Augmented Reality in Foreign Language Education: A Review of Empirical Studies
(增强现实技术在外语教学中的应用：文献综述性研究)

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Abstract: This literature review examines how Augmented Reality (AR) has been used in foreign language learning. AR is a live view of reality that is augmented by computer-generated sound, image, or videos. It allows the user to interact with the real physical environment in an enhanced way. This study provides an overview of what AR is, its history, different definitions, and how it has been used in education in general. It summarizes how AR has been used in all aspects of foreign language education, including skill development (listening, speaking, reading and writing), vocabulary, grammar, culture, the aspect of affect in language learning, what AR tools were used, and a discussion of the advantages and disadvantages of AR in language learning. At the end of the article, the author suggests further research needed to support the widespread adoption of AR in foreign language education in general and in Chinese-as-a-Foreign-Language, specifically.

摘要: 增强现实技术是将计算机生成的虚拟图像、视频、3D模型等材料叠加到现实世界，使之与现实世界融合从而增强对现实的表现。该技术近年来在很多领域得到了普遍应用，特别是在军事、旅游、医疗、商业等领域。在教育领域，其应用也越来越普遍。在外语教学方面，增强现实技术的应用则正处于起始阶段。通过对相关英文学术期刊进行穷尽式搜索与综述，本文试图回答以下几个问题：过去五年内，外语教学中增强现实技术是不是得到了应用，是如何应用的，这些应用有没有益处，如果有，有何益处？穷尽式搜索得到十篇实证性研究，多数侧重在词汇教学。研究结果表明，增强现实技术能够更好，而且多方面地提高学习效率。文章最后探讨了如何更好地将这项技术运用到外语教学，包括中文作为外语的教学中。

Key words: Augmented Reality, AR, Foreign Language Teaching, Second Language Teaching, Multimedia, CALL

关键词： 增强现实技术，外语教学，混合现实，多媒体，中文教学，计算机辅助教学

1. Introduction

Augmented Reality (AR) is "a real-time direct or indirect view of a physical real-world environment that has been enhanced/augmented by adding virtual computer-generated information to it." (Carmigniani & Furht, 2011, p.1). It is one of the latest technologies adopted in Computer Assisted Language Learning (CALL). The word "augmented" comes from "augment" which means to add or enhance. Augmented reality intends to create an enhanced user experience by adding graphics, sounds, and touch feedback to the natural world. Azuma (1997) defines AR as systems with three important features: a combination of real and virtual dimensions, interactions in real time, and adoption of 3-D. There are also less restrictive ways in defining AR. For example, Eric Klopfer, professor of urban studies and planning and an expert on augmented reality games at Massachusetts Institute of Technology, included "location-based games on handhelds and mobile phones which provide additional virtual data or information at given locations" in the realm of augmented reality (Jenkins, 2008).

1.1 AR and VR

Sometimes AR is confused with virtual reality (VR) and mixed reality. Milgram, Takemura, Utsumi, & Kishino (1994) used a reality-virtuality continuum to describe how these different types of reality relate to each other. See Figure 1. In this continuum, AR lies in the region called mediated reality, between the physical environment and an entirely virtual environment. Mediated reality includes both augmented reality, which lies closer to physical reality, and augmented virtuality, which lies closer to virtual reality.

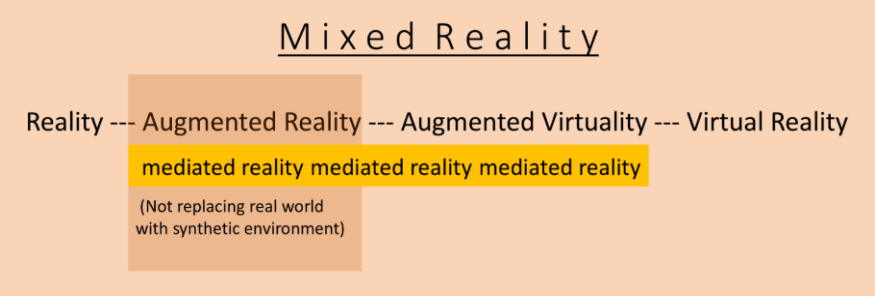

Figure 1. The location of AR in the continuum. Adapted from Milgram, Takemura, Utsumi, & Kishino (1994, p. 283).

Unlike virtual reality, which gives users an interactive computer-generated experience within an entirely virtual environment, AR takes advantage of the existing natural environment and superimposes virtual information on top of it. The co-existence of both virtual and real elements in AR provides users with a new and improved natural world with virtual information as assistance.

1.2 A short history of AR

The origins of AR studies date back to the 1950s. Morton Heilig (1926-1997), a cinematographer, thought that cinema should have the ability to draw viewers into the onscreen activity by utilizing all their senses in an effective manner (Carmigniani et al.,

2010). The term Augmented Reality was coined by Tom Caudell in 1990. He and his colleague, David Mizell, designed a head-mounted digital visualization system to guide technicians when they located cables on airplanes (Siltanen, 2012). Milgram, Takemura, Utsumi, & Kishino (1994) proposed a mixed AR technology model which represented the combination of reality and virtuality. This model had the main tenets of AR technology during the process of development (Chen & Tsai, 2012). In 1997, Azuma conducted the first survey study on the use of AR. Recently, AR has developed rapidly, with the mobile applications such as the Participatory Augmented Reality Simulations (PARS) and Mobile Augmented Reality (MAR).

