Applied Ergonomics 40 (2009) 731–744

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

An interdisciplinary heuristic evaluation method for universal building design

Yasemin Afacan [a,*], Cigdem Erbug [b,1]

[a] Department of Interior Architecture and Environmental Design, Faculty of Art, Design and Architecture, Bilkent University, 06800 Bilkent, Ankara, Turkey
[b] Department of Industrial Design, Faculty of Architecture, Middle East Technical University (METU), Inonu Boulvard 06531, Ankara, Turkey

ARTICLE INFO

Article history:
Received 26 February 2007
Accepted 15 July 2008

Keywords:
Heuristic evaluation method
Universal design
Universal usability
Cost-effectiveness
Building design

ABSTRACT

This study highlights how heuristic evaluation as a usability evaluation method can feed into current building design practice to conform to universal design principles. It provides a definition of universal usability that is applicable to an architectural design context. It takes the seven universal design principles as a set of heuristics and applies an iterative sequence of heuristic evaluation in a shopping mall, aiming to achieve a cost-effective evaluation process. The evaluation was composed of three consecutive sessions. First, five evaluators from different professions were interviewed regarding the construction drawings in terms of universal design principles. Then, each evaluator was asked to perform the predefined task scenarios. In subsequent interviews, the evaluators were asked to re-analyze the construction drawings. The results showed that heuristic evaluation could successfully integrate universal usability into current building design practice in two ways: (i) it promoted an iterative evaluation process combined with multi-sessions rather than relying on one evaluator and on one evaluation session to find the maximum number of usability problems, and (ii) it highlighted the necessity of an interdisciplinary ad hoc committee regarding the heuristic abilities of each profession. A multi-session and interdisciplinary heuristic evaluation method can save both the project budget and the required time, while ensuring a reduced error rate for the universal usage of the built environments.

1. Introduction

Despite extensive literature on usability engineering, there is little research that emphasizes how usability testing can be employed and measured in an architectural design context. Inaccessible built environments, unusable architectural design features in buildings, and facilities with barriers preventing the participation of people with diverse and changing abilities present challenges to designers to focus on usability measures and universal design criteria in a more comprehensive way. Although usability testing is the most widely used method "for minimizing mismatches between users and products" (Beecher and Paquet, 2005, p. 36), universal design, which aims to design for the vast majority of the world, has yet to be integrated into usability tests. With these observations in mind, this study explores whether heuristic evaluation, as a specific usability evaluation method, could successfully integrate universal design knowledge into current building design practice.

Three critical issues exist that make it difficult to integrate the universal design approach into current design practice: (i) theory–practice inconsistency, (ii) the designer's way of thinking, and (iii) a communication gap between designers and other professionals. Theory–practice inconsistency has emerged from a lack of universal design knowledge by design practitioners. Although there are guidelines and accessibility standards, designers have difficulty in sorting this academic source of information (Gregor et al., 2005). Moreover, most of the information on human factors is presented in pictorial, textual, and numerical form, so that it needs interpretation when incorporated into a design project (Carmichael et al., 2007). However, Nicolle et al. (2003, p. 100) added, "Designers are under a great deal of time pressure if knowledge is not presented in a usable format, it will be either discarded or ignored". Therefore, although most designers are aware of universal design, problems appear in the integration of theories and guidelines into design practice (Demirkan, 2007).

The second critical issue is related to user needs. As designers are usually not users of the environment that they design (Preiser,

* Corresponding author. Tel.: +90 312 290 1764/+90 535 389 1614.
E-mail addresses: yasemine@bilkent.edu.tr (Y. Afacan), erbug@metu.edu.tr (C. Erbug).
[1] Tel.: +90 312 210 4219/4220.

0003-6870/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.apergo.2008.07.002

Table 1
The definitions and design considerations of universal design principles (The Center for Universal Design, 1997) taken as heuristics.

Principle	Definition	Design consideration
P1. Equitable use	The design is useful and marketable to people with diverse abilities rather than segregating or stigmatizing any users.	The shopping mall should provide equality for all users in terms of usage, understanding. access, privacy, security and comfort
P2. Flexibility in use	The design accommodates a wide range of individual preferences and abilities.	The shopping mall allows flexibility and adaptability for unexpected spatial conditions and for changing requirements of all users over time.
P3. Simple and intuitive use	Use of the design is easy to understand regardless of the user's experience, knowledge, language skills, or current concentration level.	The shopping mall should be designed to be consistent with users expectations and should eliminate unnecessary complexity.
P4. Perceptible information	The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.	The shopping mall should provide adequate contrast between essential information and background conditions.
P5. Tolerance for error	The design minimizes hazards and the adverse consequences of accidental or unintended actions.	The design features of the shopping mall should be arranged to minimize hazards and errors and warnings should be provided.
P6. Low physical effort	The design can be used efficiently and comfortably and with a minimum of fatigue.	The design features of the shopping mall should minimize sustained physical effort.
P7. Size and space for approach and use	Appropriate size and space is provided for approach, reach, manipulation, and use, regardless of the user's body size, posture, or mobility.	The design features of the shopping mall should provide a clear space for approach and a clear line of sight to important elements for any seated or standing user.

2001), there is a lack of empathy for and interpretation of the requirements of diverse users and, subsequently, restricted practical solutions. Because successful universal design is typically built on the basis of gaining a better understanding of real-user needs (Clarkson et al., 2007; Darses and Wolff, 2006), the ability to capture user needs early and correctly is essential to reduce late discovery and to increase user satisfaction (Arthur and Gröner, 2005; Harding et al., 2001). Thus, eliciting, capturing, and describing diverse user needs are as important as focusing on the representation, solution, and optimization of universal design requirements. However, universal design literature lacks systematic procedures and methods that effectively identify and express user needs within built environments.

The third issue arises because of the interdisciplinary nature of the architectural design process. The responsibility of required design operations is distributed across multiple professions, ranging from product designer to urban planner (Akin, 1986; Garner and Mann, 2003; Simon, 1979). In this sense, finding an architectural solution often involves collaborative efforts between highly educated professionals and individuals representing different fields of expertise (Kalay, 2006). Interdisciplinary collaboration is important, as Erbug (1999) states: design is a dynamic process in which the priorities change during different phases; this demands that designers as coordinators of the design process should establish clear channels of communication with other professionals.

Achieving a universal design performance within a built environment is also highly correlated with an overall consideration of a range of environmental design concerns, such as ergonomics guidelines, accessibility standards, building codes, and urban planning specifications (Afacan, 2008; Canadian Human Rights Commission, 2006; Clarkson et al., 2007; Demirkan, 2007; Ostroff, 2001; Preiser, 2001). The challenge of universal design is to fully understand these criteria and to give adequate focus to each of them. For this reason, working together with various design professions would enlarge the scope of design and could lead to successful universal design solutions. In this context, the designer generally acts as a coordinator, trying to balance needs and constraints as she/he seeks to develop a design that suits the user (Erbug, 1999). A fruitful attempt, in our opinion, would be to identify how the application of heuristic evaluation methods by designers from different professions could bridge these gaps and ensure the creation of universally designed built environments.

2. Universal design

In the last decade, there has been a growth in the number of elderly and disabled people. Furthermore, the needs and demands of diverse population members (children, pregnant mothers, adults, elderly or disabled people) vary considerably. For this reason, today there is an increased awareness of universal design among designers in order to satisfy diverse user needs in many countries around the world. Universal design aims to design spaces and products for the vast majority of the world that can be used without any adaptation and without stigmatizing the user. Such design emphasizes inclusivity in the design process, regardless of the age, ability, or size of the users (Ostroff, 2001; Demirbilek and Demirkan, 2004). Furthermore, "application of the universal design principles highlights that universal design requires integration of accessibility and usability features from the onset, removing any stigma and resulting in social inclusion of the broadest diversity of users"

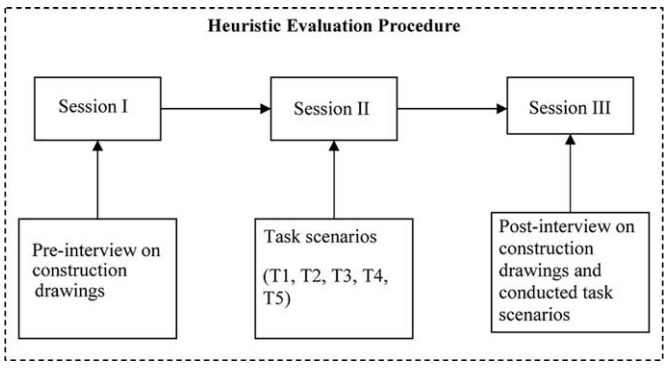

Fig. 1. The structure of the heuristic evaluation procedure applied in the shopping mall.

