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Development of auditory design guidelines for improving learning on mobile phones

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ABSTRACT

Although auditory information in mobile learning (m-learning) can be an important resource for delivering knowledge and information, the importance of guidelines for designing auditory instructions has largely been overlooked. Therefore, this study considered the characteristics of m-learning, mobility and personalization, with the aim of developing and validating auditory design guidelines to improve learning on mobile phones. The present study covers m-learning with cellphones only. Auditory design guidelines were developed and revised using an iterative educational design research process. The auditory design guidelines were developed by analyzing previous studies related to m-learning and auditory interface design, and revised using three validation methods. The expert reviews and usability evaluations were conducted as an internal validation method, and a field evaluation was used as an external validation method to confirm the feasibility and educational effects. The results showed that the auditory design guidelines could be applied effectively to the design of audio instructions delivered on smart phones. Finally, a total of ten guidelines were developed, three for auditory-only design, four for attention design, and three for personalization design. This paper discusses the theoretical, empirical and practical aspects of the design guidelines presented.

1. Introduction

The increasing popularity of mobile devices, such as smartphones and iPads, has increased the interest in mobile learning (McCrea, 2010). Students are provided with a learning environment, where they can search for information anytime and anywhere with their mobile phones because of their small device size and wireless internet capability (Hoppe, Joiner, Milrad, & Sharples, 2003; Kossen, 2001; Kukulska-Hulme & Traxler, 2005; Quinn, 2009). On the other hand, because the displays of mobile learning devices are relatively small compared to desktop or laptop computers and they can be used while walking around, most have limited capacity to display visual information. Consequently, learners may experience difficulties "maintaining" visual attention on the screen. Considering the mobile learning characteristics of portability and mobility, an auditory presentation of the instructional content might be the optimal means of obtaining information (Kim, 2012).

Despite auditory information in an instructional design field being an important design factor in conjunction with visual information, previous studies of auditory designs have only examined auditory interfaces and feedback in e-learning or m-

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learning environments in a restricted manner (Brewster, 2002; Leplatre & Brewster, 2000; Walker & Brewster, 2000). Many studies have evaluated general design guidelines for m-learning environments (Hayhoe, 2001; Parsons, Ryu, & Cranshaw, 2007; Rainger, 2005; Trifonova, 2003; Vavoula, Lefrere, O'Malley, Sharples, & Taylor, 2004). Despite this, practical guidelines on auditory information design are unavailable, leaving many instructional designers to rely on their experience when designing auditory information. Therefore, the aim of this study was to develop and validate auditory design guidelines to support a learner's self-directed learning in a mobile learning environment. Accordingly, educational design research was applied to achieve this research purpose (De Villiers & Harpur, 2013; Teras & Herrington, 2014). This paper provides useful auditory design guidelines that can help to address some of the limitations of the display size and stability in mobile learning environments.

2. M-learning and auditory information

M-learning, which emphasizes the features of "mobility" and the advantages of e-learning, can be defined as self-directed learning using portable mobile devices without tempo-spatial restrictions (Hoppe et al., 2003; Kukulska-Hulme & Shield, 2008; Quinn, 2009). Although m-learning generally covers all types of learning with mobile devices using wireless internet, such as notebooks, cellphones, iPads, and tablet PCs, the scope of this study is limited to learning from mobile devices with small displays, e.g., cellphones, which can be carried easily in one hand.

Many studies have explained the characteristics of mobile environments in terms of mobility, accessibility, interactivity, instant connectivity, etc. (Kalakota & Robinson, 2001; Kumar & Zahn, 2003; Quinn, 2009), among which mobility is an essential feature. In an e-learning environment using desktop computers, visual information is the primary source of information with auditory information being secondary. Auditory instructions, however, are very important in an m-learning environment, which features mobility and small displays. Despite this, previous studies related to the design of m-learning lessons dealt mainly with visual design guidelines (Hayhoe, 2001; Rainger, 2005; Trifonova, 2003). Few auditory design guidelines have been proposed to design m-learning configurations which treat auditory information as the primary medium for teaching knowledge and skills (Brewster, 2002; Leplatre & Brewster, 2000; Walker & Brewster, 2000). There has been no comprehensive set of validated practical guidelines to support designers in generating auditory instructions to supplement visual objects – both textual and non-textual – in m-learning lessons, which run on small-screen mobile devices, such as cellphones. Therefore, there is a need for comprehensive auditory design guidelines which have been validated.

Auditory information in m-learning lessons needs to be designed with consideration for the physical limitations of mobile devices and two important characteristics of m-learning: mobility and personalization. Mobility is the most distinguishing characteristic of an m-learning environment; m-learning often occurs on the move and in public places, such as subways, buses and cafés, which have many distractions. Therefore, *mobility* should be taken into consideration in the design so that all the information on non-text objects as well as text that is presented on the screen can be acquired by auditory information alone. Non-text objects can include visuals, graphs and tables. Learners should be able to interact with the content easily, even when on the move, and the learners' attention should be guided. According to Schannon and Schramn (1964)'s communication theory, the sender and receiver communicate in the shared field of experience using signs and symbols, during which noise can interfere with that information. Overcoming external noise in public spaces is important for maintaining the learners' attention. In addition, because m-learning occurs using personal mobile devices rather than public devices, m-learning should allow the m-learning environment to be customized according to individual preferences (See Table 1). Therefore, the aim of this study was to develop and validate guidelines on auditory information design, interaction design and environment design.

3. Research method: educational design research

Educational design research was chosen to guide this study because this study addressed an educational real-world problem for which there were no clear guidelines or solutions available (Anderson & Shattuck, 2012). An interactive

Table 1
Auditory design directions considering the challenges for m-learning.

