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Assessing the Impact of Game Modalities in Second Language Acquisition: *ELLE the EndLess LEarner*

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Abstract: This paper describes a study comparing four educational videogames designed for second language acquisition (SLA) of Portuguese vocabulary terms: three versions (one VR and two PC versions with different perspectives) of an endless-runner called *ELLE the EndLess LEarner* and a control game *This or That*, which is a digitized flashcard system. A total of 68 university students took a pre-test assessing vocabulary knowledge, played one of the four versions for a total of 20 minutes, and took a post-test that assessed vocabulary knowledge and player experience. The study showed significant learning gains for all participants, regardless of which version of the game they played, with the highest increases coming from the group playing the control flashcard game. Possible explanations for these results are discussed, along with the results from post-test gameplay items of playability, engrossment, enjoyment, gratification, and immersion.

Keywords: Game Based Learning/Gaming, Technology Enhanced Learning, eLearning Systems/Technology/Tools/Platforms, Learning Preferences
Categories: L.5.1, L.3.6, L.3.0, L.3.3

1 Introduction

Prior research suggests that presenting knowledge embedded within videogames can increase learner motivation, engagement, critical thinking, and retention [Eichenbaum, A., Bavelier, D., & Green, C. S 2014, Fullerton 2014, Gee 2003, Przybylski, Rigby and Ryan 2010, Strobach, Frensch and Schubert 2012]. This research has expanded along with technology in recent years, and scholars have

investigated learning in more widely available console and PC videogames [Charsky, D. and Mims, C. 2008, Fang and Yang 2016] as well as embodied mixed-reality [Lindgren and Johnson-Glenberg 2013] and virtual reality (VR) platforms [Martín-Gutiérrez 2016, Sousa Santos et al. 2008]. Language acquisition has also benefited from improving technology and videogames are now utilized in different ways to teach and enhance second language acquisition (SLA) [Chapelle 2008, Peterson 2010].

While a number of studies have investigated the efficacy of PC-based virtual learning environments (VLEs) for language acquisition [Lin and Lan 2015], and a few studies have compared learning outcomes between VR and PC platforms [Hsieh, Kuo and Niu 2018] we have not found any studies where participant SLA performance in head-mounted display (HMD) platforms are compared to the same or similar games played on a PC platform. As these HMD systems become more affordable and more popular, designers of educational technology should take increasing notice, given the potential these systems have for creating fully immersive VLEs for language learning.

This study explores the effects of an educational game designed by the authors called *ELLE the EndLess LEarner,* an endless-runner style game played in VR. An endless runner game is one where the player is always moving in the game, usually in the same direction. In this study, participants in the VR condition played the game on an HTC Vive. This game requires players to move their entire bodies from side-to-side to avoid obstacles, and to use the handheld controller to match written or spoken Portuguese vocabulary terms with their English translations or pictorial representations.

To better understand participant experience and learning efficacy of the VR game *ELLE*, we compare the assessments of participants' performance and experience in this VR condition to the assessments of participants across three other conditions: a PC over-the-shoulder view of the same game (*ELLE OTC*), a PC side-scroller view of the same game (*ELLE SS*), and a control condition game called *This or That*, consisting of simulated flashcards played on the PC (*TOT*).

We hypothesize participants will acquire Portuguese vocabulary terms while playing all versions of the game. Additionally, we hypothesize that the VR game and its PC versions will provide gameplay experiences superior to the PC control game, specifically the factors of usability, engrossment, enjoyment, and personal gratification. This paper describes findings from measures of vocabulary acquisition and player experience administered to postsecondary student participants and it discusses implications of the results for future SLA game design for VR as well as PC platforms.

1.1 Embodied and immersive learning environments

Everything we learn is mediated through our physical bodies in some way: we read with our eyes, listen with our ears, etc. The field of embodied cognition centers on this idea of thinking with a focus on the role of the body as a mediator [Abrahamson and Lindgren 2014, Alibali and Nathan 2012, Hadwin, Järvelä and Miller n.d., Hauk, Johnsrude and Pulvermüller 2004, Lindgren and Johnson-Glenberg 2013]. Studies suggest that outcomes are improved when participants are asked to make specific gestures during the learning process [Boulenger, Hauk and Pulvermuller 2008,

Goldin-Meadow, Cook and Mitchell 2009, Plummer 2009, Richards 2010, Shoval 2010], and it has been demonstrated that gesturing in addition to hearing or seeing a word can activate additional areas of the brain—which is a phenomenon that learning environments can capitalize on to improve outcomes [Lindgren and Johnson-Glenberg 2013].

Digital environments, especially VR games, are capable of incorporating the learner's whole body in the content. The majority of pedagogical initiatives have prioritized the activity taking place only in learners' brains, with many schools requiring students to remain seated and absorb information primarily through their ears and eyes. Embodied cognition scholars realize the importance of taking into account the bodily mediation of knowledge, however subtle or imperceptible the mediation may be. Context is another mediator of information. Retention of knowledge occurs only when the learner can make connections to new and past experiences [Gee 2003].

Virtual environments possess the capability of providing learners with specifically engineered digital worlds in which to have embodied learning experiences. These worlds can be designed to meet certain requirements associated with the information being learned, such as a culturally relevant environment specific to a certain language. The head-mounted display of several brands of VR devices afford the user visual immersion in the virtual world, blocking out any glimpse of the physical one. Pair this with a set of headphones, and two of the most commonly relied on senses are isolated from everything but the virtual environment. The lack of distraction by the non-virtual world this interface affords helps immerse users in the learning environment [Egger et al. 2017, Taekman and Shelley 2010].

