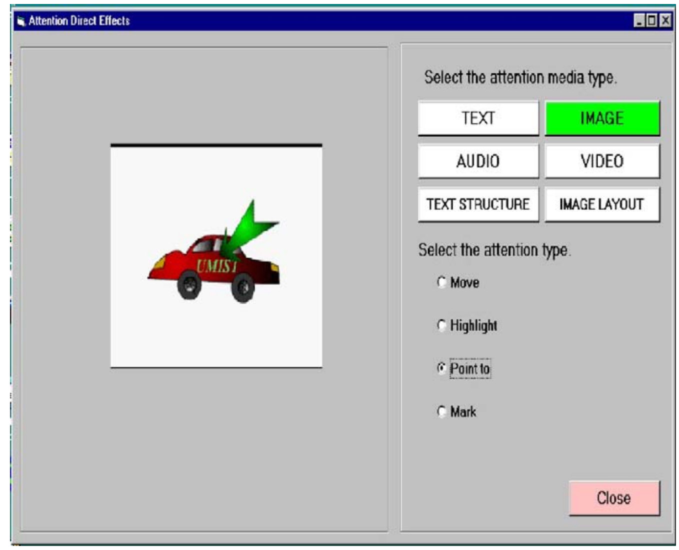


Fig. 5. Screenshot of Attention Effects Window.

6.1. Subjects

The participants of the second session were 12 BSc and MSc students (mean age 23.9 years; mean computer use 11.3 years; four female/eight male) who had taken the same module as the previous group of subjects. These participants were teamed up in pairs. Eight subjects completed both experiments, but two teams (5 and 6) participated only in the tool condition. Most subjects (87%) had experienced web development at novice level using Frontpage and/or Dreamweaver; the rest had no experience in multimedia or web development.

6.2. Experimental procedures

In the first session, the subjects were asked to complete two design tasks in pairs with paper-based guidelines but without the Multimedia Design Advisor tool. In the second experiment the subjects were asked to complete the same sets of tasks in pairs using the advisor tool. The motivation for using pairs of subjects was to gain insight into their understanding and use of the method and tool from recordings of their conversations during the experimental task. Accordingly the subjects were instructed to discuss their perceptions and reactions to the guidelines during the experiment.

The first task required the subjects to select the appropriate media for a website to promote bungee jumping, which should contain material to interest the customer, an explanation of the procedure for bungee jumping, and a reservation form to book a session. The second task was to mark up important information and contact point links on a music e-commerce website and to link thematically related information such as sales promotions, and details of CDs, artists and the promoted CD, etc. For the first task the subjects were provided with a specification of the recommended information content, media resources (e.g. photographs of bungee jumping locations, textual safety procedures, commentaries of satisfied customers, video of jumps, etc.) on cards in both conditions. Audio and video content specified on resource cards could be accessed on computer files. In the second experiment *with* the tool, the same domain and set of media resources were used but the tasks were varied to explain different aspects of bungee jumping procedure (e.g. safety), interest in a specific location and reserving jumps for a friend. Similarly the e-commerce websites and targets for attention were changed. The subjects were asked to specify the appropriate communication goals and information types for the content then select the most appropriate content using the paper method or tool. The tool did not select the appropriate media for the users; instead it acted as a help facility populated with generic examples. In the second task a list of important target items and thematic links were provided and the subjects were asked to mark the appropriate attention effect on screen dumps of the website, while describing the effect on an answer sheet.

In the second session, the subjects were provided with two sets of paper-based tasks and answer sheets to complete in their own time. Paper notes on the method and guidelines were available for the subjects to inspect at any time and they were asked to spend 30 min reading the notes before starting the experiment in the paper guidelines condition. All subjects completed the task within 50 min. There was a 2-week gap between the first and second experiments in order to minimize any learning effects. In the second experiment with the tool, one of subjects worked as a user and the other as an observer noting usability problems, but both subjects were encouraged to discuss their understanding and use of the guidelines during the experiment.

The Multimedia Design Advisor was run on personal computers with Windows XP, equipped with headsets. The session started by users completing a pre-test questionnaire; then they were given 10 min to read the instruction handouts and to familiarize themselves with the advisor tool. They completed the tasks and recorded the selected media and guidelines on an answer form. At the end of the session, the individual participants were asked to fill out the post-test questionnaire.