Mobile environments	Challenges and affordance for m-learning	Auditory design directions	Auditory design categories
Mobility	• High possibility of learning while on the move.	1) All the information presented on screen through text as well as non-text should also be provided as auditory information	Information design
		2) Interaction with contents while on the move should be easy	Interaction design
	• Learning is conducted not in separate places but in an open space with noise.	3) Support for the learner's attention should be included.	Information design
Personalization	• Learning is done with the mobile devices that the individual owns	4) The learner should be able to configure the auditory information environment	Environment design
	• Phone call or text messaging is possible during learning		

process was used to design, validate, reflect on feedback, revise and redesign the set of auditory design guidelines. The research process carried out the stages of educational design research suggested by Reeves (2006) as shown in Fig. 1.

The initial auditory design guidelines for m-learning lessons were validated using the comprehensive multi-method evaluation approach, i.e. a mixed-methods strategy (Creswell, 2009). The following three different methods were employed; expert review, usability evaluation and field evaluation (Richey & Klein, 2007). These three validation methods were used to determine the implications for modifying the auditory design guidelines and validating them. Specifically, an expert review was conducted to validate the auditory design guidelines, and a usability evaluation was carried out to determine if instructional designers could apply the guidelines to a real-world situation. The field evaluation was to determine if learners thought that an m-learning lesson that applied the guidelines was effective. The specific research questions were as follows:

1) What would effective auditory design guidelines for m-learning be?
2) To what extent do experts in educational technology consider these guidelines to be appropriate?
3) To what extent do instructional designers consider these guidelines to be appropriate, particularly in relation to the effectiveness and ease of use of materials that adhere to them?
4) To what extent do these auditory guidelines enhance learner comprehension?

4. The initial auditory design guidelines

This section discusses the auditory design guidelines form-learning content. We have drawn on existing guidelines from e-learning to help us to develop a range of empirically-referenced auditory design guidelines considering the affordability and limitations of cell phones. A total of ten guidelines are suggested; four for auditory information design, three for auditory interaction design and three for auditory environment design. These ten guidelines were validated and tested, as reported in the later sections of this paper.

4.1. Auditory information design

4.1.1. Guideline 1.1 provide an auditory explanation for non-text objects

As m-learning can be accomplished while in motion, all instructional content is delineated so the learners can understand the information from narration without the need to look at the information on the display. During an explanation, where a table or figure is referred to (e.g. “as shown in the following table”), narration is currently often insufficient to support full understanding. All tables and pictures should be fully described aurally. This guideline originates from the Web Contents Accessibility Guideline for the blind, which states that an auditory explanation should be provided for non-text objects (Caldwell, Chisholm, Vanderheiden, & White, 2004). Clark and Mayer (2011) also suggested that the use of audio rather than on-screen text to describe graphics can result in significant learning gains even in e-learning environments.

4.1.2. Guideline 1.2 explain briefly and clearly the learning content with the appropriate voice volume without a pause longer than 3 s

The brief and clear delivery of instructional content is essential because auditory information, particularly an explanative narration, is the primary information (Clark & Mayer, 2011). Kennedy, Hart, and Kellems (2011) also suggested that the learning content for creating podcasts should be narrated clearly at a speed and in a tone that are both engaging. When learning is progressed only with auditory information, a pause of more than 3 s can give the learners the impression of an error or termination. This guideline came from authors' instructional design experiences, and Riggenbach (1991) suggested that an unfilled pause of more than 3 s is generally regarded as a speech problem to non-native speakers.

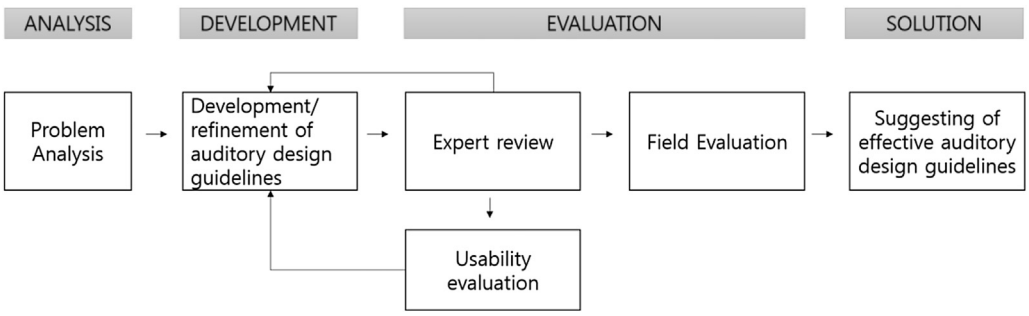


Fig. 1. Educational design research process.

4.1.3. Guideline 1.3 explain important information louder, slowly or repeatedly

Learners may have difficulty in maintaining their attention on learning content because m-learning is generally carried out in public spaces, such as in buses, subways or cafés. Learners generally select the information that they consider important and remember it (Glynn, Britton, & Tillman, 1985). Clues regarding the key information should be provided to help learners pay attention to the important information. Teachers normally explain loudly, slowly or repeatedly to emphasize the important information. Similarly, in an auditory design, the important content can be presented with a louder volume, slowly and/or repeated two to three times. This guideline can help increase the learner's attention.

4.1.4. Guideline 1.4 provide an auditory cue when a topic changes, or when learning begins or ends

Learners cannot pay continuous attention to m-learning because of the many distractions (Kukulska-Hulme & Shield, 2008). If an auditory cue is provided when a topic or subtopic changes or when a learning activity begins or ends, it will help the learner concentrate on learning (Kim, 2012). This is similar to the strategies used in visual design for e-learning content, which advocates the use of a screen transition or having a different color for the background to provide a visual cue for content transition (Jin, 2013). Presenting a range of auditory cues in a consistent manner will also be effective so the learners will clearly understand the meaning of the sound.