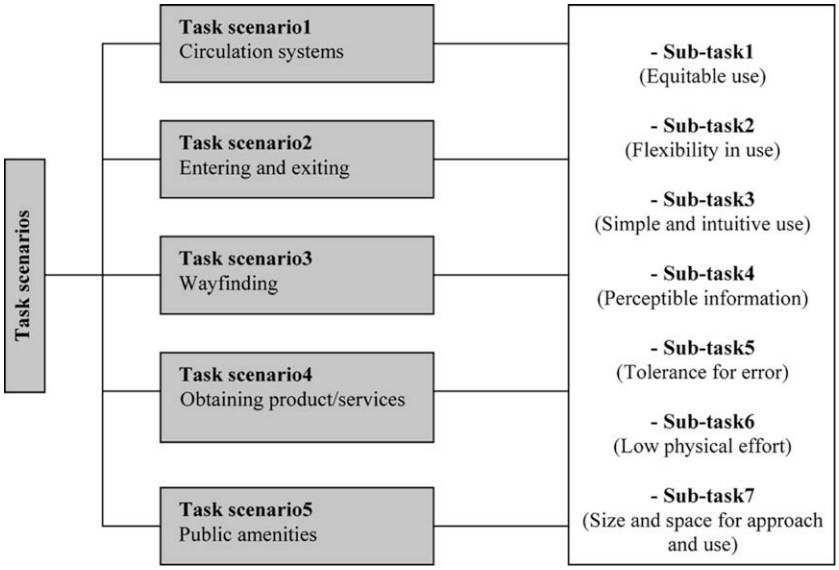

Fig. 2. The relationship between the five task scenarios and seven sub-tasks.

(Iwarsson and Stahl, 2003, p. 61). Thus, beginning with the initial design phases of a project, designers are expected to account for the pre-conditions for usability (including accessibility, adaptability, and clear understandability) so that they can reduce costs, improve designs, and solve usability problems in the universal design process (Fange and Iwarsson, 2003). Following these arguments, the desire to make technologies, products, and built environments usable to broader populations has led to new breakthroughs in usability and the concept of universal usability (Freudental and Mook, 2003; Shneirderman and Hochheise, 2001; Vanderheiden, 2000). The next two subsections deal with universal usability in detail.

2.1. Universal usability in architectural terms

People's abilities change over time, and they want to be accommodated within the built environment as efficiently, effectively, and satisfactorily as possible, regardless of their health condition, body size, strength, experiences, mobility power, or age. In the meantime, they want to expend low physical effort and have security, safety, and simplicity (The Center for Universal Design, 1997). In this respect, universal usability in architectural terms is concerned with making buildings and facilities as universally usable as possible for everyone, rather than for the vast majority of a target population. In the present study, being universally usable referred to the degree to which a built environment allows each individual to perform daily activities, regardless of age, size, or ability. The main aim of universal usability is to enable the widest possible range of users to benefit, access, use, and obtain product/services from the built environment in the widest range of situations. Reviewing the literature on universal design indicates that no recommendations exist in the architectural design context as to how universal usability can be incorporated and implemented to identify, minimize, and solve usability problems that can occur during any phase of the design process. Consequently, most design practitioners cannot take universal usability into account during the initial phases of the design process, which leads to wrong universal design decisions that can have a large impact (nearly 80%) on the overall design success and cost (Baya and Leifer, 1996). These challenges are a stimulus for a cost-effective universal usability evaluation to build usable environments for all.

2.2. Need for a cost-effective universal usability evaluation

In architectural design practice, there are many reported cases in which ergonomics is not applied, so that reduced costs and improved effectiveness are not achieved (Beevis, 2003). The complexity of handling usability problems during the late phases of the design process results in unsuccessful universal design applications that are generally discovered after construction is completed. This late identification arises from the lack of awareness of the need for multiple experts to evaluate how each design decision corresponds to universal design and to evaluate the usability of each building design feature for people with diverse abilities. Making structural changes after construction is both expensive and time consuming and requires major retrofits. Thus, design decisions related to the structural elements of a built environment, such as general layout, circulation systems, beams, and columns, are critical and cannot be redesigned or changed after the construction phase (Smith and Coull, 1991). In the present study, such problems are categorized as major usability problems.

Other design decisions that relate to the non-structural but user-friendly elements of a building, such as colour, finishing materials, and furniture, could be modified in the late phases of the design process. Although they have an impact on the cost, it is not as large as that of structural usability problems. Hence, these features are often added on late in the design process or left for the attention of architectural technicians in the final detailing design stages, which results in solutions that meet minimum standards but are ugly and relatively expensive (Harrison and Parker, 2005). This study categorizes these problems as minor. Thus, being identified as a major or minor problem is closely related to the cost-effectiveness dimension of the defined universal usability. Because each design decision requires working with specialists from different disciplines that have a significant effect on the design process (Chiu, 2002; Kolarevic et al., 2000; Kvan, 2000; Simoff and Maher, 2000), to avoid such design errors and minimize both major and minor usability problems, this study examined how an interdisciplinary approach could contribute cost-effectively to the success

Table 2
Major and minor problems reported by all the evaluators.

Major problems	
1	The inconsistency of users' expectations regarding circulation
2	The unnecessary complexity of the circulation system
3	Insufficient manocuvring space within the elevators
4	Insufficient elevators
5	Non-legibility of the elevators from the side entrances
6	Lack of elevators in the second and third basement floors
7	Lack of an escalator on the food court floor
8	Intrusion of the escalators into the path of travel
9	The curved stair, it causes accidental or unintended actions
10	Difficult and indirect access to some facilities
11	The need for a big effort to access the curved stair
12	Inaccessible entering/exiting form the side entrances
13	No multiple path of travel at the back entrance
14	Unclear path of travel on entering the mall
15	Long distances from the north-east parking area
16	No easy/direct access to entrances/exits from inside
17	Difficulty of seeing the information desk due to the elevators
18	Elevators obstructing the users' path
19	Difficult-to-read shop names because of columns
20	No usage of daylight to guide and direct users
21	Orientation problems within the mall
22	Inconsistencies caused by the four identical galleries
23	Non-legibilities caused by the symmetrical layout
24	Barriers and stigmatizing design solutions in cinemas
25	No knee clearance at service desks in the food court
26	Limited visibility of the shop windows
27	Lack of restrooms for disabled people on each floor
28	Inappropriate dimensions of the car park floor
Minor problems	
1	No auditory system in the elevators
2	Unsafe revolving doors at the main entrance
3	Lack of smooth level changes outside
4	Unusable automated doors for diverse speed of movement
5	No areas near the entrance/exit to rest or wait
6	Not enough maps, directories, and displays
7	Lack of tactile and sound correlates for visual indicators in entering/exits
8	Some advertisements boards interrupt the path of travel
9	Floor levels and their uses not well-defined
10	Wayfinding on the car park floor is not intuitive for users
11	No well-defined fire-exit in the food court/cinema floor
12	Difficult access to all products for wheelchair users
13	Uncomfortable reach-range of shelves within shops
14	Not enough space in the aisles of the food court
15	Hazardous chair–table placement on the food court floor
16	Lack of tactile materials within the shops/food court
17	Lack of tactile, sound, and visual indicators in the shops/services
18	Unusable door handles in restrooms' changing situations
19	Insufficient seating units
20	Unusable hand dryers/towel dispensers in the restrooms
21	Inappropriate dimensions of seating units for diverse users
22	Inappropriate material selection for restrooms doors
23	Lack of tactile materials within restrooms
24	Lack of tactile, sound, and visual indicators in the public amenities
25	Insufficient public phones

of universal usability, in terms of the heuristic abilities of the evaluators.

3. The active involvement of design experts

The increased annual budget commitments to accessibility, changes to construction standards, and commitment to universal access on new construction projects make the active involvement and evaluations of design experts essential (Ringaert, 2001). Preiser (2001, 2003) also emphasized expert involvement with respect to the universal design approach and pointed out that a constructed environment was different from a manufactured product, in that it is dynamic and changes over time. He proposed a universal design evaluation model based primarily on post-occupancy evaluations (POE) and performance feedback data. Preiser's model included planning, programming, construction, and occupation phases; these are defined as the life cycles of buildings. In this respect, the present study differed from both Preiser's evaluation model and other developed instruments, because it sought a cost-effective usability evaluation method to explore usability problems exclusively from construction drawings, as early as possible in the architectural design process.