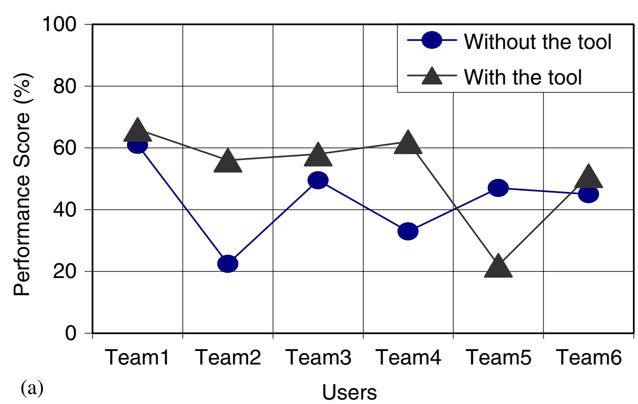
6.3. Scoring procedures

The subjects' performance was analysed to assess the utility of the advisor tool, and the experimenters' notes and recorded conversations were used to diagnose any usability problems which might reduce the utility of the tool.

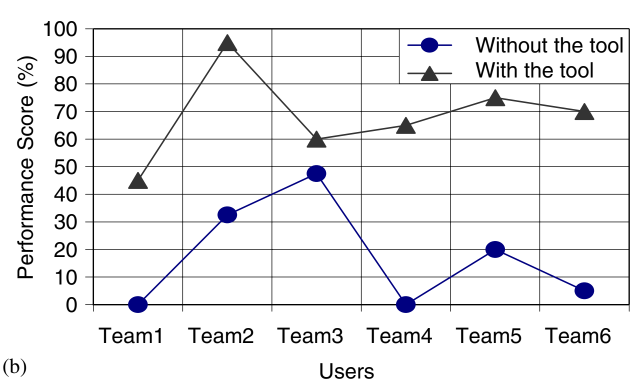
The answer sheets from the first and second experiments were assessed using pre-defined expert solutions. The users were asked to select appropriate media types for six key contents items, and to select appropriate attention effects and mark them on the paper-based screenshot of the web page. Out of 100 maximum points, 3 points were deducted for each inappropriate selection of media types, 2 points for incorrect specification of information types and 1 point for missing media resources. In task two, 2 points were deducted for each inappropriate selection of attention effects, up to 5 points for not marking appropriate items on the screen dump and 1 point for missing attention effects.

6.4. Results

As shown in Fig. 6a, performance for the first media selection task was better with the tool, although the score for team 6, whose answers were incomplete, were only slightly higher with the tool; and team 5, who completed only 5% of the task because they tried to complete the second task first, showed a slightly worse performance with the tool than with the paper-based method. Overall, performance is significantly better with the tool (df $= 5$, $\chi^2 = 15.4$, $p<0.01$). For the second attention design task, the advisor tool had a very positive impact on all the subjects' performance, with significantly higher scores (see Fig. 6b) when they used the tool (df $= 5$, $\chi^2 = 60.9$, $p<0.001$). Since all the teams had carried out the tasks with the paper-based method 2 weeks before the evaluation with the tool, we cannot rule out that a learning effect produced the performance improvement. However, as the subjects consistently referred to the printed notes during the first session and complained that they were not



(a)



(b)

Fig. 6. (a) User performance in task 1: media selection, (b) User performance in task 2: attention effects.

available in the second session, we assume that learning was probably incomplete so the effect of providing advice on demand via paper-based or electronic media was the variable being assessed.

6.6. Usability problems

The usability problems collected from the subjects' conversation and observation were categorized into four sub-sets: *software bugs, missing requirements, content problems* and *interface problems*. In addition there were three software problems. There were two image overlay errors and one video playback error. The observation notes showed that the users found difficulty in selecting the correct information type and communication goal as well as in relating the tool to the task. They also mentioned that they did not have enough familiarization time. The users recommended improvements for the following missing requirements:

- Descriptions for each communication goal.
- General help (how to use the tool).
- More examples and options for implementing the attention-directing effects.
- Suggestions for selecting attention types when media resources were selected during design.

Two users criticized the poor examples for communication goals and one mentioned the need for explanation of the relationship between information types and communication goals. Another two users experienced problems such as inconsistent pop-up windows and navigational confusion. One user commented that there should be a help system on how to use the tool and three users reported that they had needed more familiarization time to explore the tool. Two of them also commented that they needed more advice on identifying information types and communication goals. In spite of the usability problems, the results from the post-test questionnaire were positive for all teams, although the ratings of teams 5 and 6 were less favourable, which may indicate either unfamiliarity (a learning effect) or dissatisfaction arising from their poor performance (see Fig. 7).