4.2. Auditory interaction design

4.2.1. Guideline 2.1 provide an arousal message when a learner does not respond after a certain period of time

Learners need to have more self-directed learning ability in m-learning environments than in e-learning environments. If the learner does not respond to an instruction after a certain period of time (approximately 1 min), an arousal message (for example “Pay attention please”) should be offered to attract the learner's attention. This guideline was validated by expert review and usability test (Kim, 2012). For mobile content involving low levels of physical interaction with the learners, an automatic pause function should be inserted into the sub-topic or at logical points as a design default so that the contents are replayed when the volume button or any button is pressed. Schar and Zimmermann (2007) recommend that an animation is automatically stopped at logical points rather than relying on the learners to use the pause and replay buttons on their own. This guideline can be useful when presenting and following instructions on procedural knowledge or skills, with pauses to allow the learner to complete each step before moving to the next step. This can be useful for allowing hands-free voice activation to play the instructions for the next step.

4.2.2. Guideline 2.2 provide sound confirmation when a learner clicks on a menu or a button

When learners are engaging in m-learning whilst on the move task/work error rates are likely to be high. Providing auditory feedback when a menu item or button is selected can help support such mobile leaners (Brewster, 2002; Leplatre & Brewster, 2000). Providing instant sound confirmation of intended or unintended button or menu selections might be a useful strategy to support the interaction between learners and m-learning content.

4.2.3. Guideline 2.3 provide sound feedback for a learner's correct or incorrect response in evaluation activities

This guideline is generally applied when designing assessment activities in e-learning and m-learning lessons (Dempsey & Sales, 1993). Providing audio feedback regarding the students' problem-solving results during the m-learning assessment activities has the following benefits: 1) allowing the students to recognize the results instantly, and 2) providing students with a self-reflective opportunity for problem solving. Generally, a bright and cheerful sound is used for correct answers, whereas a blunt sound is used for incorrect answers (Kim, 2012).

4.3. Auditory environment design

4.3.1. Guideline 3.1 provide an alarm function to set the learning time and learning content

M-learning has in effect become a form of individual learning environment that requires learner to have good self-regulation skills, particularly time management skills. Many studies have reported that time management can be an essential factor in facilitating self-regulated learning (Zimmerman & Martinez-Pons, 1988). Learners can set their own learning schedules and be provided with audio reminders using the mobile devices' alarm functions to help them stick to their plan. The alarm function in this instance is not a simple alarm function but asks the learners whether they are going to study specific content at a specified time, and the content is played when the learner accepts it.

4.3.2. Guideline 3.2 provide a control option for the on/off, the volume, the speed and playback method of sound

One of the important design factors in an m-learning environment is to provide a function for learners to configure their own environment (Clark & Mayer, 2011; Hooper & Hannafin, 1991). In particular, in a mobile environment, which is personal, allowing an individual to configure his or her learning environment can influence the learning outcomes. In relation to auditory design, the basic functions that an individual can manipulate are sound on/off, volume control and speed control. As internet lectures are widely available, learners may prefer to play the contents at 1.2 or 1.4 times the normal audio speed to reduce the learning time. Moreover, it has been shown that learning at a faster speed does not affect the level of understanding or learning achievement (Kim & Rha, 2011; Ritzhaupt, Gomes, & Barron, 2008). Although the general playback mode

is sequential, a range of playback settings can be designed so learners can play from where they left off, skip to a desired point, and repeat desired parts.

4.3.3. Guideline 3.3 provide control options to block incoming calls and text messages

External factors can impede concentration but internal factors, such as receiving a phone call or a message, might block learning. Therefore, it is important to provide learners with control options to selectively block incoming phone calls or text messages according to their will or the perceived importance of their learning. This guideline does not have any reference; it was developed in the light of the characteristics of m-learning. Ideally, learners would be able to manually change the settings themselves as part of configuring their learning settings, but current mobile phones do not support this functionality.

5. Validations for auditory design guidelines

The initial auditory design guidelines were validated by an iterative process using three different methods. The specific sequence of validations are as shown in Table 2.

5.1. Expert review round 1

5.1.1. Participants, instrument, and analysis

Six experts participated in the 1st expert review to validate the initial auditory design guidelines. They were recruited according to their expertise in the development of design guidelines or strategies to improve e-learning or m-learning. Five experts (A, B, C, D and E) had a Ph.D. and one expert (F) was a doctoral candidate in educational technology. The1st expert review was conducted with two methods; face-to-face and online. Two experts (A and F) were directly introduced to the purpose of this study and the development process of auditory design guidelines. Their review results and comments on the guidelines were then requested. A brief explanation of the research purpose and development process were provided to the other four experts over the phone and an expert review sheet that included an explanation was sent out and returned by email.

The instrument for the first expert review was designed to evaluate the appropriateness of the ten initially developed auditory design guidelines using a 4-point Likert scale (4 = fully verified, 1 = unverified). One open-ended question, which asked the expert reviewers to write some comments, was added.

The validity of the experts' responses was analyzed using the Content Validity Index (CVI) and Inter-Relater Agreement (IRA) used by Lee and Jin (2014). The content validity index (CVI) is the number of experts who evaluated each survey item as valid divided by the total number of experts. The CVI provides the ratio of experts who assessed the items to be valid, and a CVI >.80 is considered valid. The IRA gives a score for the trustworthiness of the evaluation of the experts. The IRA was calculated by dividing the number of items evaluated equally by the total number of items. An IRA >.80 is considered valid. When the CVI and IRA are measured on a 4-point scale, the rating scores of 1 (strongly disagree) & 2 (disagree) and scores 3 (agree) & 4 (strongly agree) were paired up.