4. Heuristic evaluation method

Heuristic evaluation is the most commonly used usability inspection method (De Angeli et al., 2003; Fu et al., 2002; Nielsen and Molich, 1990). It became popular in the early 1990s because of its speed, cheapness, and ease of implementation. It could be achieved with only 4–5 evaluators using a limited set of principles to detect a high proportion of usability problems (Law and Hvannberg, 2004; Nielsen, 1993). In heuristic evaluation, each evaluator inspects the designed system or artefact alone and judges its compliance according to a set of usability principles (Nielsen, 1994). Heuristic evaluations can be implemented quickly and conveniently through a competent pool of evaluators and the most well-known heuristic principles are the 10 developed by Nielsen (1992).

Reviewing the current practice in heuristic evaluations showed that Nielsen's heuristic evaluation method has been studied from different perspectives during the last decade, such as the number of evaluators (Nielsen, 1994), evaluator effect (Hertzum and Jacobsen, 2001; Hertzum et al., 2002) and problem severity (Jacobsen et al., 1998). Moreover, there are also heuristic evaluations combined with other usability evaluation methods for a more efficient and effective usability analysis, description, and reporting process, such as heuristic evaluations combined with empirical testing at different phases of the development process (Kantner and Rosenbaum, 1997), heuristic evaluations with a hierarchical structure rather than Nielsen's flat structure of 10 heuristics (Andre et al., 2001) and heuristic evaluations combined with the Systematic Usability Evaluation (SUE) method to overcome the problems encountered in Nielsen's heuristics through a more focused usability inspection method (De Angeli et al., 2003). Furthermore, modified heuristic evaluation methods have been also proposed in a number of studies, such as three categories of heuristic application, lead, follow, and get out of the way (LF&G), which aided the creation of checklists and evaluation forms for use across all phases of developing a system (Kamper, 2002), and extended usability heuristics by introducing virtual environment (VE) specific principles (Sutcliffe and Gault, 2004).

Having reviewed the literature on usability heuristics, it is important to state that the evaluation method proposed in this study is based on a modified heuristic evaluation. Because

Table 3
Number of major and minor problems distributed into the three sessions.

	Number of problems identified in session I		Number of problems identified in session II		Number of problems identified in session III	
	Number	Percentage	Number	Percentage	Number	Percentage
Major problems	18	64.29%	24	85.71%	28	100%
Minor problems	4	16%	22	88%	22	88%

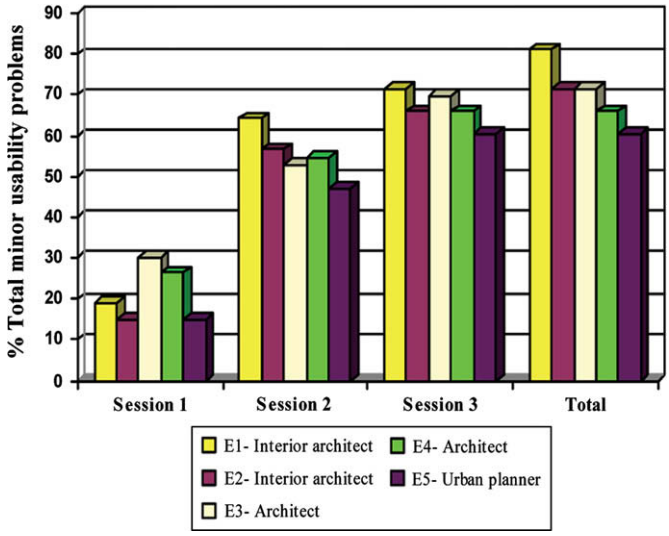

Fig. 3. The percentage of minor usability problems identified in three sessions.

evaluating buildings in accordance with universal design principles has its own design requirements and challenges, heuristics used in product and software environments cannot be applied directly to the architectural design context. Heuristics should be modified according to universal design criteria. For this reason, this study has taken the seven universal design principles as a set of heuristics for universal usability evaluation. These heuristics were evaluated by the five evaluators within the content of the developed universal design scenarios in a built environment, in a shopping mall as a case study. The details of the procedure are given in the next section.

5. Case study: the application of heuristic evaluation within a shopping mall

The authors proposed that the heuristic evaluation method, which focuses on the seven universal design principles, had the potential to be a quick and cost-effective evaluation process for improving building design. Moreover, the authors highlighted the possible contributions of the systematic inspection characteristics of a heuristic evaluation to find usability problems of a built environment, regarding a predefined list of heuristics. Accordingly, this study specified the modified list of heuristics illustrated in Table 1. This new set of heuristics was created to reflect the inclusiveness of the universal design process and the requirements of seven universal design principles. An empirical case study within a recently built shopping mall in Ankara, Turkey, was carried out to test the universal usability in architectural terms. Shopping malls are particularly important for leisure activities in large urban centres, which should ensure that all people are equally welcome and that all visitors can participate in facilities that have no design stigmatization and that enrich their lives and enhance autonomy and flexibility (Resolution ResAP 3, 2001). Inaccessible and unusable public buildings for leisure activities are lucidly holding disabled people back from productive spheres of society (Haque, 2005). Moreover, the changing leisure and consumption patterns of Turkish people have made shopping malls among the most important additions to urban life in Turkey (Erkip, 2003).

5.1. Data collection

Referring to Nielsen's (1992) statement that usability experts were better than non-usability experts in conducting heuristic evaluation, this study chose five universal design specialists from different design disciplines, who took a universal design course during their education and who worked professionally in various shopping mall projects in practice. Consequently, two interior architects, two architects, and one urban planner undertook the evaluation. In this study, the distribution of the number of evaluators in each discipline followed the proportional representation of the collaboration percentage of designers in a professional architectural project. According to the new Turkish Public Procurement Legislation, the recent architectural practice of large-scale projects requires a close collaboration between interior architects, architects, and urban planners (Law on Public Procurement Contracts, 2008). There are also regulations related to the required number of different design disciplines, depending on the project contracts and specifications.

Regarding the interdisciplinarity requirement of both universal design and the architectural design process, each designer from a different discipline becomes an important contributor in creating universally designed built environments. Interior architects have an indispensable role to concentrate on the non-structural elements of a building and the quality of the interior environment, whereas architects decide on building layouts and dimensions, structural elements, floor plans, and facades; and urban planners are responsible for achieving efficiency in the building-site relationship and for considering buildings within the urban infrastructure (Danford and Tauke, 2001; Eren, 2004; Levine, 2006; Marley, 2001; Story et al., 1998). Therefore, this study considered the discipline-specific responsibilities and capabilities of each evaluator as her/his heuristic ability.

The evaluation of the shopping mall comprised three sessions: pre-interview, task scenarios, and post-interview. The interview questions and task scenarios were grouped under five categories, based on Danford and Tauke's (2001) definitions of the following five essential design elements of a universal city, which should be considered when applying the seven principles of universal design in built environments:

1. *Circulation systems*: ramps, elevators, escalators, hallways, and corridors.
2. *Entering and exiting*: identifying and approaching the entrance and exit and manoeuvring through them.
3. *Wayfinding*: paths/circulation, markers, nodes, edges, and zones/districts; and graphical wayfinding: text, pictograms, maps, photographs, models, and diagrams.
4. *Obtaining product/services*: service desks, waiting areas, and shops.
5. *Public amenities*: public telephones, restrooms (toilets), and seating units.

Because these five elements are defined as general building issues that are commonly encountered by users in most of the facilities, they are critical to ensure usability in architectural terms, i.e., "buildings that facilitate these activities for the widest possible population are more usable by everyone" (Danford and Tauke, 2001, p. 16). Therefore, Danford and Tauke's (2001) classification was chosen for this study to explore the universal usability of the shopping mall for each building issue in terms of each universal design principle.

5.2. Procedure

The open-ended interviews and task scenarios were conducted and recorded with the five evaluators individually. Fig. 1 illustrates the structure of the heuristic evaluation procedure applied in the mall. Each session was guided by the first author in order to elicit responses more comprehensively, and later to generate an in-depth

Table 4
A detailed distribution matrix of usability problems showing which problems found in which session.