"Immersive learning environments," a phrase that is used by some to describe web-based learning environments accessed through PCs [Shen, Jiang, Grosskopf and Berryman 2012], and by others to describe augmented reality (AR) and augmented virtuality (AV) [Wu, Lee, Chang and Liang 2013], is used in this paper to describe virtual reality (VR) that is accessed through a head-mounted device that limits the user's view to only the virtual world displayed in the headset. VR, a popular trend in the field of digital education, is being used to teach a variety of topics including STEM subjects [Cecil, Ramanathan and Mwavita 2013, Huang, Rauch and Liaw 2010], archaeology [Liarokapis et al. 2017], and languages [Hastings, C., & Brunotte, J. 2017] VR platforms do not limit the user to a 2D screen that must be placed directly in front of them; rather, they allow for somewhat free movement within physical and virtual space constraints. This permits the VR user a wider range of interactions than mouse clicking or screen tapping—they can walk a few steps in any direction, move their arms about freely, and even jump or duck, within the limitations of the physical and virtual space of their environment. These affordances open the door for embodied learning experiences to occur within virtual spaces.

1.2 Language learning with interactive videogames

In the area of language learning, research on the effects of videogames on various aspects of the language learning process is still limited. The emerging studies illustrate that language learners have benefited from the improvement of technology, overall, and some learners have benefited from videogames that augment or instruct

in second language acquisition (SLA) [Chik 2014, Peterson 2011, Peterson 2010, 2012, 2016, Piirainen-Marsh and Tainio 2009, Vosburg, 2017].

Vocabulary learning in a second/foreign language is a complex process that can be approached from multiple research and pedagogical perspectives [Kamil and Hiebert, 2005]. Its importance is clear to researchers and instructors because it is connected to all other language skills: speaking, listening, reading, and writing. If a native or non-native speaker knows a word, he or she must recognize not only the word's semantic meaning but also its phonetic form, along with the syntactic function it plays in a particular context. For example, Nation [2001] acknowledges that the knowledge of a vocabulary item entails at least the following: recognition when the word is heard, familiarity with its written form, understanding what it means in the specific context in which it is used, and possibly some knowledge of its grammatical function. Moreover, there are different types of vocabulary. One distinction could be between oral and print vocabulary, for example. Another major distinction could be made between productive and receptive vocabulary. Productive is the vocabulary that speakers can use in speech or in writing. Receptive vocabulary is the vocabulary that is recognized in listening or reading activities. Second language learners would require at least 2000 words for basic proficiency in the language, but their needs may vary depending on the purposes of language learning and instruction. In an academic environment, reader and writers, in addition to high-frequency words, may need specialized types of vocabulary.

Because a lot of the research is focused on academic settings and classrooms, it is not surprising that a large number of empirical studies have looked at how vocabulary learning correlates with reading [Day, Omura and Hiramatsu 1992, Laufer and Rozovski-Roitblat 2011, 2014]. The review of the studies reveals that learning new words depends on the type of the task in which they are engaged and on the amount of exposure (for instance, how many times the words are encountered in the input). For example, when Laufer and Rozovski-Roitblat [2011] compared two tasks--reading a text with only occasional Focus on Form and reading a text with Focus on Forms—the task type was found too more important than the effect of word occurrence. These studies present important implications for vocabulary instruction and strongly indicate that vocabulary learning involves active noticing as well as practicing a word. Thus, relying on context in reading comprehension is not sufficient.

Today, as other language skills, vocabulary acquisition is mediated by many forms of digital technology, such as personal computers, digital reference sources, and mobile devices. Technology-mediated learning can be both teacher-mediated and independent. Meta-analysis studies, [Ebrahimzadeh and Alavi 2016, Elgot 2018] summarize the different types of research on technology-mediated vocabulary learning: specialized CALL software, digital reference resources such as online dictionaries, corpora-mediated learning, mobile learning, and others. From the 82 analyzed studies, only ten were related to digital games and gaming. The review of research in this area demonstrates that most of the technology-mediated vocabulary development studies focused on aspects of meaning-focused input and language-focused learning but not on the development of fluency. Elgot concludes that technology-mediated vocabulary development provides learners with opportunities for independent learning. In other words, language learners can set their own goals and the various contexts can help them notice new words.

Employing the concept of *enjoyment*, Ebrahimzadeh1 and Alavi [2016] investigated the effect that video games have on motivation in second language vocabulary learning. The authors claim that if learners enjoy playing a digital video game, their focused attention, persistence, and replays—all important in vocabulary learning--could increase and enhance the acquisition process. This particular study uses a sample of 136 Iranian high school learners of English as a foreign language, and participants were randomly assigned into two major treatment groups: Players and Watchers. The video game was *Warcraft III: The Frozen Throne*. Twenty-one simple and compound noun phrases were selected from the game, based on four criteria, for example, words that were required for playing the game or words that were needed for collecting the currency of the game. Interestingly, these words were not supposed to be known to most of the participants as they were not high-frequency and were not typical vocabulary items in their regular textbooks. The study found that enjoyment through the game was correlated with vocabulary learning, and the two different treatments (Players and Watchers) did not show statistical significance in the end. The researchers conclude that game-enhanced language learning correlates with enjoyment experienced by learners, and this, in turn, could increase their motivation and persistence.

Other studies of foreign language learning [Reynolds 2017, Sylvén and Sundqvist 2012] focus on the role of digital gaming in incidental vocabulary acquisition, revealing a positive correlation between the two, while Zheng et al. [2015] analyze how MMOGs, like World of Warcraft, can foster vocabulary learning by chatting online, including with a native speaker, and through the appropriation of resources for quests in the video game. In Zheng et al.'s study, Conan, who is a Japanese learner of English interacts with a native speaker to negotiate the meaning of unknown words. The researchers argue that, "the WOW sequence of vocabulary learning reflects the participatory, collaborative, and distributed nature of learning" (p. 786).

