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ABSTRACT

The rapid advancement of mobile and computing technologies has made the enjoyment of music in the video gaming experience more accessible and affordable, and has raised the interest of educators in the affordances of music-related games for informal music learning. This study aimed to examine the educational affordances of music-related games through content analysis. User reviews of music gaming mobile apps and video games were collected from two major digital distribution platforms and analysed to identify patterns and meanings related to their educational affordances and learning design. The findings reflected a sense of competence, autonomy and engagement resulting from playing video games, which motivated players to become self-directed learners in the context of informal learning. Several bias and limitations were identified, suggesting that an overreliance on video games may lead to unbalanced musical growth and incomprehensive musicianship training.

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KEYWORDS

Computer music; mobile apps; video games; educational affordance; informal learning

Introduction

Since computational and mobile devices have become indispensable parts of our daily life, the integration in teaching and learning is considered as a driving transformation in the educational realm. Computer-mediated learning approaches, such as blended learning and the 'flipped' classroom, are now commonplace in schools and higher education (Bonk & Graham, 2006; O'Flaherty & Phillips, 2015). Smartphones, tablets and computers are becoming more accessible to children and teenagers, who enjoy greater autonomy using these technologies for leisure and entertainment (Shifflet-Chila et al., 2016). It is also easier for them to access information and communicate, which unfolded the possibilities to learn in a self-directed manner within the informal learning context. This gives rise to the increasing engagement of video games for the younger generation, and the scholarly interest in its potential for informal learning, in particular, what players could learn during the gaming experience.

The use of game design elements in non-gaming contexts such as teaching and learning is known as gamification, which takes advantage of the stimulating effects of gameplay to increase the motivation to engage in uninteresting tasks (Deterding et al., 2011). In the educational context, gamification is an approach that increases the motivation and engagement of learners (Kiryakova et al., 2014). It is a method well suited to today's young learners, who have grown up with digital technologies and developed particular attitudes towards the learning process, and thus require novel and stimulating approaches to become active in their own learning

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(Annansingh, 2019). With the vast range and form of video games and gaming mobile apps now available in the commercial market, gamification has become a fashionable approach to informal learning worldwide (Chaika, 2020). The pedagogical use of games has also garnered increasing research attention (e.g. Dondlinger & McLeod, 2015; Kankaanranta et al., 2017; Pang et al., 2022).

The acquisition of music knowledge is different from that of other disciplines in which the former one also includes the training of multimodal sensory and auditory–motor skills that are unique to the learning of music, which might synergise particularly well with the interactivity and media-richness of video games and gaming mobile apps. They can also provide a private and virtual space for learners to work through learning difficulties in a safe environment (Nouwen et al., 2016). For example, music learners who are too shy to perform in front of others can engage with music through mobile apps while wearing headphones until they feel sufficiently comfortable and competent to perform (Hein, 2014).

Despite the potential of video games and gaming mobile apps for informal music learning, their educational affordances have yet to be fully examined. Although the effectiveness of music video games and gaming mobile apps in supporting creative learning outcomes is supported in the literature (e.g. Nouwen et al., 2016), there have been no in-depth studies of the relationship between music gaming design and educational affordances from the perspective of end users. In the context of the increasing importance of informal music learning through game playing, this article presents a study that uses content analysis to examine the educational affordances of video games and gaming mobile apps.

Theoretical and conceptual framework

This study is grounded in self-determination theory (SDT), which explains the motivation behind people's choices (Deci & Ryan, 1985). SDT focuses on the degree to which human behaviour is self-motivated and self-determined, as these properties are related to a person's inherent growth tendencies and innate psychological needs (Ryan & Deci, 2017). Similar to play and sports, video games are intrinsically motivating because players feel challenged, autonomous and engaged, who do not derive extra-game rewards or approval (Malone, 1981; Ryan et al., 2006). Once they are intrinsically motivated, they will spend more time and effort engaging in the gaming experience and unconsciously develop knowledge and skills related to the conceptual elements of the gaming content. Countryman and Rose (2017) argued that the intrinsically rewarding gaming experience has potential to explore students' needs for autonomy, relatedness and competence, thereby contributing to the self-determination of their music learning journey.