The post-test questionnaire consisted of 16 questions in four categories: questions about (1) media selection for information types; (2) media selection for communication goals; (3) media attention effects; and (4) general usage. The satisfaction ratings of the 12 users (teams 1–6) for each question are shown in Table 4. The users found the tool satisfactory except for advice on media selection for communication goals. Although they rated the contents of advice and examples for the communication goals as satisfactory, usefulness and ease of finding advice were rated less favourably. From the observers' notes, one cause appeared to be that the tool did not provide the definitions of communication goals.

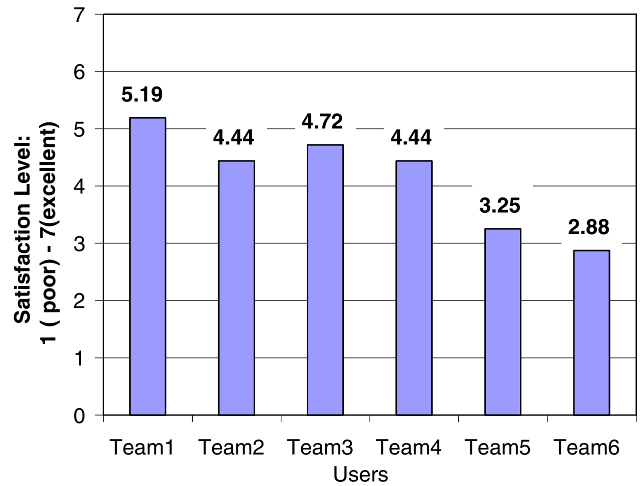


Fig. 7. Post-test questionnaire (overall satisfaction).

Table 4
Usability questionnaire ratings for the advisor tool

Post-test questions (1 = poor, 7 = excellent)		Average rating ($N = 12$)
Media selection for information types	Usefulness of advice	4.1
	Content of advice	4.0
	Usefulness of examples	4.1
	Content of examples	4.6
	Ease of finding advice	4.0
Media selection for communication goals	Usefulness of advice	3.8
	Content of advice	4.2
	Usefulness of examples	3.5
	Content of examples	4.0
	Ease of finding advice	3.3
Media attention effects	Usefulness of advice	4.7
	Content of advice	4.6
	Helpfulness of examples	4.3
General usage	Ease of use	4.4
	Usefulness of the tool	4.8
	Interface design	4.2

6.7. Subjects' discussion

A qualitative analysis of the subjects' discussions during the experimental tasks, using both the paper-based guidelines and the tool, was carried out to investigate the more frequently occurring comments on understanding of the guidelines and judgement about the applicability of the advice for the task in hand.

6.7.1. Comments on paper-based guidelines

The communication goals Persuade, Explain and Demonstrate were used by four out of six teams; the other two teams only used Explain. The communication goals were considered easy to understand; however, apart from demonstrations, no interactive effects were planned. The information type physical/conceptual distinction caused confusion especially with the procedures for bungee jumping, some of which (e.g. safety) appeared to be conceptual whereas the main procedure was physical. The aesthetic heuristics for colour and consistency were understood and used, while the advice on shape, symmetry and use of space was confusing for most of the teams.

6.7.2. Comments on tool-provided guidelines

Several subjects reported that definitions of the communication goals would have helped, as would further examples to improve understanding. Four of the six teams discussed improvements to the Entertain goal, where they considered the advice to be underspecified. Suggestions were made to add more examples for popular games, ideas about scripting storylines, use of characters and surprise effects which were triggered when the character approached certain areas and objects. The difference between the Explain and Demonstrate goals was confusing for some teams since they noted that for physical tasks they would expect to give a demonstration as part of the explanation. All teams noted that content was frequently important for achieving most of the goals but no guidelines were given on content selection or design, e.g. how to make an exciting simulation for bungee jumping using virtual reality. The most commonly used goals were Explain (all teams), Persuade (customers to take a bungee jump) by five teams, and Demonstrate procedures by four teams. Two teams commented on the possibility of designing interactive applications but both felt the advice in communication goals was not clear on this aspect.