Problems reported by all experts	S1	S2	S3
Major problems:			
1. The inconsistency of users' expectation regarding circulation			
2. The unnecessary complexity of the circulation system			
3. Insufficient manoeuvring space within the elevator			
4. Non-legibility of the elevators from the side entrances.			
5. Insufficient elevators			
6. Lack of elevators in the second and third basement floors			
7. Lack of one escalator on the food court floor			
8. Intrusion of the escalators into the path of travel			
9. The curved stair; it causes accidental or unintended actions			
10. Difficult and indirect access to some facilities			
11. The need for a big effort to access the curved stair			
12. Inaccessible entering\exiting from the side entrances			
13. No multiple path of travel at the back entrance			
14. Unclear path of travel on entering the mall			
15. Long distances from the north-east parking area			
16. No easy\direct access to entrances\exits from inside			
17. Difficulty of seeing the information desk due to the elevators			
18. Elevators obstructing users' path			
19. Difficult-to-read shop names because of columns			
20. No usage of daylight to guide and direct users			
21. Orientation problems within the mall			
22. Inconsistencies caused by the four identical galleries			
23. Non-legibilities caused by the symmetrical layout			
24. Barriers and any stigmatizing design solutions in cinemas			
25. No knee clearance at the service desks in the food court			
26. Limited visibility of the shop windows			
27. Lack of restrooms for the disabled people on each floor			
28. Inappropriate dimensions of the car park floor			
Minor problems:			
1. No auditory systems in the elevators			
2. Unsafe revolving doors at the main entrance			
3. Lack of smooth level changes outside			
4. Unusable automated doors for diverse speed of movement			
5. No areas near the entrance\exit to rest or wait			
6. Not enough maps, directories, and displays			
7. Lack of tactile, sound, and visual indicators in entering\exiting			
8. Some advertisements boards interrupt the path of travel			
9. Floor levels and their uses not well-defined			
10. Wayfinding on the car park floor is not intuitive for users			
11. No well-defined fire-exit in the food court\cinema floor			
12. Difficult access to all products for wheelchair users			
13. Uncomfortable reach-range of the shelves within shops			
14. Not enough space in the aisles of the food court			
15. Hazardous chair-table placement on the food court floor			
16. Lack of tactile materials within the shops\food court			
17. Lack of tactile, sound, and visual indicators in the shops\services.			
18. Unusable door handles in restrooms' changing situations			
19. Insufficient seating units			
20. Unusable hand dryers\towel dispensers in the restrooms			
21. Inappropriate dimensions of seating units for diverse users			
22. Inappropriate material selection for restrooms doors			
23. Lack of tactile materials within restrooms			
24. Lack of tactile, sound, and visual indicators in the public amenities			
25. Insufficient public phones			

S1=Session I, S2=Session II, S3=Session III

Legend:

- Non-reported usability problems
- Reported usability problems
- Correlated usability problems
- Correlated usability problems
- Correlated usability problems

Table 5
A detailed distribution matrix of usability problems showing who found which problem in which session.

Problems reported by all the evaluators	E1			E2			E3			E4			E5		
	S 1	S 2	S 3	S 1	S 2	S 3	S 1	S 2	S 3	S 1	S 2	S 3	S 1	S 2	S 3
1. Circulation systems															
1. The inconsistency of users' expectation regarding circulation			■			■		■	■		■	■		■	■
2. The unnecessary complexity of the circulation system			■			■		■	■		■	■		■	■
3. Insufficient manoeuvring space within the elevator	■	■	■		■	■									
4. Non-legibility of the elevators from the side entrances		■	■				■	■	■	■	■	■	■	■	■
5. Insufficient elevators	■	■	■	■	■	■	■	■	■	■	■	■		■	■
6. No auditory systems within the elevators		■	■		■										
7. Lack of elevators in the second and third basement floors		■			■		■	■	■	■	■	■	■	■	■
8. Lack of one escalator on the food court floor		■	■		■	■	■	■	■	■	■	■	■	■	■
9. Intrusion of the escalators into the path of travel			■			■		■	■		■	■			■
10. The curved stair; it causes accidental or unintended actions	■	■	■	■	■	■									
11. Difficult and indirect access to some facilities									■			■			■
12. The need for a big effort to access the curved stair	■		■	■		■			■			■			■
2. Entering and exiting															
13. Unsafe revolving doors at the main entrance		■	■		■	■								■	■
14. Inaccessible entering\exiting from the side entrances		■	■												
15. Lack of smooth level changes outside		■			■	■		■	■						
16. Unusable automated doors for diverse speed of movement		■													
17. No multiple path of travel at the back entrance		■	■		■	■	■	■	■	■	■	■		■	■
18. Unclear path of travel on entering the mall								■	■		■	■		■	■
19. No areas near the entrance\exit to rest or wait											■	■	■	■	■
20. Long distances from the north-east parking area							■	■	■	■	■	■		■	■
21. No easy \ direct access to entrances\exits from inside		■	■		■	■		■	■		■	■			
22. Difficulty of seeing information desk due to the elevators		■	■		■	■	■	■	■	■	■	■		■	■
23. Elevators obstructs the direction of the users	■	■	■		■	■	■	■	■	■	■	■			
24. Not enough maps, directories, and displays			■			■			■						
25. Lack of tactile, sound, and visual indicators in entering\exiting		■			■										
26. Difficult-to-read shop names because of columns		■	■				■	■	■	■	■	■			■
27. Some advertisements boards interrupt the path of travel		■			■										
28. Floor levels and their uses not well-defined			■			■			■			■			
29. No usage of daylight to guide and direct users							■	■	■	■	■	■	■	■	■
3. Wayfinding															
30. Wayfinding on the car park floor is not intuitive for users								■	■		■	■		■	■
31. Orientation problems within the mall			■			■		■	■		■	■		■	■
32. Inconsistencies caused by the four identical galleries							■	■	■		■	■		■	■
33. Non-legibilities caused by the symmetrical layout			■			■			■			■			■
34. No well-defined fire-exit in the food court\cinema floor		■	■		■	■									
4. Obtaining product/services															
35. Difficult access to all products for wheelchair users		■	■		■	■		■	■		■	■		■	■
36. Uncomfortable reach-range of shelves within shops		■	■		■	■		■	■		■	■		■	■
37. Not enough space in the aisles of the food court		■	■		■	■		■	■		■	■		■	■
38. Barriers and any stigmatizing design solutions in cinemas	■	■	■	■	■	■	■	■	■	■	■	■		■	■
39. No knee clearance at the service desks in the food court	■	■	■	■	■	■	■	■	■	■	■	■			
40. Limited visibility of the shop windows									■			■			
41. Hazardous chair-table placement on the food court floor		■	■		■	■					■	■		■	■
42. Lack of tactile materials within the shops\food court	■	■	■	■	■	■	■								
43. Lack of tactile, sound, and visual indicators in the shops\services			■			■			■			■			
5. Public amenities															
44. Lack of restrooms for disabled people on each floor	■	■	■	■	■	■	■	■	■	■	■	■		■	■
45. Unusable door handles in restrooms' changing situations		■	■		■	■									
46. Insufficient seating units					■	■		■	■		■	■	■	■	■
47. Unusable hand dryers\towel dispensers in the restrooms		■	■		■	■									
48. Inappropriate dimensions of seating units for diverse users		■	■					■	■						
49. Inappropriate dimensions of the car park floor							■	■	■	■	■	■	■	■	■
50. Insufficient public phones		■	■		■	■					■	■		■	■
51. Inappropriate material selection for restroom doors		■	■		■	■									
52. Lack of the tactile materials within restrooms	■	■	■	■	■	■	■		■						■
53. Lack of tactile, sound, and visual indicators in the public amenities		■	■		■	■			■						■
TOTAL = 53	**43**			**38**			**38**			**35**			**32**		

E1=Evaluator 1-Interior Architect, E2=Evaluator- Interior Architect 2, E3=Evaluator 3- Architect, E4=Evaluator 4-Architect, E5=Evaluator 5-Urban planner
S1= Session 1, S2= Session 2, S3= Session 3

Legend:

- Non-reported usability problems
- Reported usability problems
- Major usability problems
- Minor usability problems

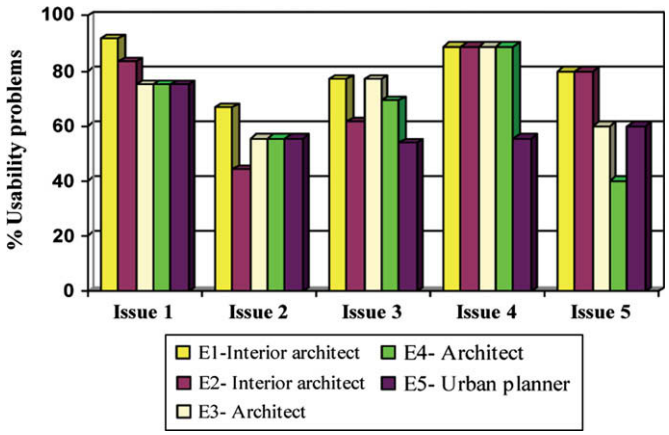

Fig. 4. The percentage of usability problems reported by the five evaluators regarding the five building issues.

discussion. There were no time lapses between the sessions. Sessions I and III lasted about 1 h, whereas session II lasted from 4 to 5 h for each evaluator. Before the heuristic evaluations began, a summary of the procedure was provided to each evaluator. First, in the pre-interview session, each design evaluator was visited in their own office environment to be interviewed on the construction drawings. Having finished, the authors and the evaluator went to the shopping mall for the task scenarios. Immediately after completing the task scenarios, the post-interview session was held in a café in the mall in order to discuss the construction drawings and conducted task scenarios.

