

A Systematic Review of Current Research on Affordances and Challenges of Technology-Assisted Grammar Learning

Akbar Bahari (Bahariakbar2020@gmail.com)
Urmia University, Iran

Javad Gholami (j.gholami@urmia.ac.ir)
Urmia University, Iran

Abstract

The integration of emerging educational technologies for the second language (L2) learning purposes in general and L2 grammar learning, in particular, is perceived to have mass appeal among e-learning practitioners. Reporting challenges and affordances highlighted in the research findings of existing literature in the technology-assisted language learning (TALL) field was the main goal of this research. To this end, a rigorous systematic review was conducted to shed light on the current state of research in terms of the challenges and affordances of technology-assisted L2 grammar learning. Following a rigorous screening of major databases, sixty-eight peer-reviewed articles published from 2010–2020 were included. The results concerning the reported challenges and affordances were separately discussed and synthesized. The findings of the study have theoretical implications for researchers about challenges and problems that need to be researched in future studies. Pedagogically, the findings inform teachers about the available affordances that can be used to facilitate grammar learning in TALL environments.

Keywords: technology-assisted language learning (TALL); second language (L2); grammar learning; systematic review; e-learning

Introduction

The use of technology-assisted pedagogies for teaching the second language (L2) grammar began around the 1960s under the dominant structural view of language teaching (Heift & Vyatkina, 2017). Since then, technology-assisted language learning (TALL) in general and technology-assisted L2 grammar learning, in particular, have benefited from different technology-assisted learning tools and platforms (e.g. computer, mobile, tablet, virtual reality, robot, etc.) to develop distinctive aspects of linguistic knowledge (e.g. grammar usage, rule formation, etc.; Fang, et al., 2021). Grammar, as one of the important aspects of linguistic knowledge, plays a significant role in L2 proficiency and has been “the center of attention of CALL researchers and developers since the very beginning of the discipline” (Kılıckaya, 2013, p. 3).

The following subsections provide an overview of the reported affordances (i.e. tested and confirmed efficacies) available in different TALL platforms (computer-

assisted language learning, mobile/tablet-assisted language learning, virtual-assisted language learning, and robot-assisted language learning). Each section provides a lay overview of the extant literature and sheds light on TALL potentials in developing grammar proficiency.

Computer-Assisted Language Learning (CALL)

CALL offers a wide range of feedback-generating systems that reportedly facilitates instructing and developing language learners' grammatical accuracy (Dikli & Bleyl, 2014; Li et al., 2017). It also offers interactive web-based grammar instruction that reportedly facilitates collaborative learning (AbuSeileek, 2009; Baturay et al., 2010; Kılıckaya, 2013; Romeo, 2009; Torlakovic & Deugo, 2004). By offering a variety of tools that can be used to improve grammar (e.g. online dictionaries, spell checkers, morphological analyzers, etc.) CALL remains the most frequently used TALL platform among language learners (Cowan et al., 2014; Hamel, 2010; Heift, 2010; Wood, 2011). The next widely used and analyzed affordance is corpora and data-driven learning that facilitates grammar instruction by pattern defining and pattern hunting (Anthony, 2013; Kennedy & Miceli 2010; Reppen, 2010; Romer, 2011; Vyatkina, 2016a, 2016b).

Mobile/Tablet-Assisted Language Learning (MTALL)

Using state-of-the-art technologies, MTALL has significantly developed L2 learners' grammatical proficiency (Chen, et al., 2019; Kayapinar et al., 2019; Sung et al., 2015; Wu & Huang, 2017; Zhang & Zou, 2020). Reportedly, the MTALL via gamification (Cornillie et al., 2018; Dehghanzadeh et al., 2019; Thompson & von Gillern, 2020) improves L2 learners' grammatical proficiency and creates a motivating environment with enhanced awareness of learners (Rachels & Rockinson-Szapkiw, 2018). Exploring the efficacy of mobile immersion in developing participants' grammatical proficiency, Lai (2016) confirmed the affordance of MALL in developing learners' grammatical proficiency. To expand the use of MALL from simple grammar exercises to more diverse learning activities, Jung (2020) introduced Taylor's Integrated Moodle e-Learning System as one of the engaging MALL platforms to develop learners' grammar.

Virtual Reality-Assisted Language Learning (VRALL)

Virtual reality-assisted language learning (VRALL) is another platform that provides L2 learners with a variety of affordances that facilitate L2 grammar learning. Among them is reducing affective filters by providing persistent records and native-like environments where learners are afforded with linguistic and physical copresence (i.e. real-time shared collaborative activities) that improves learner autonomy by allowing some degree of avatar control (Henderson et al., 2018). Exploring the potentials of VRALL, Chen (2016) reported a broad range of affordances "Results show that students improved their phonological, morphological, grammar and syntax knowledge, and virtual world learning assisted in the development of a more complex and higher level of thinking" (p. 1). Elaborating on teaching grammar via VRALL, Bikowski (2018) confirmed the affordance of dynamic devices and spaces in VRALL that makes it possible to establish innovative grammar tasks via interactive and intelligent technologies.