While involvement in the gaming experience can be intrinsically motivated, improved gaming design can enhance players' engagement with video games and, consequently, increase the opportunities for learning music through gameplay. In this study, SDT offers insights into motivating players through music gaming mobile apps and video games. While research building on SDT often incorporates scales and quantitative measurements (e.g. Cheng & Leung, 2020; Yip et al., 2023), qualitative studies that employ SDT have also been found in the existing body of literature, examining the relationship between players' motivation and their gaming experiences (e.g. Kahraman & Kazançoğlu, 2023; Yoo et al., 2022). Furthermore, there have been studies that employed content analysis, the research method adopted in this current study, to investigate the motivational effects of mobile apps and video games in different contexts (e.g. Choi et al., 2014; Neys et al., 2014). Content analysis can provide an understanding of the presence of autonomy, competence and relatedness, as described by SDT, in players' gaming experiences with music gaming mobile apps and video games.

Prensky (2001) proposed a digital game-based learning (DGBL) theory, which was grounded in SDT and argued that the entertainment power of video games can serve educational purposes. DGBL assesses the balance between learning and entertainment to realise the idea of intrinsic motivation: that learners can be self-determined and self-motivated when tasks are interesting and fit their

abilities (Gee, 2007). Indeed, music video games show their strongest educational potential when they make the work feel like play (S. Dillon, 2007).

DGBL suggests that commercial games can be educational even when they are not specifically designed for music learning purposes. For example, a player could develop his/her rhythmic skills by playing rhythmic games even though s/he has no intention to learn. Therefore, it is important to gain in-depth understanding of the educational values of music video games and gaming mobile apps for the effective incorporation in the teaching and learning process. This observation enables introduction of the concept of educational affordances, which refers to the characteristics of an artefact that determine whether and how particular forms of learning behaviour can take place in a given context of its use (Kirschner, 2002). Put in the informal learning context, the educational affordance of music video games and gaming mobile apps is the educational values that the players could perceive during their gaming experience (Cheng & Leong, 2017). This concept can be applied to examine the enhancement of musical skills and knowledge through gaming by investigating the interactions between players and video games (S. C. Dillon & Brown, 2010).

Literature review

Since the notion of gamification was coined in the early 2010s, the relevant scholarship has drastically increased, especially on its effectiveness in social and educational contexts. Hansen and Sanders (2010) addressed the association of video games with sedentary behaviours by studying students' experiences with exergames in physical education class, and found that active gaming can increase children's physical activity levels. Through the design and implementation of a gamification plug-in on an e-learning platform, Domínguez et al. (2013) found that students were more motivated to learn and achieved higher scores on practical assignments but also that they performed poorly on written assignments and participated less in class activities. Their findings challenged some common beliefs about the benefits of gamification, which could be a double-edged sword in the teaching and learning context. Fitz-Walter et al. (2011), who designed and implemented a gamified application presenting information about orientation to first-year university students, drew similar conclusions. They argued that the addition of gaming elements can be enjoyable but might encourage undesirable use if the technology usage is not properly enforced. Given the importance of balancing learning and entertainment when embedding game elements into learning, many practitioners and scholars have also proposed approaches to deploying learning materials seamlessly and effectively into game content (Rosyid et al., 2018).

The music game genre is distinct owing to its interactive and creative elements, which support a range of different styles of gameplay (Soszyński et al., 2016). The genre can be further divided into the generative and reactive subcategories, with the former focusing on the creation or modification of music being played and the latter involving the influence of pre-defined musical content on game dynamics (Soszyński et al., 2016). Hein (2014) argued that most overtly educational music games explicitly focused on the educational aspect, without including sufficiently entertaining elements to motivate learners and facilitate the learning process. These included gaming products for 'drill-and-skill' practice, identifying intervals and scales, and reading and writing musical notation. He addressed the imbalance of learning and entertainment by suggesting good practices of music games for education, including interaction with generative music systems, avoiding a blank canvas, encouraging play with music tools outside of the game and motivating the creation of music within the gaming experience.

Scholarship investigating the effectiveness of music video games and gaming mobile apps for educational purposes has emerged alongside the growing trend of gamification, including both generative and reactive games. Through the investigation of players' experience in two music video games, Studley et al. (2022) explored the interplay of real-time music creation and competitive gameplay. They found that music video games can be simultaneously competitive and creatively stimulating, where the competitive elements can support music creation for players. Raziūnaitė et al.