1.3 AR technologies

Tracking technology is the essential part of AR. Two basic categories of tracking are distinguished: marker-based tracking and location-based tracking. Marker-based tracking refers to tracking by a fiducial marker, i.e., an optical image (or an interest point), which is an object placed in a scene as a fixed point of reference of position (see Figure 2). These markers, which sometimes use Quick Responsible (QR) code, provide an interface between the physical world and the augmented reality content such as 3D models or videos. Location-based AR tracking ties the augmented reality content to a specific, real-time location. Digital geo-spatial data are gathered and placed over the actual physical surroundings, allowing users to access the data. Accuracy is a critical factor in this case (Juegostudio, 2018; Kudan, 2017). The popular game Pokémon GO is an example of location-based tracking.

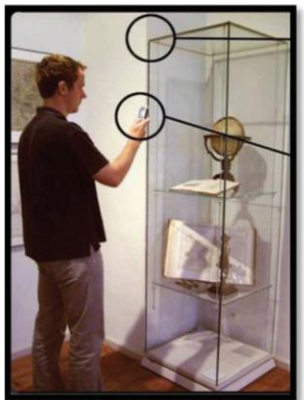

Figure 2. Using AR in a museum. (Carmigniani & Furht, 2011, p. 31)

Technologies used in AR are not limited to any particular type of display technology such as head-mounted display (HMD), and neither are they limited to the sense of sight. AR can potentially be used to augment smell, touch, and hearing (Carmigniani, 2011). “Technology has caught up with the idea of augmented reality as devices have become cheaper, smaller, and sufficiently powerful to run applications” (Salmon & Nyhan, 2013). In addition to HMD, smartphones, webcams, and digital projectors have also been used to augment reality. Smart phones play an important role in AR because they are equipped with cameras, apps and the internet connection. They make it possible to overlay virtual graphics and media over a physical object, such as a picture or an object. Using the smart phone camera to point at the picture or object, the user is exposed to the augmented virtual layers, such as video, 3D animation, or text explanation. This makes it feasible to “transform a classroom setting to a virtual learning environment: for example, real cultural artifacts triggering images or videos of their history, wall maps displaying geographical locations, portraits bringing to life real interviews” (Carmigniani & Furht, 2011, p. 20). See Figure 3 for an example of using AR in a classroom setting: The mobile scans a marker on the textbook and videos about that part of the grammar/culture are triggered.

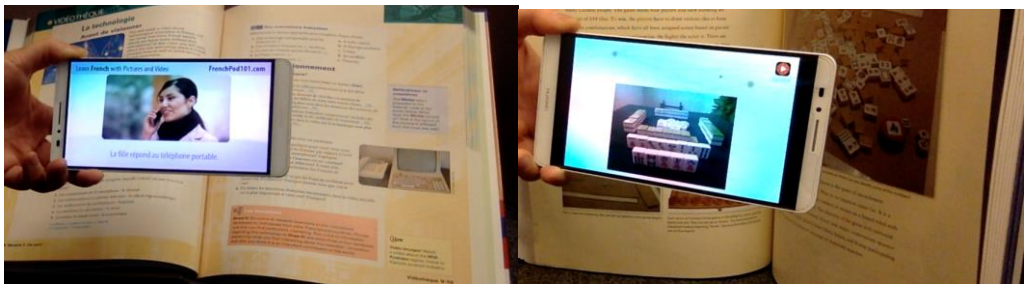

Figure 3. Using AR with a mobile device in a classroom setting

1.4 The application of AR

AR has been widely adopted in many areas of modern life, such as in advertising and marketing (Hampp, 2009; Yuen, Yaoyuneyong, & Johnson, 2011), in architecture and construction (Rankohi & Waugh, 2013), in entertainment (Von Itzstein, Billinghurst, Smith, & Thomas, 2017), medicine (Samset et al., 2008), and the military (Sisodiaa et al., 2007). It has also been used in education (Bacca, Baldiris, Fabregat, Graf, & Kinshuk, 2014; Yuen, Yaoyuneyong, & Johnson, 2011), for example, in science and math as well as in literacy education (Billinghurts & Duenser, 2012; Bower, Howe, McCredie, Robinson, & Grover, 2014). Research has demonstrated many favorable outcomes for AR, such as enhancing problem solving and collaboration (Dunleavy, Dede, & Mitchell, 2009; Wasko, 2013), creating contextual awareness (Ivanova & Ivanov, 2011), helping better understand abstract concepts by concretizing them (Dori & Belcher, 2005; Klopfer & Squire, 2008), offering authentic learning experiences (Klopfer & Squire, 2008; Yuen, Yaoyuneyong, & Johnson, 2011), and motivating learners and enhancing learners' enjoyment and attitude (Billinghurts & Duenser, 2012; Dunleavy, Dede, & Mitchell, 2009; Jerry & Aaron 2010). AR has been employed for learners at all levels, from elementary school students to students at university (Klopfer & Squire, 2008).

