

Received: 28 February 2021

Accepted: 20 May 2021

DOI: 10.1002/pan3.10242

NATURE ON SCREEN: THE IMPLICATIONS OF VISUAL MEDIA FOR HUMAN-NATURE RELATIONSHIPS

Research Article



The educational value of virtual ecologies in Red Dead Redemption 2

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Sarah L. Crowley

Email: s.crowley@exeter.ac.uk**Handling Editor:** Jamie Lorimer**Abstract**

1. Playing video games is often perceived as the antithesis of engaging with, and learning about, the natural world. Nevertheless, there is growing recognition that digital media is now a central part of many people's lives. This has led to increased efforts to harness the power and popularity of digital games for both ecological education and conservation advocacy.
2. Games designed for educational purposes may be perceived as too niche, or have insufficient resources, to reach wider audiences. In contrast, big budget video games reach many millions of players, but are generally designed for entertainment rather than education. Red Dead Redemption 2 (RDR2), a Western-themed action-adventure game, is one such product. Nevertheless, due to its detailed, open-world simulation of late 19th century North American ecosystems, it provides opportunities for players to learn about real-world wildlife.
3. We surveyed self-described gamers who both had, and had not, played RDR2. Participants undertook a wildlife identification quiz focusing on 15 species depicted in the game. We also asked participants about their self-reported learning and experiences of playing RDR2.
4. We found that participants who had played RDR2 correctly identified more species in the quiz, with this improvement enhanced by having completed the game's main storyline, played more recently or played online in a 'Naturalist' role. The difference in performance was greatest for ungulate and fish species which have high in-game utility value.
5. In addition to species identification, participants reported learning about animal behaviours and interspecies interactions. Their most memorable experiences were associated with RDR2's immersive environment and ability to provoke emotional responses.
6. We conclude that big-budget video games can have educational as well as entertainment value and should be taken seriously by educators, ecologists and conservationists as a communicative force.

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KEYWORDS

ecological education, experience of nature, natural history, video games, visual media, wildlife identification

1 | INTRODUCTION

Digital technologies have a potentially significant role in the future of education (Barab & Luehmann, 2003; Tewksbury et al., 2014), particularly in communicating with learners via media to which they are accustomed (Annetta, 2009). Non-traditional educational formats, including digital technologies, have many benefits, including novelty, immersion, a rich sensory environment and 'learning through play' (Behrendt & Franklin, 2014; Guerrero & Reiss, 2020; Waite, 2011).

Video games are an underexplored and underused educational tool. As they increase in complexity, they can provide immersive, sensory learning environments (Squire, 2011). Playing video games can have cognitive benefits (Granic et al., 2014), promote active learning (Johnson & Johnson, 2008; Michael, 2006; Prince, 2013) and provide learning autonomy, strengthening the acquisition of knowledge and skills (Mouaheb et al., 2012; Squire, 2008; Turkay et al., 2014). Research with higher education students has found that video games require players to exercise and improve a range of skills including communication, adaptability and resourcefulness (Barr, 2017, 2018). Despite this potential, most efforts to use them in educational settings have been limited to teaching about coding and game design (Squire, 2008), rather than exploiting the possibilities of gaming to immerse players in complex learning environments and teach them about a wider range of subjects.

One subject that could benefit from digitally enhanced teaching is natural history. Broadly conceived as the 'description of nature' (Schmidly, 2005), natural history involves the study of organisms, environments, evolution and the changing relations between these (Tewksbury et al., 2014). Understanding of natural history underpins much of biology (Greene, 2005). Without it, we would not have ecology, evolutionary biology or animal behaviour (King & Achiam, 2017). While education in natural history has declined over recent decades, there has recently been a movement towards reintroducing this more explicitly into curricula: in the UK, for example, OCR (a national examination board) has proposed a Natural History GCSE (OCR, 2020).

Knowledge of natural history, and its emphasis on biological diversity, further acts as a crucial tool for applied scientists working to address challenges in human health, food security, climate change and biodiversity conservation (King & Achiam, 2017; Tewksbury et al., 2014). We are not arguing here that knowledge about an organism automatically causes people to care about it (indeed, there is plenty of evidence to suggest that there is a minimal link between education and behaviour change; Schultz, 2011). Nevertheless, basic awareness of a species' existence is arguably fundamental to an interest in its conservation (King & Achiam, 2017), and ecological knowledge can both inspire people to care and empower those who do (Carlone et al., 2015).

1.1 | Video games and conservation education

Employing video games for conservation has potential (Sandbrook et al., 2015). Games have been successfully used for education and training purposes in other settings; they provide engaging, fun educational experiences that reinforce learning through repetition. However, games risk: distracting players from the real world and its problems; and/or providing 'a hyper-real and cognitively satisfying alternative to real nature that reduces concern about conservation' (Sandbrook et al., 2015). Conservationists designing games to inform about and generate support for a cause must therefore strike a balance between entertainment, education and advocacy. Recent examples include Kakapo Run (Dunn & Verissimo, 2020), designed to entertain while raising awareness of the plight of the kakapo *Strigops habroptilus*, and the forthcoming Wildchain (<http://wildchain.io>), in which players donate funds to digitally adopt virtual representatives of real endangered animals.

Pokémon is a franchise comprising video games, television series, manga comics and a trading card game, in which players collect fictional animal species. Its creator, Satoshi Tajiri, used to collect insects as a child and designed Pokémon to recreate this experience for modern children (Balmford et al., 2002). Almost 20 years ago, Balmford et al. (2002) showed that children were better able to identify species of Pokémon than UK wildlife, arguing that conservationists have been less effective than game developers at teaching children species diversity and identification. In 2016, the augmented reality mobile game Pokémon Go also attracted interest from conservation scientists, who suggested that such games could be harnessed as educational and engagement tools (Dorward et al., 2017). Small-scale versions of this idea using real-world rather than fictional species have been trialled (<http://pocketpalsapp.com>; <https://www.safaricentralgame.com/>) but not widely promoted. Edwards and Larson (2020) recommend several strategies to engage digitally oriented young people with nature. These include effectively marketing games to reach and appeal to intended audiences and incorporating gamification techniques into educational programme design. These strategies respond to the challenge that 'nature-oriented' games are most likely to appeal to those already interested in natural history, and that educational games might struggle to reach broader audiences. Most educational video games are perceived as such and are therefore unpopular when compared with entertainment games. Educational games often have much smaller development budgets than those produced by major publishers and can therefore disappoint those who play premium games at home, leading to disengagement and limited educational impact (Elliott et al., 2002).

However, games that are not designed to be educational, and that already reach broad audiences, might nevertheless contribute to ecological education. In short, if educational games are unpopular, can popular games be educational? Recent research has begun investigating the effects of entertainment-focused forms of visual media (e.g. movies and narrative nature documentaries) on people's understanding of, and interactions with, the natural world (Dunn et al., 2020; Fernández-Bellon & Kane, 2020; Siriwat et al., 2020; Verissimo et al., 2020; see also Silk et al., 2018). Video games are another widespread form of visual media that have not yet received the same research focus. A notable exception (Truong et al., 2018) found a preference for green and natural landscapes among players of *World of Warcraft*, interpreted in terms of 'virtual biophilia': an attraction to healthy, vegetated landscapes that many found difficult to access in real life. Here we examine whether and how another popular video game (*Red Dead Redemption 2*: Rockstar Studios, 2018), designed primarily for entertainment, could also have educational value through its realistic simulation of real-world ecosystems. We are particularly interested in the role of 'vicarious experiences' of nature produced through interactions with virtual animals, ecologies and dynamic landscapes.