5.3. Task scenarios

During the task scenarios, the evaluators were asked whether the shopping mall demonstrated the characteristics of a universally designed built environment (see Appendix A for the task scenarios). Five task scenarios related to the five building issues were given to each evaluator to complete for each floor of the mall. Each task scenario comprised seven sub-tasks with reference to the seven heuristics: seven principles of universal design (Fig. 2). Each sub-task is concerned with the relevant questions of each universal design principle to judge the conformity of the mall to universal usability. In this respect, all five tasks were conducted by inspecting their correspondence to the seven heuristics. The first task was to use the circulation systems of the mall on each floor: all the stairs, elevators, and escalators. The second task was to use the entrances/exits of the mall on each floor from the inside and outside. The third task was to find a destination using all pictorial, verbal, and tactile wayfinding elements: signage systems, maps, graphic information, and marking systems on each floor. The fourth task was to pass in and around all the shops on each floor and the food court. The fifth task was to use the public amenities, such as restrooms, information displays, public telephones, and seating units of the mall on each floor. After completing the first task, the evaluator was asked to do the second, the third, and so on, until all five tasks with their sub-tasks were performed. These task scenarios helped them to make in-depth observations. The evaluators performed these tasks with the guidance of the author, who recorded their observations. Each evaluator was also asked to think aloud, while inspecting the mall. Finally, the post-interview session was conducted to elicit more detailed evaluations, and it helped to identify further usability problems and suggestions for the improvement of the mall that had not arisen during the previous two sessions.

6. Results

Fifty-three usability problems were identified by the five evaluators at the end of the three sessions, which were classified into two categories: major and minor (Table 2). This categorization was based on the cost-effectiveness dimension of universal usability, defined in Section 2.2, which stands for evaluating a built environment in terms of structural and non-structural design decisions and their related usability problems. The results of this study were analyzed in terms of two issues: the role of the iterative sequence of heuristics and the effect of an interdisciplinary approach for the efficient application of heuristics.

6.1. The role of the iterative sequence of heuristic evaluation

By iterative sequence, this study referred to the three consecutive sessions of heuristic evaluation, including the incremental increase of usability problems (Table 3). Compared to the major problems, most of the minor problems were found in session II, which verified the statement that non-structural design features were discarded or left to the attention of architectural technicians. This was because, in the pre-interview session, evaluators dealt in depth with major problems, i.e., the structural elements of the mall, and they ignored the minor problems, i.e., non-structural design elements. However, in session II, as the evaluators worked each task, they recorded further observations regarding the minor problems, 22 of 25 (Fig. 3). Barriers, hazards, and unusable design features of the mall took evaluators' attention and hindered their task performance, regardless of whether they were minor or major. Thus, the iterative sequence of heuristic evaluation becomes essential for architectural design projects, which are failing to accommodate usability because of the late identification of both major and minor problems.

Concerning all the reported major problems, it is important to note that most of the major problems, which were identified in session I, were closely related to the problems identified in subsequent sessions. Table 4, which gives a more detailed analysis of this distribution, presents the reported major usability problems in the set of interrelations. To exemplify, the major usability problem 22, 'Inconsistencies caused by four identical galleries', which was reported by the evaluators in session I, matched the empirical evidence of the following major usability problems that were identified in sessions II and III: problem 1: 'The inconsistency of users' expectations regarding circulation', problem 21: 'Orientation problems within the mall', and problem 23: 'Non-legibilities caused by the symmetrical layout'. Because the major problem (22) was intertwined with the orientation, layout, and user expectation issues regarding the circulation system, there was a reciprocal interrelationship between the four major problems 1, 21, 22, and 23. In this respect, solving one of the interrelated usability problems is essential in terms of overall universal design success, because each problem is closely connected to each other, so that one causes the other. Thus, for example, it is not possible to ensure a universally designed circulation system by only providing a legible layout or by fulfilling one of the related universal design principles. A similar interrelation was also valid for the major problems 12, 14, and 15 as one set and for 19 and 26 as another set. This characteristic of universal usability means that it is not adequate to respond to a selective set of universal design requirements in order to satisfy the diverse user needs. So, the results also confirmed that achieving a successful universal design solution necessitated the overall and

Table 6
A detailed distribution matrix of the overlapped usability problems according to the five evaluators.

Problems reported by all the evaluators	E1	E2	E3	E4	E5
Major problems:					
1. The inconsistency of users' expectation regarding circulation					
2. The unnecessary complexity of the circulation system					
3. Insufficient manoeuvring space within the elevator					
4. Non-legibility of the elevators from the side entrances.					
5. Insufficient elevators					
6. Lack of elevators in the second and third basement floors					
7. Lack of one escalator on the food court floor					
8. Intrusion of the escalators into the path of travel					
9. The curved stair; it causes accidental or unintended actions					
10. Difficult and indirect access to some facilities					
11. The need for a big effort to access the curved stair					
12. Inaccessible entering\exiting from the side entrances					
13. No multiple path of travel at the back entrance					
14. Unclear path of travel on entering the mall					
15. Long distances from the north-east parking area					
16. No easy\direct access to entrances\exits from inside					
17. Difficulty of seeing the information desk due to the elevators					
18. Elevators obstructing users' path					
19. Difficult-to-read shop names because of columns					
20. No usage of daylight to guide and direct users					
21. Orientation problems within the mall					
22. Inconsistencies caused by the four identical galleries					
23. Non-legibilities caused by the symmetrical layout					
24. Barriers and any stigmatizing design solutions in cinemas					
25. No knee clearance at the service desks in the food court					
26. Limited visibility of the shop windows					
27. Lack of restrooms for the disabled people on each floor					
28. Inappropriate dimensions of the car park floor					
Minor problems:					
1. No auditory systems in the elevators					
2. Unsafe revolving doors at the main entrance					
3. Lack of smooth level changes outside					
4. Unusable automated doors for diverse speed of movement					
5. No areas near the entrance\exit to rest or wait					
6. Not enough maps, directories, and displays					
7. Lack of tactile, sound, and visual indicators in entering\exiting					
8. Some advertisements boards interrupt the path of travel					
9. Floor levels and their uses not well-defined					
10. Wayfinding on the car park floor is not intuitive for users					
11. No well-defined fire-exit in the food court\cinema floor					
12. Difficult access to all products for wheelchair users					
13. Uncomfortable reach-range of the shelves within shops					
14. Not enough space in the aisles of the food court					
15. Hazardous chair-table placement on the food court floor					
16. Lack of tactile materials within the shops\food court					
17. Lack of tactile, sound, and visual indicators in the shops\services					
18. Unusable door handles in restrooms' changing situations					
19. Insufficient seating units					
20. Unusable hand dryers\towel dispensers in the restrooms					
21. Inappropriate dimensions of seating units for diverse users					
22. Inappropriate material selection for restrooms doors					
23. Lack of tactile materials within restrooms					
24. Lack of tactile, sound, and visual indicators in the public amenities					
25. Insufficient public phones					

E1=Evaluator 1-Interior Architect, E2=Evaluator- Interior Architect 2, E3=Evaluator 3- Architect, E4=Evaluator 4-Architect, E5=Evaluator 5-Urban planner

Legend:

Non-overlapped usability problems
Overlapped usability problems
Non-reported usability problems

simultaneous consideration of the correlated design requirements, which made decision making in the universal building design process a complex, difficult, and multi-parameter task for designers.

