Received: 30 September 2022 | Accepted: 15 March 2023

DOI: 10.1111/bjet.13318

ORIGINAL ARTICLE

British Journal of Educational Technology BERA

Exploring how children with reading difficulties respond to instructional supports in literacy games and the role of prior knowledge

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Funding information

Horizon 2020 Framework Programme, Grant/Award Number: 731724

Abstract

Digital literacy games can be beneficial for children with reading difficulties as a supplement to classroom instruction and an important feature of these games are the instructional supports, such as feedback. To be effective, feedback needs to build on prior instruction and match a learner's level of prior knowledge. However, there is limited research around the relationship between prior knowledge, instruction and feedback in the context of learning games. This paper presents an empirical study exploring the influence of prior knowledge on response to feedback, in two conditions: with or without instruction. Thirty-six primary children (age 8–11) with reading difficulties participated: each child was assessed for their prior knowledge of two suffix types—noun and adjective suffixes. They subsequently received additional instruction for one suffix type and then played two rounds of a literacy game—one round for each suffix type. Our analysis shows that prior knowledge predicted initial success rates and performance after a verbal hint differently, depending on whether instruction was provided. These results are discussed with regards to learning game feedback design and the impact on different types of knowledge involved in gameplay, as well as other game design elements that might support knowledge building during gameplay.

KEYWORDS
children with reading difficulties, feedback, literacy games, prior knowledge

Practitioner notes

What is already known about this topic

- Instructional supports, such as elaborative feedback, are a key feature of learning games.
- To be effective, feedback needs to build on prior instruction and match a learner's level of prior knowledge.
- Prior knowledge is an important moderator to consider in the context of elaborative feedback.

What this paper adds

- Providing additional instruction (eg, pre-training) may act as a knowledge enhancer building on children's existing disciplinary expertise, whereas the inclusion of elaborative feedback (eg, a hint) could be seen as a knowledge equaliser enabling children regardless of their prior knowledge to use the pre-training within their gameplay.
- Highlights the importance of children's preferred learning strategies within the design of pre-training and feedback to ensure children are able to use the instructional support provided within the game.
- Possible implications for pre-training and feedback design within literacy games, as well as highlighting areas for further research.

Implications for practice and/or policy

- Pre-training for literacy games should highlight key features of the learning content and explicitly make connections with the target learning objective as well as elaborative feedback.
- Pre-training should be combined with different types of in-game feedback for different types of learners (eg, level of prior knowledge) or depending on the type of knowledge that designers want to build (eg, metalinguistic vs. epilinguistic).
- Modality, content and timing of the feedback should be considered carefully to match the specific needs of the intended target audience and the interaction between them given the primary goal of the game.

INTRODUCTION

Reading is a foundational skill that underpins a child's education. Teaching of decoding skills is required to make the mappings between the visual (grapheme) and spoken (phoneme) form explicit (Castles et al., 2018). Children learning English will also be taught to read sight words (ie, irregular words) that cannot be easily decoded, as well as rules around morphology (ie, prefixes, suffixes) to aid the reading process (Bowers & Bowers, 2017). With regular practice and instruction most children develop the necessary skills to become proficient readers, gradually increasing the fluency at which they can process written text. However, some children continue to struggle with acquiring the necessary literacy skills well into primary school and beyond (Snowling & Hulme, 2013). Children who experience reading difficulties in the later years of primary school typically receive additional targeted instruction outside of the classroom. Intervention for such pupils will often target the lower-level reading skills (ie, phonics) and will require systematic, repeated learning of content that is usually introduced in the early years of learning to read (Carroll et al., 2011). For some, this may lead to reduced motivation to read and disengagement with literacy learning due to frequent failures and difficulties with traditional classroom instruction techniques (Morgan & Fuchs, 2007; Ronimus et al., 2019).

Digital learning games offer an opportunity to repeatedly practise the same skills/content in an alternative way that provides a sense of novelty from more traditional classroom-based approaches. This is particularly relevant for reading, which often requires repeated practice to automatise certain skills. Prior research has highlighted the potential of digital games for supporting learning (Wouters & Van Oostendorp, 2013) and there is some evidence that digital literacy-based games can be beneficial, in particular, for children with reading difficulties as a supplement to classroom instruction (Holmes, 2011; Ronimus et al., 2019; van Gorp et al., 2017).