Although SLA is an interdisciplinary field—containing competing theoretical approaches and diverse contexts of learning and teaching—communication and interaction in the target language have become increasingly important to scholars and practitioners. Examining the literature shows that sociocultural approaches have emerged as dominant in the investigation of the use of videogames [Lantolf and Thorne 2006, Ryu 2013]. Lantolf and Thorne [2006], for example, embrace activity theory to illustrate the nature of language interaction, asserting that SLA necessitates interactions that are repeated, collaborative, and occur within the situated contexts.

Drawing on sociocultural theory, Thorne [2008] outlines a framework to help analyze computer-mediated communication (CMC) and specifically the use of videogames as cultural tools that provide contextualized, immersive environments for meaning making and negotiation of meaning. He argues that educational researchers, teachers, and students themselves must recognize that CMC provides important opportunities for scaffolding and improving intercultural communication. Drawing on a case study involving a Ukrainian player and an American player, Thorne stressed the potential for videogames to provide a heightened sense of engagement as videogames encourage goal-oriented activities.

Many of the studies have explored interaction mediated through multiplayer videogames. Peterson [2012] used a sociocultural framework to explore four English language learners' language usage and attitudes toward gaming in an English-based

massively multiplayer online role-playing game (MMORPG) environment called *Wonderland*. This predominantly qualitative study employed four participants between the ages of 23-25. One was from China, another was from Iran, and two were Japanese. The linguistic analysis centered on features of politeness as well as means of establishing and maintaining intersubjectivity. The study revealed that the participants' attitudes toward the game were largely positive even though they found the learning curve of mastering the game somewhat difficult.

In another study, Peterson [2016] conducted a critical meta-analysis of ten peer-reviewed research articles, five of which were from a sociocultural theoretical orientation, and another group of five from a cognitive orientation. Peterson found out that, so far, the use of videogames in SLA has proven to support key concepts in sociocultural theory, such as collaboration, assistance, and co-construction of meaning. Videogames, Peterson claims, can help provide communities of practice for language learners. According to the study, cognitive and sociocultural perspectives are crucial areas in the investigation of interaction in videogame environments.

Piirainen-Marsh and Tainio [2009], while choosing Conversational Analysis (CA) as the main approach in their study, similarly focused on how language learners participate collaboratively by playing a one-person console video game called *Final Fantasy X*. Two male Finnish-speaking English learners took part in the study. The authors utilized CA to investigate the participants' other-repetition of lexical and prosodic linguistic elements from the video game characters. Although the learners chose to speak in their native language, Finnish, Piirainen-Marsh and Tainio observed that that they also frequently used language play to draw attention to prosody and English vocabulary because of humorous aberrances in English pronunciation. The study claimed that even though only one player could control the in-game avatar, both participants were actively engaged in the social actions and goals they wished to complete.

Reinders and Wattana's [2014] work points to the importance of communication and interaction in second language as well. In their study on willingness to communicate, the two scholars focused on 30 English language learners in Thailand who played a closed version of the MMORPG *Ragnarok Online*. Although the Thai learners rarely used English outside of the classroom, they were very familiar with playing MMORPGs in their native language. The authors shared the results from pre- and post-test questionnaires in relation to six 90-minute lessons the English learners had. Specifically, Reinders and Wattana utilized a mixed-mode approach, combining the questionnaire data with transcripts of written and oral speech produced by the learners while playing game; they also analyzed interview data. The study claimed that students' willingness to communicate and their perceived communicative competence increased significantly compared to the pre-test survey.

1.3 *ELLE the EndLess LEarner*: Language learning in videogame

This paper describes a study designed to investigate the efficacy of an educational SLA videogame *ELLE the EndLess LEarner* designed by the interdisciplinary team of authors, each drawing from their areas of expertise. This game is designed to be easily modifiable for researchers, language instructors, and language learners to allow for investigating of specific aspects of SLA in structured experimental settings to investigate the impacts of various types of term formats, the role of embodiment, and

even the role of various aspects of player identity, all while also allowing instructors and students themselves to customize their learning experience.

This novel game is playable using both VR and PC platforms, and it was created to be an engaging way for second language learners to practice foreign vocabulary terms. Because motivation is such an influential facet of learning a language, it seemed logical to the team that a game that allowed players to practice vocabulary terms—a traditionally mundane task that can be viewed by less eager learners as drudgery—should encourage language students to more readily and more frequently engage in vocabulary practice.

ELLE the EndLess LEarner is a robust database-driven game that can be easily customized for players to practice vocabulary words, phrases, and even pictograms from any semiotic domain, regardless of language or subject. Vocabulary retention is often a challenge for language learners and a frequent frustration for their instructors. The "endless" nature of this videogame encourages repeated practice of terms in several formats (text, image, and audio) in a game environment, which the authors believe lessens the learners' fear of failure. The game continues until players make 3 incorrect matches; then it displays the player's score and players may play again.

Though plans are in place to explore socio-cognitive variables of domain language acquisition, language learner identity, and more, in its current iteration, *ELLE,* across modalities, is basically a translation game for vocabulary practice. In all 3 versions of *ELLE,* players are constantly in motion and have to select the correct translation for the term that appears. Currently, the possible matching media are English text to Portuguese text, Portuguese text to English text, Portuguese text to image, spoken Portuguese to English text, and spoken Portuguese text to image. Players gain 10 points for each correct match across platforms, and the door toward which their avatar is running opens. Incorrect matches lose 10 points and the avatar breaks through the unopened door. Additional corrective feedback is provided to the player by means of the term cards themselves: correct answers are shown with a checkmark overlaid on top of the term, and incorrect answers are shown with an X mark on them (Figure 1).