6.2. The effect of the evaluator's profession on finding usability problems

The analyses from the findings indicated that there was an effect of the evaluator's profession on finding usability problems within a built environment. All the evaluators examined the construction drawings in detail, conducted task scenarios precisely, and reported most of the usability problems. However, the interior architects performed better than the architects, who, in turn, were better than the urban planner. (See Table 5 for a detailed distribution matrix of usability problems.) The individual differences in finding usability problems corresponded to the heuristic abilities of each evaluator. The interior architects found usability problems related to the interior design of the mall; the architects, to building elements; and the urban planner, to the building-site relationship. Particularly, there was a difference between the interior architects and the urban planner. The urban planner focused more on the path of travel, approaches inside and outside the mall, and movement patterns, such as problems 18, 19, 20, 29, 30, 32 and 49, which could be overlooked by the interior architects. This difference between the urban planner and the other professionals was more visible regarding the fourth building issue 'Obtaining product/services' (Fig. 4). Moreover, regarding the first building issue 'Circulation systems' and the second building issue 'Entering and exiting', both the architects and the urban planner uncovered the same percentage of usability problems. As observed from Table 5, in session I, there were no commonly found usability problems among the five evaluators. However, in session II, there were seven major and three minor usability problems, which were found commonly among all the evaluators. In session III, the number of commonly found usability problems increased, 12 major and 3 minor usability problems were reported by all the evaluators.

Table 6 presents a summary of the three sessions and indicates the overlapped usability problems after completing the three sessions. Of 53 problems, 16 or 24.5% were detected by all the evaluators, regardless of their profession. These results can be discussed under the question of what matters: the overlap between evaluators of different professions versus the overlap between evaluators in the same profession. The answer lies behind the attitudes of evaluators in judging the problem severity in terms of their heuristic abilities. By problem severity, we refer to our definition of universal usability regarding the structural and non-structural elements of a built environment, i.e., major versus minor problems. In this study, there was a relationship between problem severity and common problem discovery rate. The necessity of achieving the minimum universal design requirements for the design, construction, and maintenance of a built environment mattered for the overlap in the large number of reported major usability problems between evaluators of different professions. The broad focus of the interior architects on good detailing and correct specification of interior design requirements created differences in their uncovered minor usability problems. Thus, the reason for the overlap between evaluators in the same profession was the similarity of their observations and concentration levels on building issues, which later affected their identification of usability problems. In this respect, in this study, the effects of the interdisciplinary characteristics of the evaluators increased the problem discovery rate.

7. Conclusions

This study provided a definition of universal usability that was applicable to an architectural design context and was characterized by the cost-effectiveness dimension. In addition, a sequential heuristic evaluation based on this definition was demonstrated to be an efficient method for evaluating how well the usability of a newly designed shopping mall conforms to universal design. This study substantiated what Lewis (1994) stated, that the likelihood of the discovery of additional problems increases with the iterative sequence approach. With the help of the three sessions of this heuristic evaluation, usability problems were reported that could not have been detected solely through an analysis of the construction drawings. Based on the findings, there was a substantial evaluator effect. A single evaluator from one profession was insufficient to identify both major and minor usability problems within a built environment, but collectively, the five evaluators detected an increased number of usability problems. Thus, this study promoted an interdisciplinary heuristic evaluation process combined with multi-sessions, rather than relying on one evaluator and on one evaluation session, to find the maximum number of usability problems and to increase the robustness of the evaluation. Heuristic evaluation in this study identified many minor usability problems that are often not seen from an examination of the construction drawings of an architectural project.

The increasing globalization and specialization in the current architectural design and building industry requires an interdisciplinary design and collaboration methods for universal usability. Designers should consider the effective and efficient role of different professions' approaches to universal usability evaluation. Thus, in this study an interdisciplinary collaboration on a universal design project was widely seen as a valuable goal. Because universal design touches every aspect of the urban environment, it has to be practiced by industrial designers, interior architects, architects, urban planners and landscape architects (Ostroff, 2001). For a successful universal design process, paying more attention to interior facilities is as essential as establishing the connection between a building and its site context to ensure a completely usable building. Therefore, the heuristic abilities of each profession become important early on and highlight the necessity of an ad hoc committee composed of an interior architect, an architect, and an urban planner to achieve universal usability.

To summarize, the combined expertise of such an interdisciplinary committee in the architectural design context is essential to enhance the cognitive approach of designers to universal usability and to augment their problem-solving abilities during each of the three main operations of the design process: defining a set of objectives (analysis), generating alternative design solutions in relation to the defined objectives (synthesis), and evaluating the solution alternatives (evaluation) (Akin, 1986). Supporting the cognitive needs of designers during these three operations through the use of a cost-effective heuristic evaluation is also crucial for the success of the final solution. Tackling usability problems in each operation through the heuristic evaluation method can save both the project budget and the required time, while ensuring a reduced error rate for the universal usage of the built environments. In this respect, this study is an initial step for heuristic evaluation in architectural terms to raise awareness for universal usability within built environments. Future studies could include further developing and conducting the interdisciplinary heuristic evaluation method, beginning from the conceptual phase right through to the occupation phase of the universal design process. It would be beneficial to the design process to consider universal usability from the beginning and to organize the design process as an interdisciplinary collaboration between different professions.

Appendix A. Five task scenarios including their seven sub-task descriptions

Task Scenarios	Task descriptions	
Task Scenario1 (T1)	Would you please inspect the use of the circulation systems of the mall by:	
	Sub-task 1	Using all the stairs/elevators and escalators in each floor regarding their equitable use, i.e. - Do they provide same means of use for all users? - Do they provide privacy, security and safety that are equally available to all users? - Do they make the design appealing to all users?
	Sub-task 2	Using all the stairs/elevators and escalators in each floor regarding their flexibility in use, i.e. - Do they provide choice in methods of use? - Do they accommodate right- or left-handed access and use? - Do they provide adaptability to user's pace?
	Sub-task 3	Using all the stairs/elevators and escalators in each floor regarding their simple and intuitive use, i.e. - Do they eliminate unnecessary complexity? - Are they consistent with user expectations and intuition regardless experience, knowledge or language skills? - Do they arrange information consistent with its importance? - Do they provide effective prompting and feedback during and after task completion?
	Sub-task 4	Analyzing the appropriate use of the tactile, aural, visual design features, such as materials, lighting and furniture within the stairs/elevators and escalators regarding their perceptible information, i.e. - Do they communicate necessary information effectively? - Do they maximize legibility of essential information? - Do they provide compatibility with a variety of techniques and devices used by people with sensory limitations?
	Sub-task 5	Using all the stairs/elevators and escalators in each floor regarding their tolerance for error, i.e. - Do they minimize hazards and adverse consequences of accidental and unintended actions? - Provide fail safe features? - Provide warnings of hazards and errors?
	Sub-task 6	Approaching all the stairs/elevators and escalators from the shopping corridors regarding their low physical effort, i.e. - Do they allow maintaining a neutral body position? - Are they used with reasonable operating forces? - Do they minimize sustained physical effort?
	Sub-task 7	Using all the stairs/elevators and escalators in each floor regarding their size and space for approach and use, i.e. - Do they provide a clear line of sight to important elements for any seated or standing user? - Are all components comfortable to reach? - Do they provide adequate space for use assistive devices or personal assistance?
Task Scenario2 (T2)	Would you please inspect the use of entrances/exits of the mall by:	
	Sub-task 1	Using all the entrances/exits in each floor regarding their equitable use, i.e. - Do they provide same means of use for all users? - Do they provide privacy, security and safety that are equally available to all users? - Do they make the design appealing to all users?
	Sub-task 2	Using all the entrances/exits in each floor regarding their flexibility in use, i.e. - Do they provide choice in methods of use? - Do they accommodate right- or left-handed access and use? - Do they provide adaptability to user's pace?
	Sub-task 3	Using all the entrances/exits in each in each floor regarding their simple and intuitive use, i.e. - Do they eliminate unnecessary complexity? - Are they consistent with user expectations and intuition regardless experience, knowledge or language skills? - Do they arrange information consistent with its importance?
	Sub-task 4	Analyzing the appropriate use of the tactile, aural, visual design features, such as materials, lighting and furniture, within all the entrances/exists in each floor regarding their perceptible information, i.e. - Do they communicate necessary information effectively? - Do they maximize legibility of essential information? - Do they provide compatibility with a variety of techniques and devices used by people with sensory limitations?
	Sub-task 5	Using all the entrances/exits in each floor regarding their tolerance for error, i.e. - Do they minimize hazards and adverse consequences of accidental and unintended actions? - Provide fail safe features? - Provide warnings of hazards and errors?
	Sub-task 6	Approaching all the entrances/exits in each floor from both inside and outside regarding their low physical effort, i.e. - Do they allow maintaining a neutral body position? - Are they used with reasonable operating forces? - Do they minimize sustained physical effort?
	Sub-task 7	Using all the entrances/exits in each floor in each floor regarding their size and space for approach and use, i.e. - Do they provide a clear line of sight to important elements for any seated or standing user? - Are all components comfortable to reach? - Do they provide adequate space for use assistive devices or personal assistance?
Task Scenario3 (T3)	Would you please inspect the use of wayfinding systems of the mall by:	
	Sub-task 1	Finding your destination through using all pictorial, verbal and tactile wayfinding elements, signage systems, maps, graphic information and marking systems in each floor regarding their equitable use, i.e. - Do they provide same means of use for all users? - Do they provide privacy, security and safety that are equally available to all users? - Do they make the design appealing to all users?
	Sub-task 2	Finding your destination through using all pictorial, verbal and tactile wayfinding elements, signage systems, maps, graphic information and marking systems in each floor regarding their flexibility in use, i.e. - Do they provide choice in methods of use? - Do they facilitate user's accuracy and precision? - Do they provide adaptability to user's pace?