1.2 | Vicarious experiences

Playing video games is often perceived as the antithesis of experiencing the natural world. Digital media compete for time with 'nature-based' activities (Larson et al., 2019), and there is widespread concern that urbanisation and risk aversion to unstructured outdoor play for children in post-industrial nations (Edwards & Larson, 2020; Skår & Krogh, 2009) are producing societies that are more 'video-philic' than 'biophilic' (Pergams & Zaradic, 2006). Less time physically spent in green or blue spaces has been linked with consequences for health and well-being, environmental attitudes and participation in pro-environmental behaviours (Bratman et al., 2019; Cervinka et al., 2011; Soga & Gaston, 2016). Further, self-reported 'connectedness to nature' (Mayer & Frantz, 2004) is higher in those who are more likely to take part in outdoor and environmental protection activities (Hartig & Kahn Jr., 2016). Consequently, there has been growing interest in determining how more people, and particularly young people, might be 'reconnected with nature' (Cohen, 1995; Ives et al., 2018; Miller, 2006).

Here, following Clayton et al. (2017), we take a broader view of what constitutes 'experiences of nature'. A person's understanding of the world they inhabit is formed not only through direct interactions with physical living beings and landscapes, but also *vicariously* (Kellert, 2002), through the representation of wildlife, ecosystems, weather and other natural entities in art, stories and symbolism. These vicarious experiences are not new: artistic depictions, tales and received knowledges of the biophysical world are ancient, and often central to the transmission of ecological knowledge. It is likely, however, that the ratio of direct to vicarious experiences has shifted in post-industrial societies where people

can now live with few direct interactions with 'nature'. It is worth noting two things at this juncture. First, this perception of disconnection is just that: a perception. Even individuals who rarely venture outdoors are connected to the rest of the socio-natural world through networks of extended relations, including the food and energy they consume, the products they use, and the politics they endorse. Second, we recognise fundamental challenges with both (a) the continued reference to nature as something external to humans that must therefore be connected with (see Fletcher, 2017) and (b) the reduction of 'experiences of nature' to a selection of benign, often ethnocentric practices such as walking in woodlands and observing wildlife. We broaden this framework by recognising the validity and potential impact of vicarious, virtual experiences, as well as the existence of more violent practices and interactions with wildlife.

With growing urbanisation and use of digital technologies, experiences are not necessarily lost, but transformed (Clayton et al., 2017). As Truong and Clayton (2020) argue, technological or virtual representations of natural entities may increasingly outnumber material experiences *with* them. While they lack some of the sensory and place-based elements of embodied experiences, virtual experiences are not necessarily less affecting or informative than those taking place in the 'real world' (Pallavicini et al., 2018): indeed, some commentators on video games prefer the term 'actual world' over 'real world' to emphasise that digital experiences are still 'real'. Consequently, 'rather than dismissing these [virtual] forms as inauthentic... we have to examine the consequences such a shift could have on people's lives in the long run' (Truong & Clayton, 2020). Calls for reconnecting people, and children especially, with nature often revolve around recreating the experiences of previous generations, assuming these will lead to pro-environmental behaviours (Clayton et al., 2017). However, these calls tend to rely on a set of culturally specific activities and behaviours that often fail to acknowledge class, race and gender politics (Dickinson, 2013). These experiences can also be nostalgically idealised, glossing over the environmental disconnects and challenges that were equally pressing for previous generations (Kahn, 2002). Today's social contexts are incomparable to those of the past, not least due to far greater presence of technologies. Vicarious and virtual experiences are therefore worthy of investigation, including exploration of their dimensions—are they positive or negative, shared or solitary, observational or interactive (Clayton et al., 2017)?—and their effects. We therefore focus on the role of 'vicarious experiences' with simulated wildlife and ecosystems in *Red Dead Redemption 2*.

1.3 | Red Dead Redemption 2

Red Dead Redemption 2 (RDR2) is a AAA video game, meaning that it was produced and distributed by a major publisher (Rockstar Games), had a long development time (~8 years), and a large development team (~1,600 staff) and budget (reportedly >£100 million). Released in October 2018, as of February 2021 it has sold more

than 36 million copies (Knezevic, 2021). RDR2 is an adult action-adventure game set in the USA c1899. The player assumes the role of Arthur Morgan, an outlaw gang member. The storyline follows Arthur as he questions his lifestyle and place in a changing America, while engaging in shootouts, raids and gang conflicts. The game features an honour system, through which players experience different consequences depending on their actions.

RDR2 has a large, immersive 'open world' setting. RDR2 is unusual among contemporary AAA games in that its fictional world aims to realistically depict (a snapshot of) 19th century America. The world depicted includes richly detailed simulations of a range of natural environments (Figure 1), many inspired by real-world locations such as Yosemite Valley, California Redwoods, the Great Plains and the Mississippi Bayou. The game's environment is more than a backdrop: it affects Arthur and his horse; it acts as resource and antagonist; and it renders interactions in high detail (Holmes, 2019). Its virtual ecosystems contain an abundance of wildlife (~200 species), that can all be 'studied', photographed and hunted for food or resources, though some are more common and accessible than others. The game's animals have been programmed to appear, sound and behave in realistic ways, interacting with their environment, other species and the player.

Red Dead Online (RDO) is the online version of RDR2, in which players create and customise their character's aesthetic and actions. RDO takes place in the same game world but is separate from the main story. Rather than a narrative storyline, RDO focusses on freedom of choice and inter-player interactions, both cooperative and competitive. Players can choose to specialise in several 'roles', with distinct tasks, challenges and rewards. Of particular relevance is the 'Naturalist' role which rewards players for studying and protecting wildlife. 'Naturalists' are encouraged to interact non-violently with wildlife through photography, tracking, sample collection and protection from poachers. As it is only available in RDO, the Naturalist role is unrelated to the main game storyline. It is technically available as soon as players begin a game in RDO but requires a specific amount of in-game experience to be accessed.

This study aimed to investigate whether immersion in the virtual environment of RDR2 and RDO teaches players about the



FIGURE 1 Screenshot of white-tailed deer *Odocoileus virginianus* from Red Dead Redemption 2. Image credit: Instacodez via Flickr/Rockstar Games

real-world wildlife and ecology of their setting, and how. We employed mixed methods to address this central aim, applying different methodological approaches to ask questions about different aspects of learning. We used a wildlife identification quiz to quantify, across a broad sample of gamers, whether playing RDR2 is consistently associated with greater species identification skills. In doing so, we aimed to identify whether there is objective evidence of learning having taken place independently of participants' perceptions or memories of playing the game. We compared players of RDR2 against non-players in a natural experiment, to identify whether playing RDR2 was associated with improved quiz performance. Additionally, to consider the more subjective, experiential dimensions of learning, we conducted a qualitative analysis of open survey questions to explore whether and what participants felt they had learned, and to identify the in-game experiences perceived as most memorable.