2. Literature Review

While AR has been adopted in educational fields, it is at the beginning stages in language education. Only four studies have discussed the use of AR in language learning. Ramya & Madhumathi (2017) reviewed five publications concerning AR in literature study to assess the overall effect of the incorporation of AR on learning outcomes. Of the five studies, only two were published in peer-reviewed journals. Their overall conclusion was that the studies "favored the efficiency of Augmented Reality" (p. 358). However, no methodology in searching relevant literature was specified, which resulted in missing quite a few relevant studies that should be included.

Godwin-Jones (2016) introduced AR as an emerging technology in language learning and explored different ways in which it is being used in this area from a practical point of view. He first discussed the potential that such games as Pokémon GO could provide for language learning, such as the social interactions that accompany gameplay. Then he explained what marker-based AR was and how students could benefit by creating markers and helping to create the augmentation (Bower, Howe, McCredie, Robinson, &

Grover, 2014; Slussareff & Boháccková, 2016). In addition, Godwin-Jones (2016) introduced place-based AR. He took *Mentira*, one of the better-known place-based mobile game for Spanish language learning, as an example and illustrated how it worked. He cited the result of the *Mentira* developers and researchers, Holden and Sykes's (2011; 2013) research to show that playing the game increased the students' awareness of pragmatic issues in Spanish. At the end of the article, Godwin-Jones explained how to use some AR tools such as ARIS and TaleBlazer and how AR could be used in promoting the learning of target historical, cultural or literary topics. Godwin-Jones's article provided a very comprehensive introduction to how AR could be used in the field of language learning.

Salmon & Nyhan (2013) proposed an evaluative framework that could be used as a baseline for making decisions on the use of AR applications for language teaching in a classroom setting. They used five exemplary studies that examine effective language teaching and learning and the role of technology in order to build the framework. They first summarized effective language teaching and learning principles with the use of technology. Then they established a framework based on the principles, and from the framework developed criteria for evaluating AR technology for language teaching and learning. For example, the software should have clearly stated pedagogical objectives; it should focus on specific language skills; it should enable the integration of different language skills; it should allow for task-based, exploratory language learning; and it should enable learners to build on existing knowledge and to develop this knowledge further. The last part of the article examined this framework using four AR applications: the Specialist Schools and Academies Trust (SSAT) AR Quizzes, *ZooBurst*, *Mentira*, and Context-Sensitive Microlearning of Foreign Language Vocabulary.

Davis & Berland (2013) focused their research on participatory AR simulations (PARS). They evaluated the possible merits and difficulties of utilizing PARS with English language learners in K-12 science classrooms. They identified elements of PARS that met the requirements for effective learning of English as a second language and these elements included modality, engagement, collaboration, and language use.

All of the above studies have reviewed literature of AR in the field of language education. Each of them approached AR from different perspectives, either to provide a big picture of how AR is used in a practical sense, or to establish a framework for evaluating the use of AR. However, a more comprehensive review of the recent empirical studies in the recent years is needed in order to understand the use of AR in language education and what research has said about the advantages and disadvantages of using AR in language education.

3. Research Questions

The current study explored the use of AR in teaching any language as a foreign or second language. It intended to answer the following research questions.

1) What does the literature say about using AR in foreign/second language education in the past five years?

2) Is there evidence that shows the advantage of adopting AR in foreign/second language education? If such evidence exists, what advantage(s) does the adoption of AR bring to foreign/second language education?

4. Methodology

Five databases were used in this study: Communication Abstracts (EBSCO), Education Resources Information Center (ERIC), J-STOR, Google Scholar, Linguistics and Language Behavior Abstracts (ProQuest). The year of publication was set from 2013 to the present in the searches. That is to say, as long as a study that was published in the previous five years met the following criteria, it was included in this study.

There were five criteria that a study had to meet to be included. First, it must have been published in a peer-reviewed journal. Second, it had to be an empirical study. Third, it must have been related to second-language or foreign-language learning in any language. Fourth, the study must have been written in or have been translated into English. Fifth, the term "Augmented Reality" had to be in the title. Because the definition of AR is so broad, if the term "Augmented Reality" was not in the title, it would have been extremely difficult to justify whether the core technology in the articles was defined as AR. In order to ensure the search was exhaustive and relevant, in addition to the query word "Augmented Reality" in the title, one of the following query words was also used in the database search: Language, English, Spanish, German, Russian, French, Chinese, Japanese, Korean, Indonesian, Malay, Arabic, TEFL, TESL, ELL, Vocabulary, Grammar, Writing, Reading, Listening, Speaking.