(*continued on next page*)

Appendix A (*continued*)

Task Scenarios	Task descriptions	
	Sub-task 3	Finding your destination through using all pictorial, verbal and tactile wayfinding elements, signage systems, maps, graphic information and marking systems in each floor regarding their simple and intuitive use, i.e. - Do they eliminate unnecessary complexity? - Are they consistent with user expectations and intuition regardless experience, knowledge or language skills? - Do they arrange information consistent with its importance?
	Sub-task 4	Analyzing the appropriate use of the tactile, aural, visual design features, such as materials, lighting and furniture, within all wayfinding elements, signage systems, maps, graphic information and marking systems in each floor regarding their perceptible information, i.e. - Do they communicate necessary information effectively? - Do they maximize legibility of essential information? - Do they provide compatibility with a variety of techniques and devices used by people with sensory limitations?
	Sub-task 5	Analyzing the appropriate use of the tactile, aural, visual design features, such as materials, lighting and furniture, within all wayfinding elements, signage systems, maps, graphic information and marking systems regarding their tolerance for error, i.e. - Do they minimize hazards and adverse consequences of accidental and unintended actions? - Provide fail safe features? - Provide warnings of hazards and errors?
	Sub-task 6	Using all wayfinding elements, signage systems, maps, graphic information and marking systems regarding their low physical effort, i.e. - Do they minimize repetitive actions? - Do they minimize sustained physical effort?
	Sub-task 7	Using all wayfinding elements, signage systems, maps, graphic information and marking systems regarding their size and space for approach and use, i.e. - Do they provide a clear line of sight to important elements for any seated or standing user? - Are all components comfortable to reach? - Do they provide adequate space for use assistive devices or personal assistance?
Task Scenario4 (T4)	Would you please inspect the use of obtaining product/services of the mall by:	
	Sub-task 1	Passing in and around all the shops in each floor and food court regarding their equitable use, i.e. - Do they provide same means of use for all users? - Do they provide privacy, security and safety that are equally available to all users? - Do they make the design appealing to all users?
	Sub-task 2	Passing in and around all the shops in each floor and food court regarding their flexibility in use, i.e. - Do they provide choice in methods of use? - Do they facilitate user's accuracy and precision? - Do they provide adaptability to user's pace?
	Sub-task 3	Passing in and around all the shops in each floor and food court regarding their simple and intuitive use, i.e. - Do they eliminate unnecessary complexity? - Are they consistent with user expectations and intuition regardless experience, knowledge or language skills? - Do they arrange information consistent with its importance?
	Sub-task 4	Analyzing the appropriate use of the tactile, aural, visual design features, such as materials, lighting and furniture, within all shops in each floor and food court regarding their perceptible information, i.e. - Do they communicate necessary information effectively? - Do they maximize legibility of essential information? - Do they provide compatibility with a variety of techniques and devices used by people with sensory limitations?
	Sub-task 5	Analyzing the appropriate use of the tactile, aural, visual design features, such as materials, lighting and furniture, within all shops in each floor and food court regarding their tolerance for error, i.e. - Do they minimize hazards and adverse consequences of accidental and unintended actions? - Provide fail safe features? - Provide warnings of hazards and errors?
	Sub-task 6	Passing in and around all the shops in each floor and food court regarding their low physical effort, i.e. - Do they allow maintaining a neutral body position? - Do they minimize repetitive actions? - Do they minimize sustained physical effort?
	Sub-task 7	Passing in and around all the shops in each floor and food court regarding their size and space for approach and use, i.e. - Do they provide a clear line of sight to important elements for any seated or standing user? - Are all components comfortable to reach? - Do they provide adequate space for use assistive devices or personal assistance?
Task Scenario5 (T5)	Would you please inspect the use of public amenities – restrooms, information displays, public telephones and seating units of the mall by:	
	Sub-task 1	Using all the restrooms, information displays, public telephones and seating units in each floor regarding their equitable use, i.e. - Do they provide same means of use for all users? - Do they provide privacy, security and safety that are equally available to all users? - Do they make the design appealing to all users?
	Sub-task 2	Using all the restrooms, information displays, public telephones and seating units in each floor regarding their flexibility in use, i.e. - Do they provide choice in methods of use? - Do they facilitate user's accuracy and precision? - Do they provide adaptability to user's pace?
	Sub-task 3	Using all the restrooms, information displays, public telephones and seating units in each floor regarding their simple and intuitive use, i.e. - Do they eliminate unnecessary complexity? - Are they consistent with user expectations and intuition regardless experience, knowledge or language skills? - Do they arrange information consistent with its importance?

Appendix A (*continued*)

Task Scenarios	Task descriptions	
	Sub-task 4	Analyzing the appropriate use of the tactile, aural, visual design features, such as materials, lighting and furniture, within all the restrooms, information displays, public telephones and seating units in each floor regarding their perceptible information, i.e. - Do they communicate necessary information effectively? - Do they maximize legibility of essential information? - Do they provide compatibility with a variety of techniques and devices used by people with sensory limitations?
	Sub-task 5	Analyzing the appropriate use of the tactile, aural, visual design features, such as materials, lighting and furniture, within all the restrooms, information displays, public telephones and seating units in each floor regarding their tolerance for error, i.e. - Do they minimize hazards and adverse consequences of accidental and unintended actions? - Provide fail safe features? - Provide warnings of hazards and errors?
	Sub-task 6	Using all the restrooms, information displays, public telephones and seating units in each floor regarding their low physical effort, i.e. - Do they allow maintaining a neutral body position? - Do they minimize repetitive actions? - Do they minimize sustained physical effort?
	Sub-task 7	Using all the restrooms, information displays, public telephones and seating units in each floor their size and space for approach and use, i.e. - Do they provide a clear line of sight to important elements for any seated or standing user? - Are all components comfortable to reach? - Do they provide adequate space for use assistive devices or personal assistance?

References

Afacan, Y., 2008. Designing for an aging population: residential preferences of the Turkish elderly to age in place. In: Langdon, P., Clarkson, P.J., Robinson, P. (Eds.), Designing Inclusive Futures. Springer, London, pp. 241–252.

Akin, O., 1986. Psychology of Architectural Design. Pion, London.

Andre, S.T., Hartson, H.R., Belz, M.S., Mccreary, F.A., 2001. The user action framework: a reliable foundation for usability engineering support tools. International Journal of Human–Computer Studies 54 (1), 107–136.

Arthur, J.D., Gröner, M.K., 2005. An operational model for structuring the requirements generation process. Requirements Engineering 10 (1), 45–62.

Baya, V., Leifer, L.J., 1996. Understanding information management in conceptual design. In: Cross, N., Christiaanas, H., Dorst, K. (Eds.), Analysing Design Activity. Elsevier Science, Amsterdam, pp. 151–167.

Beecher, V., Paquet, V., 2005. Survey instrument for the universal design of consumer products. Applied Ergonomics 36 (3), 363–372.

Beevis, D., 2003. Ergonomics: costs and benefits revisited. Applied Ergonomics 34 (5), 491–496.

Canadian Human Rights Commission, 2006. International Best Practices in Universal Design: A Global Review [CD-ROM]. Betty Dion Enterprises Ltd., Canada.

Carmichael, A., Newell, A.F., Morgan, M., 2007. The efficacy of narrative video for raising awareness in ICT designers about older users' requirements. Interacting with Computers 19 (5–6), 587–596.

Chiu, M.L., 2002. An organizational view of design communication in design collaboration. Design Studies 23 (2), 187–210.

Clarkson, J., Coleman, R., Hosking, I., Waller, S., 2007. Inclusive Design Toolkit. Cambridge Engineering Design Centre Press, Cambridge. Retrieved from: www.inclusivedesigntoolkit.com/betterdesign (1.10.07).