2 | METHODS

We distributed an online survey using the Qualtrics (Provo, Utah) platform. The survey's main component was designed as a quiz in which participants were asked to identify 15 animal species from photographs. Participants who indicated that they had previously played RDR2 were offered optional questions about their experiences of wildlife and natural environments within the game. This study received ethical approval from the University of Exeter (Ref: eCORN002008). The full survey is included as S11.

2.1 | Survey design

An introductory page informed participants about the survey structure, that participation was voluntary and anonymous, and that they could exit at any time. Participants were required to confirm their consent and that they were over 18 years old before proceeding.

2.1.1 | (i) Species and image selection

The quiz was designed to test whether players of RDR2 are better able to identify real-life wildlife species than non-players. Fifteen species featured in RDR2 (Table 1) were selected for the quiz based on several criteria: (a) they are common enough in-game to be encountered by most players; (b) they represent a range of taxonomic groups and (c) they include species commonly and less commonly used as resources in-game. We excluded domestic animals and minimised 'charismatic megafauna' that may be easily identifiable by all participants (e.g. bears, wolves) which could subsequently have made it more difficult to identify a learning effect of gameplay. Clear photographs of each species were presented for participants to identify. We used photographs of real animals (rather than images from RDR2) but avoided photographs in which a species appeared

TABLE 1 Full list of animal species used in the quiz

Common name	Latin name	Class
American bullfrog	<i>Lithobates catesbeianus</i>	Amphibian
Blue jay	<i>Cyanocitta cristata</i>	Bird
Golden eagle	<i>Aquila chrysaetos</i>	Bird
Little egret	<i>Egretta garzetta</i>	Bird
Roseate spoonbill	<i>Platalea ajaja</i>	Bird
Scarlet macaw	<i>Ara macao</i>	Bird
Pronghorn	<i>Antilocapra americana</i>	Mammal
Black-tailed jackrabbit	<i>Lepus californicus</i>	Mammal
Nine-banded armadillo	<i>Dasypus novemcinctus</i>	Mammal
White-tailed deer	<i>Odocoileus virginianus</i>	Mammal
Lake sturgeon	<i>Acipenser fulvescens</i>	Ray-finned fish
Steelhead trout	<i>Oncorhynchus mykiss</i>	Ray-finned fish
Alligator snapping turtle	<i>Macrochelys temminckii</i>	Reptile
Cottonmouth	<i>Agkistrodon piscivorus</i>	Reptile
Green iguana	<i>Iguana iguana</i>	Reptile

markedly different from its in-game representation (e.g. due to intraspecific variation).

2.1.2 | (ii) Quiz design

We gave participants two opportunities to identify each species. First, they were offered the photograph with a 'text entry' box to determine whether they could identify the species without prompting. Participants unable to identify the species could leave this box blank. Participants were then shown the same photograph again and presented five multiple-choice options. For the four incorrect options, we selected species that were either taxonomically similar to, or had species names that could reasonably refer to, the correct answer (e.g. incorrect options for the blue jay *Cyanocitta cristata* included 'blue finch' *Porphyrospiza caeruleascens* and 'mountain bluebird' *Sialia currucoides*). Participants could not return to the text entry box once they had seen the multiple-choice options. This design assumes that participants who correctly named a species in the text entry box demonstrated a higher level of identification skill than those who only picked the correct option out of five. All 15 species were presented in random order, but the multiple-choice question always immediately followed its associated text entry question. Multiple-choice options were presented in a random order for each participant.

2.1.3 | (iii) Gameplay and demographic questions

Following the quiz, we asked participants whether they played video games and whether they had ever played RDR2 (from hereon, those who reported ever having played RDR2 are referred to as 'RDR2 players'). We further asked RDR2 players: (a) whether they had completed

the main storyline (indicating an average of 40–60 hr in-game); (b) an estimated number of hours played; (c) an estimated number of species encountered and (d) whether they had played the 'Naturalist' role in RDO. We also asked participants' age, gender and country of residence.

2.1.4 | (iv) Follow-up questions for RDR2 players

Participants who had not played RDR2 ('non-players') were then shown debriefing information and their quiz results, which concluded the survey. To better understand RDR2 players' subjective experiences of learning, and explore factors that could influence what they learned, RDR2 players were offered additional questions about their time playing the game. We used multiple-choice questions to ask in what ways participants regularly interact with wildlife, both in RDR2 and real life. We also asked two open-ended questions: (i) *Please tell us what, if anything, you have learned about real-world wildlife, animal behaviours, or ecosystems from playing Red Dead Redemption 2* and (ii) *Please tell us about any memorable experiences you had with wildlife or wild landscapes in Red Dead Redemption 2. What happened and why was it memorable?*

2.2 | Survey distribution

We piloted the survey with 16 participants and subsequently made minor adjustments to wording and survey logic. We distributed the final survey using social media platforms Reddit, Facebook and Twitter. We targeted self-identified 'gamers' including both those who had played RDR2 (using dedicated groups and threads) and those who had not (using more general gaming groups and threads). The survey was advertised as a 'Wildlife Quiz for Gamers'; RDR2 was not mentioned by name. The survey was open from 25 October to 15 November 2020.

2.3 | Statistical analysis

For each of the free text and multiple-choice answers to the quiz we tested (i) whether playing RDR2 was associated with more correct answers overall; (ii) what gameplay characteristics of RDR2 players were associated with more correct answers overall; (iii) whether playing RDR2 was associated with answering correctly on a species-by-species basis and (iv) what gameplay characteristics of RDR2 players were associated with answering correctly on a species-by-species basis.

For all analyses, we excluded poorly represented groups from the final dataset to improve statistical inference. Therefore, we did not analyse people aged 65 or older ($n = 2$), people who did not identify as either female or male ($n = 38$), or (for analyses ii and iv) those who were unsure whether they had completed the game ($n = 1$).

For free text answers we used a set of acceptable answers (provided in Table S1). We used fuzzy text matching with a maximum allowable distance of 10% (default) to allow for any spelling errors.

2.3.1 | (i) Is playing RDR2 associated with more correct answers overall?

To test the hypothesis that RDR2 players would answer more questions correctly we fitted either a binomial generalised linear mixed model (GLMM; multiple choice answers) or zero-inflated binomial GLMM (free text answers) with the number of correct and incorrect answers as a response variable. We included: whether the participant had played RDR2; gender; and age group as explanatory variables, and their country of residence as a random intercept. For the zero-inflated model the same explanatory terms and random intercept were included in both parts of the model. We then assessed the importance of whether a participant had played RDR2 or not by comparing the Akaike information criterion (AIC) of a model containing the effect to a null model without it.

2.3.2 | (ii) What gameplay characteristics of RDR2 players are associated with more correct answers overall?