The VR version of *ELLE* has the player running straight through a rather sparsely decorated museum. The player is presented with a term (spoken in Portuguese, written in English, written in Portuguese, or an image) that must be matched with the corresponding image or text translation. The term to be matched is presented beside the door they are running toward, while the 3-5 match selections (3 for easy level, 4 for medium, and 5 for hard) appear above the door. They must use the handheld game controller to point and click a laser at the corresponding correct match over the door. If their choice is correct, the door will open. If the choice is incorrect, the door will remain closed and the avatar will simply 'break' through the door, to indicate to the player the inaccuracy of their choice. Additional game elements are included in this version—brick walls that players need to dodge by stepping left or right—intended to increase player engagement and embodiment by encouraging them to physically move throughout the game. Players earn 10 points for correct matches and 1 point for dodging each obstacle. They lose 10 points for incorrect matches and 1 point for not dodging an obstacle. During this time, the correct match is highlighted by a checkmark and the incorrect selections receive X marks over them to help the player understand the answer (Figure 1).

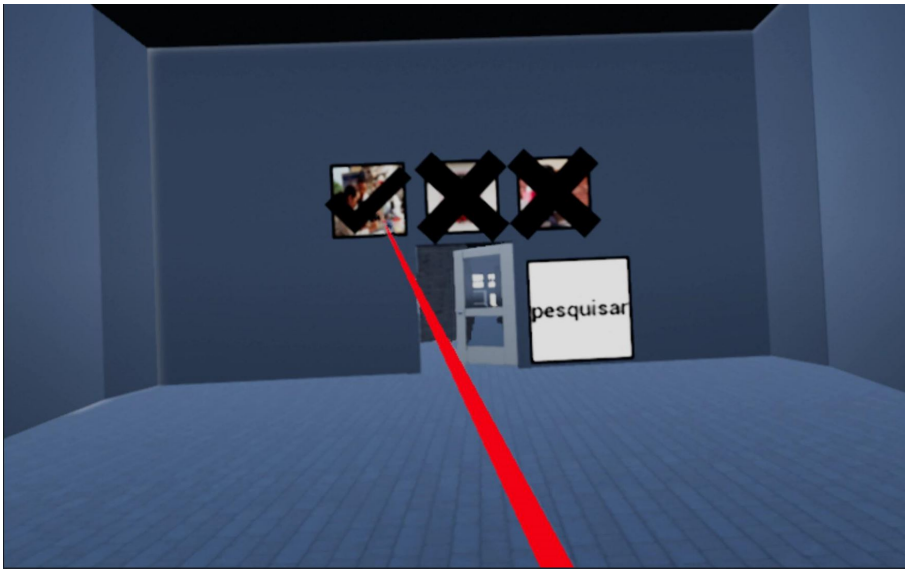

Figure 1: Screenshot from ELLE VR, incorrect match selected

In an effort to increase player engagement, additional obstacles were added in the game. The player must dodge virtual brick walls (VR and over-the-shoulder versions) or hurtle blocks (side-scroller version). Each obstacle that is avoided earns the player an additional point. Obstacles that are not avoided break apart, and points are not awarded. Obstacles such as these are common and expected in endless runner videogames, and the design team felt they would add to player motivation and enjoyment. The game will continue to randomly generate matching puzzles until the player incorrectly matches a total of three terms. At this point, the round ends, and the screen displays the player's total score, a list of the terms the player has matched, and the choices they were presented.

The PC over-the-shoulder (OTS) version of *ELLE* is played on a desktop computer but retains a similar point of view as the VR version (Figure 2). In the OTS version, the players' view is just behind their avatar, so they can see it running in front of them. To control the avatar in this game, players utilize the arrow keys to move left and right to dodge the same brick walls as the VR version. In this version, terms are presented above a series of 3-5 doors (3 for easy, 4 for medium, 5 for hard). Above each door is a possible translation option. To select a translation, the player must direct their avatar left or right into the corresponding doorway. If the selected term is correct, the door opens. If it is not correct, the door remains closed and the avatar breaks through it. Like the VR version, players earn 10 points for correct matches and 1 point for dodging each obstacle. They lose 10 points for incorrect matches and 1 point for not dodging an obstacle.