As with the paper-based method, all the teams found the distinction between physical and conceptual information types confusing in some cases. For instance, the instructions for bungee jumping clearly involved physical actions yet the safety advice was more conceptual. Four teams felt that the tool should have presented better advice on how to integrate the media selected from the information types rather than presenting a list with examples of each medium. Four teams also commented on the need for additional information types that were not present, such as categories, classes and time-based information. Generally the information types and media suggestions produced by the tool were considered appropriate but all teams noted that the examples could be improved and made more realistic, rather than using clipart-like images.

6.8. Summary of evaluation

In addition to the evaluation and tutorial testing of the method and tool reported in this paper, previous versions of the method were tested with industrial designers as reported in Sutcliffe (1999). The lesson learned from that study were that the media selection guidelines need to be simplified, but some design concerns were not covered. This resulted in the additions for aesthetics and communication goals in the current version of the method. Validation is an ongoing exercise of iterative improvement via formal experimental evaluations as reported in this paper and industrial case studies. Our current agenda is to improve the tool using the lessons from this study before testing the method in industrial practice.

7. Conclusion and discussion

The contributions of this paper have been to describe a comprehensive multimedia design method that is based on previous experimental investigations and a synthesis of the literature on multimedia design. The method breaks new ground by considering not only selection of media but also by providing advice on visual and aesthetic design. A further contribution has been development of a design advisor tool specifically for multimedia to support the method. The evaluation results showed that both the method and the tool provided advice that was comprehensible and usable and its application had a positive impact on the quality of the resulting multimedia design. The SMALTO tool (Luz and Bernsen, 2001; Bernsen, 2002) provides more restricted advice for use of speech and combination of speech with other modalities; however, it presents advice as a compilation of positive and negative claims, leaving the designer to judge their collective merit. In contrast, our tool focuses on more directed advice for output multimedia and covers a wider scope of media combinations.

Our information types and media framework developed concepts in the modality theory (Bernsen, 1994) into a more comprehensive categorization of information coupled with a media-type classification that is closer to a common sense understanding of media. Common sense suggests text, image and video rather than the modality theory's more abstract definitions such as analogue v. discrete, which refer to properties that can be represented rather than the medium of representation. The distinction we draw between media that are created by human design rather than being captured from the natural world is, we argue, useful since it indicates how media are captured as well as mapping between abstract information and design media such as diagrams, graphs and special notations. However, we acknowledge that taxonomic distinctions are always fraught with difficulties, such as the confusion over conceptual and physical types of information which this study revealed. Simpler classifications seem to work better. Our information types are related to Heller et al.'s (2001) taxonomy; however we have adopted types which are intended to be more familiar to software engineers (e.g. object, attribute, event, state, action) as well as complex types for causation and procedure. This, we hope, will make the types more tractable to software engineers who are our prime target audience.

The causal information type we propose and its associated media selection pattern owe much to the experimental investigations and design principles of Narayanan and Hegarty (1998, 2002), who provide more comprehensive advice on selecting not only media but also content for pedagogical purposes. While their work is focused on training applications it does point towards further extension for our work to provide more advice on design of information architectures for specific communication goals. The schema in Rhetorical Structure Theory (Mann and Thompson, 1988) and discourse structures employed in multimodal planners (André et al., 1996; Zhou and Feiner, 1998) could be developed as design patterns to fulfil that need.

The Design Advisor tool we developed has demonstrated its effectiveness, although the evaluation study was limited in terms of subject numbers, and learning effects between the method and tool may have influenced the result. Bailey et al. (2001) have developed a sketch-based, interactive multimedia storyboard tool to support the designer's need for exploring design ideas early in the design process, while Patchwork (Wilson et al., 1997) provides automated support that bridges paper-based sketching and multimedia prototyping. However, none of these tools gives practical design guidelines on media selection and attention effects concerning information types and communication goals. Unlike our previous tool, which integrated media selection with a design sketching system (Faraday and Sutcliffe, 1999), in this Design Advisor we chose to keep design advice separate from the prototyping/storyboarding functionality. This, we argue, will enable more adaptive integration with different development environments, ranging from storyboarding support tools such as SILK (Landay and Myers, 2001) to more automated multimedia specification-sketching tools (Bailey et al., 2001) and software engineering tool-sets based on UML. Indeed, as Bailey et al. note from their investigations with multimedia designers, design advice might encounter considerable resistance if it is directly embedded in prototyping tools. Design guidelines have been embedded in user interface development environments (Van der Donckt, 1999; Van der Donckt et al., 2001) which automatically lays out windows according to specifications of tasks and information requirements. However, most user interface design environments (UIDEs) (e.g. HUMANOID: Szekely et al., 1992; Concur Trees: Mori et al., 2002) produce standard graphical user interfaces from task/information descriptions and do not address multimedia. One possible future direction for our work is to transfer the media selection rules in our tool into a multimedia UIDE. The main problem we will have to resolve, as shown in this study, is overcoming users' problems with classification of information with types. Some possibilities are to use information extraction algorithms (Cowie and Wilks, 2000; Black et al., 2004) to automatically index information specifications and databases of media resources. The information types could then form an internal ontology for an intelligent multimedia interface design system.