A few types of studies were, however, excluded because they concentrated on one specific application or on culture instead of language learning, such as studies that focused on the usability of the application developed with AR and/or the gamification idea with foreign language learning. If the study used language cards and used AR solely to determine if the cards could promote culture learning, the study was excluded. If the study developed a web portal and/or a container application with image recognition and AR technologies, but the main purpose of the study was to test if the web portal or the application worked, this study was also excluded.

5. Findings

The search resulted in ten relevant studies. Two obvious trends can be observed from these studies. First, the number of published studies about AR in language learning has progressively increased year by year (Figure 4). Second, the journals in which these studies were published are very scattered. Only two of the studies were published in the same journal. The journals where these studies were published include: *Procedia: Social and Behavioral Sciences* (in which two studies were published)*; British Journal of Educational Technology; The Journal of Educators Online; International Journal of Game-Based Learning; Research and Practice in Technology Enhanced Learning; Human-Computer Interaction; Computer and Education; Educational Technology &*

Society; Eurasia Journal of Mathematics Science and Technology Education.

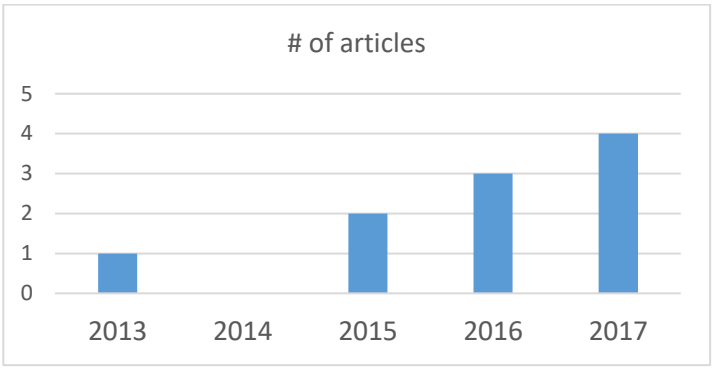

Figure 4. Publication year of the studies.

5.1 A general description of the studies

Of the ten studies, there were five experimental studies, three case studies, one descriptive study, and one exploratory study (Figure 5). While some studies addressed more than one language, others focused on only one. Nine studies focused on the application of AR in teaching English as a second language. Four studies examined the use of AR in teaching Basque, French, German, and Filipino, respectively (Figure 6).

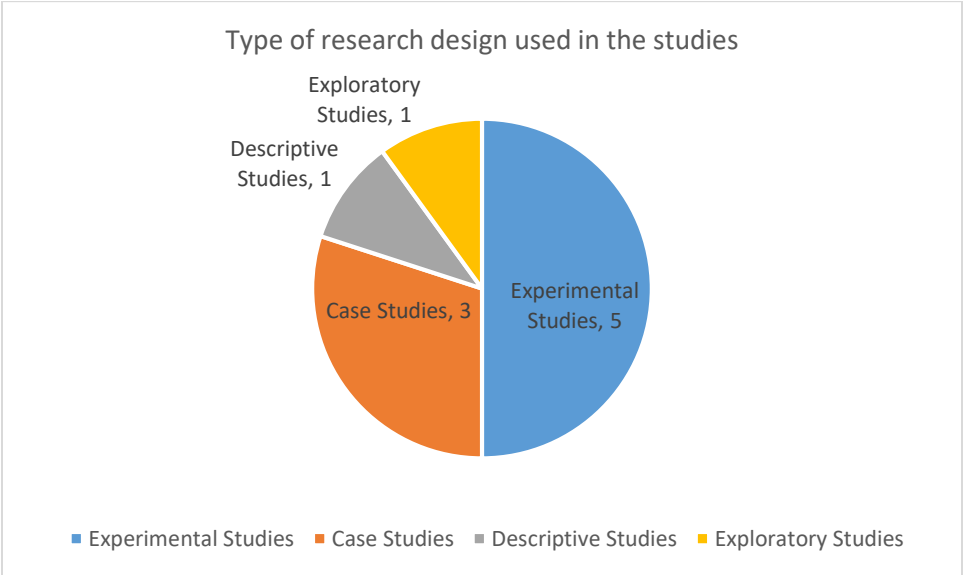

Figure 5. Research methods adopted in the studies

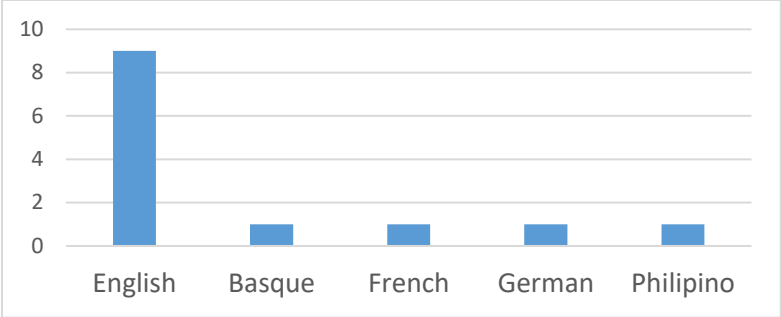

Figure 6. Focus languages represented in the studies

While some studies examined multiple aspects of learning and the learning experience, some had only one focus. Six of the ten studies focused on vocabulary learning and three on the learners' learning experience with AR, which included the flow experience, cognitive load, and learning anxiety. One of the ten studies focused on writing, one on alphabet learning, and one on culture understanding (Figure 7).