5.1.2. The result of the expert review round 1

The results of the 1st expert review were on average, 3.57 out of a 4.0 rating scale; the CVI and IRA values for each guideline were >.8 except for Guideline 2.2 (See Table 3). Six experts, who participated in the expert review, recommended removing the general auditory design guidelines that had been applied in the design activities, even though they were useful in m-learning content design. In particular, Expert B pointed out that the design guidelines should be categorized according to the design objectives reflecting the characteristics of m-learning instead of classifying the guidelines into information, interaction and environment design.

The comments by the experts on each design guideline are as follows: Expert B recommended separating G 1.2 into “Explain more than 3 s without mute” and “Explain briefly and clearly at the appropriate volume”, and also pointed out that the latter aspect is an obvious auditory design guideline. Expert C recommended that “Insert an automatic pause by subtopics or by logical points during the absence of a physical interaction between the learner and the m-learning content, and design it to play when the volume button or any button on the mobile device is pressed” in G 2.1 be included as a separate design guideline. Regarding G 3.2, Experts A and B suggested focusing on the sound speed and play mode because the sound on/off and volume are general functions offered in mobile devices, and they both stated that it would be good for the learners to

Table 2
The sequence of the validation process.

Methods	Outputs
Expert review round 1	1st revised auditory design guidelines
Expert review round 2	1st validated guidelines
Usability evaluation	2nd revised auditory design guidelines (final version)
Expert review round 3	2nd validated guidelines
Field evaluation	Effective guidelines on learning

Table 3
Result of the expert review round 1.

Item		Expert response						M	SD	CVI	IRA
		A	B	C	D	E	F				
1 Auditory information design	Guideline 1.1	3	4	4	4	4	3	3.66	.52	1	1
	Guideline 1.2	4	3	3	2	3	3	3.00	.63	.83	
	Guideline 1.3	4	4	4	3	3	3	3.50	.55	1	
	Guideline 1.4	4	4	4	4	4	4	4.00	.00	1	
2 Auditory interaction design	Guideline 2.1	3	4	4	4	3	3	3.50	.55	1	.67
	Guideline 2.2	4	3	4	2	2	4	3.17	.98	.67	
	Guideline 2.3	4	3	4	2	4	4	3.50	.84	.83	
3 Auditory environment design	Guideline 3.1	3	4	4	4	3	4	3.67	.52	1	1
	Guideline 3.2	4	3	4	4	4	3	3.67	.52	1	
	Guideline 3.3	4	4	4	4	4	4	4.00	.00	1	
Total mean: 3.57											

choose the sound type. Experts C and F stated that G 3.3 is an indispensable guideline. Therefore, they suggested putting it earlier within the guidelines. G 2.2 and G 2.3 are both general auditory design principles and G 2.2 should be deleted because providing sound feedback for every menu and button press can interrupt learning (Experts B, E, & F). Finally, Expert A suggested that G 1.1 be redefined to clarify its meaning.

5.2. The 1st revised auditory design guidelines

As a result of the first expert review, the general design guidelines were excluded, and only the auditory design guidelines that consider the mobility and use of a personal device in an m-learning environment were included and revised. As a result, G 1.2 and G3.2 were revised and G2.2 and G2.3 were deleted.

Current guideline 2.1 was divided into two guidelines and re-defined to make its meaning clearer. The overall guidelines were categorized into: auditory-only; attention design; and personalization design. Auditory-only design suggests that the learning content is acquired sufficiently with only auditory information. Table 4 lists the amended auditory design guidelines.

5.3. Expert review round 2

5.3.1. Participants, instrument, and analysis

Four (A, B, C and D) out the six experts, who participated in the 1st expert review were contacted by email to review the revised design guidelines following the results of the 1st expert review. The responses were received by email. The instrument for the second expert review consisted of nine items to ask the appropriateness of the revised design guidelines using a 4-point Likert scale (4 = fully verified, 1 = unverified). One open-ended question was added. The Content Validity Index (CVI) and Inter-Relater Agreement (IRA) were used to analyze the validity of the experts' responses. The specific analysis method is the same as that used in the 1st expert review.

5.3.2. The result of the expert review round 2

The results of the 2nd expert review on the revised auditory design guidelines were averaged 3.81 on a 4.0 rating scale; the CVI and IRA values for each guideline were both 1 (See Table 5). This indicates that all the guidelines were strongly valid and reliable.

Table 4
Amended auditory design guidelines by the 1st expert review.

Purpose	Auditory design guidelines
1 Auditory-only design	*Guideline 1.1* Explain all non-text objects (tables, graphs, photos etc.) included in the m-learning content.
	Guideline 1.2 Avoid pauses that are more than 3 s long when explaining the learning content.
2 Attention design	*Guideline 2.1* Provide an attention attracting message when the learners do not respond to an instruction for a certain amount of time.
	Guideline 2.2 Design to automatically stop the learning content explanation by sub-topic or by logical point and play when any button on the mobile device is pressed (if there is little physical interaction between the learner and m-learning content)
	Guideline 2.3 Explain the important information louder, slowly or repeatedly (2~3 times)
	Guideline 2.4 Provide a cue sound when a learning topic is switched or learning begins or ends.
3 Personalization design	*Guideline 3.1* Provide control options to block incoming calls and text messages
	Guideline 3.2 Provide an alarm function that informs the learner of the learning time for the m-learning content that the learner specifies.
	Guideline 3.3 Provide a sound playback configuration function to change the speed (1.2/1.5/1.8/2.0×) and playback modes (sequential, repeated, returned or skip play) for the learner.

Table 5
Result of the expert review round 2.