To test what aspects of playing RDR2 were associated with more correct answers in the quiz we reanalysed the subset of participants who were RDR2 players. We again fitted either binomial (multiple choice answers) or zero-inflated binomial (free text answers) GLMMs with the number of correct and incorrect answers as a response variable and country of residence as a random intercept. For each answer type, we fitted seven competing models (Table 2) that contained a different combination of three fixed effects related to gameplay: (a) whether or not a participant had completed the main storyline of RDR2 (two-level categorical variable); (b) whether or not a participant had played RDR2 online in the Naturalist role (two-level categorical variable); and (c) when a participant had last played RDR2 (three-level categorical variable, where Current = within the last week, Recent = between 1 week and 1 month ago, and Past = more than 1 month ago). We included age

group and gender as additional fixed effects. We determined the most parsimonious explanation of our results by selecting the model with the lowest AIC from the candidate set.

2.3.3 | (iii) Are there species differences in the association between playing RDR2 and answering correctly?

To test for species differences in the association between having played RDR2 and answering correctly we analysed the answer to each question separately using a logistic regression approach. We used binomial family GLMMs and included random intercepts of both participant ID and participant country of residence alongside fixed effects of species (question), whether a participant had played RDR2 or not, their interaction (species × played game), age group and gender. We then assessed the importance of whether a participant had played RDR2 or not by comparing the AIC of a model containing the interaction effect to a null model without the interaction.

2.3.4 | (iv) Are there species differences in the association between RDR2 players' gameplay characteristics and answering correctly?

We used a similar logistic regression approach to test the importance of how and when people had played RDR2 for the probability of correct answers. Similar to analysis (ii), we compared seven competing models with different combinations of whether a participant had completed the main storyline of RDR2 or not, whether a participant had played RDR2 online in the Naturalist role or not, and when a participant had last played RDR2 fitted as interactions with species (Table 2). Age group and gender were also included as fixed effects, and participant ID and participant country of residence as random effects.

TABLE 2 Candidate model set used for quantitative analyses (ii) and (iv)

Model name	Full model for analysis (ii)	Full model for analysis (iv)
1. Completed	No. Correct/No. Incorrect ~ Completed + Age + Gender + (1 Country)	Correct ~ Completed × Species + Age + Gender + (1 ParticipantID) + (1 Country)
2. Naturalist	No. Correct/No. Incorrect ~ Naturalist Role + Age + Gender + (1 Country)	Correct ~ Naturalist Role × Species + Age + Gender + (1 ParticipantID) + (1 Country)
3. Last Played	No. Correct/No. Incorrect ~ Last Played + Age + Gender + (1 Country)	Correct ~ Last Played × Species + Age + Gender + (1 ParticipantID) + (1 Country)
4. Completed and Naturalist	No. Correct/No. Incorrect ~ Completed + Naturalist Role + Age + Gender + (1 Country)	Correct ~ Completed × Species + Naturalist Role × Species + Age + Gender + (1 Country)
5. Completed and Last Played	No. Correct/No. Incorrect ~ Completed + Last Played + Age + Gender + (1 Country)	Correct/Incorrect ~ Completed + Last Played + Age + Gender + (1 ParticipantID) + (1 Country)
6. Naturalist and Last Played	No. Correct/No. Incorrect ~ Naturalist Role + Last Played + Age + Gender + (1 Country)	Correct ~ Naturalist Role × Species + Last Played × Species + Age + Gender + (1 ParticipantID) + (1 Country)
7. Completed, Naturalist and Last Played	No. Correct/No. Incorrect ~ Completed + Naturalist Role + Last Played + Age + Gender + (1 Country)	Correct ~ Completed × Species + Naturalist Role × Species + Last Played × Species + Age + Gender + (1 ParticipantID) + (1 Country)

We determined the most parsimonious explanation of our results by selecting the model with the lowest AIC from the candidate set.

2.3.5 | (v) Are the patterns identified similar for participants in North America and participants elsewhere?

Given the North American setting of RDR2, we repeated each analysis related to the multiple-choice questions (four in total) separately for subsets of the data that (a) included only participants residing in USA and Canada ($n = 196$) and (b) from all other countries excluding those where no country information was provided ($n = 323$). These analyses were repeated without country as a random intercept, hence models for quiz scores were re-fitted as generalised linear models (GLMs). We re-fitted only the best-fitting model as identified by AIC in the full analysis where relevant (RDR2 players only data).

All analyses were conducted in R 3.6.1 (R Core Team, 2020). We used the package `LME4` (Bates et al., 2015) to fit most statistical models described and the package `GLMMTMB` (Brooks et al., 2017) to fit zero-inflated binomial models for free text answers for analyses (i) and (ii). Full R code and model results are provided in SI2 and SI3.

2.4 | Qualitative analysis

The two open-ended questions about RDR2 players' experiences were qualitatively analysed in NVivo (v1.3.1) by a single coder. All responses to these questions (no participants or responses were excluded from the qualitative analysis) were coded through an inductive process of close reading, labelling responses in relation to thematic categories, and then refining the groupings. For question (i), which asked what players had learned, responses were coded into broad 'subject areas' of knowledge such as species appearance, animal behaviour and interspecies interactions. For question (ii), which asked about players' memorable experiences, responses were coded twice, according to both type of experience (e.g. an interaction with wildlife) and by explanation as to why it was memorable (e.g. an emotional response). Further details of the coding categories are provided in Section 3.4.

3 | RESULTS

3.1 | Participants

Five hundred and eighty-six participants completed the quiz. Of these, 444 had played RDR2 and 141 had not (one response not recorded). Our sample was male-biased; 431 participants identified as men and 114 identified as women (20 preferred to self-identify and 18 elected not to say). The majority of participants were younger adults (18–24: 289; 25–34: 173; 35–44: 61; 45–54:

17) with 55–64-year-olds ($n = 4$) and those 65+ ($n = 2$) poorly represented. This is broadly consistent with demographic data from the USA which indicate that the majority of console action game players are males aged between 18 and 54 (ESA, 2020). The age structure of participants who had played RDR2 was similar to that of participants overall. Participants resided in 55 countries (see Table S2). A total of 196 participants resided in North America (173 USA and 23 Canada) with countries in Europe also well represented in the sample, especially the UK (127). Of participants who had played RDR2, the majority ($n = 381$) had completed the game and approximately half ($n = 241$) had played in the Naturalist role online. The majority had played RDR2 within the last month ($n = 315$), but some had not played for some time (e.g. 23 had last played more than a year ago).

3.2 | Quiz performance

Among participants in the dataset analysed (younger than 65, and either identifying as men or women), the number of species correctly identified in the free text answers was low (mean = 1.92, median = 1, interquartile range = 0–3) and 215 participants (39.5%) failed to identify any photos correctly. Only 28 participants (5.1%) answered more than half of these questions correctly. The number of species correctly identified was much higher in the multiple-choice answers (mean = 9.14, median = 9, interquartile range = 7–11).

3.3 | Quantitative findings

3.3.1 | (i) Is playing RDR2 associated with more correct answers overall?