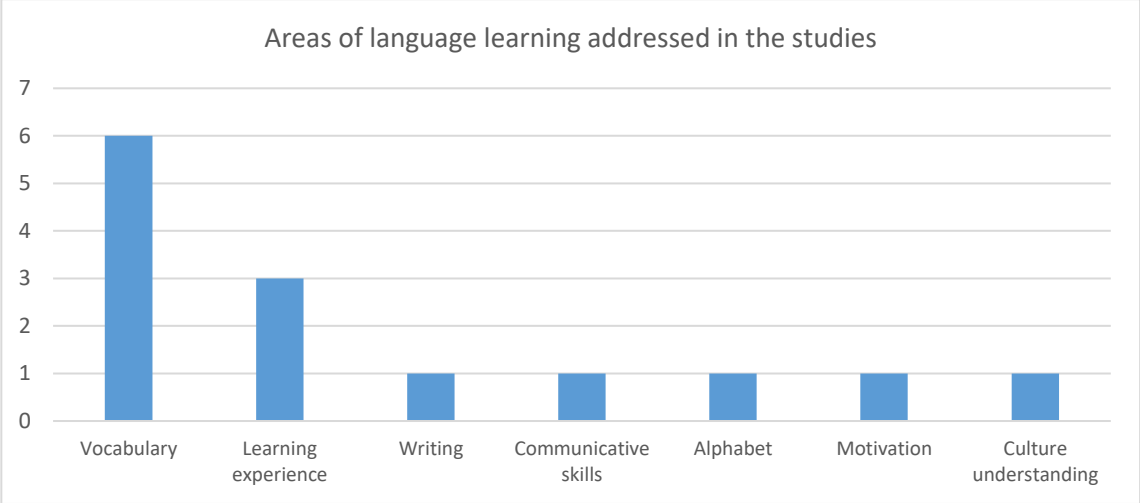

Figure 7. Areas of language learning that were addressed in the studies

Most the studies were conducted with students at the university level. Only one had graduate students as participants, one had 3rd graders as participants, and one had kindergarteners as participants. Participants in one study included both undergraduate students and employees from different professions in the local community (Figure 8).

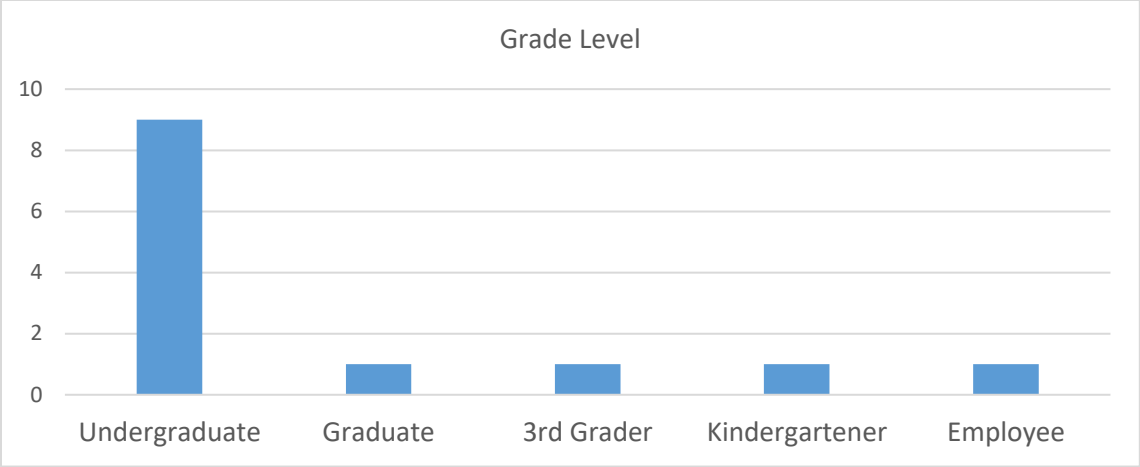

Figure 8. Participants' grade level

Most of the studies (6) examined how beginning level language learners performed with the implementation of AR technology. One study worked with participants who were intermediate level learners, and one worked with advanced level learners. Two studies did not specify the language level of their participants (Figure 9). Table 1 presents a summary of the ten studies.