Item		Expert response				M	SD	CVI	IRA
		A	B	C	D				
1 Auditory-only design	Guideline 1.1	4	4	3	3	3.5	.58	1	1
	Guideline 1.2	4	3	4	3	3.5	.58	1	
2 Attention design	Guideline 2.1	4	4	4	4	4.0	0	1	1
	Guideline 2.2	4	3	4	4	3.75	.50	1	
	Guideline 2.3	4	4	4	4	4.0	0	1	
	Guideline 2.4	4	4	4	4	4.0	0	1	
3 Personalization design	Guideline 3.1	4	4	4	3	3.75	.50	1	1
	Guideline 3.2	4	4	4	3	3.75	.50	1	
	Guideline 3.3	4	4	4	4	4.0	0	1	
Total mean: 3.81									

5.4. Usability evaluation

5.4.1. Participants, procedures, materials, instruments, and data analysis

Three instructional designers (IDs), each with more than three-year experience, were involved in the usability evaluation to validate the auditory design guidelines. The usability evaluation took place in five steps: 1) the designers were asked to fill out a background questionnaire; 2) the purpose of this study and the tasks for the usability evaluation were explained; 3) the designers were asked to design auditory information, interaction and environment in the given storyboard slides based on their experiences without auditory design directions (See Appendix A); 4) after being introduced to the nine auditory design guidelines, they were asked to modify or add some auditory design elements to their storyboard slides based on the given guidelines; and 5) they were asked to fill out a questionnaire and attend an interview. The guidelines were modified based on the results of the usability evaluation.

The materials for the usability evaluation were storyboards for the development of an m-learning lesson on "Basic English Grammar: Simple Present & Present Continuous." The storyboards were designed using visual information only without any auditory design element, following a typical systemic instructional design process involving the analysis, design and development stages (Dick, Carey, & Carey, 2005). The visual information was designed according to general information and interaction design guidelines for m-learning content suggested by Hayhoe (2001) and Rainger (2005) (See Fig. 2). The learning content was reviewed by an expert from the college of English education and the visual design was reviewed by Expert A, who participated in the expert reviews of the auditory design guidelines. The storyboard included blank spaces for the auditory design elements.

The usability evaluation items were developed with reference to Nokelainen (2006) and Jin (2013), and were assessed using the following three measuring scales: learnability (2 items), effectiveness (5 items) and satisfaction (2 items). The participants were asked to rate their response on a five-point Likert-type scale (strongly disagree to strongly agree). The learnability scale measures how easily the instructional designers understand and apply the guidelines to the design of m-learning content. The effectiveness scales measure the helpfulness of the design guidelines when an instructional designer is designing auditory information for m-learning content. The satisfaction scales gauge the satisfaction of the instructional designers when applying the suggested design guidelines while designing mobile learning content. Interviews were also conducted with the instructional designers to evaluate strength, weakness and problems with the current design guidelines.

A questionnaire and interviews were used to assess the impacts and usability of the given auditory design guidelines. The analysis of these is presented in the next section.

5.4.2. Results of usability evaluation

Appendix A presents the results of the auditory design activities from the usability evaluation by the three instructional designers. The instructional designers first designed the sound in the "Auditory Design" space in black based on their experience and knowledge. After receiving the auditory design guidelines, they designed additional auditory elements in red. The usability evaluation and interview were conducted after the auditory design activities.

Table 6 lists the responses of the three instructional designers. The results showed that the instructional designers were satisfied with the auditory design guidelines, with learnability, effectiveness and satisfaction being above average.

As a summary of the interviews, the instructional designers responded that the developed design guidelines included all the essential design elements and organized them in a comprehensible manner, which would assist in the auditory design of mobile learning content.

From the interview with ID 1: "Among the suggested auditory design guidelines, those design guidelines that reflect the characteristics of the m-learning content are the strengths, e.g. explaining the content of tables or figures and providing alarms for incoming phone calls and text messages." From the interview with ID 2: "They will be excellent guidelines for novice instructional designers because the guidelines include the elements essential to auditory design. In addition, it is also remarkable that the design strategies are suggested to help regulate the possible distractions in an m-learning environment, such as phone calls or SMS."

Fig. 2. Screenshots of the traditional version for the control group.

Table 6
Instructional designers' responses to the usability test items.

Category	Question items	IDs' responses
Learnability	The suggested auditory design guidelines were easy to comprehend.	5 5 5
	I can easily design the sound of the m-learning contents according to the guidelines	5 5 5
Effectiveness	The suggested auditory design guidelines were helpful in designing auditory information to improve m-learning.	5 5 5
	The suggested auditory design guidelines were helpful in designing the learning contents for on-the-move purposes.	5 5 5
	The suggested auditory design guidelines were helpful in designing auditory information to gain the learners' attention to learning	5 5 5
	The suggested auditory design guidelines were helpful in designing the contents for the learners to manipulate effectively.	5 5 3
	The suggested auditory design guidelines were helpful in designing the sound configuration	5 5 5
Satisfaction	I am satisfied with designing m-learning contents according to the suggested auditory design guidelines.	5 5 5
	When designing the mobile contents in the future, I would like to apply the suggested auditory design guidelines.	5 5 5

ID 1 suggested that G 2.2 be presented as an optional function for learners to choose so as to make the most of a flexible m-learning environment. Moreover, ID 2 suggested the addition of "listening to audio only" to the configuration setting because m-learning frequently occurs while on the move. For the instructional designers' activities, ID 3 designed an automatic page turner function which was not related directly to the auditory design.

5.5. The 2nd revised auditory design guidelines

As a result of the usability evaluation, Design Guideline 1.3 "Provide an audio-only function to present learning content without a screen display" was added. The 2nd revised guidelines are listed in Table 7.