A key feature of learning game design is the inclusion of instructional supports, which have been shown to facilitate learning in games and are particularly beneficial for novice learners (Wouters & Van Oostendorp, 2013, p. 412). Wouters and Van Oostendorp (2013, p. 412) defined these supports as including a ‘broad range of techniques and methods that aim at different cognitive activities’. In her meta-analysis, Ke (2016) identified cues, feedback and content instruction as the most common types of instructional supports found in learning games, but goes on to suggest there is still a need for further research into the design and effectiveness of these supports. In particular, feedback has been shown as a key instructional support that has the potential to positively impact learning outcomes in games (Clark et al., 2016; Ke, 2009; Wouters & Van Oostendorp, 2013) and extensive research around the use of feedback in education more generally has demonstrated it to be one of the most effective instructional influences on learning (Hattie & Timperley, 2007; Shute, 2008).

We also know that feedback should build on prior instruction and is ‘most powerful when it addresses faulty interpretations, not a total lack of understanding’ (Hattie & Timperley, 2007, p. 82). Furthermore, previous research has highlighted that the content of the feedback needs to be matched to the learner's current level of knowledge for it to be most effective (Hattie & Gan, 2011). Thus, while feedback may enhance prior instruction, its impact may also be mediated by prior knowledge. The question of whether game feedback enhances instruction for children with less prior knowledge is particularly important for children with reading difficulties, for which instruction alone may not be sufficient. Therefore, in this paper we explore the role of feedback and its interaction with prior knowledge with the view to inform best practice for future learning game design. We present an exploratory quantitative study that explores the influence of prior knowledge on children's performance on a literacy game (accuracy of their first attempt on a trial and subsequent response to feedback), in two conditions: with or without instruction. This is achieved in a population of primary school children with reading difficulties and in the context of literacy gameplay on specific derivational morphemes.

BACKGROUND

Feedback design

Feedback has been defined as ‘any information about performance or understanding that the learner can use to confirm, reject or modify prior knowledge’ (Fyfe & Rittle-Johnson, 2016, p. 1); and, within the context of learning games, feedback is used to support a player's performance, motivation and learning outcomes (Shute, 2008). There are two broad types of feedback in games. Outcome feedback, which simply informs the learner of the correctness of their response, and elaborative feedback which provides the learner with additional information, hints, strategies or processes they can employ within the game to reach a desired outcome (Johnson et al., 2017; Narciss et al., 2014). Reviews consolidating empirical research in this area have shown that elaborative feedback is particularly effective in game-based learning, as compared to outcome feedback (Johnson et al., 2017; Mayer, 2014; Shute, 2008). Lämsä et al. (2018) note the provision of 'immediate, supportive and corrective feedback' as a key benefit of reading and mathematics games for struggling learners, but there has been limited research in this area.

Hattie and Gan (2011) highlighted the importance of feedback being appropriate for the learner's current level. Previous research has indicated elaborative feedback is particularly beneficial for novice learners with low prior knowledge in the game content domain (Mayer & Johnson, 2010; Moreno, 2004). There is, however, little evidence around how particular characteristics of the learner, such as their level of prior knowledge, interact with feedback in learning games (Johnson et al., 2017; Narciss et al., 2014; Shute, 2008). Within the context of a digital literacy game activity on morphology and syntax, Vasalou et al. (2021) found that children with reading difficulties tended to check the accuracy of the sentences they constructed by reading for meaning. They thus relied on their implicit procedural knowledge of language, rather than using the declarative knowledge embedded in the elaborative feedback, which took the form of a metalinguistic language rule. They also suggest that in order to understand more complex elaborative feedback there may be a need to introduce the specific learning concept presented in the game (eg, how a suffix changes the form/meaning of a word) through explicit instruction prior to gameplay. This could boost a child's level of prior knowledge and strengthen the metalinguistic link between the target concept within the game and the feedback provided.

In relation to when this feedback is displayed, Grawemeyer et al. (2015) found that high-interruptive feedback (eg, pop-up windows) was more effective for children who are feeling frustrated, confused or who had otherwise 'negative' affect with the gameplay experience; while low-interruptive feedback (eg, feedback that players access voluntarily) aggravated this negative effect. Contrastingly, Ke et al. (2019) describe that game-based learners have low attention to text-based feedback and are only likely to interact meaningfully with supports when they deem them as 'legitimate investments' to avoid continued error-making. In other words, players enjoying the gameplay experience (positive affect) would not want to access these supports as it may interrupt the game flow. They recommend the use of non-interruptive, multimodal feedback mechanisms. Thus, highlighting the requirement for the specific needs of the learner group to be considered in the feedback design.