(2018) designed an educational mobile app for preschool children and revealed the learners' interest in exploring and creating musical sounds in their first experience of music education. Lesser (2020) conducted a pre-post-test study to examine the effectiveness of DBLG for music education and found that participants who had access to educational video games with the assistance of an instructor achieved better learning results. Gower and McDowall (2012) interviewed music teachers and children about the use of music video games as educational tools. They responded positively that music video games may help develop music skills and knowledge and can possibly be incorporated into the music curriculum. The music teachers acknowledged both the affordance and limitation of the gaming technology, particularly for its weakness in helping students to create and compose. Further improvement is needed to improve the capacity of music video games for a greater educational affordance. The pre-post-test study conducted by Kang and Ritzhaupt (2021) provided further evidence for this argument. The study compared students' learning achievement between web-based and game-based music learning environments, in which the former group yielded better academic achievement. It indicated that extraneous gaming features not directly related to learning have to be eliminated at the instructional design stage to prioritise educational goals. However, how such elimination would affect the gameplay was not discussed.

Soszyński et al. (2016) proposed and implemented several approaches to incorporate music information retrieval (MIR) methods as an educational tool into the design of music video games. They suggested that the application of pitch-tracking, onset detection, instrument recognition and other MIR approaches could provide novel forms of interaction within music games that offer new possibilities for musical skills development, and improved accuracy in targeting the different learning needs of particular age groups and learning levels (Soszyński et al., 2016). Denis and Jouvelot (2004) argued that gamepads were appropriate user interfaces for enabling the music gaming experience without being hindered by the limitations of real instruments and emphasised that music video games could increase learners' motivation, foster collaboration among players and improve learners' abilities to express creativity. Darrow (2012) compared the gaming experiences between persons with typical hearing and hearing losses, using *Guitar Hero*, a reactive music video game as the medium. Despite not being able to listen when playing the game, no significant differences were found between the scores of the two groups. This finding suggests that music video games can be a viable means of musical expression and music-making for people with hearing loss.

Although studies have been conducted on the use of music video games and gaming mobile apps for educational purposes, investigations based on the concept of educational affordances have been rare; only a small body of research has been identified in the game-based learning context (Pawar et al., 2020), while the majority of work focuses on other learning areas such as music theory and composition (e.g. Bell, 2015; Gall & Breeze, 2005; Gutierrez, 2019). Cheng and Leong (2017) examined the educational affordances of music software for classroom teaching and learning from the perspective of music teachers and software developers. They revealed that a lack of cross-disciplinary knowledge sharing had led to poor learning designs in the music software development process, which could be improved through more effective cross-disciplinary collaboration (Cheng & Leong, 2017). Mooney (2010) proposed a model for examining the relationship between non-music tools and technologies and their affordances for music-making, which could be applied to the music teaching and learning context. Given the dearth of research into the educational affordances of music video games and gaming mobile apps, this study fills a gap in the literature in the interdisciplinary area of music education and digital game-based learning.

Aims and research questions

Since SDT determines that players are self-motivated and can unconsciously develop music knowledge and skills, an in-depth understanding of what learning could be afforded within the gaming experience can help better inform the gamified approaches in music teaching and learning. This

study examined the educational affordances of music video games and gaming mobile apps to shed light on the better gaming design to improve for educational purposes and how gaming experiences can benefit music learning. The following research questions guided the study:

- (1) What musical knowledge and skills can be developed through the music gaming experience?
- (2) What are the educational affordances of music video games and gaming mobile apps from the players' perspective?
- (3) How can the use of music video games and gaming mobile apps support music learning?

Methodology

Content analysis, which is a systematic process of deriving meanings, intentions, consequences and contexts from content (Downe-Wamboldt, 1992), was adopted to examine the educational affordances of music video games and gaming mobile apps from the players' perspective. Reviews posted on major digital distribution platforms were retrieved as the data source, and content analysis was used to provide an objective, systematic and quantitative description of the manifest content from this large amount of behavioural data (Berelson, 1952). In this study, music video games and gaming mobile apps are defined as those that require players to evoke or create musical sound (Collins, 2013), incorporate formal elements that are inherently musical in nature (Austin, 2016) and provide progressive levels of difficulty and rewards for success and persistence (Gower & McDowall, 2012). Games that do not meet these criteria were excluded from the data analysis.

Data source

The data source was public reviews of music gaming apps and video games posted on the major digital distribution platforms using their official feedback mechanisms. Steam and the Google Play Store were selected as the music game digital distribution platforms from which the data were harvested. Both of these platforms make players' feedback available, in the form of ratings and reviews of individual games, to provide references for other players to consider before commencing a purchase or download.