5.6. Expert review round 3

5.6.1. Participants, instrument, and analysis

The participants for the 3rd expert review were four experts (A, B, C and D) who were contacted by email to review the 2nd revised design guidelines following the results of the usability evaluation. The responses were also received by email. The

Table 7
The 2nd revised auditory design guidelines.

Purpose	Auditory design guidelines
1 Auditory-only design	*Guideline 1.1* Explain all non-text objects (tables, graphs, photos etc.) included in the m-learning content. *Guideline 1.2* Avoid pauses that are more than 3 s long when explaining the learning content. *Guideline 1.3* Provide an audio-only function to present the learning content without a screen display.
2 Attention design	*Guideline 2.1* Provide an attention attracting message when the learners do not respond to an instruction for a certain period of time. *Guideline 2.2* Design to automatically stop the learning content explanation by sub-topic or by logical point and play when any button on the mobile device is pressed (if there is little physical interaction between the learner and m-learning content) *Guideline 2.3* Explain the important information louder, slowly or repeatedly (2~3 times) *Guideline 2.4* Provide a cue sound when a learning topic is switched or learning begins or ends.
3 Personalization design	*Guideline 3.1* Provide control options to block incoming calls and text messages *Guideline 3.2* Provide an alarm function that informs the learner of the learning time for the m-learning content that the learner specifies. *Guideline 3.3* Provide a sound playback configuration function to change the speed (1.2/1.5/1.8/2.0×) and playback modes (sequential, repeated, returned or skip play) for the learner.

instrument consisted of ten items about the appropriateness of the revised guidelines and one open-ended question. The Content Validity Index (CVI) and Inter-Relater Agreement (IRA) were used to analyze the validity of the experts' responses. The specific analysis method was the same as that for the 1st expert review.

5.6.2. The result of the expert review round 3

The 2nd revised auditory design guidelines were found to be valid with both CVI and RAI having values of 1. This indicates that all the guidelines were valid and reliable, and so the 2nd revised guidelines were adopted as the final version.

5.7. Field evaluation

A field evaluation was performed to validate the effects of the m-learning lesson that applied the auditory design guidelines. Previous research verifying the design elements of an m-learning environment generally did not consider the "mobility" of m-learning. Most experiments have been carried out in a computer laboratory, where mobile versions of the content were installed on a desktop PC. As the aim of this study was to develop auditory design guidelines that reflect the mobility and personalization of m-learning, field evaluation was conducted to verify the effects of the guidelines in natural learning settings.

5.7.1. Participants

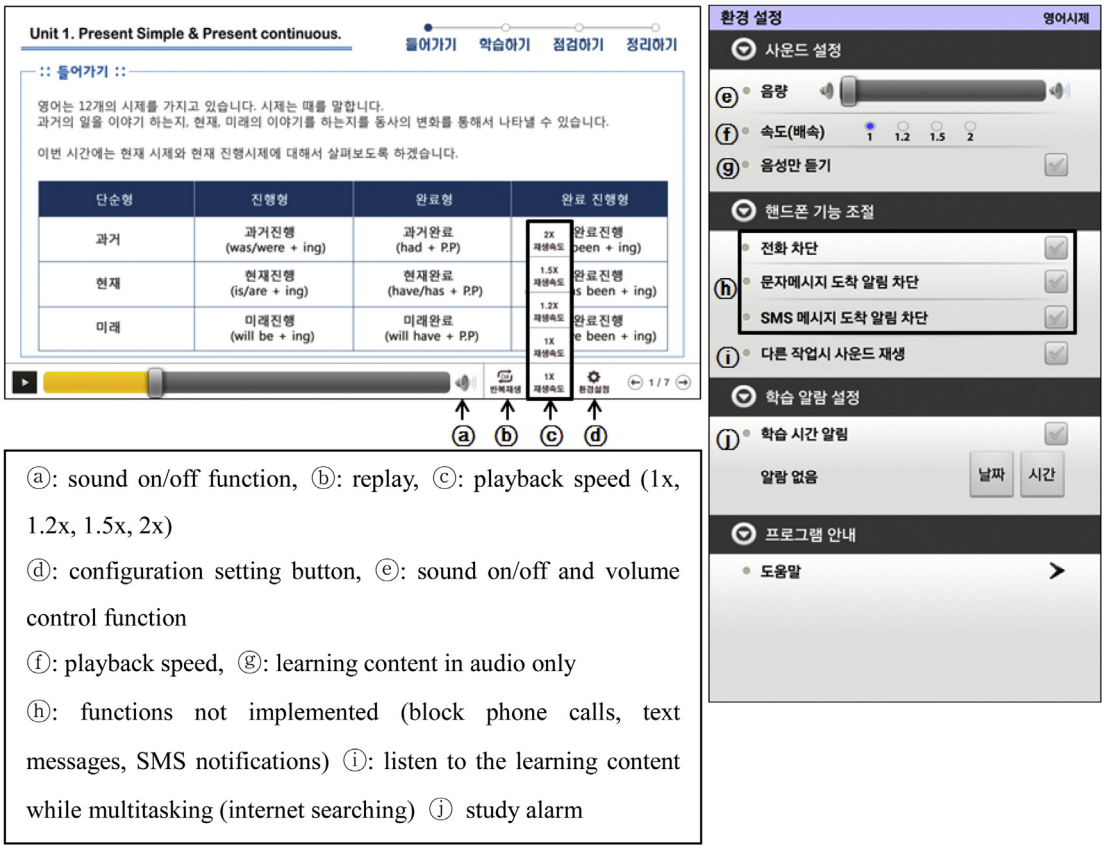
The participants were recruited from a university in South Korea, where flyers were sent by e-mail to find volunteers who were freshmen with no prior experience of taking TOEIC (Test of English for International Communication) or any other English course. The participants, 60freshmen (male = 42, female = 18), were compensated financially for their participation.