Danford, G.S., Tauke, B. (Eds.), 2001. Universal Design New York. Vanguard Direct, New York.

Darses, F., Wolff, M., 2006. How do designers represent to themselves the users' needs? Applied Ergonomics 37 (6), 757–764.

De Angeli, A., Matera, M., Costabile, M.F., Garzotto, F., Paolini, P., 2003. On the advantages of a systematic inspection for evaluating hypermedia usability. International Journal of Human–Computer Interaction 15 (3), 315–335.

Demirbilek, N., Demirkan, H., 2004. Universal product design involving elderly users: a participatory design model. Applied Ergonomics 35 (4), 361–370.

Demirkan, H., 2007. Housing for the aging population. European Review of Aging and Physical Activity 4 (1), 33–38.

Erbug, C., 1999. Use of Computers to teach ergonomics to designers [CD-ROM]. In: Mondelo, P., Mattila, M., Karwowski, W. (Eds.), Proceedings of the International Conference on Computer-Aided Ergonomics and Safety. Universitat Politecnica de Catalunya, Barcelona.

Eren, Y., 2004. Exploring the Potential of Mat-building for the Creation of Universally Designed Environments. Unpublished Master Thesis. Middle East Technical University.

Erkip, F., 2003. The shopping mall as an emergent public space in Turkey. Environment and Planning A 35 (6), 1073–1093.

Fange, A., Iwarsson, S., 2003. Accessibility and usability in housing: construct validity and implications for research and practice. Disability and Rehabilitation 25 (23), 1316–1325.

Freudental, A., Mook, H.J., 2003. The evaluation of an innovative intelligent thermostat interface: universal usability and age differences. Cognition, Technology and Work 5 (1), 55–66.

Fu, L., Salvendy, G., Turley, L., 2002. Effectiveness of user testing and heuristic evaluation as a function of performance classification. Behaviour and Information Technology 21 (2), 137–143.

Garner, S., Mann, P., 2003. Interdisciplinarity: perceptions of the value of computer-supported collaborative work in design for the built environment. Automation in Construction 12 (5), 495–499.

Gregor, P., Sloan, D., Newell, A., 2005. Disability and technology: building barriers or creating opportunities. In: Zelkowitz, M. (Ed.), Advances in Computers. Elsevier, Amsterdam, pp. 284–346.

Haque, S., 2005. Accessibility for all: Role of architects to make a barrier free environment. In: Proceedings of UIA Region IV Work Programme 'Architecture for All' UIA/ARCASIA Workshop. 3–10 Istanbul, Turkey, pp. 8–14.

Harding, J.A., Popplewell, K., Fung, R.Y.K., Omar, A.R., 2001. An intelligent information framework relating customer requirements and product characteristics. Computers in Industry 44 (1), 51–65.

Harrison, J., Parker, K., 2005. Designing for real people's lifelong needs. In: Proceedings of UIA Region IV Work Programme 'Architecture for All' UIA/ARCASIA Workshop. 3–10 Istanbul, Turkey, pp. 15–24.

Hertzum, M., Jacobsen, N.E., 2001. The evaluator effect: A chilling fact about usability evaluation methods. International Journal of Human–Computer Interaction 13 (4), 421–443.

Hertzum, M., Jacobsen, N.E., Molich, R., 2002. Usability inspections by groups of specialists: Perceived agreement in spite of disparate observations. In: Proceedings of CHI 2002. Minneapolis, MN, pp. 662–663.

Iwarsson, S., Stahl, A., 2003. Accessibility, usability and universal design—positioning and definition of concepts describing person-environment relationships. Disability and Rehabilitation 25 (2), 57–66.

Jacobsen, N.E., Hertzum, M., John, B.E., 1998. The evaluator effect in usability tests. In: Proceedings of CHI 1998. Los Angeles, USA, pp. 255–256.

Kalay, Y.E., 2006. The impact of information technology on design methods, products and practices. Design Studies 27 (3), 357–380.

Kamper, R., 2002. Extending the usability of heuristics for design and evaluation: lead, follow and get out of the way. International Journal of Human–Computer Interaction 14 (3), 447–462.

Kantner, L., Rosenbaum, S., 1997. Usability studies of www sites: heuristic evaluation vs. laboratory testing. Reprint of paper from SIGDOC 97 Proceedings (Salt Lake City, UT). Published by Association for Computing Machinery, Inc. Retrieved from: http://www.teced.com/PDFs/sigdoc97.pdf [01.12.05].

Kolarevic, B., Schmitt, G., Hirschberg, U., Kurmann, D., Johnson, B., 2000. An experiment in design collaboration. Automation in Construction 9 (1), 73–81.

Kvan, T., 2000. Collaborative design: what is it? Automation in Construction 9 (4), 409–415.

Law, E.L., Hvannberg, E.B., 2004. Analysis of strategies for improving and estimating the effectiveness of heuristic evaluation. In: Proceeding Series of ACM International Conference, vol. 82, pp. 241–250.

Law on Public Procurement Contracts, 2008 Retrieved from: http://www.ihale.gov.tr/english/english47351.htm (21.02.08).

Levine, D. (Ed.), 2006. Universal Design New York 2. IDEA.Publications, New York.

Lewis, J.R., 1994. Sample sizes for usability studies: additional considerations. Human Factors 36 (2), 368–378.

Marley, S., 2001. Creating an accessible public realm. In: Preiser, F.E.W., Ostroff, E. (Eds.), Universal Design Handbook. McGraw-Hill, New York, pp. 58.1–58.22.

Nicolle, C., Rundle, C., Graupp, H., 2003. Towards curricula in design for all for information and communication products, systems and services. Education and evaluation – resources and methods at student level. In: Proceedings of Include 2003. Royal College of Art, London, pp. 99–105.

Nielsen, J., Molich, R., 1990. Heuristic evaluation of user interfaces. SIGCHI Bulletin April (Special Issue), 249–256.

Nielsen, J., 1992. Finding usability problems through heuristic evaluation. In: Proceedings of CHI '92, California, USA, pp. 373–380.

Nielsen, J., 1993. Usability Engineering. Academic Press, New York.
Nielsen, J., 1994. How to conduct a heuristic evaluation. In: Nielsen, J., Mack, R.L. (Eds.), Usability Inspection Methods. John Wiley and Sons, New York, pp. 25–36.
Ostroff, E., 2001. Universal design: the new paradigm. In: Preiser, F.E.W., Ostroff, E. (Eds.), Universal Design Handbook. McGraw-Hill, New York, pp. 1.1–1.12.
Preiser, W., 2001. Toward universal design evaluation. In: Preiser, F.E.W., Ostroff, E. (Eds.), Universal Design Handbook. McGraw-Hill, New York, pp. 9.1–9.16.
Preiser, W., 2003. Inclusiveness through universal design feedback and evaluation. Education and evaluation – resources and methods at student level. In: Proceedings of Include 2003. Royal College of Art, London.
Resolution ResAP 3, 2001. Towards Full Citizenship of Persons with Disabilities Through Inclusive New Technologies, Adopted by the Committee of Ministers of the Council of Europe on 24 October 2001 Retrieved from: http://wallis.kezenfogva.iif.hu/eu_konyvtar/projektek/vocational_rehabilitiation/instr/coe_002.htm (9.12.07).
Ringaert, L., 2001. User/expert involvement in universal design. In: Preiser, F.E.W., Ostroff, E. (Eds.), Universal Design Handbook. McGraw-Hill, New York, pp. 6.1–6.8.
Shneirderman, B., Hochheise, H., 2001. Universal usability as a stimulus to advanced interface design. Behaviour and Information Technology 20 (5), 367–376.
Simoff, S.J., Maher, M.L., 2000. Key centre of design analyzing participation in collaborative design environments. Design Studies 21 (2), 119–144.
Simon, H.A., 1979. The Sciences of the Artificial, seventh ed. MIT Press, London.
Smith, B.S., Coull, A., 1991. Tall Building Structures: Analysis and Design. Wiley, New York.
Story, M.F., Mueller, J.L., Mace, R.L., 1998. The Universal Design File: Designing for People of All Ages and Abilities. North Carolina State University Press, North Carolina.
Sutcliffe, A., Gault, B., 2004. Heuristic evaluation of virtual reality applications. Interacting with Computers 16 (4), 831–849.
The Center for Universal Design, 1997. Principles of Universal Design. NC State University. Retrieved from: www.design.ncsu.edu./cud/univ_design/udprinciples.htm (23.09.03).
Vanderheiden, G., 2000. Fundamental principles and priority setting for universal usability. In: Proceedings of ACM International Conference on Universal Usability, pp. 32–38.