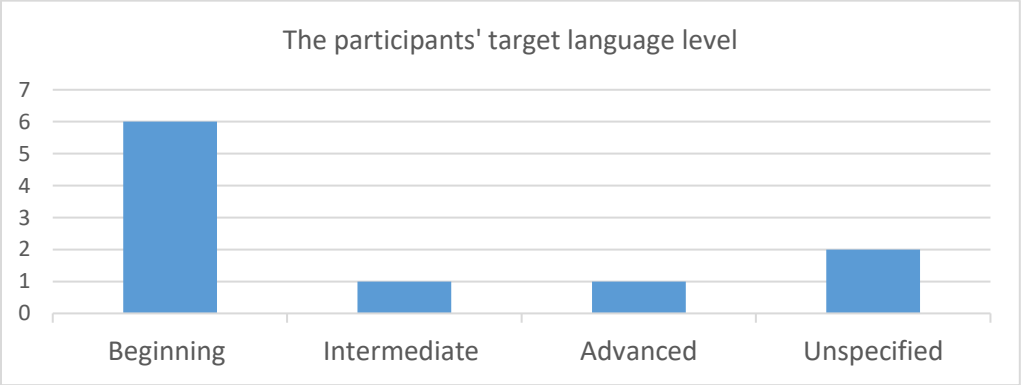

Figure 9. Participants' target language level

5.2 AR tools used in the studies

Five of the ten studies applied global positioning technology and AR in foreign language learning. Three of the five gamified it to motivate students. Two used open-source platforms for creating and playing AR games: ARIS (Augmented Reality and Interactive Storytelling platform) or Aurasma. Perry (2015) used ARIS to create *Explorez*. *Explorez* is similar to *Mentira*, the AR mobile game for learning Spanish. *Explorez* was said to have transformed the university campus "into a virtual francophone world, where students interact with characters, items, and media as they improve their French language skills and discover their campus" (p. 2308). It was designed to bridge the "gap between gaming and education through quest-based learning and augmented reality" (p. 2309).

Table 1. Empirical studies using AR in teaching a second or foreign language published in peer-reviewed journals

Study and year	Research Method	Target Language	Aspect of language	Participants' Language Level	Grade Level	Tools Used
Liu & Tsai (2013)	Case Study	English	Writing	Not specified	College	AR-based mobile learning materials
Perry (2015)	Case Study	French	Learning experience	Beginning	College	Mobile learning tool: *Explorez*
Solak & Cakir (2015)	Descriptive	English	Vocabulary; Motivation towards vocabulary learning	Beginning	College	A material designed with support of AR technology
Liu, Holden, & Zheng (2016)	Exploratory	English	Vocabulary learning; Culture understanding; Communicative skills	Intermediate	College	AR mobile game: *Guardians of the Mo'o* designed with ARIS
Richardson (2016)	Multiple case studies	English	Learning experience	Advanced	College	Location-based AR game: Mission Not Really Impossible using *Aurasma* mobile app
Santos, et al. (2016)	Experimental	Filipino; German	Vocabulary	Beginning	Graduate	Handheld AR system
Safar, Al-Jafar, Al-Yousefi (2017)	Experimental	English	Alphabet	Beginning	Kindergarten	AR apps: AR Flashcards Animal Alphabet and AR Alphabet
Ho, Hsieh, Sun & Chen (2017)	Experimental	English	Learning performance (Vocabulary)	Not specified	18-30 years old: college students and employees	Ubiquitous Learning Instruction System with AR features (UL-IAR)
Hsu (2017)	Experimental	English	Flow experience; Cognitive load; Foreign language learning anxiety, Learning effectiveness (vocabulary)	Beginning	3rd graders	Two AR educational games system
Ibrahim et al. (2017)	Experimental	Basque	Vocabulary (nouns)	Beginning	College	*ARbis Pictus* – A novel system for immersive language learning through dynamic labeling of real world objects in AR.

Liu, Holden, and Zheng (2016) created a mobile game called *Guardians of the Mo'o* using ARIS. It was a non-linear, "place-based quests using GPS tracking functions on mobile devices without an on-site program" (p. 370). The game theme was based on Hawaiian mythology. In the game, the students, i.e., the game players, were the helpers or guardians of the Mo'o, a figure of Hawaiian mythology, who was sick and needed help.

Richardson (2016) used AURASMA to develop a location-based AR game, *Mission Not Really Impossible*. This game provided a series of challenging language tasks for the learners when they moved around the city of Karlsruhe in Germany. The game had a video introduction to the game. After the introduction, the learners were given a map which they needed to find a "trigger" image in the gameplay area. Once the player found and scanned this image, the mysterious Danlod, the game's main character, appeared and showed a short video clip telling the players what still needed to be done.

Two studies used global positioning technology but were not designed as games. Ho, Hsieh, Sun, and Chen (2017) developed a Ubiquitous Learning Instruction System with Augmented Realty Features (UL-IAR). The design "incorporated AR technology and extensive computing power within a context-aware u-learning system to provide adaptive learning strategies to assist English learning" (p. 179). The site for which the UL-IAR was developed was Kaohsiung West Bay in Taiwan. The reason for choosing that site was that the West Bay has many popular scenic spots and food from street vendors, on which the learning materials were based.

In Liu & Tsai (2013), the EFL learners executed the AR-based mobile learning material on campus. When they used the mobile phone to point in a specific direction, their location was identified, the embedded camera automatically captured the peripheral images, and related information such as names and descriptions of the buildings were shown on the screen. If the learner wanted to know more about a certain building, the learner could click on that piece of information and details would appear.