Robot-Assisted Language Learning (RALL)

While highlighting the scarcity of research on the efficacy of robot-assisted language learning (RALL), Engwall and Lopes (2020) and Randall (2019) confirm the potential of this platform in grammar learning in keeping with previous studies (Chang et al., 2010; Kanda et al., 2007). Drawing on Total Physical Response methodology, Wu et al. (2015) asserted the efficacy of integrating the RALL and the affordance of kinesthetic language learning. Exploring the efficacy of robot tutors in teaching the times tables, Konijn and Hoorn (2020) confirmed the efficacy of robot tutors and suggested interactive robots for grammar teaching rather than expressive robots that are more useful in teaching oral language skills and vocabulary. Fridin (2014) explored the efficacy of interactive robotic technology and confirmed the affordance of the robot's facilitative role in helping teachers complete their educational tasks. Lee et al. (2011) explored the efficacy of RALL and confirmed enhanced motivation, confidence, satisfaction, and interest among the participants in general and improvement in grammar in particular.

Statement of the Problem

According to Gillespie (2020), 3.5% of the CALL research is related to grammar learning, which reflects significance as a research topic. Accordingly, Bahari (2020a) and Hjetland, et al. (2020) called upon theoretical and pedagogical development and contextualization of emerging educational technologies to facilitate grammar learning.

Despite being among the most researched topics, the problem that needs to be addressed is the lack of an overview of current research conveying affordances and challenges of grammar learning via the TALL. To bridge this gap, the present review article conveys the latest findings and challenges to inform the TALL practitioners and computer programmers about the limitations and potentials of grammar learning via the TALL platforms.

The presence of a variety of TALL tools (e.g. grammar checkers, corpora and concordances, self-regulate assessment, etc.) does not guarantee grammar learning and reporting tools that need to be elaborated and this calls upon a systematic review that synthesizes the findings of current research towards facilitating the TALL grammar learning as part of the transition from classroom grammar learning to blended/distance grammar learning.

Purpose of this Study

Research on emerging educational technologies has led to the identification of a variety of tools and devices that can be used to facilitate language learning. The purpose of the current systematic review was to convey the reported challenges and affordances of TALL studies in the extant literature. To this end, a rigorous systematic review was conducted to shed light on the current state of research in terms of the challenges and affordances of technology-assisted L2 grammar learning.

Providing an overview of the affordances that can be integrated into the TALL pedagogy and the challenges that need to be addressed in future TALL research are among the contributions of the present study. The articles included in the study were

rigorously reviewed to find the required data in response to the following research questions:

1. What were the affordances of technology-assisted L2 grammar learning reported in studies conducted from 2010-2020?
2. What were the challenges of technology-assisted L2 grammar learning reported in studies conducted from 2010-2020?
3. Which platform (computer, mobile, tablet, virtual reality, robot) has been used more frequently in technology-assisted L2 grammar learning in studies from 2010-2020?

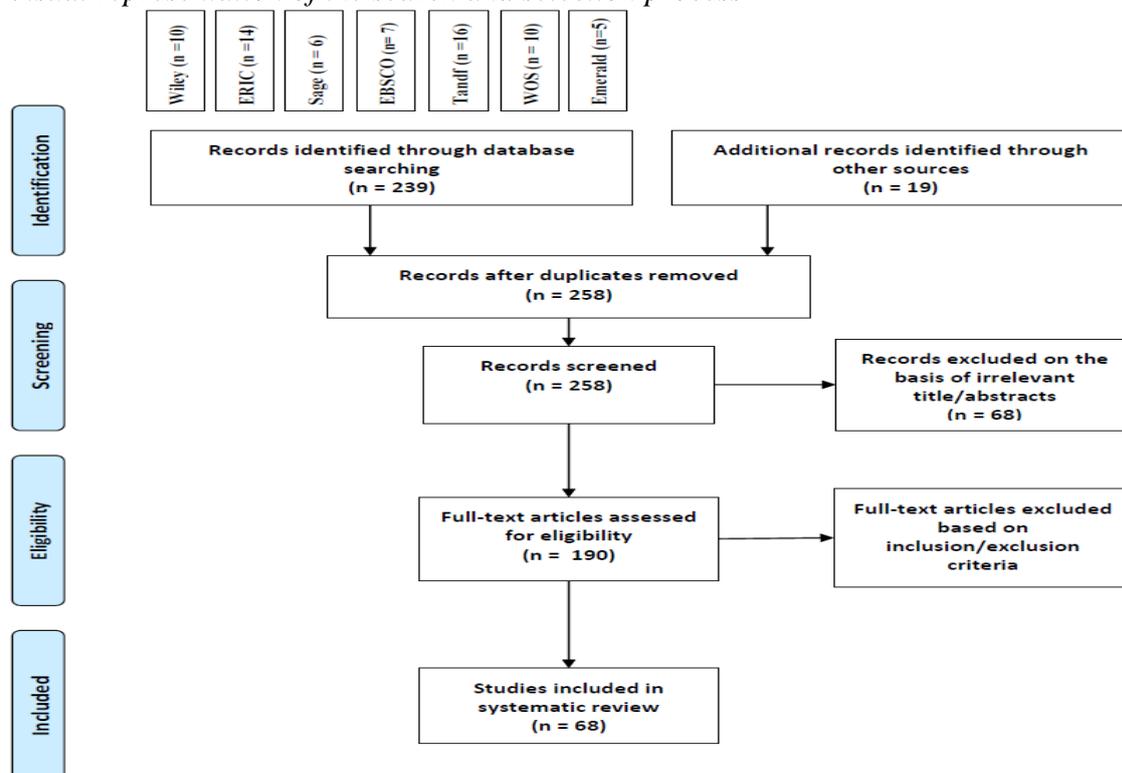
Method

Data Source and Search Strategy

To capture the challenges and affordances of technology-assisted L2 grammar learning reported by studies, the publication dates of related articles published by journals specializing in the CALL research were set to the years 2010–2020. To arrive at a comprehensive set of relevant studies, potentially relevant sources were systematically screened and tested to identify relevant sources by searching primary electronic databases and platforms (Wiley, ERIC, Sage, EBSCO, Tandf, Emerald, and Web of Science) plus hand searching of related key journals, networks and associations, websites, personal contacting, and literature snowballing (see Figure 1).