RDR2 players identified more species correctly, both in the multiple-choice (Figure 2) and free-text questions (Figure S1). Non-players had a median score of 7 (IQR: 6–9) when answering multiple choice questions and a median of 0 (IQR: 0–1.5) answers correct in the free text version. RDR2 players had median scores of 10 (IQR: 8–12) and 1 (IQR: 0–3) respectively. For multiple choice answers, the log-odds estimate for having played RDR2 was 0.56 ± 0.06 , which represents RDR2 players being 1.76 times more likely to get an answer correct (or an increase from a 50.1% to a 64.6% chance of a correct answer for women in the 18–24 age group). For the free text answers, playing the game was associated with a lower probability of failing to answer any question correctly (log-odds estimate for zero correct answers: -1.01 ± 0.26) but there was no association with the probability of answering multiple questions correctly (log-odds estimate: 0.07 ± 0.11). For multiple-choice answers, having played RDR2 had a similar effect size both for participants in North America (0.63 ± 0.09) and those residing elsewhere (0.54 ± 0.07), although participants in North America typically got more answers correct overall (Table S3). Full model results are provided in Tables S3 and S4.

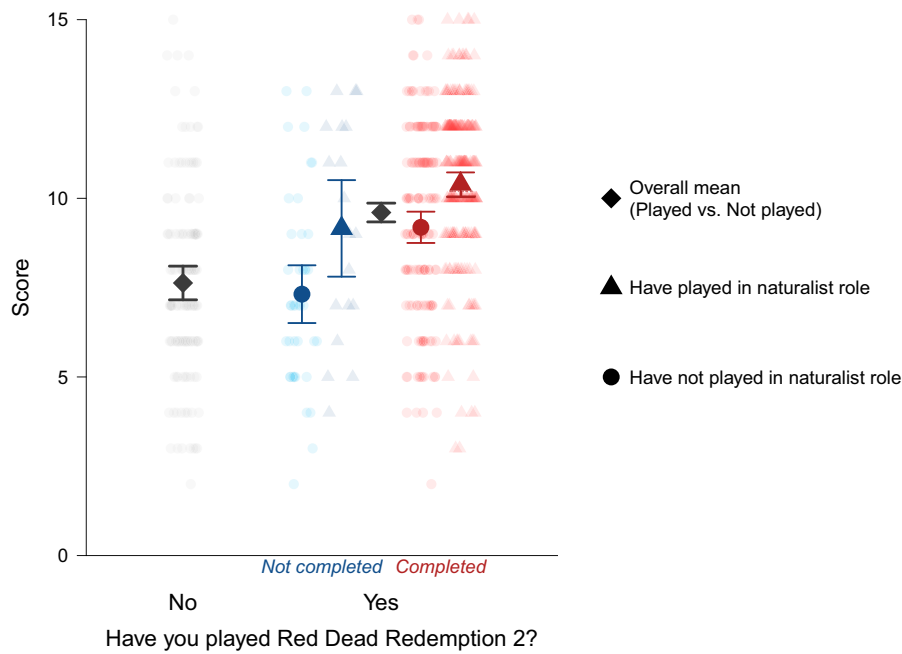


FIGURE 2 Quiz performance is associated with whether participants have played RDR2, and whether they have completed the main storyline or played the Naturalist role online. Small points are raw data (x-jittered for graphical representation). Large points are means for each category shown (including the overall mean for RDR2 players). Error bars show the mean $\pm 95\%$ confidence intervals

Model name	Quiz score		Species-by-species analysis	
	Multiple choice	Free text	Multiple choice	Free text
1. Completed	1,994.0	1,785.1	6,048.6	3,589.8
2. Naturalist	1,988.6	1,784.1	5,972.8	3,566.8
3. Last Played	1,964.7	1,768.9	5,990.6	3,534.2
4. Completed and Naturalist	1,950.6	1,783.9	5,968.5	3,623.4
5. Completed and Last Played	1,934.1	1,769.5	5,990.4	3,531.3
6. Naturalist and Last Played	1,955.4	1,772.7	5,967.9	3,539.5
7. Completed, Naturalist and Last Played	1,926.6	1,773.4	5,971.7	3,536.7

TABLE 3 AIC-based comparison of model performance in our candidate model sets. Shaded cells and bold text indicate the best-fitting model for each of the four model sets

3.3.2 | (ii) What gameplay characteristics of RDR2 players are associated with more correct answers overall?

Among RDR2 players there was evidence that all three variables considered (how recently they had last played, whether they had completed the storyline and whether they had played in the Naturalist role) affected the likelihood of answering more questions correctly (Table 3).

For the free text answers, the only variable included in the best fitting model was when a participant had last played. Current players (played within the last week) were significantly more likely to get any answer correct than other players (zero-inflation log-odds: 0.87 ± 0.38 for Recent vs. Current, 0.77 ± 0.32 for Past vs. Current). For those who answered free-text questions correctly, not having played for more

than a month (Past players) were associated with lower scores (log-odds: -0.40 ± 0.11 for Past vs. Current), while Current and Recent players performed similarly (log-odds: 0.01 ± 0.13 for Recent vs. Current).

For the multiple-choice answers, all three gameplay-related variables were included in the best-fitting model. Participants who had completed the main storyline (Figure 2; log-odds estimate: 0.39 ± 0.08), had played in the Naturalist role online (Figure 2; log-odds estimate: 0.21 ± 0.07) or had played RDR2 recently (log-odds estimate: -0.40 ± 0.08 for Past vs. Current, -0.16 ± 0.09 for Recent vs. Current) had more correct answers in the quiz. Qualitatively similar results were found for players in North America and those elsewhere, although the association between having completed RDR2 and answering more questions correctly was stronger for players outside North America (Table S5). Full model results are provided in Tables S5 and S6.

3.3.3 | (iii) Are there species differences in the association between playing RDR2 and answering correctly?

For both the multiple-choice and free text answers there were statistically significant differences between species in how having played RDR2 was associated with the probability of answering correctly (Figure 3). For the free text answers, playing RDR2 was associated with a striking increase in the probability of answering correctly for both pronghorn *Antilocapra americana* and white-tailed deer *Odocoileus virginianus*. Playing RDR2 was also associated with a substantial increase in the probability of these two species being identified correctly in multiple-choice questions. There were also notable effects for the two fish species (steelhead trout *Oncorhynchus mykiss* and lake sturgeon *Acipenser fulvescens*) and smaller positive effects for a range of other species, especially reptiles and amphibians (excluding the green iguana *Iguana iguana*). Results were qualitatively similar for participants in North America and elsewhere (Table S7). Participants in North America were more likely to identify some species overall (e.g. black-tailed jackrabbit, blue jay and white-tailed deer). Correspondingly, participants outside North America were more likely to correctly identify these same species only if they had played RDR2. Full model results are provided in Tables S7 and S8.

3.3.4 | (iv) Are there species differences in the association between RDR2 players' gameplay characteristics and answering correctly?