Steam is the largest digital distribution platform for personal computer games and provides game installation and automatic updating for its clients, alongside other services such as digital rights management, server hosting and social networking (Sifa et al., 2021). The platform had more than 53 million monthly active players in 2017 and over 30,000 games available for a variety of operating systems and consoles, including Windows, MacOS and most of the available virtual reality (VR) consoles (Bolding, 2019; Supor, 2017). Google Play Store is a digital distribution service developed and operated by Google for its Android operating system, the most widely used mobile operating system with more than two billion monthly active users and three million apps available in 2017 (Protalinski, 2017).

Data collection

Data were collected by using the corresponding application programming interfaces (API) to request the desired data from Steam and Google Play Store. Reviews were collected from games with the 'Music' tag on Steam. On the Google Play Store, music gaming apps are categorised as a subcategory of 'Games', differentiating them from music apps that are not games. For the purposes of this study, only reviews of music apps in the 'Games' subcategory were collected. 'Music' tags on Steam and the categorisation of music games on Google Play Store are assigned by the developers or publishers.

The data harvesting process was performed in mid-April 2021, and two days were needed to collect 242,060 reviews of 282 music games on the two digital distribution platforms. Of these reviews 28,854 were sourced from video games on Steam and the rest were sourced from music

Table 1. Number of reviews and music-based games on Steam and Google Play Store.

	Steam	Google Play Store
Number of music games	224	58
Number of reviews	28,854	213,206

gaming mobile apps on the Google Play Store. [Table 1](#) shows the numbers of reviews and music-based games on the two digital distribution platforms.

Data analysis

A theory-driven approach was selected as the coding method because this study brings the remote concept of educational affordances into the analysis of music video games and gaming mobile apps. This approach involves generating codes using existing theories and concepts; reviewing and revising the codes; and determining the inter-coder reliability (Boyatzis, 1998). The research team first reviewed the relevant literature concerning the theoretical and conceptual frameworks adopted for the study, and then arrived at potential codes and their definitions through discussion. The code labels were then revised according to the data collected in order to fit in the context. A custom list of code labels was created (see [Table 2](#)), in which word variations (know, knew, knows) and synonyms were catered for in the look-up process. The list of code labels, and their variations and synonyms, were used to filter out irrelevant data, leaving data relevant to the theoretical and conceptual frameworks of this study for further analysis. The computer-aided text analysis (CATA) software package Linguistic Inquiry and Word Count (LIWC) was used for matching code labels to the textual data. Reviews that contained relevant information were further analysed by the research team to compile a set of recurring ‘themes’ by literally interpreting the text as guided by the frameworks of this study, during which the team members met to discuss and refine the screening protocol. Different interpretations and discrepancies were resolved through discussion until the inter-coder reliability score exceeded 90% (Krippendorff, 2004).

Limitations

There are several limitations acknowledged by the research team. The wide sample of data collected in this study was sourced from the reviews of games under the music category on the two digital distribution platforms. Whether a game was categorised under music depends on the decision by the developer or publisher, but not any agreed standards. The aforesaid

Table 2. Code labels for the extraction of data from music game reviews.

Accredit	Convergent	Learn
Advise	Curriculum	Motivate
Afford	Develop	Music
Appraisal	Discipline	Pedagogy
Apprentice	Divergent	Problem
Assertive	Education	Self
Assess	Enhance	Semiotic
Attain	Enrich	Situate
Aural skill	Evaluate	Subject
Autonomy	Feedback	Summative
Benchmark	Formative	Syllabus
Blended learning	Improve	Tacit
Construct	Instruct	Teach
Cognitive	Instrument	Train
Competence	Knowledge	Tutor

definition of music video games and gaming mobile apps is not exhaustive, and it may exclude certain games that have potential for informal music learning. Additionally, there are games available on other digital distribution platforms, such as the Epic Games Store and the App Store for Apple devices, for which the research team did not have access to the API for extensive retrieval of reviews. While many games are distributed across multiple platforms, the research team believes that these two digital distribution platforms have covered the majority of music video games and gaming mobile apps necessary for gaining insights into their educational affordances.

By employing content analysis on existing data that were not originally generated for addressing the research question of this study (Vartanian, 2011), the research team acknowledges that they have no control over the data quality, which may include biased views from reviewers. Anyone can register an account and add a review on the two platforms, even if they are not good at playing video games or knowledgeable about music teaching and learning. While the learning behaviour and approach may vary based on the age difference among music learners (Crowther & Durkin, 1982), the age of the reviewers was not publicly accessible. These may pose validity issues to the findings, and suggestions for future studies should follow.