Teaching instruction in games

The use of learning games to activate pre-taught knowledge is a common feature of prior research. Ke (2016) and Wouters and Van Oostendorp (2013) highlight the beneficial impact on learning of well-designed game instructional supports such as 'pre-training' (ie, providing the player with domain-specific content before playing the game). In the context of educational games focused on business and science/technology learning, Barzilai and Blau (2014) and Tsai et al. (2013) respectively, found that providing external scaffolds before gameplay increased performance relative to others who did not receive these scaffolds. It is suggested that these initial external scaffolds may help to conceptualise learners' game understandings by linking it to their existing disciplinary knowledge (Ke et al., 2019).

Pre-training is an instructional principle proposed by Mayer and Pilegard (2014) in the context of multimedia learning, which states that an awareness of the names and characteristics of the key learning concepts that are part of the task supports deeper learning, which in their work consisted of naming the parts of a car and how they work together. Equipping learners with relevant prior knowledge in this way can support their working memory by mitigating ineffective use and reducing cognitive effort (Mayer & Moreno, 2003; Mayer & Pilegard, 2014; Wouters & Van Oostendorp, 2013). However, it is important that this instruction is domain-relevant and integrated with the learning game content (Clark et al., 2016). Furthermore, within the context of a science game for secondary students, Law and Chen (2016) demonstrated that elaborative feedback was only effective when supported by 'knowledge prompts' which focus on corrective action by prompting the correct conceptual knowledge (eg, referencing concepts or knowledge to be attended to and learnt in the game).

Role of prior knowledge

Fyfe and Rittle-Johnson (2016) propose a number of reasons why prior knowledge is an important moderator to consider in the context of elaborative feedback, which include the following:

- The need to connect prior knowledge with new information provided within the feedback to achieve a successful learning outcome
- The impact of prior knowledge on the effectiveness of different instructional techniques, with some techniques more beneficial for low-knowledge learners
- Previous research has shown levels of prior knowledge can frequently be a predictor for learning from feedback

A commonly cited finding from examining instructional supports (such as feedback and pre-training) and the role of prior knowledge is that support that benefits novice learners can hinder learners with more expertise in the domain, known as the 'expertise reversal' effect (Fyfe & Rittle-Johnson, 2016; Kalyuga, 2014). This finding has also been reflected within the feedback literature, with high prior knowledge learners able to learn more with less elaborated feedback (Attali & van der Kleij, 2017; Smits et al., 2008). This effect is explained through cognitive load theory whereby the more comprehensive feedback reduces the cognitive load of a novel task but results in redundant processing for learners who already have the relevant prior knowledge (Attali & van der Kleij, 2017; Kalyuga, 2014). To date, there is limited research that has explored this phenomenon within the context of game feedback (Johnson et al., 2017). Supporting children with reading difficulties offers a particularly critical case in which to explore these nuances.

Aim and research questions

Previous research has highlighted the need to examine game feedback from a multidimensional perspective that recognises task characteristics, alongside learner characteristics and the instructional context (Johnson et al., 2017; Shute, 2008). Our review of prior work has highlighted that despite there being substantial previous research around feedback, this has been limited in relation to literacy games. Literacy game tasks have a high verbal load, given the nature of the learning tasks, which may be exacerbated with game feedback. Despite the positive role that instructional supports, namely instruction and game feedback, contribute to children's learning, debates remain on whether these supports increase cognitive overload for learners with more prior knowledge, suggesting that further study is warranted. Therefore, exploring the nature of the relationship between game feedback, instruction and prior knowledge in the context of literacy is important.

By measuring the game performance of children with reading difficulties before and after receiving elaborative feedback, and with and without instruction, and relating it to their former knowledge of the game learning objective, the present study aimed to build on current research to explore the role of prior knowledge and instructional supports, such as pre-training and feedback. We explored this relationship through a preliminary study within the context of literacy games and children with reading difficulties. Specifically, we compared accuracy and recovery within two conditions, with and without pre-training (instruction) of the target language feature in the game, asking the following research questions (RQ) for each condition:

RQ1: Does prior knowledge predict game accuracy rates in all initial attempts (ie, prior to receiving feedback) and does this differ depending on whether pre-training was given?
RQ2: Does prior knowledge predict recovery from errors following in-game elaborative feedback (in the form of a verbal hint) and does this differ depending on whether pre-training was given?