For both multiple-choice and free text answers there were statistically significant differences between species in how participants' gameplay characteristics were associated with the probability of answering correctly. We found strong support for a recency effect, with when a participant had last played RDR2 in both best-fitting

models. The recency effect was generally strongest for species for which having played RDR2 was associated with larger increases in the likelihood of answering correctly. For free text answers, the recency effect was especially clear for pronghorn, white-tailed deer and alligator snapping turtle *Macrochelys temminckii*. For multiple-choice answers it was strongest for white-tailed deer, steelhead trout, alligator snapping turtle and black-tailed jack rabbit *Lepus californicus* (Figure S1). For multiple-choice answers, the recency effect was much less apparent for pronghorn, with all RDR2 players having a very high success rate with this question (Figure S2). We also found some evidence that the association between the likelihood of a correct answer and both completing the main storyline (free text answers only) and playing in the Naturalist role online (multiple-choice answers only) differed between species. Completing the storyline was associated with a slightly higher probability of correct free text answers in several species (including representatives of all classes; Figure S3). Playing in the Naturalist role was most strongly associated with a higher likelihood of answering correctly for the black-tailed jackrabbit, steelhead trout, pronghorn, nine-banded armadillo *Dasypus novemcinctus* and roseate spoonbill *Platalea ajaja* (Figure S4). Results were generally qualitatively similar for multiple-choice answers between players in North America and those elsewhere in the world (Table S7), with a small number of exceptions (e.g. black-tailed jackrabbit). Full model results are in Tables S9 and S10.

3.4 | Qualitative findings

3.4.1 | (i) Please tell us what, if anything, you have learned about real-world wildlife, animal behaviours, or ecosystems from playing Red Dead Redemption 2

We received 181 responses to this question. The majority reported having learned specific information from playing RDR2; 12 participants

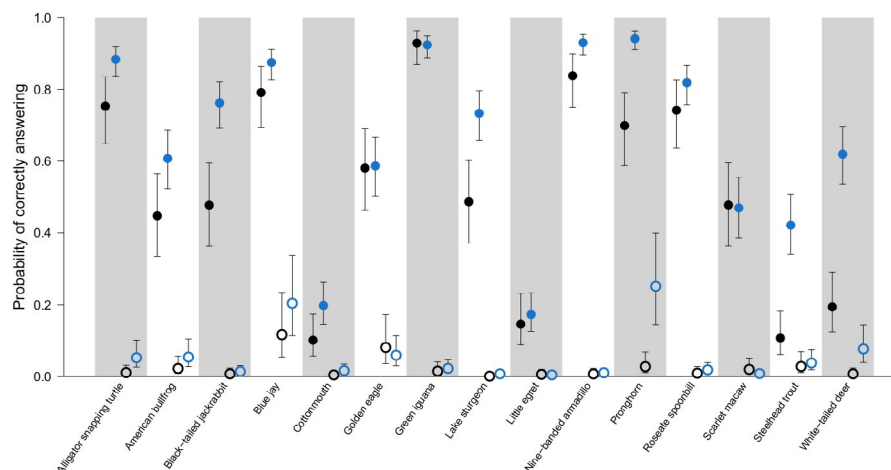


FIGURE 3 Species-by-species comparison of the probability of a correct answer in the quiz for people who have and have not played RDR2. Points represent model estimates, and error bars the 95% confidence intervals around model predictions. Blue points are predictions for RDR2 players and black points for non-players. Solid symbols are estimations of the probability of a correct answer in the multiple-choice quiz and open symbols are estimations of the same probability for free text answers

stated that they had not learned anything new. Comments were coded into five thematic categories relating to broad 'subject areas' of reported learning, ordered by coding frequency: (a) *species awareness and identification skills*; (b) *wildlife distributions and habitats*; (c) *natural history, behaviour and interactions*; (d) *human–animal interactions* and (e) *environmental change*. A further category, (f) *personal reflection*, was created to explore participants' additional comments about how they had been affected by the game (outside of learning experiences). All the quotes in this section are from separate participants.

(a) *Species awareness and identification skills*

Participants most frequently reported learning about the existence, names and appearance of a range of species. Some highlighted improved recognition of specific animals and taxonomic groups, including differentiation between ungulate species and breeds of horse *Equus caballus*. Participants noted their surprise at the diversity of wildlife encountered in-game, for example, '*There's lots of different variations I didn't know about before, and it is genuinely interesting for someone who does not know loads about animals*'. As well as visual identification (the focus of our quiz), participants reported learning to identify a range of species by sound, in one case '*to the point where I can hear a bird in real life sometimes and think I know which one it is*'.

(b) *Wildlife distributions and habitats*

RDR2 features five different territories, broadly reflecting different North American biomes. Wildlife 'spawns' in appropriate territories and habitats, and participants reported learning which species were associated with different ecosystems and/or regions.

(c) *Natural history, behaviour and interactions*

Participants reported learning about species morphology, physiology, behaviour and ecological interactions through their gameplay. Several noted appreciating the 'real' size of some species, notably moose *Alces alces*, and learning about physiological features such as muskrat *Ondatra zibethicus* scent glands and the neck length of alligator snapping turtles. Many more, however, recounted learning about animal behaviours and interactions through in-game observations. Comments referred to generally improved understanding of behavioural ecology (e.g. activity times, scavenging behaviour, predation strategies and group living), as well as learning about specific behaviours such as opossums *Didelphis virginiana* feigning death, foxes *Vulpes fulva* pouncing into snow, and horses rolling in mud.

(d) *Human–animal interactions*

Hunting and fishing are key components of gameplay in RDR2. In addition to learning about wildlife, participants also learned about (simplified versions of) tracking, baiting, shooting and skinning animals. One commented that, '*virtually none of the details of killing an animal, skinning it and then selling it or making clothes from it are skipped. What I got most from this was a deeper understanding of how this was a real livelihood [in] 19th century America. In other*

words, how close the animal ecosystem was to the human ecosystem'. Experiences of hunting, and of more peaceful interactions with wildlife, are reported in further detail below. Participants also reported learning about risks wildlife can pose to humans, including both predatory and defensive behaviours. Notably, multiple participants reported learning the comparative difference in defensive aggression between grizzly bears *Ursus arctos* and black bears *Ursus americanus*, and about 'bluff charges'. Recognising aggressive behaviours didn't only apply to predators: '*I learned how to spot how a ram will headbutt you from the game, no joke saved me from breaking a leg in real life*'. Others commented learning that the predatory tactics of cougars meant that, '*if I ever [see one] in the wild... it's already too late to do anything*'. Several also noted, however, that the depicted aggressiveness of species such as wolves, cougars and alligators, and the risk they pose to humans, are not realistic representations.

(e) *Environmental change*

A small number of participants reported that the game had drawn their attention to environmental change since the period of RDR2's setting, commenting on the impacts of urbanisation and industrialisation: '*I also saw how pollution could impact the ecosystem (e.g. the animals are in bad condition and the water is polluted at Elysian Pool)*'. Other comments referred to the comparative rarity of wildlife today (this assumes that relative wildlife abundance in RDR2 is accurate for the period), and the presence, in the game, of now-extinct species (e.g. the Carolina Parakeet *Conuropsis carolinensis*).