Findings

Motivation

The players' reviews reflected the stimulating effects of music video games and gaming mobile apps for music learning. These include the desire to attain higher scores within the games, which usually requires drills and practice in the gaming exercises that train the music skills of the players.

By far my favourite mobile game out there! You can see just how much effort they put into this game. Every song note is meticulously matched to the music and leaves me feeling great after scoring a S. (Reviewer A on *Cytus II*)

Addictive rhythm-based game ... Gameplay-wise the leveling system with unlockable characters/skins keeps one motivated in the long run. Each character/skin has different benefits for the gameplay and enables the player to reach an even higher score. (Reviewer B on *Muse Dash*)

Apart from the extrinsic motivation that is offered by scoring, the reviews also revealed the intrinsic motivational effect of being rewarded by the improvement of music skills within the gaming experience.

This isn't really a game I would play just for fun, as I'm not super into the whole exercise phenomenon, but you should buy it anyway. I certainly feel like I'm getting some much-needed exercise into my daily routine, and it is definitely a motivational way of working out with a great feeling of personal progress. (Reviewer C on *BOXVR*)

Elements of gamification were also mentioned in the game reviews, indicating the motivational effect of being stimulated to learn through the gaming experience. One example is the incorporation of digital storytelling into the music training process.

The game uses a simple but entertaining way to teach players musical knowledge ... The story is touching and funny at the same time. For [the] non-rhythm game player that suffers from the difficulty, don't worry. There is an option to lower the difficulty or even disable the gameplay just to listen to songs and experience the story. (Reviewer D on *Rhythm Doctor*)

Teaching resources

Game players revealed a vast range of resources that had facilitated their music learning process. One very important characteristic of the game-based learning approach is its interactivity, which sets it apart from traditional teaching resources, such as books and videos.

The Lessons portion of the software actually teaches you, in a very interactive manner, things you need to know to play guitar, as well as own them and take care of them. . . . It'll teach you what you need to know, and coach you with advice such as 'It sounds like you have a finger touching the G string' . . . 'try it again, being sure your second finger is only touching the string(s) it should be'. (Reviewer E on *RockSmith*)

The latest technological developments have also been incorporated into the game designs and have improved their effectiveness for music learning. These include, among others, the use of artificial intelligence (AI) for real-time feedback, music information retrieval (MIR) techniques with assessment for learning and VR for simulated learning.

The new version [of this game] is much more polished and [has] lots of new fun features [compared with] the first release. Arcade games are better and the learning process for each song has improved too with feedback and recommendations after you play, [and there are] built-in video lessons from professionals that you learn at your own pace. (Reviewer F on *RockSmith*)

Even though you don't get the feedback of hitting a real surface, it still feels like you are playing the drums and certainly the timing and spatial aspects would transfer to real life. I'm using Vive Trackers on my feet to work the high-hat and bass drum. They controlled the pedals as soon as I turned them on – no setup required... It is probably a good tool for drummers to practice new techniques quietly or when you don't have access to your drum kit. This would also be good ported to the Oculus Quest – bring it to work to practice at lunch break, for the college dorm, etc. (Reviewer G on *Paradiddle*)

No more mashing on coloured buttons rhythmically on cheap toy controllers, because *Rocksmith* lets you use real guitars and basses to play along and learn songs. It reads the output of your instrument, so it knows if you are playing the right notes or not at the right timing. This is incredible for noobs – beginners just starting out who want to learn a few popular songs – because *Rocksmith* is less of a game and more of a gamified teaching tool. It tracks your progress, adapting to your apparent skill level, so you will see a few notes flying on the screen at first, but if you play more notes, *Rocksmith* doesn't punish you, but instead decides to display more and more notes until the full guitar/bassline is finally revealed. (Reviewer H on *RockSmith*)

For those with prior music training and/or instrumental learning experience, music video games and gaming mobile apps were able to substitute for some of the roles of teachers, especially with the stimulating effect of the gaming experience.

I love music and after my music teacher presented this app to me, became obsessed with it. Super recommended! (Reviewer I on *Incredibox*)

I would almost say that this could be a full supplement for traditional guitar tutoring, with a combination of typical tutorials and a fantastic Guitarcade which gamify all the fundamentals and muscle memory training in a sometimes cheesy, but very effective manner, before getting you to the pièce de résistance. (Reviewer J on *RockSmith*)

Autonomous learning

Referring to the smooth learning curves and the vast array of choices offered, the reviews demonstrated the affordances of music video and gaming mobile apps for players to become autonomous in their music learning progress. Players appreciated being able to control the learning pace and modify the learning experience at their will.