Five of the ten studies did not use global-positioning technology when they applied AR. Four of the five studies used AR to connect multimedia (images, animations, and text) with real objects in real environment. Although these four studies integrated multimedia materials in the designed AR system, they were based on different concepts and underlying theories in the design. For example, Santos et al. (2016) treated AR "as a type of multimedia that is situated in authentic environments" (p. 1), and they applied multimedia learning theory as a framework for developing the application. They created a handheld AR system which displayed different combinations of multimedia in sound, image, animation, and text in real environments.

Hsu (2017), however, designed two AR systems based on the way learners approached the system: self-directed or task-based linear approach. One of the findings was that the AR educational system based on a self-directed learning approach did not restrict the learning sequence and provided more support in learning. Ibrahim et al. (2017), on the other hand, designed *ARbis Pictus*, a novel system for immersive language learning through dynamic labeling of real-world objects in AR. Learning in this study occurred in a controlled learning environment while learners used Microsoft HoloLens with an AR head-

mounted display. The application was set up in a room where all the objects were placed. The learner could walk around the room with the head-mounted display to locate the object, see labels, and interact with the labels to get multimedia information about the object.

One study chose ready-made AR applications. Safar et al. (2017) "reviewed a wide range of AR software available at the online App Store designed to be viewed using iPad tablets" and chose two applications. One was "AR Flashcards Animals-Alphabet" and the other was "AR Alphabet Flashcards." Both apps presented English alphabet initials of different pets and their predators. When the pets were clicked, a three-dimensional letter would appear accompanied by the sound and animated movements of each animal.

In short, of the ten studies, half used global positioning technology with AR and the other half utilized AR as multimedia. While nine were designed by a research team, one study utilized ready-made apps.

5.3 Advantages that AR has brought to language learning

The published studies reviewed here suggest that using AR in language learning brings many benefits. It engages not only beginning-level and intermediate level foreign language learners in learning (Ho et al., 2017; Liu & Tsai, 2013; Perry 2015) in both the virtual and the physical world (Liu, Holden, & Zheng, 2016), but it also engages and challenges advanced-level learners (Richardson, 2016). It improves learner satisfaction (Ibrahim et al., 2017; Santos et al., 2016; Solak & Cakir; 2015), gives a satisfying feeling of accomplishment (Solak & Cakir, 2015), enlivens learning experience (Solak & Cakir, 2015), increases learners' flow experience, and lowers learners' cognitive load (Hsu, 2017). In addition, it motivates learners (Liu, Holden, & Zheng, 2015; Perry, 2015; Solak & Cakir, 2015) and increases the effectiveness of language learning (Ibrahim et al., 2017; Liu & Tsai, 2013; Safar et al., 2017), regardless of whether the AR was designed using a self-directed or a task-based approach (Hsu, 2017). Specifically, the use of AR leads to better word retention (Ho et al., 2017; Hsu, 2017; Ibrahim et al., 2017; Santos et al., 2016; Solak & Cakir, 2017), helps students construct linguistic and content knowledge (Liu & Tsai, 2013), and supports learners in gaining content knowledge (Liu & Tsai, 2013). Furthermore, it is beneficial to adopt AR at the primary stage of education such as pre-school and kindergarten (Safar et al., 2017), with college students (Ho et al., 2017; Perry, 2015; Liu et al., 2016; Richardson, 2016; Solak & Cakir, 2015; Hsu, 2017; Liu & Tsai, 2013), and with graduate students (Santos, et al., 2016).

There are a variety of reasons why the use of AR offers these positive outcomes. First, AR increases learners' active interaction with the learning materials (Hsu, 2017; Safar et al., 2017; Santos et al., 2106; Solak & Cakir, 2015). Well-designed AR enhances the presentation of information and helps attract learners' attention to the learning materials by using "eye-catching" formats of presentation, such as stories, pictures, audios, animations stimulate curiosity (Solak & Cakir, 2015).

Second, AR technology combined with the GPS-positioning allows learning to take place outside of the classroom and provides a contextual and immersive learning experience for learners (Liu & Tsai, 2013; Perry, 2015; Solk & Cakir, 2015). This learning experience makes learning more relevant to the learners' life and therefore enhances the meaningfulness of learning. Learning is naturally tied to authentic activities and contexts (Brown, Collins, & Duguid, 1989). AR provides an opportunity to participate in authentic activities in semi-realistic contexts. Furthermore, learning that takes place out of the classroom is a change from the day-to-day setting in the classroom repetition and the change itself makes learning exciting (Perry, 2015).

Third, AR-enhanced games provide opportunities for dynamic negotiation and collaboration (Liu, Holden, & Zheng, 2016). In an AR-enhanced game, collaborative negotiation in the target language is frequently required in order to proceed in game playing. Through negotiation with peers and with strangers in the social context, learners are able to apply the language they are learning in real contexts. Furthermore, collaboration helps learners build a sense of community and relationships in a course, which can also maximize learning (Dörnyei & Ushioda, 2011; Richardson, 2016).