(f) *Personal reflection*

Some participants used this question to reflect on other ways (beyond learning per se) in which playing RDR2 had affected their thoughts and actions with relation to wildlife. Twelve reported no learning or affect through playing the game, and one was sceptical that this was possible ('*you cannot actually form an opinion on real world issues through video game portrayal, unless stated as specifically educational*'). A handful of others commented, however, that playing RDR2 had inspired changes to attitudes ('*it taught me to appreciate and respect all animals. I don't know why or how, but I now enjoy the company of birds singing, or a cat walking over the street*') and real-life behaviours ('*after interacting with the animals in-game I will sometimes research them to learn more*', and '*thanks to RDR2 I got [in]to animal photography*').

3.4.2 | (ii) Please tell us about any memorable experiences you had with wildlife or wild landscapes in Red Dead Redemption 2. What happened and why was it memorable?

We received 175 responses to this question; five could not recall a specific memorable experience. There are two parts to this question: the first asks players 'what happened?'. We coded responses to this into three thematic categories, ordered in relation to frequency

of coding: (a) *human–animal interactions*; (b) *observing wildlife*; and (c) *aesthetic scenes*.

(a) *Human–animal interactions*

Interactions between the player's human character and animals were the most frequently recalled experiences. The most prominently recounted human–animal interactions were wildlife attacks (both predatory and defensive) on the player, often unexpected, by a range of species: *'I was exploring the swamp areas... suddenly I hear a hiss and before I could do anything to defend myself an alligator killed me'*. Hunting and fishing also produced memorable experiences, both positive (*'I'd make going hunting an event: dressing appropriately for the weather, camping in the wilderness, tracking wildlife in the right habitat... It's not something I've ever done in the real world'*) and negative (*'Was hunting bison for a challenge but shot with wrong weapon and rather than killing it the bison just fell and started crying. Felt bad and reloaded the save and didn't hunt for the rest of the day'*). Participants also, however, reported more peaceful memorable interactions with wildlife, such as riding alongside a herd of running bison *Bison bison*. Others recalled how their play influenced the _virtual ecology of the game (e.g. scavengers eating carcasses left by players).

(b) *Observing wildlife*

Participants recalled memorable observations of animal behaviour and interspecies interactions. These included: watching predators and birds of prey hunting; canids playing; cats catching rats; and egrets riding alligators. A particularly remarkable behaviour, independently reported by six participants, was grey wolves *Canis lupus* appearing to mourn killed pack members. For a few players, this ability to observe a dynamic world was a key part of their experience: *'it is the only game I have ever played where I would often prefer to put down the controller and watch the world pass me by, from a thunderstorm to a pack of American Buffalos, to a rabbit startled by my horse, than to actually play it'*.

(c) *Aesthetic scenes*

Finally, some memorable experiences related to landscapes rather than wildlife: *'I really love the scenery, landscape, light and weather in the game'*. Some specified preferred biomes or regions, such as the bayou and 'Big Valley'; others commented on discovering particularly attractive landscape features such as waterfalls and 'Window Rock'.

We also asked *why* RDR2 players' experiences were memorable. Almost all explanations referred to the immersive qualities of the gameplay, either directly (*'creates a great feeling of immersion in a world that is alive and dynamic'*) or indirectly, referencing an experience's emotional impact or attention to detail. Many participants noted RDR2's ability to provoke real emotional reactions. Wildlife attacks tended to be memorable due to their element of surprise, which could also be accompanied by either tension or fear (*'walking through Tall Trees is usually relaxing, but a sneaky cougar made it terrifying. Don't think I've ever been so scared from a non-horror*

videogame before') or, in some circumstances, comic relief (*'I once was headbutted off a cliff by a deer...which was pretty funny'*). Calmer moments also inspired a range of affective responses, from awe (*'Seeing a moose in RDR2 is just like seeing a moose irl [in real life]. Very awe inspiring'*) to the *jouissance*—intellectual satisfaction—of finding all the species (*'I spent hours searching for various types of birds. This was memorable because I've never been quite [so] addicted to bird watching ever in my life'*).

Some encounters produced more complex feelings, including the guilt of failing to kill an animal quickly when hunting or of hunting a species to extinction:

there was a hidden quest to kill a certain species of bird, after enough kills I got a notification of a finished quest, reading the description it said they were wiped from the face of the earth. It made me feel really bad for doing it, and the fact that all I got was that message with no reward, showed how evil and careless I was...

The game also provoked both memories of real-life experiences and places (*'I got caught in a dust storm, and it was so realistic to the sunsets and weather patterns of Arizona it was like being back home'*) and feelings of connection to the real world:

If you accidentally glitch outside the map, all the animals are frozen in place... I remember walking up to every animal I could find just to stare. Each and every one was so beautiful and life-like. Even down to the twitch of a deer's nose... I just remember thinking hey, this is real. You can go outside right now and see all of this.

Participants reported feeling both impressed by this attention to detail and that it contributed to the immersive experience:

I was riding by a lake and suddenly saw an eagle dive... to catch a snake in its talons. It was memorable because until then I hadn't realized that animals could interact in that kind of player-independent manner. The game continually blew me away with its realistic approach to the world it's depicting.

4 | DISCUSSION

Our findings indicate that, despite RDR2 not being designed as an educational game, it can nevertheless improve players' ability to identify the North American species it features, for both players in North American and those elsewhere in the world. This effect is most evident among those who have played more recently, spent more time playing and played in the Naturalist role online. Our qualitative findings, though not statistically generalisable in the same way as the quantitative results, provide insights into players' experiences

of the game, and suggest that beyond simple visual identification skills, the virtual ecology of RDR2 has also indirectly taught players about animal sounds, behaviours and habitats.

The effect of playing RDR2 on correctly identifying species was not consistent across all 15 animals, which provides some indication of the mechanisms by which players learn from the game. RDR2 players were markedly better at identifying both the ungulate and fish species than non-players. These species would be regularly encountered by players undertaking hunting and fishing activities in-game. This suggests that players learn to recognise species through the regular use and 'added value' of quarry species. Playing in the Naturalist role was associated with being able to identify a broader range of species correctly, especially smaller and frequently encountered species that are not commonly considered as quarry. These findings are reinforced by evidence that players who had completed the storyline (a proxy for at least 40–60 hr in-game) scored more highly than those who had not, as more time playing will increase number of wildlife encounters. In contrast, RDR2 players were no more successful at identifying species rarely encountered in-game than non-players. Examples are the scarlet macaw *Ara macao* (featured only briefly, in a special location), and the golden eagle *Aquila chrysaetos* which is uncommonly encountered in-game and often only observed from distance. There is also a clear recency effect, suggesting the knowledge gained through playing RDR2 may be gradually lost over time, mirroring how effective retention of basic science knowledge requires frequent use or testing (Custers, 2010). In general, findings were consistent regardless of country of residence, although participants in North America had higher baseline likelihoods of answering correctly for some species, which at times corresponded with a smaller difference in the probability of answering correctly between those who had and had not played RDR2. While it may be that some of the improved performance is driven through simply knowing the names of relevant species through gameplay, our qualitative results support the notion that many players are indeed learning to identify species using distinctive characteristics. Additionally, as the survey was entitled a 'Wildlife quiz for gamers' there is a possibility that, to some degree, we attracted gamers with a greater than average interest in wildlife. Nevertheless, our results still indicate that some learning has taken place.