You will absolutely learn how to play guitar exactly the way how it is supposed to be played. You can learn at your own pace and modify the learning experience to meet any need that you have. If the song is too fast, you can slow it down; too many notes, [it] lets [you] break it down and remove a few; or if you want to really learn a groove you can put it on repeat. The song library is generous for all genres and the downloadable content is well worth its price . . . If you want to play bass but only own a guitar, the game can also emulate bass. This is the perfect education program to get into learning guitar. (Reviewer K on *RockSmith*)

One unique learning characteristic of games over traditional methods is the ability to develop motor skills before performing in front of others, which most beginners lack confidence in doing.

It is not a music teacher, and it can't spot things that you're physically doing wrong, but this will teach you more than enough to be confident in picking up a guitar at a party and playing in front of everyone. (Reviewer L on *RockSmith*)

This fine piece of educational gam[ing] really helps you [take] it up from where you left off. I don't know if it would let you learn from zero but if you learned at one point and want to continue but don't have the courage, this game might be the thing that you need. The session mode is awesome if you don't have a band to train with. (Reviewer M on *RockSmith*)

The reviews also reflected game players' self-directed learning through the gaming experience. They were able to learn instrumental skills with the music video games on their own while enjoying the learning process.

I will add that this is currently the only way that has helped motivate me into learning an instrument. I have tried to self-teach ... the piano, drums, etc... I could never learn proper notes on a sheet, let alone get used to the hand positions and hitting the right notes, etc... I can see this game becoming quite fun once I start getting pretty good at it. (Reviewer N on *RockSmith*)

[This game] can teach you how to play guitar with no prior experience. It is not going to teach you perfect technique, but it will get you started on the basics. ... It provides the motivation, enjoyment, and sense of progression to keep you playing (and learning), and while I'm by no means 'good' after 100+ hours, I'm definitely learning, improving, and having a lot of fun. (Reviewer O on *RockSmith*)

Levels of learning

There were different views on the appropriateness of gaming applications and video games for different learning levels, with contrasting views found within comments on the same game. For example, the reviews of *Rocksmith 2014* were mixed in terms of whether it was suitable for learners at different learning levels.

Don't go into this game thinking it's going to teach you how to become a guitar god or something like that. This game is more suitable for beginners than it is for intermediate players. The songs sound accurate but there are weird note positions that make simpler songs more awkward to play. The game is good for finger exercises and muscle development but not that good at ear training and/or teaching more complex guitar techniques. (Reviewer P on *RockSmith*)

I would not recommend it for somebody who has just bought a guitar and is just now learning simple [techniques] because one could become entirely dependent – for learning – upon the mechanisms in the game instead of learning to read sheet music or tab. Anybody who has played for more than a month would most likely benefit from it assuming he/she had sufficient knowledge on basic chords and an elementary understanding of scales. (Reviewer Q on *RockSmith*)

Would I recommend someone brand new to guitar to buy this game and learn using this game? No. What I would recommend is to take actual guitar lessons and familiarise yourself with your instrument and develop good techniques prior to buying this game. This is a tool that helps already experienced players learn more about their instrument and it makes learning new songs a lot easier. (Reviewer R on *RockSmith*)

However, there was a consensus on the need to supplement the games with other teaching resources for a more comprehensive learning experience.

With practice and dedication, you will be a better guitar or bass player, and after that if you still want some proper music education you can always pay for lessons or a teacher, but you won't be struggling anymore with the basics and your teacher will see that you're not a beginner. (Reviewer S on *RockSmith*)

This game rocks, literally. [It is] great for motivating you to practice. You will need to seek additional instruction outside the game if you choose to continue your musical journey, but this is a fun way to get started and is useful for both the beginner and long-time player. (Reviewer T on *RockSmith*)

I think the software cannot stand [on] its own. It is an add-on to other more traditional sources of learning. Get to know tabs with a teacher or online learning. I think the software is good to either learn some basics or have it as a kind of add-on. (Reviewer U on *RockSmith*)

Music knowledge and skills development

The reviews alluded to how music knowledge and skills were embedded into the game elements, which scaffolded players' prior gaming experience for a smooth learning curve within the games.