Fourth, the use of AR provides opportunities for the learner to use the language in a spontaneous and unplanned way (Richardson, 2016). In most classroom settings, students lack the opportunity to step out of their comfort zone and speak on the spot. Intermediate and advanced learners should be exposed to situations like these to improve their language skills and to prepare them to use the target language in real life (Richardson, 2016; White, 1971).

5.4 Other findings

In addition to the findings about the benefits of AR in language learning, some studies focused on other aspects of learning. For example, Solak and Cakir (2015) found that the motivation to use AR technology in language learning was not affected by gender or the students' majors. In other words, the use of AR could help increase college students' motivation in learning the target language without privileging specific majors or gender. Furthermore, Hsu (2017) found that the self-directed learning approach implemented in the AR educational game system could cause some learning anxiety and that this increased anxiety promoted effective learning more than the task-based learning approach, which limited the learning sequence.

5.5 Problems of using AR in language education

The studies also found some problems in using AR in language education. The biggest problem was that learners need "sufficient familiarity with the AR-based mobile learning material" (Liu & Tsai, 2013, p. 4) and they must know how to use the device before any learning can happen (Liu, Holden, & Zheng, 2016; Perry, 2015; Richardson, 2016). Therefore, in implementing AR, sufficient time should be scheduled to familiarize learners with operation of the devices as well as the application's rules. Furthermore, learners needed to be provided with adequate game-play scaffolding in the gaming system (Perry, 2015). As Gee (2003) pointed out, well-developed video games provide sufficient

guidelines for new players at the beginning. Perry (2015) stated that when creating an AR game system, developers and instructors should keep in mind to not only "provide sufficient language-learning scaffolding, but also include adequate game-play scaffolding" (p. 2313).

One limitation of using AR is that instructors cannot readily gauge to what extent students use the target language and cannot monitor usage so that the students do not revert to their first language (Perry, 2015). Instructors can participate in the field experience with the learners to monitor their use of language. However, it is not practical that all the learners can be monitored. A solution to this problem is needed.

In designing an AR system, two additional elements should be kept in mind. The first is that more information should be provided so that students could access a wide variety of information, selected from the same topic (Liu & Tsai, 2013). For example, to explain about the cultural phenomenon "playing Mahjong" in China, not only the rules of Mahjong should be introduced, but also who plays Mahjong, its significance for the players, and the diverse cultural images of Mahjong need to be provided. The second is that sufficient and effective feedback should be available to students. Feedback is important, especially in the game-based AR system. It should be instantaneous, and it should let the players know whether they are engaging the game in the appropriate manner (Gee, 2003).

6. Conclusion

AR is being increasingly explored in the field of language education. The advantage of using it in supporting language learning have been shown in the studies reviewed here. These studies have adopted various research methods to answer different research questions. English as a foreign language is the most studied language among the ten studies, and vocabulary learning has gained much attention. Although the ten studies were published in non-language learning journals, language-learning journals are likely to attract more articles on AR in language education in the near future.

Future studies that focus on adopting AR in foreign language education must, however, overcome one significant hurdle. As Safar et al. (2017) pointed out, there is a limited availability of specialists and experts in the field of AR technology. To have more research conducted in this area, language teachers need to learn how to develop AR. Of the ten studies, only three specified what tools they used to develop AR, and two tools were mentioned: ARIS and Aurasma. Both ARIS and Aurasma are open-source AR platform for creating and playing video games. ARIS consists of an authoring tool to create augmented reality games or interactive stories. It also has an application for IOS devices to play the games. Aurasma is an AR platform which uses a smartphone's camera to identify real-world images and overlay the images with an "aura". The aura can be an image, video, audio, animation, 3D model or a webpage. Each aura can be triggered by using the phone's camera to point at the corresponding image of the pre-selected object. Both ARIS and Aurasma do not require the developer to have programming knowledge. However, there is a steep learning curve to mastering the platform (Perry, 2015).

An additional suggestion for research on AR is that more design-based research is needed. Design-based research usually focuses both on developing the solution to a problem and on describing the result. By describing the details of the design process, both researchers and practitioners can learn how to apply AR in teaching the target language. However, only one of the ten studies reviewed here adopted a design-based research approach.

Furthermore, research on how AR can change language classroom dynamics is needed. Only after we have learned how the classroom dynamics have or have not been changed by the adoption of AR can we make the corresponding decision on how to change the other aspects of our teaching which do not involve the use of AR.

Unfortunately, none of the studies focused on learning Chinese as a foreign language. As a tonal and logographic language, Chinese presents students with additional challenges in the language learning process. There is, therefore, an urgent need to determine how the adoption of AR technology and techniques could make the learning of Chinese both more fun and more effective. A series of measured and deliberative steps needs to be taken. For example, a small-scale study on the adoption of AR could investigate how to improve learners' tones, character learning, and speaking. Gradually, gamification can be added with location-based techniques. Technology support is a critical key to success. However, its absence should not be a barrier. Teachers and researchers can try to start with using Mayer's (2005; 2009) multimedia design principles to design AR and produce multimedia, e.g. as the AR as Santos et al. (2016) did.

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