Figure 1

Visual representation of the search and selection process



Inclusion/Exclusion Criteria

To ensure a balance between specificity and sensitivity of the articles, the specifications of each electronic database and platform were considered for the modification of the search terms strategy (e.g. keyword and/or topic and/or theme searches). RefWorks were used to track each identified citation and manage and document the databases imported into it throughout the search process. The inclusion-exclusion criteria observed during the screening of the title and abstract were identifying and removing theoretical/conceptual studies, book reviews, and duplicate studies irrelevant to the topic of technology-assisted grammar learning (see Table 1). The data from the selected studies (n=68) were coded in terms of study methods, participants, type of grammatical problem/aspect addressed, reported issues and challenges, and reported affordances and opportunities. In keeping with Dochy (2006), narrative content analysis was used to synthesize findings. Based on suggestions, the meta-analysis was excluded to ensure the diversity of included studies (Garg et al., 2008; Petticrew & Roberts, 2006).

Table 1
Inclusion/Exclusion Criteria

Criteria	Inclusion	Exclusion
Date	2010-2020	Prior to 2010 and after 2020
Type	Peer-reviewed scholarly articles	Dissertations, technical reports, proceedings, book chapters
Focus	Articles on technology-assisted grammar learning (CALL, MALL, VRALL, etc.)	Articles did not include technology-assisted language learning
Methodology	mixed methods, quantitative, qualitative	Reviews (book review, articles reviews, systematic and meta-analysis reviews)
Language	English	Other languages

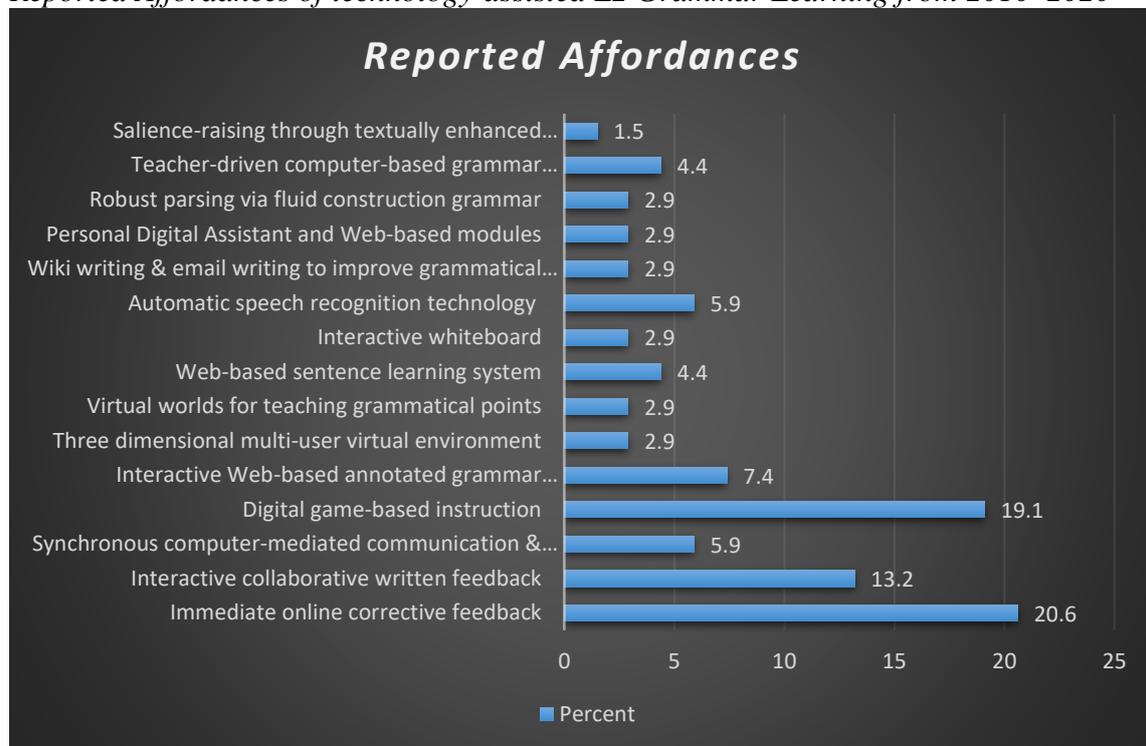
Results

Research question 1. What were the affordances of technology-assisted L2 grammar learning reported in studies conducted from 2010-2020?

To facilitate the use of the article, the findings of the systematic review were classified in terms of affordances and challenges. Table 2 displays a sample of the reported affordances and opportunities of technology-assisted L2 grammar learning by articles published from 2010 to 2020. Figure 2 displays the most frequently reported affordances of technology-assisted from 2010–2020. According to the obtained results, immediate online corrective feedback (20.59%) is the most frequently reported affordance by TALL studies (see Figure 2).