The game is really simple, but it's anything [but] easy – new mechanics and new tempos are introduced with nearly every level, which keeps the gameplay engaging and entertaining. These new mechanics keep the game challenging and can even help teaching new things to the player, as all of these mechanics are rooted in music theory. (Reviewer V on *Rhythmic Doctor*)

While both practice- and theory-based music knowledge and skills were mentioned, much of the learning context was related to drills and practice as the player moves through different levels and stages within the gaming experience.

A cute rhythm game that doesn't hold back. It gets up there in difficulty, but you learn muscle memory over time, [and it] never gets any less fun. (Reviewer W on *Space Channel 5: Part 2*)

It developed my hand eye coordination as well as learning classic and contemporary pieces. It isn't easy to keep up with the speed the game is programmed. It helps to know the music, It is quite addictive in the sense that you try to improve and compete with yourself... Fun and stimulating. (Reviewer X on *Dream Piano – Music Game*)

In other words, the achievement of higher levels and scores within the competitive gaming environment has stimulated players to sustain their music learning journey.

slowly improving and achieving higher and higher scores as well as pulling off difficult block chains is so satisfying. (Reviewer Y on *Beat Saber*)

I love rhythm games of all types, and this one is one of the better ones I've played. It is very well made and has lots of features, although it's a little confusing at first, learning how to level up stars and get higher scores. It's really fun to play and I recommend it to anyone who loves rhythm. (Reviewer Z on *TAPSONIC TOP – Music Grand prix*)

Many of the reviews left by game players reflected on the effectiveness of drills and practice on the development of instrument-playing skills. They mentioned the affordability of current gaming technology that allows real musical instruments to be used instead of simulating instruments with gaming controllers, which greatly increases the transferability of the instrument playing skills from gaming to the real world.

It is both a game and [a] learning tool for use with a real electric guitar or bass. You plug in your guitar to a USB port with a special cable and can play through step by step guitar lessons, learn specific songs and riffs and play a variety of arcade style games with your guitar as the controller. (Reviewer AA on *RockSmith*)

The game also comes with a collection of arcade-style games designed to help you develop muscle memory, [and] teach you chord names, fretting, scales, bends and harmonics. (Reviewer BB on *RockSmith*)

Limitations

Despite the possibility of using real musical instruments for console and PC games, some still rely on gaming controllers, which does not offer an authentic experience of making music with an instrument.

I am a drummer and would have to relearn drumming to play this game. Missing lots of notes that should be easily hit if it was real drums; so personally, I can't get into this game. [I] might change my recommendation if I have the time to relearn muscle memory. (Reviewer CC on *Ragnaröck*)

If [your] budget [is] tight, and [you] still want to learn, this program can help. But bear in mind, just because you can play drums on this program does not mean you can play them in real life. (Reviewer DD on *DvDrum, Ultimate Drum Simulator!*)

While the educational affordances were identified by many players, some reviews mentioned that the learning experience could not substitute for teachers or instructors.

Before it came out, I was expecting this game to make me a decent guitar player. I thought that I would be getting a combination of a computer game with scoring, levels and such, and a professional guitar teacher. Yet, after spending many hours on it, I can safely say that it is mostly a game and less a teacher. (Reviewer EE on *RockSmith*)

Some reviews also reflected on the deficiencies of music video games and gaming mobile apps in terms of teaching particular aspects or techniques, because limitations of the technology and the gaming context do not favour the development of certain kinds of music knowledge and skills or of musical expressiveness and creativity.

It is great and fun, and will benefit [your] understanding of individual songs, but you may not understand how they were written and other fundamentals. (Reviewer FF on *RockSmith*)

There are also sections where you are asked to compose your own song/jingle which is cute. However, I thought it was a missed opportunity to have a pre-planned song for people with limited musical abilities. (Reviewer GG on *Wandersong*)

I am an actual pianist trying this game for fun. I think playing this game and my own habits in music made me realise there is a bigger problem with the way we teach music. Music is an expressive art form but following notes and robotically clicking away takes the art out of it. I do not feel like it is my feelings that make the tree grow. I feel like I am a machine for translating #REALMUSIC made by a #REALARTIST into key presses. (Reviewer HH on *DEEMO -Reborn-*)

Discussion

The findings of this study reveal the educational affordances of music video games and gaming mobile apps, and the ways that players develop their music knowledge and skills through the gaming experience. The reviews reflected feelings of competence, autonomy and engagement resulting from the gaming experience, which provided intrinsic motivation to the players to become self-directed learners, as proposed by SDT in the informal learning context (Nouwen et al., 2016). Popular music video games and gaming mobile apps equipped with a smooth learning curve can scaffold players' learnt skills and ability level while becoming progressively more difficult at different stages of the gaming process, allowing for the balance between learning and entertainment considered necessary in DGBL theory for learners to become self-determined and self-motivated (Gee, 2007; Prensky, 2001).