5.7.2. Materials and treatment conditions

Two types of m-learning application were developed to validate the effects of the auditory design guidelines. Both were based on the visual designs used in the usability evaluation activity. The contents were developed for the Android operating system because most students in South Korea use android phones. The learning content was "Basic English Grammar: Simple Present & Present Continuous". The m-learning content consisted of 9 pages on-screen in total, 1 page for introduction, 6 pages for learning content, 1 page for evaluation, and 1 page for the configuration settings. The introduction page allowed the learners to select from the level of high-medium-low knowledge regarding English tenses, to align with their level of prior knowledge. Eight multiple choice questions were presented in the "review" section to measure the learners' understanding of the learning content. The tables were designed in two pages in order to examine the validity of *G 1.1 Provide an auditory explanation for non-text objects*.

The traditional version of m-learning application was provided to the control group, where most of the developed auditory design guidelines were not applied. Fig. 2 presents screenshots of the traditional version. An explanation of the learning content was provided by narration at the proper speed and volume. In the configuration settings, the learners could turn the sound on and off and adjust the volume (see the upper right screenshot in Fig. 2). Sound on/off control was also included on the learning screen and the volume could be controlled using the volume buttons on the cell phone.

Fig. 3 presents screenshots from the advanced version of the m-learning application for the experimental group. All the auditory design guidelines except for guideline *3.1 Provide control options to block incoming calls and text messages* were applied. Guideline 3.1 couldn't be applied because the developed application was unable to control the basic features of the



ⓐ: sound on/off function, ⓑ: replay, ⓒ: playback speed (1x, 1.2x, 1.5x, 2x)

ⓓ: configuration setting button, ⓔ: sound on/off and volume control function

ⓕ: playback speed, ⓖ: learning content in audio only

ⓗ: functions not implemented (block phone calls, text messages, SMS notifications) ⓘ: listen to the learning content while multitasking (internet searching) ⓙ study alarm

Fig. 3. Screenshots of the advanced version for the experimental group.

smart phones, such as phone calls or text messages. Instead, the participants in the experimental group were asked to manually change the settings during the learning time if they did not want to receive any calls or messages. In contrast to the traditional version, the advanced version provided an explanation slowly or repeatedly for the important learning content as well as a detailed explanation of the tables. In addition, an arousal message ("Please pay attention") was provided when the learners did not respond within a certain period of time (1 min) after completing one page or during the evaluation. Fig 3 shows the other applied design guidelines.

To determine if the auditory design guidelines developed in this study had been implemented appropriately, the revisions were made based on discussions between the researcher and developer. For the final two versions of the m-learning applications, an expert validation test was carried out on how appropriately the auditory design guidelines, except for G 3.1, were implemented. Three experts (A, B, C), who participated in the former expert reviews, participated in this validation. The experts were asked to rate the implementation suitability on each design guideline using a five-point Likert-scale (strongly disagree/strongly agree). All the experts responded with at least a score of four for each element. This suggests that the auditory design guidelines had been applied appropriately in the developed m-learning application.

5.7.3. Instruments, procedures, and data analysis

A pre-test and a post-comprehension test were conducted for the field evaluation. The pre-test consisted of the self-efficacy (three items, $\alpha = 0.91$) and attitudes (three items, $\alpha = 0.94$) to m-learning. The same scales that were validated in previous research were used (Cheon, Lee, Crooks, & Song, 2012). The items used a five-point Likert-scale (strongly disagree/strongly agree). The attitude scale measures the degree to which the learners have a favorable or unfavorable feeling regarding m-learning. A sample item was 'I would like my coursework more if I used m-learning.' The self-efficacy scales measure the degree of learners' beliefs regarding their ability and motivation to perform m-learning. A sample item included 'I am confident about using a mobile device for my courses.' A post-comprehension test, which evaluated the learner's understanding of the present tense, was developed on the m-learning application. The test items were developed by a subject matter expert teaching English at a university. The expert selected eight multiple choice questions based on the difficulty level from the section on the present tense from Choi (2004)'s "Basic English Grammar". The bottom left screenshot in Fig. 2 shows the test items.

The participants were assigned randomly to either the control group or experimental group. The participants in each group were introduced to the study aims and the way to participate in this study. Each group was treated separately. The participants undertook a pre-test on the m-learning self-efficacy and attitude to confirm the homogeneity of the two groups. They were then guided to use a specific m-learning application, either while on the move or in public places, such as a café within 24 h; the control group used the traditional version and the experimental group used the advanced version. After completing the lesson, the evaluation activity was designed and the results of the evaluation were sent automatically to the server designated by the researcher. The means of the two groups were compared.

Two types of statistical analysis were conducted for the field evaluation. An independent sample *t*-test was used to confirm the homogeneity on the participants' self-efficacy and the attitude of m-learning between the two groups. An analysis of the covariance (ANCOVA) was conducted on the post comprehension test scores to determine the effects of the auditory design guidelines in the simple field evaluation, and the mediating influences of the prior knowledge of the present tense. In the m-learning application, the post-comprehension test scores were the dependent variable, and the level of prior knowledge regarding the present tense was the covariate. The data were examined for normality, the presence of outliers, homogeneity of the variances, and the basic linear relationship of the covariate with the dependent variable. The partial eta-squared (η^2) was calculated to determine the effect size. According to Richardson (2011), partial η^2 values of approximately .01, .06 and .14 indicate small, medium and large effects, respectively.