Figure 2

Reported Affordances of technology-assisted L2 Grammar Learning from 2010–2020

**Table 2**

Sample of reported TALL Affordances for L2 Grammar Learning from 2010–2020

Author(s)	Method	Participants	Type of grammatical problem/aspect addressed	Reported Affordances & Opportunities
Lin et al. (2020)	Quantitative -Qualitative	55	lexicon, grammatical range & accuracy	The efficacy of contextual game-based learning approach on training grammar
Chen (2020)	Quantitative -Qualitative	9	In terms of error-free T-units, error-free clauses, and correct verb forms	The efficacy of three-dimensional multi-user virtual environment on developing grammatical proficiency of the L2 learners and emphasized that the adopted syllabus design was task-based rather than grammar-based

Reynolds & Kao (2019)	Quantitative -Qualitative	45	Grammatical error correction in learners' English articles	Developing grammatical accuracy via digital game-based instruction & stronger retention of grammatical knowledge and error correction among the L2 learners
Cintrón-Valentín et al. (2019)	Quantitative -Qualitative	176	Supporting grammar development via grammar captioning	The efficacy of saliency-raising through textually enhanced captioned video
Ali (2019)	Quantitative -Qualitative	68	The modal verbs	The web-based course facilitates English grammar instruction
Kruk (2018)	quasi-experimental study	40	Simple present tense	Reported the affordance of <i>Active Worlds</i> for teaching grammatical points
Bodnar et al. (2017)	Quantitative -Qualitative	31	Oral grammar practice	Automatic speech recognition-enabled CALL systems are suitable environments for oral grammar practice
Hedjazi et al. (2017)	Quantitative -Qualitative	60	Grammatical points	"text messages can be useful for learning grammar points, since they engage learners' interest and encourage them to study more to text the correct answers when they are outside their classrooms"
Chang et al. (2016)	Quasi-experimental design	34	Grammar and sentence structure	Confirmed the efficacy of self-explanation strategy in a CALL environment
Eslami & Kung (2016)	Quasi-experimental study	60	Incidental focus-on-form	The efficacy of synchronous computer-mediated communication and incidental focus-on-form
de Vries et al. (2014)	Quantitative -Qualitative	29	Grammatical and ungrammatical sentences	The efficacy of automatic speech recognition technology for grammar training purposes

Beuls (2014)	Quantitative -Qualitative	40	Verb morphology	“FCG can rightfully be used as the language-processing component in an Intelligent CALL system”
Pirasteh (2014)	Quantitative -Qualitative	52	Different grammatical points	Efficacy of e-mail as a useful way of teaching large numbers of grammar points
Kılıckaya (2013)	Quantitative -Qualitative	50	Adverbial clauses	The efficacy of teacher-driven computer-based grammar instruction in learning adverbial clauses
Castañeda & Cho (2013)	Quantitative -Qualitative	53	Grammatical knowledge	wiki writing was helpful in improving grammatical knowledge
İlin et al. (2013)	Action research	4	Grammar skills	The efficacy of videos for teaching grammar in ESP classes
Baturay, et al., (2010)	Quantitative -Qualitative	54	Gap-filling, combo-box, and drag-and-drop exercises	Efficacy of interactive Web-based grammar instruction
Guerrero et al. (2010)	Quantitative -Qualitative	32	Grammar skills	Efficacy of Personal Digital Assistant and Web-based modules for a collaborative learning activity to support teaching grammar both synchronously and asynchronously
Bettsworth (2010)	Quantitative -Qualitative	58	Understanding and retention of specific grammar points	Confirmed the efficacy of the interactive whiteboard particularly where visual features of the interactive whiteboard were related to elements of language

Immediate Online Corrective Feedback (20.59%). Kılıckaya (2013) reported the affordance of teacher-driven computer-based grammar instruction in learning adverbial clauses. He confirmed that the use of computer-based grammar instruction facilitates further practice and revision for students with limited time and resources. He also reported the affordance of receiving immediate feedback for every learner that was

not available in face-to-face large classes. Bodnar et al. (2017) explored the efficacy of computerized L2 grammar learning and confirmed the affordance of producing online corrective feedback on learners' output during oral grammar practice. Highlighting on CALL context as a less threatening environment, they described it as a safe environment that is a more favorable condition for providing corrective feedback that was later confirmed by other studies (Bahari et al., 2021b).

Digital Game-Based Instruction (19.12%). Reynolds and Kao (2019) reported the affordances of digital game-based instruction in terms of stronger retention of grammatical knowledge and error correction among L2 learners by analyzing the relationship between gameplay and written corrective feedback. Ali (2019) reported the affordances of *Hot Potatoes* software services and applications in terms of providing authentic learning situations via multimedia features and boosting learner autonomy by allowing real control over the learning process in game-based instruction. Analyzing the instructional potentials of the contextual gaming approach, Lin, et al. (2020) reported the efficacy of game-based English grammar instruction among L2 learners and emphasized considering learners' individual differences before developing game-based grammar learning programs.

Interactive Collaborative Written Feedback (13.24%). Liu et al. (2018) analyzed the impact of a student response system as a medium to organize interactive activities and confirmed its efficacy in facilitating grammar learning by providing interactive collaborative written feedback in flipped learning activities. To encourage interactive collaborative activities, they suggested teachers use a student response system "to organize group projects, discussions, debates and give exercises concerning pre-class videos" (p.6). Such findings suggest that learning activities equipped with TALL affordances can optimize grammar learning by improving learners' impression and motivation (Amiryousefi & Geld, 2019).

Interactive Web-Based Grammar Instruction (7.35%). Li and Hegelheimer (2013) confirmed the affordance of interactive web-based grammar instruction in terms of facilitating grammar acquisition by providing outside-of-the-classroom grammar exercises. Abdelaziz and Zehmi (2020) investigated e-cognitive scaffolding and confirmed its affordance in developing English grammar usage among the participants who received educational intervention based on e-cognitive scaffolding and using interactive activities to practice each segment of the grammar lesson. To this end, they presented grammar points via interactive activities (e.g. elaborations, drilling, and modelling activities) that were included in PowerPoint presentations. For example, they used interactive modeling to deliver grammar lessons and to demonstrate different meanings during web-based grammar instruction.