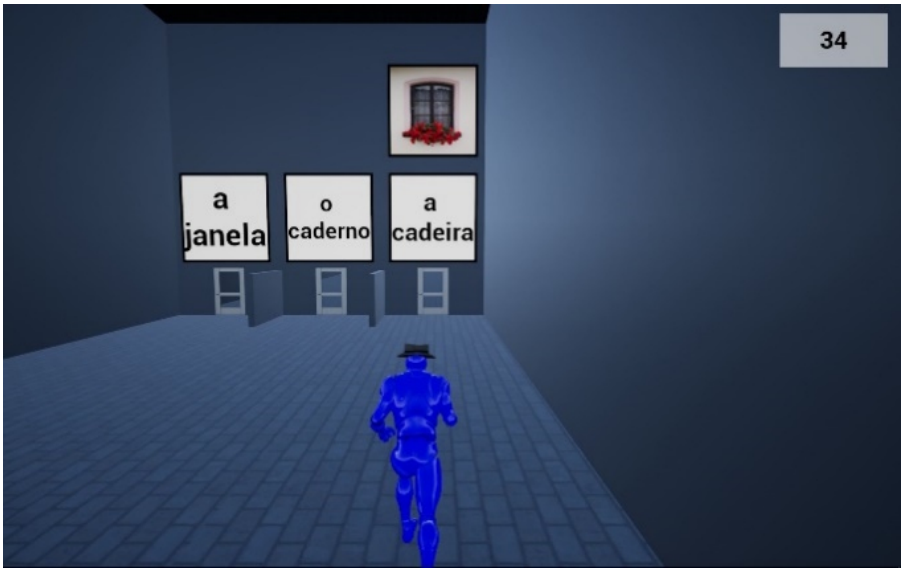

Figure 2: ELLE over-the-shoulder for PC, no match selected

The PC sidescroller version of *ELLE* is also played on a desktop computer but takes a side view of the avatar, which is continually running from left to right (Figure 3). This version has the player use the space bar to make the avatar jump over logs (in lieu of brick walls) and use the same key to jump when the term to be translated is directly under the correct match. This version went through several iterations to keep the controls intuitive but also allow the player adequate time to read the term and all of the choices. The version in the study appears to "jump ahead" of the avatar, presenting the player with the term and matches a few seconds before the avatar "arrives" at the puzzle. When the avatar reenters the screen, the term and its yellow arrow moves left to right under each of the 3-5 choices (3 for easy, 4 for medium, 5 for hard). The player must hit the space bar while the arrow is beneath the correct match. As in the other versions, if players select the correct match, the door opens for the avatar, and if they do not, the avatar "breaks" through the doorway. Like the other versions, players earn 10 points for correct matches and 1 point for dodging each obstacle. They lose 10 points for incorrect matches and 1 point for not dodging an obstacle.

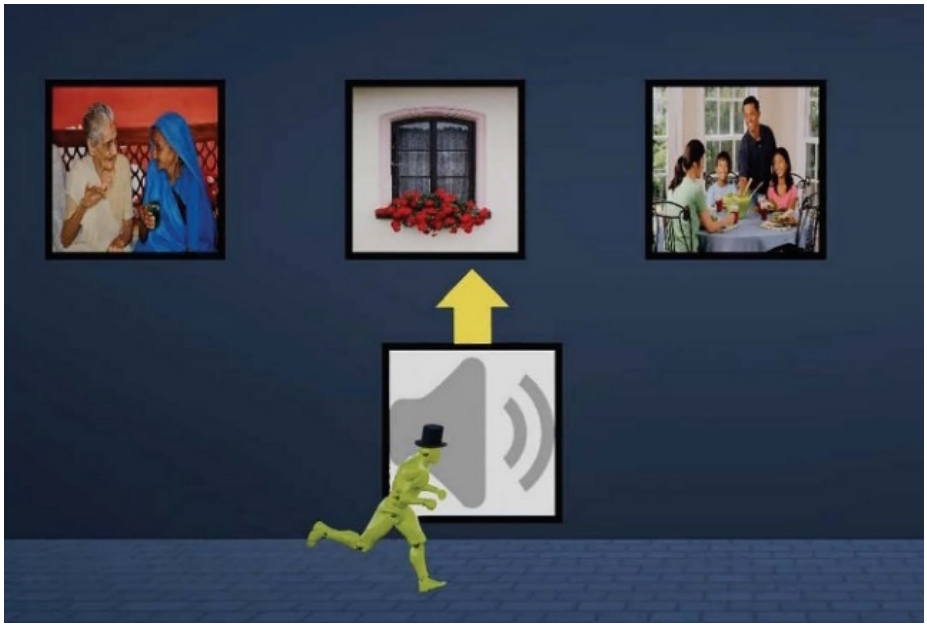

Figure 3: ELLE side-scroller for PC, match not selected

The control game, *This or That*, is a PC game that is played within our university's learning management system (LMS). Developed by our institution's Center for Distributed Learning, it is an electronic quiz game. The self-paced game presents the player with one term (English text, Portuguese text, or an image) and two choices for translation (Figure 4). The player uses the computer's mouse to click the image of their choice. There is no audio in this modality. Correct choices earn 1 point each, and incorrect images do not earn points. This game cycles through each of the terms 3 times (one image, one English text, and one Portuguese text) for a total of 30 questions and then concludes. Players in this study were asked to play again until their allotted 20 minutes of gameplay time was completed. This game was selected as a control because it is similar to physical and virtual flashcards, a common technique for studying terms for academic purposes. A commercial website popular with our students for studying, Quizlet (https://quizlet.com/) allows anyone with an account to create their own custom digital flashcards. The site boasts 335,784,000 study sets at the time of writing and 50 million monthly users (https://quizlet.com/mission). The authors selected the university-created *This or That* game for the control condition because it is so similar to this widely used format that students are likely to use to study on their own in the absence of other (even those potentially more engaging and effective) SLA activities.

Figure 4: This or That, no match selected

Thus, the four games, while containing the same basic mechanic of matching terms and translations across formats, have different user interfaces. *ELLE VR* players point and click handheld VR controllers while using their whole bodies to move left and right to avoid walls. *ELLE OTS* has players use the keyboard's left and right arrow keys; *ELLE SS* relies solely on the keyboard's spacebar, and *TOT* has players click with the computer mouse. These are summarized in Table 1 as an easy reference to the main input differences in each condition.