5.7.4. Results of the field evaluation

The results of the pre-test showed no significant difference in the participants' self-efficacy of m-learning (control group: M = 4.20, SD = .71, experimental group: M = 4.06, SD = .73, $t = .71$, $p > 0.05$) and the attitudes to m-learning (control group: M = 3.77, SD = .81, experimental group: M = 3.83, SD = .83, $t = -.31$, $p > 0.05$) between the two groups. The results confirmed the homogeneity of the two groups. To conduct comparison analysis of the effects of the auditory design guidelines, the field evaluation method was used to measure the differences in achievements between the control group and experimental group in the natural learning environments. The mean score of the control group who studied the traditional version was 5.47 (SD = 1.35), whereas the mean score of the experimental group was 6.33 (SD = .96). The main effects of the auditory design guidelines were significant for the students' achievements ($F(1, 58) = 7.943$, $p = 0.007$, $\eta^2 = .122$).

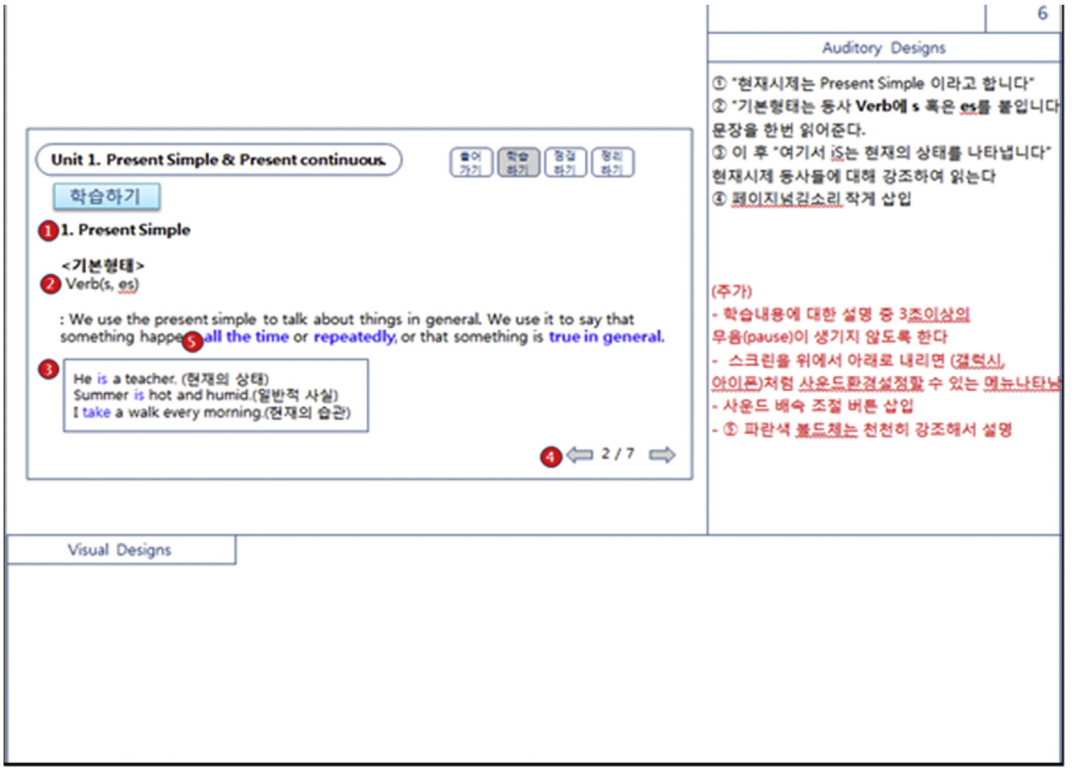
6. Discussion and conclusion

Although the auditory information in m-learning can be an important resource for delivering knowledge and information, there has been little research on how to design auditory instructions. In this respect, this study contributes to the auditory design research field in a little explored area. In particular, this study adds to the field by considering how the affordability and limitations of different devices affect the design. This study showed that the auditory design guidelines reflecting the mobility and personalization of m-learning were both effective and satisfactory. The final revised guidelines are as shown in Table 7. These guidelines emerged from a thorough process of the development of the initial guidelines, 1st and 2nd expert reviews, usability evaluation, 3rd expert review, and field evaluation.

Expert reviews and usability evaluation were conducted for an internal validation, and the auditory design guidelines were modified and supplemented in the academic and practical perspectives of the experts and instructional designers. The revised guidelines form-learning content and their effectiveness in supporting learning underwent an external validation. The field evaluation method used in this study can be useful for examining the learning effects considering the mobility and personalization of m-learning. Previous studies were conducted mostly in laboratory settings or while walking outside (Brewster, 2002; Walker & Brewster, 2000), but these attempts did not involve natural settings and they failed to consider the wide range of factors in the external environment. Therefore, they may be unsuitable for examining a mobile environment. Accordingly, the research participants were recruited and asked to learn with a specific m-learning application either while on the move or in public places, such as a café. Considering that the aim of study was to develop auditory design guidelines based on the mobility and personalization of the m-learning environment occurring in public places, the field evaluation method, although unable to control the individual learning environment, can provide more meaningful information than a laboratory setting.

Nevertheless, despite the use of an extensive process of reviewing, revising and validating the auditory design guidelines with experts, instructional designers and end users, there were some limitations. The field evaluation took place within a short application in a natural setting. Further research will be needed to determine if the same results can be obtained in a laboratory environment and a natural environment with longer learning applications. In addition, the auditory design guidelines were tested for their effects on an m-learning application by applying all the guidelines. The result do not show exactly which of the guidelines are responsible for the differences in the outcomes for the control and experimental groups. Further research will be needed to examine the effects of each guideline presented in this study and determine which of the guidelines have a strong effect on the learning outcomes.

Appendix A. A sample storyboard page for the auditory design activities of the instructional designer



Black texts in the "Auditory design" spaces: Auditory design results without guidelines.
Red texts in "Auditory design" spaces: Additional auditory design results with the auditory design guidelines.

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