Automatic Speech Recognition Technology (5.88%). de Vries, et al., (2014) analyzed the instructional potentials of automatic speech recognition technology and confirmed the affordance of it for grammar training purposes among learners with different L1 backgrounds. They also confirmed the affordance of automatic speech recognition-based CALL systems for providing intensive and consistent corrective feedback among L2 learners. The study confirmed the positive perception of the experimental group who received the treatment and emphasized the need for better recording technology and stable internet connections to enhance the efficacy of the automatic speech recognition technology.

Synchronous Computer-Mediated Focus-On-Form (5.88%). Eslami and Kung (2016) conducted a quasi-experimental study and reported the affordance of synchronous computer-mediated communication with incidental focus-on-form in terms of improving L2 learning and accuracy of L2 use that was later confirmed by additional studies (Bahari, 2018). Jiang and Yu (2020) confirmed the affordance of automated computer-mediated feedback in adjusting learners' focus to meaning rather than formulaic patterns that leads to a constructive learning process. Exploring the efficacy of gamifying on English grammar learning, Hong et al. (2020) confirmed the affordance of it in terms of boosting learners' epistemic curiosity that leads to content learning. Their findings support the interplay between cognitive and behavioral engagement on the one hand and the significant relationship between learners' focus on content and task on the other hand that can be enhanced via synchronous computer-mediated focus-on-form.

Web-Based Sentence Learning (4.41%). Chang, et al. (2016) analyzed the self-explanation strategy in the CALL environment and reported the affordance of a web-based sentence learning system to improve grammar and sentence structure. Guerrero, et al. (2010) reported the affordance of Personal Digital Assistant and Web-based modules in terms of developing L2 learners' grammar skills by engaging them in synchronous and asynchronous collaborative learning activities. Exploring the efficacy of videos for teaching grammar in ESP classes, İlin, et al. (2013) reported the affordances of more permanent learning, boosting learner motivation, and facilitating self-study outside the class time (Bahari, 2020b; Bahari et al., 2021a). Exploring the efficacy of providing syntactic scaffolding via TALL, Park et al. (2019) reported the affordance of visual-syntactic text formatting for developing writing strategies, written convention, and word analysis.

Interactive Whiteboard (2.94%). Bettsworth (2010) analyzed the instructional potentials of interactive whiteboards and reported the affordance of the device for developing L2 learners' retention and understanding of specific grammar points. The use of an interactive whiteboard encourages the collaborative construction of meaning as a result of the high degree of interactivity that needs to be under the teacher's management. Reducing the pace of teaching and causing boredom among learners who are not actively involved in collaborative interaction are among the reported challenges of using interactive whiteboards (Lopez, 2010; Smith, Hardman, & Higgins, 2006).

Robust Parsing via Fluid Construction Grammar (2.94%). Beuls (2014) analyzed fluid construction grammar as a language processing component in the CALL system and reported the affordances of robust parsing via fluid construction grammar that facilitates diagnosing and repairing L2 learners' grammatical errors plus providing constructive feedback. The study highlighted the need to recruit the potentials of fluid construction grammar for developing the meta-layer efficiency (van Trijp, 2012).

Wiki and Email (2.94%). Castañeda and Cho (2013) investigated the instructional potential of Wiki technology for developing grammatical skills of L2 learners and reported the affordance of improving grammatical knowledge via Wiki writing. Accordingly, this platform as a social environment can be utilized to enhance collaborative learning activities among L2 learners (Kost, 2011; Lee, 2010). Exploring the efficacy of technology-assisted grammar learning, Pirasteh (2014) reported the affordance of email as a tool to improve the grammatical skills of EFL learners.

Virtual Worlds (2.94%). Kruk (2018) investigated the instructional potential of virtual worlds for teaching grammar and reported the affordance of *Active Worlds* for

teaching grammatical points (i.e. simple present tense). Recruiting the affordances of virtual worlds including *OpenSim*, *Second Life*, and *Quest Atlantis* were previously reported in the CALL studies (Wang, 2014; Wang, Petrina, & Feng, 2017). Exploring the potentials of a three-dimensional multi-user virtual environment, Chen (2020) confirmed the affordance of a three-dimensional multi-user virtual environment on developing grammatical proficiency of the L2 learners in terms of error-free T-units, error-free clauses, and correct verb forms and emphasized that the adopted syllabus design was task-based rather than grammar-based. Despite reported VRALL affordances for grammar teaching, there is a critical challenge ahead of scholars as highlighted by Kruk (2018) “empirical research on the use of virtual worlds in foreign language learning and teaching is still in its infancy, particularly when it comes to utilizing such worlds in teaching grammar (p.492).

Research question 2. What were the challenges of technology-assisted L2 grammar learning reported in studies conducted from 2010-2020?

To facilitate the use of the article, the findings of the systematic review were classified in terms of affordances and challenges. Table 3 displays a sample of the reported issues and challenges of technology-assisted L2 grammar learning by articles published from 2010 to 2020.