Most respondents to our open-ended questions highlighted that the game had helped them learn to identify different species, potentially prompted by the preceding wildlife quiz. Participants also reported, however, gaining natural history knowledge through observing programmatically displayed, in-game animal behaviours, from vocalising to 'playing dead'. This suggests that players are learning through immersion in the dynamic simulated ecosystems of RDR2 rather than (for example) learning the facts about species' diets that are displayed in the game's 'animal compendium'. While participants reported an impressive variety of behaviours and ecological interactions, the repetition of many of these in open text responses (e.g. bears bluff-charging, canids playing, horses rolling in mud) hints at the limits of RDR2's capacity to fully replicate

real-world ecology, and reflects the developers' choices to focus on particular traits and interactions. These choices influence what players learn, intentionally or not, and while there is a focus on realism and scientific accuracy, compromises are also made to deliver an entertaining experience. A key example of this is the overtly aggressive behaviour of RDR2's predators, particularly wolves, bears and cougars, which do not accurately reflect the contemporary risk to humans these animals pose. As the game is a work of fiction, many players will understand this poetic licence. However, as the developers also pride themselves on their realistic renderings of landscapes and wildlife, and many of our respondents assumed these renderings were accurate, such behavioural anomalies might be misleading. That the player is vulnerable to this sometimes-antagonistic wildlife is also interesting, however; the natural world players experience in RDR2 is always lively, risky and to be negotiated with, rather than mute, benign and there to be observed. As Clayton et al. (2017) note, these more challenging interactions can serve as a 'reminder that biodiversity is not designed to satisfy human interests and does not conform to an idealised view of nature'.

RDR2's main narrative frame reproduces a particular (white, colonial and 'ruggedly masculine': Humphreys, 2012) frontier ideology of 'living off the land', in which wildlife is generally considered a natural resource to be harvested. Despite the violence of the gameplay, however, RDR2 also opens up novel—and perhaps surprising—spaces for social and ethical reflection (Westerside & Holopainen, 2019). Other characters present alternate worldviews, notably RDO's Naturalist and conservationist 'Harriet Davenport', but also wildlife photographer 'Albert Mason', and American Indian pacifist 'Rains Fall', who commends players if they choose not to shoot a pack of scavenging wolves. It is not possible to complete RDR2's storyline, however, without killing a small number of animals as part of specific missions. As several participants noted, the game does not skim over any aspect of its hunting mechanic; wounded animals are visibly distressed (causing some players to feel guilty), and skinning is brief but graphic. The game also includes features (brought to our attention by participants) that are informative and thought-provoking on environmental issues without being overtly moralistic. These include the player's ability to hunt Carolina parakeets to extinction (reflecting real events), for which they receive no reward, and the pollution of a water body due to toxic mining run-off, resulting in unhealthy flora and fauna. A handful of participants felt inspired: to learn more about wildlife, take up photography or just to appreciate real-world biodiversity around them. Our sample size did not enable us to profile the characteristics of respondents who reported this sort of transformative experience. Nevertheless, scaled up to 36 million players worldwide, many of whom have little access to the diverse ecosystems featured in RDR2, it is possible that this immersive game has had no small impact on thousands of players' ecological understanding and appreciation. This would be a valuable direction for future research. This kind of game is also able to reach 'digitally oriented' (Edwards & Larson, 2020) and

urban audiences who might otherwise have little enticement or opportunity to engage with wildlife and non-urban landscapes. Several participants commented, unprompted, that playing RDR2 provided a means of (vicariously) experiencing natures to which they have little physical access. Immersive virtual experiences of wildlife and natural landscapes could even be proffered as an alternative to their real-world visitation, thereby both increasing the accessibility of, and reducing anthropogenic pressure on, protected areas (for example); this idea was included in E. O. Wilson's ambitious 'Half-Earth' proposal (Wilson, 2016). Such a move would carry the risk, however, that experiences of wildlife and wilder places become 'flattened': standardised and sensationalised to meet public demand and increasingly removed from the actual world (Truong & Clayton, 2020; Verma et al., 2015). Experiences with virtual natures are generally considered less beneficial than actual nature (Mayer et al., 2009)—though arguably this depends on the dynamics of the experience—and we are not proposing that virtual encounters replace embodied ones. Nevertheless, there is clearly a role for simulated wildlife and ecosystems in environmental education and engagement. Big-budget entertainment games can educate and maybe even inspire people, even if it is not part of their mission statement, and should therefore be taken seriously as a communicative force. Future work might engage with developers to investigate means by which the educational value of such games might be enhanced without counteracting their primary goal of entertainment.

RDR2 is not a children's game, and we are not suggesting that it has educational value for under-18s. Other widely available games also provide educational opportunities without focusing on learning. For an immersive experience, players of *Abzû* (Giant Squid Studios, 2016) explore underwater environments populated with (simulated) real-world marine species; for ecological understanding, *Viva Piñata* (Rare/Chrome Studios, 2006) contains lessons about habitats, food webs and environmental management. Educators and conservationists might also adopt and adapt ideas from these games: digital media and a big budget are not required to 'gamify' natural history teaching through immersive role-play (e.g. as explorers) and the regular application of knowledge (e.g. teaching foraging, growing produce and creating bird lists).

5 | CONCLUSION

For many people, most experiences of wildlife and natural landscapes will be vicarious, mediated by their depictions in books, images and, increasingly, digital media. While vicarious experiences have different qualities from material interactions, they are nevertheless influential in shaping people's knowledge and understanding of the living world. We found that an immersive video game with simulated wildlife and ecosystems can effectively teach players to identify real-world species, both visually and, potentially, by sound. We also present initial evidence to suggest that simulated ecosystems can teach players about animal behaviour and ecology. Our

qualitative findings indicate that immersive gameplay and active learning are key mechanisms for learning vicariously. We therefore conclude that video games, both those designed for education and those designed for entertainment, are worth taking seriously as providers of both environmental education and vicarious experiences of the natural world.

ACKNOWLEDGEMENTS

The authors would like to thank all participants of the survey for their contribution to this research, and two reviewers for their constructive feedback on the original manuscript.

CONFLICT OF INTEREST

S.L.C. and M.J.S. are guest editors for the People and Nature special issue 'Nature on Screen', but were not involved in the peer review, editorial or decision-making process for this manuscript.

AUTHORS' CONTRIBUTIONS

E.J.C. and S.L.C. conceived the ideas; E.J.C., S.L.C. and M.J.S. designed the methodology; E.J.C. collected the data; M.J.S. analysed the quantitative data; S.L.C. analysed the qualitative data; S.L.C. and E.J.C. led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

DATA AVAILABILITY STATEMENT

Raw data and R code can be accessed via Zenodo at the following URL: <https://doi.org/10.5281/zenodo.4899586> (Crowley et al., 2021). Qualitative coding structure and details are available on request.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

How to cite this article: Crowley, E. J., Silk, M. J., & Crowley, S. L. (2021). The educational value of virtual ecologies in *Red Dead Redemption 2*. *People and Nature*, 00, 1–15. <https://doi.org/10.1002/pan3.10242>