RQ1 was proposed to first check whether our measure of prior knowledge for the target learning objective in the game was a good predictor of game performance in the first place (before receiving any feedback). While previous qualitative research has suggested that children did not report using elaborative feedback in a literacy game (Gauthier et al., 2022; Vasalou et al., 2021), here we seek to quantitatively explore the role of elaborative feedback to aid error recovery when instruction (hereafter referred to as 'pre-training'; ie, teaching of the concept) is provided. To explore this, in the present study, children received pre-training for noun suffixes but no instruction for adjective suffixes. Comparisons are made across the two conditions (pre-training: taught vs. untaught). Related to RQ2, we hypothesised that elaborative feedback would encourage children to reflect on any errors made and have a positive impact on error recovery for children with reading difficulties. We also explored whether the use of elaborative feedback yields greater accuracy when children received pre-training in the target feature (ie, noun suffixes), which would suggest that instruction prior to gameplay helps to strengthen the metalinguistic link between the concept and the feedback provided. Furthermore, in line with the 'expertise reversal effect' (Fyfe & Rittle-Johnson, 2016), we predicted that elaborative feedback would have a detrimental effect on game performance in those children with better knowledge of the target learning objective.

METHODOLOGY

Participants

Thirty-six children aged 8–11 years (average = 9.64) participated in the study. Children attended four urban state primary schools in the United Kingdom and were identified as having reading difficulties by their teachers, which meant they received additional targeted literacy support within their school. Three of these children were not included in the final data analysis as in two cases the screen recordings were lost, and another child's game crashed and, therefore, resulted in incomplete activity. Thus, the final sample comprised 33 children (13 females; 20 males).

Study procedure

This research was undertaken in line with the BERA code of ethics. We obtained full approval from the university ethics committee prior to undertaking the study. Both children and their parents provided explicit informed consent to participate, as well as for both audio and screen recordings to be made of their gameplay (and stored for later analysis). Children were given specially designed child-friendly information and consent forms.

Language feature

The language category 'Suffixes' was selected to focus on within the game. This focus was decided upon after consultation with the children's teachers who identified suffixes as a common area of difficulty and one in which children would benefit from further practice. Within this category, two specific suffix types were chosen: noun suffixes (-ent, -ence, -ity, -ness) and adjective suffixes (-able, -ible, -ing, -ed). Both of these language features are initially introduced at the same point in the UK national curriculum (Year 2—ages 6–7 years), where it is explicitly stated as a statutory requirement for teachers to introduce the formation of both nouns and adjectives using suffixes (DfE, 2014). Therefore, all children in the study would have previously encountered these language features as part of their formal schooling. Additionally, teachers' selection of these features indicated continued instruction on these two features.

Session design

Each child participated in one gameplay session in groups of 4–6 at a time, facilitated by 2-3 researchers in a separate room outside of their normal classroom. The session length was between 10 and 15 minutes. The protocol comprised (i) a *pretest* to establish prior knowledge of the features, (ii) *pre-training* for the targeted taught feature (noun suffixes) and then (iii) children engaged in *gameplay*. Each step is detailed below.

Pretest

At the start of the session, we verified children's existing knowledge of the target features by administering a short paper-based pretest (see Figure 1). The pretest was compiled by a speech and language therapist who was part of the research team and was based on existing methods for assessing morphological skills/suffix knowledge (Apel et al., 2013). The children completed the test independently. Answers were scored by a researcher, with 1 mark given per correct answer. A maximum of 6 marks could be scored. Performance on this task represents prior knowledge of the two target features.

Pre-training

Next, the children were given some teaching instructions for noun suffixes only. This involved them watching a short teaching video (designed by a literacy teaching expert) on a laptop, which introduced the suffixes (-ent, -ence, -ity, -ness), gave a linguistic hint that suffixes are always at the end of nouns (aligned to the elaborative feedback given in the game activity) and gave some examples of words containing the four different noun suffix types and their meaning (eg, 'With the suffix –ness, kindness is a noun. Showing kindness means that you are being kind'.), along with an illustrative image of each word. This process of explicitly directing attention to morphological units has been suggested to increase morphological awareness (eg, access to the meaning and structure of morphemes within words) and facilitates the development of metacognitive skills (Ebbers, 2017), which children may then draw upon when hearing the elaborative feedback in the game.


Complete the following sentences using the word in brackets:

Examples:

(paint) Picasso was a great sculptor and .... painter....

(connect) They could not get a good internet ...... connection....