Table 3

Sample of reported TALL Challenges for L2 Grammar Learning from 2010–2020

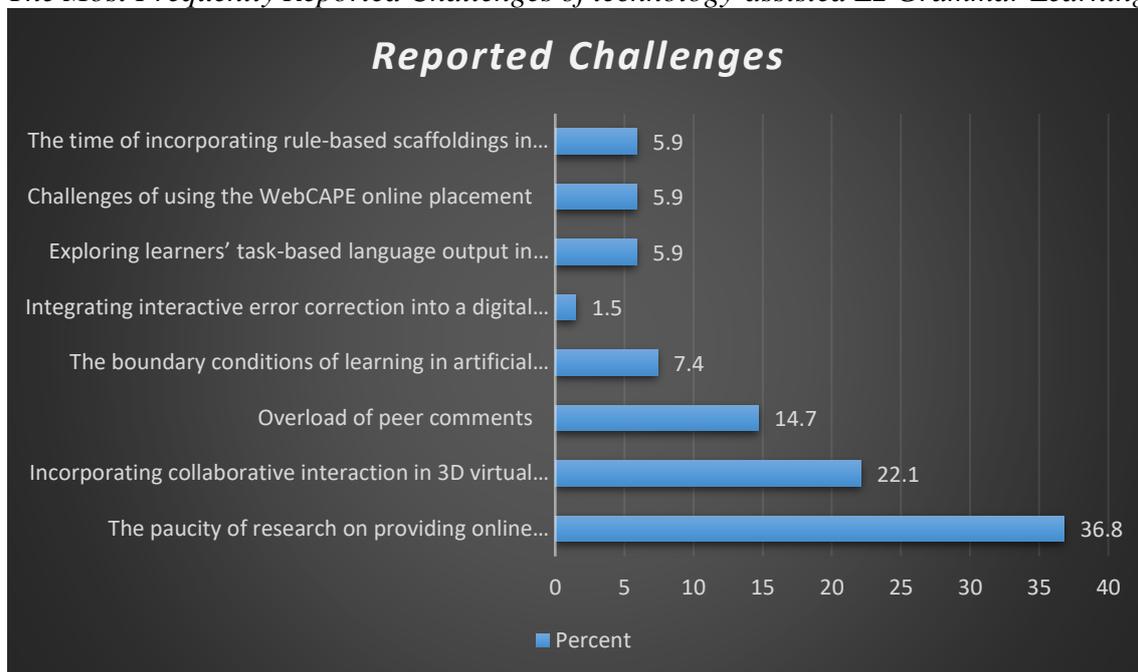
Author(s)	Method	Participants	Type of grammatical problem/aspect addressed	Reported Issues & Challenges
Alharbi (2020)	Quantitative -Qualitative	60	The effect of video-grammar	The challenge of overload of peer comments made following watching grammar videos
Chen (2020)	Quantitative -Qualitative	9	In terms of error-free T-units, error-free clauses, and correct verb forms	The need to explore the extent to which the quality and quantity of learners’ task-based language output can progress over time in 3D environments
Jiménez et al. (2020)	Experimental	20	Artificial grammar learning paradigms	The challenge of the boundary conditions of learning in artificial grammar learning paradigms

Kılıçkaya (2019)	Quantitative -Qualitative	64	Timing of feedback in computer-supported grammar instruction	The paucity of research on providing online corrective feedback
Cintrón-Valentín, et al. (2019)	Quantitative -Qualitative	176	preterite/imperfect, ser/estar, gustar-type verbs, & the subjunctive	“the importance of tailoring TE to specific target structures so that the appropriate inflectional, syntactic, and functional considerations are emphasized”
Yamazaki (2018)	Quantitative -Qualitative	11	3D virtual world	The efficacy of learning in a 3D virtual world
Turner III (2017)	Quantitative -Qualitative	52	The WebCAPE online placement	“the lack of granularity in individual scores and the limited level of prediction associated with the test”
Liu et al. (2014)	Quasi-experimental	53	Story grammar rules	“Educators may need to be cautious regarding the time point at which rule-based scaffoldings would be most effectively integrated with learning activities”
Wang & Smith (2013)	Quantitative -Qualitative	56	Grammar learning through mobile learning	The challenge of integrating phones into a learning environment

Figure 3 displays the most frequently reported challenges of technology-assisted L2 grammar learning in reviewed studies conducted from 2010–2020.

Figure 3

The Most Frequently Reported Challenges of technology-assisted L2 Grammar Learning



According to the results, the paucity of research on providing online corrective feedback (36.76%) is the most frequently reported challenge by TALL studies (see Figure 3). This finding calls for further consideration as providing online corrective feedback was the most frequently reported affordance in reviewed articles. This contradictory result reflects both under-researched aspects of TALL and tested affordances that despite emerging developments, require conducting further research.

The Paucity of Research on Providing Online Corrective Feedback (36.76%). Kılıçkaya (2019) investigated the timing of feedback in technology-assisted L2 grammar learning in keeping with Chong (2018) and Storch (2018). These studies emphasized the paucity of research on providing online corrective feedback and called for further research to investigate this issue. Exploring the potential of developing grammar learning via captioning, Cintrón-Valentín, et al. (2019) reported the affordance of “salience-raising through textually enhanced captioned video on L2 vocabulary and grammar development” (p.2) in keeping with Lee and Révész (2018). They also reported the challenge of adjusting textual enhancement to a specific target structure with a focus on functional, syntactic, and inflectional aspects.

Collaborative Interaction in 3D Virtual World Instruction (22.06%). Yamazaki (2018) reported the affordance of 3D virtual world instruction in terms of communicative competencies (e.g. awareness of audience, persuasive talk, and collaborative communication) and the challenge of integrating collaborative interaction in 3D virtual world instruction. Exploring the efficacy of virtual reality in developing grammatical accuracy, Chien et al. (2020) confirmed the affordance of this platform form in creating collaborative interaction among learners. For example, when learners collaboratively interacted to evaluate/correct their peers' grammatical mistakes and discussed the reasons for their arguments, they were developing their critical thinking skills as well. Following a study on the efficacy of virtual reality, Scrivner et al. (2019)

confirmed the affordance of this platform in developing grammatical constructions via hand-held mobiles rather than head-mounted displays that open up a new window in expanding studies that aim at integrating virtual reality into language learning.