This study has produced some advances in multimedia design advice; however, it has not directly demonstrated the effectiveness of design advice in real-world practice. The comparative evaluation of the design tool and method was limited so conclusions about the advantages of tool-based advice have to be tentative. While the evaluation of the method did show adoption of the design advice and an impact on design solutions produced by designers with a software engineering background, the evaluations did not test the control condition without any design advice. Although qualitative evidence indicates that the guidelines do have a positive impact on solution quality we cannot rule out that good-quality solutions might be produced by talented individuals without such advice. Further experimental investigations are necessary to demonstrate this effect as well as to test the relative contributions of different aspects of the method, such as communication goals, attractiveness heuristics and media guidelines, on solution quality.

Appendix A

The Media selection is shown in Table A1

Table A1
Media selection

Information type / Media type	Causation	Conceptual	Continuous action	Descriptive	Discrete action	Event	Physical	Procedure	Relationship	Spatial information	State	Value
Realistic audio	Sound of rain and storms		Sound of skiing		Click of ON switch	Sound of the starting gun	*Noise of a tornado*			Echoes in a cave	Sound of snoring	Musical note encodes a value
Non-realistic audio		Rising tone illustrates increasing magnetic force	Continuous tone signals progress of action	Morse code describes a ship	Tones signal open/close door	*Alarm siren*			Tones associate two objects	Sonar and doppler effect	Continuous sound in a heart beat monitor	
Speech	*Tell someone why El Nino happens*	Tell someone about your religious beliefs	Tell someone what a ski turn looks like	Verbal description of a person	Tell someone how to turn computer on	*Tell someone race has started*	Tell someone how it feels to be in a storm	Speak instructions on engine assembly	Tell someone Jack and Jill are related	Tell someone pathway to and location of railway station	Tell someone "Jane's asleep"	Verbal report of numbers, figures
Realistic still image	*Photograph of El Nino storms and ocean currents*	Statue of Liberty photograph represents "freedom"	Set of photographs showing snap shots of action	*Overview and detail photographs of a car*	*Photograph of computer ON switch*	Photograph of the start of a race	*Photograph of a person's face*	*Photographs showing engine assembly*		*Photograph of a landscape*	Photograph of a person sleeping	
Non-realistic still image	*Diagrams of ocean currents and sea temp. to explain El Nino*	*Hierarchy diagram of plant taxonomy*	Diagram with arrow depicting ski turn motion	Histogram of ageing population	Diagram showing where and how to press ON switch	Event symbol in a race sequence diagram		Explode parts diagram of engine with assembly numbers	*Graphs, histograms, ER diagrams*	*Map of the landscape*	Waiting state symbol in race sequence diagram	*Charts, graphs, scatter plots*
Text	*Describe reasons for El Nino storms*	*Explain taxonomy of animals*	Describe ski turn action	*Describe a person's appearance*	Describe how to turn computer on	Report that the race has started	Report of the storm's properties	*Bullet point steps in assembling engine*	*Describe brother and sister relationship*	Describe dimensions of a room	*Report that the person is asleep*	*Written number one, two*
Realistic moving image	*Video of El Nino storms and ocean currents*		*Movie of person turning while skiing*	Aircraft flying		*Movie of the start of a race*	*Movie of a storm*	*Video of engine assembly sequence*		Fly through landscape	Video of a person sleeping	
Non-realistic moving image	*Animation of ocean temperature change and current reversal*	Animated diagram of force of gravity	Animated mannequin doing ski turn		Animation showing operation of ON switch	Animation of start event symbol in diagram		*Animation of parts diagram in assembly sequence*	Animation of links on ER diagram			
Language-based: formal, numeric	Equations, functions formalizing cause and effect	*Symbols denoting concepts, e.g. pi*			Finite state automata	Event-based notations		Procedural logics, process algebras	Functions, equations, grammars		State- based languages, e.g. Z	Numeric symbols

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