1. (sad) What's the reason for his ~~Sadest~~ Sadur ?
2. (confident) They took the exam with Confidention .
3. (accept) Her attitude to the teacher was not accepion .
4. (charm) He was a cheerful and charmfull person.
5. (safe) For your own Safeful , always have your seatbelt fastened in the car.
6. (concern) Alice looked very concenter .

FIGURE 1 Example of completed pretest.

Gameplay

Following the teaching instruction, each child played the two game activities. During the session, each child was provided with a tablet on which to play the game and a researcher pre-selected the game activity/feature combination for them to play. The order of the two target features was counterbalanced within each group of children. The child played independently on their tablet wearing headphones. Children were asked to attempt to resolve issues themselves prior to asking for help from the researcher, who gave additional instructions for difficulties with game mechanics and encouragement to make their best guess where the children were unsure of the answer. There were three trials per game, with three possible choices for each question asked within the game.

Game activity selection

The study used the Navigo literacy game,[1] which has been designed and developed as part of an EU-funded project to support the acquisition of literacy skills for both novice readers and older primary children with reading difficulties. Navigo has 15 game mechanics used across around 900 literacy game activities.

Two different game activities were selected from the subset of available games that each addressed the two chosen language features. However, due to the difficulties, the children experienced with one of these activities (as it required precise positioning of words), in this paper, we focus on the second game which presented a multiple choice. The chosen game activity was ‘Perilous Paths’ (see Figure 2), which incorporates a multiple-choice mechanic where the player is required to complete a sentence by selecting the option with the correct suffix from a fixed number of three options. Each option is presented on a different bridge. If the player chooses an incorrect answer, the bridge is highlighted in red (Figure 2, left image) and will then snap and throw the player back to the starting position where they will receive elaborative feedback in the form of a hint (see Table 1). When a player chooses the correct answer, the bridge is highlighted in green (Figure 2, right image) and the player can cross the bridge. The elaborative feedback hint was designed to provide conceptual knowledge by prompting the player to apply a particular metalinguistic rule to the game learning task. For these particular features the feedback ‘Look for a noun/adjective’ highlights the word class function and effect to the player, prompting the child to consider the options in this way.

Data collection and analysis

Table 2 presents the average scores by feature from the pretest. There were three questions per feature within the pretest and children scored 1 point for each correctly completed sentence (maximum 3 points per feature). Notably, a slightly higher score was observed for average performance on the adjective suffixes pretest. However, a higher proportion of children demonstrated no knowledge in the noun suffixes pretest.

FIGURE 2 Screenshots from Perilous Paths.

TABLE 1 Overview of game feedback in Perilous Paths.

Suffix feature	Type of feedback	Example
Noun suffixes: -ent, -ence, -ity, -ness	Outcome feedback	Bridge breaks/sphynx moves, red highlight, red gems lost, player returned to starting position
	Elaborative feedback (hint)	‘Look for a noun’
Adjective suffixes: -able, -ible, -ing, -ed	Outcome feedback	Bridge breaks/sphynx moves, red highlight, red gems lost, player returned to starting position
	Elaborative feedback (hint)	‘Look for an adjective’

TABLE 2 Average pretest score for suffix language features.

Language feature	Pretest average scores (standard deviation)	% children with no knowledge (ie, score of 0)	Instruction before gameplay?
Noun suffixes (-ent, -ence, -ity, -ness)	1.2 (1.01)	33%	Yes
Adjective suffixes (-able, -ible, -ing, -ed)	1.6 (1.05)	21%	No

Each gameplay session was screen-recorded using software installed on the tablet. Verbal utterances were also audio-recorded to document any confusion that was voiced during the session. Where consent to screen and/or audio record was not given, the researcher noted down the child's actions/answers within the game using a structured observation protocol, which was a template that enabled the researcher to note the interactions made by the child at each stage of the game, the choices selected and space to note any verbalisations from the child.

We followed a deductive approach to coding the data. As a team, we generated an initial coding scheme which enabled the coding of initial correct/incorrect game responses, feedback hints given and game responses after the hint. A training session on how to apply the initial coding scheme was run by a senior researcher and then each gameplay screen recording was coded by one member of the research team, with a second researcher coding a subset of the data. The research team then met several times to discuss and ensure consistent application of the codes.