Although many people have effectively used music video games and gaming mobile apps for educational purposes, especially owing to their stimulating effect, several biases were revealed in the findings of this study that must be considered when relying on games for music teaching and learning. DGBL has its roots in informal learning outside the classroom context, which is based on personal choices and preferences (Green, 2005), rather than the comprehensive approach adopted in structured and formal learning, which covers all of the necessary components of a music education. This was well reflected in the findings of this study, as the most popular games with the most reviews were all associated with popular music, including the extensive use of rock and pop music for training on band instruments. While Denis and Jouvelot (2004) argued using gamepads to play music can help bypass the prior instrumental skills needed for music-making and lead to greater enjoyment, the players reflected that the use of real musical instrument, as afforded by the gaming technology, can also result in a stimulating edutaining experience for different learners. They were able to develop instrumental and rhythmic skills through the gaming experience, which echoed with

the findings by Gower and McDowall (2012); however, the question for how the gaming technology could help learners create and compose music has also been raised, as the reviews reflected a limited development of players' musical expressiveness and creativity. Subject matters that are less suited to gamification, such as music history and world music (Prendergast & Robinson, 2020), went unmentioned and were not addressed in the content of the games offered on the digital distribution platforms. An overreliance on music video games and gaming mobile apps as an informal learning approach might therefore lead to unbalanced personal musical growth and fail to provide the comprehensive musicianship training that is fundamental to music education (Willoughby, 1990).

The use of music video games and gaming mobile apps for the purpose of music education should therefore be supplemented with other teaching aids and resources or serve as a supplement to other regulated learning approaches. This argument is partly based on the aforementioned bias of overemphasising personal preferences in music learning, and partly on findings from reviews reflecting on the diverse needs of music learners at different stages. Although games might facilitate self-directed learning to a certain extent in players with different levels of prior knowledge and different skillsets, they have limitations that prevent learners from being entirely self-determining without other learning support. These include technological limitations that restrict the full assessment of a player's performance and biased gaming designs that prioritise entertainment over musical correctness. The reviews left by game players indicate that they were aware of the limitations of video games and gaming mobile apps for music learning, which should be supplemented with formal instruction by teachers and tutors or by using teaching videos and other online resources. These are appropriate for stimulating learners, especially to engage in the repetitive drills and practice that are required when learning a musical instrument.

Although educational affordances were identified in music video games and gaming mobile apps, their limitations and the priorities of game developers may hinder the music learning process and affect the quality of learning. These games, even those aiming at the educational market, are commercial products that have profitmaking as their top concern (Cheng, 2013). Self-awareness of what and how to learn when using games for music teaching and learning is important to avoid the undesirable use of the gaming technology (Fitz-Walter et al., 2011), either on an individual basis or within situated learning contexts. These could include prior knowledge of the music learning process and the musical content, acknowledgement of the technological limitations, and awareness of the learning needs and behaviour of individuals or groups.

Conclusion

Informal learning is becoming increasingly important in music education. As the ever-advancing computational and mobile technology makes it possible for learning to take place anytime and anywhere (Sarraf et al., 2012), the extreme circumstances of the global pandemic have catalysed the adoption of digital technology for music teaching and learning (Camlin & Lisboa, 2021). This is not only transforming the meaning of music and music education in the digital era (Cheng, 2019) but also augmenting and diversifying the realm of music teaching and learning. This study of the educational affordances of music video games and gaming mobile apps in music learning revealed their learning characteristics in the development of specific music knowledge and skills and the motivational effects of these games on players' self-directed learning.

The use of video games and gaming mobile apps could supplement formal and regulated music learning, provided that inappropriate applications of technology are safeguarded against to avoid undesirable learning outcomes. As the involvement of mobile and gaming technologies increases in our daily lives and in educational contexts, the usefulness of adopting commercial software for teaching and learning has been questioned in the research and practice of music education for more than a decade (Gouzouasis, 2005). Given the 'digital turn' in music education under the current circumstances of COVID-19, future research directions informed by this study could include the development and adoption of new or existing frameworks dedicated to informal music learning with

video games and gaming mobile apps, and the investigation of the effectiveness on music learners of different age groups and music competence using quasi-experimental or qualitative approaches.

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