Overload of Peer Comments (14.71%). Exploring the efficacy of integration of video in teaching grammar, Alharbi (2020) reported the affordance of video grammar for teaching grammar and the challenge of overload of peer comments following watching the videos. Exploring the efficacy of promoting metalinguistic awareness by automation, Chen (2016) reported the challenge of cognitive overload among beginner learners when automation of learning activities is deficient. Therefore, it is highly critical to consider the required elaboration and abstraction in designing learning activities that aim at boosting metalinguistic awareness.

The Boundary Conditions (7.35%). Jiménez et al. (2020) analyzed the impact of surface features on artificial grammar learning and reported the challenge of the boundary conditions of learning in artificial grammar learning paradigms and the need to address it in future studies. Using artificial language stimuli to test language learning, Zuidema et al. (2020) emphasized the boundary conditions as the challenge ahead of TALL programmers in including markers that indicate word boundaries. These findings reflect the need to develop a more reliable and valid measure of language learning in artificial grammar learning.

Integrating Interactive Error Correction into Digital Learning (5.88%). Wang and Smith (2013) analyzed the instructional potential of mobile-assisted grammar learning and reported the challenge of integrating phones into a learning environment and integrating interactive error correction into a digital learning environment. They suggested delivering modular chunks such as grammar quizzes to overcome the issue. Crosthwaite (2020) reported the challenge of error correction via corpus consultation that decreases meaningful learning on the part of learners that can be overcome by encouraging the use of indirect written corrective feedback.

Task-Based Language Output in 3D Multi-User Virtual Environments (5.88%). Providing relevant empirical evidence and discourse, Chen (2020) confirmed the need to address the challenge of the need to investigate task-based language output in 3D multi-user virtual environments (MUVES) in terms of quality and quantity. Task-oriented activities for developing language output is among the reported affordances of virtual reality environments provides learners with more autonomy compared to social virtual environments (e.g. *Second Life*; Scrivner et al., 2019; Wigham & Chanier, 2013)

The WebCAPE Online Placement (5.88%). Turner III (2017) investigated the impact of the WebCAPE online placement as a proxy for advanced grammar evaluation and reported the challenges of using The WebCAPE online placement for advanced grammar classes in terms of “the lack of granularity in individual scores and the limited level of prediction associated with the test” (p.2). Since the reliability data about the WebCAPE online placement is 30 years old, further research is required to measure the reliability and to check the validity of the test for different grammar levels. Investigating whether a technology-assisted learning environment facilitates outcome assessment, Houston, 2005) called upon further research to address the inconsistency of reported assessments of grammar by the WebCAPE online placement.

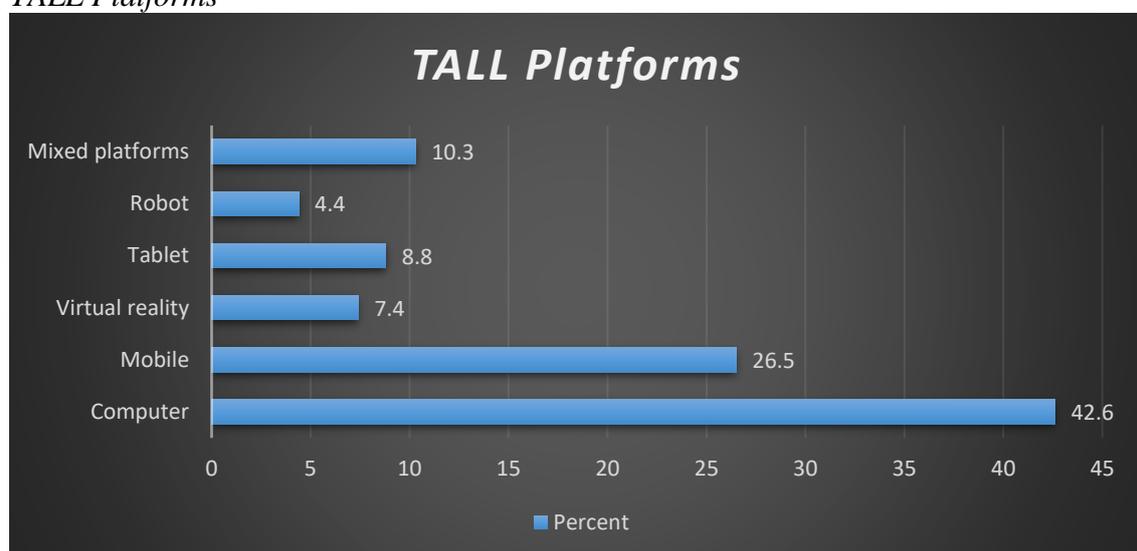
Incorporating Rule-Based Scaffoldings (1.47%). Liu, et al. (2014) explored the possible relationship among creative self-efficacy, rule-based scaffoldings, and storytelling products and raised the issue of the need to be cautious about the time of

incorporating rule-based scaffoldings with learning activities during digital storytelling. The study also confirmed the affordance of rule-based story grammars in terms of the creation of stories while reminding the issue of the small size of the research.

Research question 3. Which platform (computer, mobile, tablet, virtual reality, robot) has been used more frequently in technology-assisted L2 grammar learning in studies from 2010-2020?