Condition	**Player Controls**	**Player Actions**
ELLE VR	handheld VR controllers	Point & click terms Physically dodge virtual walls
ELLE OTS	Keyboard arrow keys	Move avatar left and right to: select correct term doorway dodge walls
ELLE SS	Keyboard space bar	Make avatar jump to: select correct term avoid obstacles (logs)
TOT	Mouse	Select correct term

Table 1: User interfaces in each condition

2 Materials and Methods

2.1 Participants

This study was comprised of 69 adults (ages 18-over 57; 34 males, 30 females, 6 choosing not to indicate gender) actively enrolled in courses at our university. The study was unfunded, though some professors chose to offer extra credit in various courses for participation. Participants were asked to select one of four cards—each card listed one of the 4 study conditions, and all cards lay face-down on a desk. If a participant selected a condition that was already in use (only one VR headset was available in the lab), they were simply asked to choose another card. The 4 conditions included: a *VR* version of *ELLE the EndLess LEarner* (n=19), a *PC over-the-shoulder (OTS)* view of *ELLE* (n=18), a *PC side-scroller (SS)* view of *ELLE* (n=18), and *This or That (TOT),* a PC flashcard game that acted as a control condition (n=15). There were 5 participants not answering one or more user experience items, but because they had completed all of the items used in learning analysis, were excluded from the analysis of gameplay only and included in the learning analysis. One participant indicated that Portuguese was their native language, and so that participant's responses to the knowledge items were not included in the analysis, though they were retained in the gameplay analysis. A breakdown of demographics by condition is listed in Table 2.

Condition	N	Gender Identity	Racial Identity	Age Range
ELLE VR	19	10 Female 6 Male 3 No Response	2 African -American 5 Asian 1 Hispanic 1 Multiracial 10 White	10 age 18-24 5 age 25-34 2 age 35-44 2 age 45-56
ELLE SS	18	6 Female 11 Male 1 No Response	1 African-American 4 Asian 1 Hispanic 1 Multiracial 10 White 1 No Response	15 age 18-24 3 age 25-34
ELLE OTS	18	7 Female 10 Male 1 No Response	1 African-American 3 Asian 4 Hispanic 1 multiracial 7 White 2 No Response	10 age 18-24 7 age 25-34 1 age 57+
TOT	14	7 Female 6 Male 1 No Response	3 African American 1 Hispanic 1- Multiracial 7 White 2 No Response	11 age 18-24 3 age 25-34

Table 2: Demographics of participants by condition

2.2 Procedure

The three different modalities of *ELLE* used in this study were created using different builds from the same project base (the game-development platform, *Unreal*) and therefore consist of the same graphics and audio. They differ in the way the player controls the game as well as perspective the player sees. In the VR version, players do not see any avatar in their head-mounted display and use their bodies and handheld VR controllers to manipulate the game. In the PC over-the-shoulder modality, players see the back of the avatar's head and use left and right arrow keys to play the game. In the side-scroller version, players see the full avatar from the side and use the space bar only. *This or That* displays flashcards (the game has no avatar) and is played using the PC mouse.

All participants completed a survey that included items assessing their knowledge of the vocabulary terms in the game in addition to their expertise with non-English languages. Participants then played their randomly assigned game and completed a post-survey assessing knowledge of the same vocabulary terms as well as their gameplay experience and basic demographic information. Both the pre- and post-surveys were administered using a web-based questionnaire. Gameplay for all conditions was specified at 20 minutes, and the full study session had a duration of 30-40 minutes.

2.3 Learning and gameplay measures

2.3.1 Vocabulary items

All of the game conditions contained the same ten words, selected by the researchers from the textbook used by one of the authors in her university language courses [de Jouët-Pastré, C., Klobucka, A., Sobral, P.I., de Biaji Moreira, M.L., & Hutchinson, A. 2012]. These terms were specifically chosen for their ability to be depicted in picture form and for their dissimilarity to Spanish, which our initial study showed students at our university were particularly apt at guessing correctly on the pretest [Author 2017].

To assess vocabulary acquisition in each condition, we asked all of the participants to translate the ten words on the pre-test and post-test (Table 3). These items in the computer-based assessments presented the term in Portuguese and provided a blank box for the participant to type the English translation. These were scored as correct or incorrect (1 or 0).

Portuguese Term	English Translation
a cadeira	the chair
a caneta	the pen
a cartiera	the desk
a janela	the window
chato	boring
debaixo	under
falar	to speak
jantar	to eat dinner
o caderno	the notebook
pesquisar	to research

Table 3: Terms included in all game conditions

2.3.2 Gameplay items

We were interested in investigating a variety of aspects of participant perception of gameplay. Our post-test utilized items from the Game User Experience Satisfaction Scale (GUESS) asking participants to use the same Likert scale to report their satisfaction with a game in nine categories: playability, narrative, play engrossment, enjoyment, creative freedom, video aesthetics, personal gratification, social connectivity, and visual aesthetics [Phan, Keebler and Chaparro 2016] as well as a videogame immersion questionnaire [Jennett et al. 2008]. Both of these assessments ask participants to self-assess their level of immersion within the videogame in response to Likert-scale statements. To avoid testing fatigue, we selected a total of 31 items, including at least one from each factor but several more from the factors more relevant to study and improvement of the game (i.e. we selected several playability items but only one assessing social connectivity, as all of the game conditions were single-player). Because the measures were previously validated individually, we determined it unnecessary to additionally test the reliability and validity of the combined instrument.

3 Results

3.1 Vocabulary Acquisition

All groups improved their ability to provide the English translations for the ten Portuguese words (Table 4). The *ELLE* VR group improved their knowledge an average of 6.26 (*SD*= 2.35), while the *ELLE* OTS group improved 6.39 (*SD*=3.05). The *ELLE* SS group mean increased 7.82 (*SD*=1.88), and the control group had the largest increase of 9.14 (*SD*=1.10), (Tables 4 and 5).

For the knowledge items on the pre-test, the mean for the *ELLE* VR group was .26 (*SD*=.733), the *ELLE* OTS group mean was .11 (*SD*=.323), the *ELLE* SS group mean was .67 (*SD*=1.910), and the *TOT* group averaged .36 (*SD*=.633).

Condition	N	Pre-test *M (SD)*		Post-test *M (SD)*		Gain *M(SD)*	
ELLE VR	19	.26	(.73)	6.53	(2.48)	6.26	(2.35)
ELLE OTS	18	.11	(.32)	6.50	(3.13)	6.39	(3.05)
ELLE SS	17	.24	(.56)	8.06	(1.98)	7.82	(1.88)
TOT	14	.36	(.63)	9.50	(1.09)	9.14	(1.10)

Table 4: Pre-test and post-test knowledge items by condition

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	98.654	3	32.882	5.995	.001
Within Groups	356.515	65	5.485		
Total	455.159	68			

Table 5: ANOVA of learning gains

When knowledge gains were compared among the *number* of languages participants reported any experience with (any language they mentioned having any level of prior knowledge of on the pre-test), the mean increase is slightly higher for each additional language about which the participant reported listed as being knowledgeable in any capacity, ranging from 6.40 for those exposed to only one language other than their native tongue, to 8.80, for participants who listed having some knowledge of 5 different languages. We speculate that the process of learning a second language is likely similar to learning a third, fourth, etc. and that these participants may have the ability to scaffold their learning of the vocabulary in this study onto prior foreign vocabulary learning.

Interestingly, this pattern was not as noticeable when comparing knowledge gains to participants' self-reported language abilities. We used participants' freeform reporting of their level of experience with non-English languages to place them on an 8-point "language abilities" rubric. This rubric was author-created and attempted to further assess the data for any connection between prior SLA experience and learning gains in this study. Participants reporting knowledge of 4 or lower on a scale from 1-10 of one additional language were assigned a rubric score of 0. If participants reported their fluency in only one additional language as a 5 or above, they were rated a rubric score of 1, and so forth (Table 6).

Score	Language experience, rated on a score of 1-10 (with 10 = fluent)
0	One language, under 5
1	One language over 5 OR two languages under 5
2	One language over 5 AND one language under 5
3	Two languages over 5 OR one language over 5 and two languages under 5
4	Two languages over 5 AND one language under 5
5	Three languages over 5
6	Three languages over 5 AND one language under 5

Table 6: Language abilities rubric

3.2 Player experience

Players indicated on a 5-point Likert-scale their level of agreement to statements regarding their perception of the gameplay. Of the nine factors included on the GUESS [Phan et al. 2016], we were interested in the factors dealing with playability, play engrossment, enjoyment, personal gratification; as well as immersion, which was measured using items from Jennett et al. [2008].

A multivariate ANOVA (MANOVA) with the five dependent variables (playability, engrossment, enjoyment, gratification, and immersion) showed that Box's M was not violated, so Wilks' Lambda was used. The Wilks' Lambda of the player experience items was .477, F (3.117, 15.000) =152.232, $p < .001$ (Table 7), showing there are significant differences among groups.

Results of the test between subjects were significant for playability, engrossment, enjoyment, and immersion. Though the effect size for gratification was not significant at .05, a moderate effect was apparent at .079, which could be due to the small sample size (N=68) as well as the small number of items in this category (only 2).

Dependent Variable	df	F	*p*	Partial η^2
Playability	3	5.976	.001	.233
Engrossment	3	4.662	.005	.192
Enjoyment	3	4.172	.010	.175
Gratification	3	1.695	.178	.079
Immersion	3	4.284	.008	.179

Table 7: Between-subjects effects

Players found the control *TOT* game to be the most playable, followed by *ELLE* VR, *ELLE* SS, and *ELLE* OTS modalities. The VR version of *ELLE* was reported to be the most engrossing and enjoyable, followed by the *ELLE* SS, *ELLE* OTS, and TOT modalities, respectively (Table 8).

Participants rated the VR (M_Δ=.576, p=.003) modality as more playable than the OTS version, and the TOT (M_Δ=.638, p=.003) version as more playable than the OTS, though playability violated the assumption of homogeneity of variances (Levene's F (3,59) =2.792, p=.048). On the engrossment items, participants rated *ELLE* VR (M_Δ=1.075, p= .008) and *ELLE* SS (M_Δ=1.056, p=.009) higher than *TOT*. Similar trends were seen in player enjoyment, with *ELLE* VR (M_Δ=1.063, p=.012)

and *ELLE* SS (M_{Δ}=.972, p=.024) again ranking above *TOT*. Participants reported higher feelings of immersion for the *ELLE* SS (M_{Δ}=.815, p=.011) modality over *TOT*. No significant differences were found between the 4 conditions for the gratification items (Table 8).

	ELLE VR *M (SD)*		*ELLE* OTS *M (SD)*		*ELLE* SS *M (SD)*		*TOT* *M(SD)*	
Playability	4.788	(.383)	4.213	(.524)	4.589	(.547)	4.850	(.271)
Engrossment	3.686	(.960)	3.271	(.863)	3.667	(.750)	2.611	(.862)
Enjoyment	4.147	(.656)	3.625	(1.118)	4.056	(.889)	3.083	(.821)
Gratification	4.471	(.646)	4.354	(.970)	4.778	(.443)	4.250	(.653)
Immersion	3.719	(.472)	3.368	(.851)	3.963	(.620)	3.148	(.751)

Table 8: Tukey's HSD

4 Discussion

This study indicates vocabulary retention can occur effectively using videogames. All participants increased their ability to translate the terms included in the game from Portuguese to English. The differences in participant learning between conditions can be analyzed to suggest modifications to strengthen their teaching efficacy. The highest learning increase was seen by participants in the control flashcard condition, *TOT*. This game is an electronic simulation of a deck of 30 flashcards, with each term represented in the deck on three different cards. There are no walls or other game elements in the game between the terms; participants make their selection, the computer indicates if the choice was correct or incorrect, and the next term and pair of options appears. Players matched English text to Portuguese text, Portuguese text to English text, and Portuguese text to images. There was no audio in this game, and the assessment used to measure learning also did not include audio, so participants spent their full 20 minutes of allotted gameplay time viewing terms and images. All participants completed this game at least once during the timeframe and the majority repeated the game, viewing the full deck multiple times in the 20 minutes. Thus, they were exposed to each term more frequently, which presumably helps to explain these participants' higher scores on the post-test.