Figure 4 displays the share of different TALL platforms in offering L2 grammar learning affordances. CALL with 42.65% was the most frequently used platform in reviewed studies that provided a broader range of affordances that can be used to develop L2 grammar learning.

Figure 4
TALL Platforms



Discussion

The present systematic review identified several affordances (see Figure 2) and challenges (see Figure 3) of technology-assisted L2 grammar learning reported in studies conducted from 2010 to 2020. The affordances can be used to inform CALL practitioners about the available tools and features that can be used during teaching grammar.

The results also inform CALL researchers about the challenges and problems that require further investigation to facilitate grammar learning through educational technologies.

The study also revealed that computer-assisted language learning was the most frequently adopted platform for teaching/learning grammar among different technology-enhanced language learning platforms (e.g. mobile, virtual reality, etc.). This finding justifies the necessity of conducting comparative and exploratory studies to shed light on the potentials of other platforms for grammar learning versus computers.

Among them is the need to include L2 learners' concerns and needs in programming technology-assisted grammar learning courses plus learning evaluation that makes individual learner development monitoring possible by incorporating a visual representation of grammar learning.

The next finding is the fact that there is thin literature on technology-assisted grammar learning and further research with a focus on grammar learning is highly critical as emphasized by previous studies (Castañeda & Cho, 2016; Lin et al., 2020). Modifying and designing games for instructional purposes in general and implementing game-based grammar learning activities, in particular, requires a lot of precision and expertise on the part of the programmers. To enhance affordances of game-based grammar learning, they need to consider the L2 learners' prior knowledge, prior gaming experience. They should provide sufficient tutorials for novice learners and make sure the cognitive load and difficulty level match the learners' level (particularly in low-achieving learners).

The review of the studies also revealed that learning tasks for technology-assisted L2 grammar learning need to be designed on a sound theoretical and pedagogical basis to facilitate relating the tasks to the real world and tap into learners' nonlinearity and dynamicity of L2 motivation (Bahari, 2019a) and nonlinearity and dynamicity of L2 learner differences (Bahari, 2019b). Visualizing tools and affordances of multimedia learning need to be incorporated for technology-assisted L2 grammar learning. Visualizing syntactic structures and components of text by using text formatting technology enhances L2 learners' grammar gains and provides a motivating practice environment that unconsciously improves learners' syntactic processing skills (Park & Warschauer, 2016).

Implications

Theoretical Implications

Given the thin literature and the small number of eligible articles on the topic, theoretically, the findings suggest the need to bridge this gap in future studies by addressing the aforementioned challenges and expanding the use of affordances. Given the short-term nature of adopted designs in the reviewed studies and the significance of the longitudinal design of research, future studies are recommended to use longitudinal designs to appraise the efficacy of technology-assisted L2 grammar learning from a variety of aspects. Given the lack of a study highlighting the distribution of various data analysis procedures used in technology-assisted L2 grammar learning studies, a further review is suggested to address this issue. Likewise, as most studies of technology-assisted L2 grammar learning are conducted at the primary or secondary education level, further investigation at the higher education level is recommended. Given the lack of a study addressing L2 teachers' and learners' perceptions of technology-assisted L2 grammar learning in a low-tech information environment (i.e. with under-developed internet infrastructure) versus high-tech information environment (i.e. with over-developed internet infrastructure) and their corresponding challenges and affordances, a further meta-analysis is recommended to bridge this gap in the literature.

The review of the articles revealed contradictory results concerning the efficacy of hands-on and hands-off data-driven learning for L2 grammar teaching purposes.

Therefore, further analysis is required to investigate their impact of them on learners by including different variables such as richness of linguistic input (Frankenberg-Garcia, 2014) for learners with different proficiency levels (Boulton, 2012), and the necessity of including tutorial program (Heift & Vyatkina, 2017). In response to the call made by previous studies (Montero Perez et al., 2015; Muñoz, 2017), future studies are recommended to adopt eye-tracking methodologies to develop our understanding of technology-assisted L2 grammar learning.

Pedagogical Implications

Pedagogically, L2 teachers are recommended to take advantage of the affordances described in this research to facilitate L2 grammar learning, innovate teaching practices, and adopt CALL strategies (e.g. interactive learning, collaborative learning, gamification, cooperative problem solving, etc.) and reduce pedagogical workload. The L2 teachers are also recommended to take necessary pedagogical measures in response to the reported challenges in advance. For example, to avoid boredom and a slow pace of teaching, they need to make sure that every member of the learner group is involved in collaborative-interactive activities.

To associate collaborative learning techniques with every suggested tool, teachers are suggested to try them prior to actual use and transform the potential software information into practice and avoid unpredicted issues. To reduce the classroom workload, teachers are suggested to encourage learners to do part of their grammar exercises via portable technologies and their affordances (e.g. gamification, text messaging, etc.). To implement textual enhancement-captioned media, L2 teachers are recommended to consider structure-specific features that mediate the saliency of grammatical items as emphasized in the reviewed articles.

Conclusion

The study revealed two main findings that need to be addressed pedagogically and theoretically. First, reported L2 grammar learning affordances that facilitate grammar learning beyond potentials available in face-to-face environments to require some pedagogical modifications to be utilized in blended learning environments. Second, reported challenges in reviewed studies need to be included in the short-term plans of editorial boards of the leading journals of the field (by publishing special issues). Exposing L2 learners to technology-assisted learning environments does not lead to grammar learning, therefore teachers are recommended to contextualize the reported affordances and take innovative pedagogical measures to overcome unreported limitations as part of the educational technology integration movement.

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