Without the distractions of the walls and the constant movement through the game, participants in this condition were better able to focus solely on the written terms and images. This aligns with work on cognitive load [Plass, Moreno and Brünken 2010]. It appears, however, that the lack of distractions had a negative impact on player engagement. This group's average engagement score was the lowest of any of the three conditions, and a few participants commented on their way out that they were glad they could finally stop playing that game. This is also demonstrated on the posttest item that asked participants to rate their agreement with the statement, "If given the chance, I want to play this game again." Average responses by condition showed TOT with the lowest agreement at 3.01, followed by ELLE SS at 3.67, ELLE OTS with 3.94 and ELLE VR with the highest agreement average of 4.11.

One of the main goals of most VR experiences is that of engrossment. With the positioning of the VR headset over the participants eyes and (with most models) headphones over their ears, participants are ostensibly unable to focus on anything other than the VR game. We see this as a potential benefit for educational games on this platform—when learners are be distracted by their phones, friends, or anything else, it stands to reason that they may be more effectively acquiring knowledge from the game. This is evidenced in the responses to the engrossment items (Table 7).

Similarly, it is important to note the differences in the frequency words are presented to players in the *ELLE* versions. In these games, the player's running speed increases when they successfully dodge obstacles (logs in *ELLE SS* and brick walls in *ELLE VR and ELLE OTS*). Therefore, it is reasonable to assume that players who were more adept at avoiding these obstacles moved through the game at a faster pace and therefore experienced more opportunities to practice vocabulary translation than players who remained at the slower starting pace throughout the game.

Because frequency of exposure to new vocabulary terms is an important aspect of learner vocabulary retention [Laufer and Rozovski-Roitblat 2015] this is an important aspect of the game conditions to investigate since it is likely that players who have some skill in videogame movement will interact with far more terms in the same amount of play time at the faster pace than their less adept peers. Future work will include pretest items asking participants to list gaming experience to fully analyze this observation.

Likewise, because the mean vocabulary gains were noted to increase with the number of languages participants reported having any level of prior experience with, a vocabulary acquisition game such as *ELLE* may better serve leaners with prior language experience, at least without prior instruction in the language they are acquiring in the game, as they experienced in the laboratory setting. On the other hand, this pattern may also simply be indicative of these participants' overall abilities to acquire foreign vocabulary terms – prior knowledge affords the content retention strategy known as scaffolding, where knowledge of similar content eases the learner in grasping and retaining new concepts by way of comparing and contrasting them to the prior knowledge (Gee, 2003). In the case of this study, players with more SLA experience may have drawn upon additional cognitive and metacognitive strategies for learning such information that they may have acquired during previous SLA experiences. This study was aimed at assessing the potential of the games to augment traditional language instruction. In this regard, we view the endeavor as a positive indication that when coupled with traditional language instruction in a university Portuguese language course next semester, rather than in isolation in a laboratory setting, it has great potential to enhance language learning.

Participants' reports of engagement are promising for the *ELLE* modalities. All 3 versions of *ELLE* seem to keep player attention, which is typically difficult to do using more traditional vocabulary practice methods—even some participants playing the control game appeared reluctant to continue playing *TOT* over and over for the full 20 min. Players in the VR condition of *ELLE* reported higher levels of playability and enjoyment than the other conditions. *ELLE* VR players also rated the game second-highest in play engrossment, personal gratification, and immersion. This metric is vital for an educational game like *ELLE*, as we intend for it to be used as out-of-class practice to reinforce the rich, contextual language instruction taking place

within the classroom, though it is important for future work to take into consideration the potential novelty effect of the new technology [Clark 1983].

5 Conclusions and Future Work

This study has informed future iterations of the game to increase the frequency of player interaction with terms, as well as fewer, less intimidating obstacles. While obstacles for players to dodge or avoid are common game mechanics and do seem to contribute to player engagement and enjoyment, they can also work to distract the player from the vocabulary element of the game.

Striking a balance between fun and educational content is a common issue for learning games. While players in the control *TOT* flashcard condition effectively acquired vocabulary terms, they reported that it was not as engaging, and some participants even seemed reluctant to continue playing for the full 20 minutes during the study. This lack of engagement suggests that students not participating in a research study will probably lack motivation to play this type of game on their own time. Our team is committed to creating an effective educational game that language learners will be eager to play outside of formal learning environments.

Future work includes larger sample sizes that take into account English language speaking proficiency as well as foreign language exposure. In addition, future work will seek to better adjust the frequency of words presented to the player (and tracking term exposure through gameplay data) modify of the obstacles mentioned above, increase a sense of cultural context within the three *ELLE* modalities, further capitalize on the affordances of the VR technology to include different and more meaningful motions within the game, and add measures to counteract potential novelty bias. Further work is also planned to help determine which combinations of verbal, textual, and pictorial representations of the vocabulary terms are most effective, or, perhaps most effective for specific levels of fluency and competency in the language.

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