Regressions were conducted to answer the two research questions. RQ1 assessed the effect of prior knowledge on the initial game accuracy rate. Children's pretest score on each feature was used as the predictor variable, while the proportion of correct responses on their first attempt was used as the outcome variable. RQ2 assessed the effect of prior knowledge on children's recovery rate following an error. Children's pretest score on each feature was again used as the predictor variable, while the proportion of correct responses after a hint was used as the outcome variable. For both RQs, given the two different target language features and that pre-training differed, we ran two separate models: one for noun suffixes (-ent, -ence, -ity, -ness), which were taught before the game session, and one for adjective suffixes (-able, -ible, -ing, -ed), which were not taught. The approach to run two separate regressions was governed by the sample size and how many predictors could be entered into the model. Because the outcomes were expressed as a proportion of correct responses and were not normally distributed, a beta-regression for proportionate and count data was used to model the regressions, using the betareg() function (Cribari-Neto & Zeileis, 2010) in R (R Core Team, 2020). Zero-order Spearman correlations between the variables of interest are presented in the first instance.

RESULTS

Descriptive results

The frequency of response to the feedback hint depending on feature type is presented in Table 3. A recovery corresponds to an instance where a child picked the right answer after receiving a hint, while a non-recovery corresponds to an instance where a child still chose an incorrect answer after receiving a hint. Visual inspection of the table indicates that in the noun suffix games, children recovered after a hint more often than not, while the opposite tendency was observed in adjective suffix games (ie, children were more likely not to recover after a hint). There were also more hints given in noun suffix games (n = 36) than in adjective suffix games (n = 28), indicating more incorrect answers in the first attempts of the games on noun suffixes.

RQ1: Does prior knowledge predict game accuracy rates in all initial attempts (ie, prior to receiving feedback) and does this differ depending on whether pre-training was given?

Spearman correlations between the pretest score on prior knowledge and the proportion of correct responses on the first attempt were significant for noun suffixes ($n=33$, $r=0.46$, $p=0.007$), but not for adjective suffixes ($n=33$, $r=0.32$, $p=0.07$). The more successful children were at the noun suffixes pretest (before receiving the pre-training of the feature), the better they were on their first attempt in the game. This was not the case for adjective suffixes.

As shown in Table 4, the regression model for noun suffixes was a good fit ($\chi^2(3)=12.38$, $p<0.001$), with a significant contribution of the pretest score to children's correct response rate for their first attempt. However, this was not the case for adjective suffixes ($\chi^2(3)=47.01$, $p>0.05$). Thus, prior knowledge (as measured by pretest scores on each feature) impacted children's accuracy on their first attempt significantly and positively for noun suffixes (that were pre-taught), but not for adjective suffixes (that were not pre-taught).

RQ2: Does prior knowledge predict recovery from errors following in-game elaborative feedback (in the form of a hint) and does this differ depending on whether pre-training was given?

The findings in Table 3 demonstrated that elaborative feedback resulted in recovery more often than not for those items that children received prior instruction in (eg, noun suffixes), but not for those without prior instruction. The findings presented here examine whether higher prior knowledge impacts game performance (eg, 'the expertise reversal effect'). Spearman correlations between the pretest score and the proportion of correct responses after a hint were significant for adjective suffixes ($n=13$, $r=-0.69$, $p=0.009$), but not for noun suffixes ($n=24$, $r=0.07$, $p=0.73$). The more successful children were at their adjective suffixes pretest, the worse they were on their second attempt (after a hint). This was not the case for noun suffixes, which children received the pre-training on.

As shown in Table 5, the regression model for adjective suffixes was a good fit ($\chi^2(3)=9.17$, $p<0.001$), with a significant contribution of the pretest score to children's correct response rate after hint—this was not the case for noun suffixes ($\chi^2(3)=27.76$, $p>0.05$). Thus, prior knowledge negatively predicted children's recovery rate in adjective suffixes (which were not pre-taught), but held no relationship with recovery rates in noun suffixes (that were pre-taught).

DISCUSSION

We explored the relationship between prior knowledge, instruction and feedback within literacy games through an empirical study. Specifically, we investigated the influence of prior

TABLE 3 Contingency table for the frequency of recovery versus non-recovery depending on the feature type.

	No recovery after feedback hint	Recovery after feedback hint	Total rows
Noun suffixes (-ent, -ence, -ity, -ness)—Taught (pre-training)	16	20	36 (56%)
Adjective suffixes (-able, -ible, -ing, -ed)—Untaught (no pre-training)	15	13	28 (44%)
Total columns	31 (48%)	33 (51%)	

TABLE 4 Regression model assessing the impact of prior knowledge on the proportion of correct responses on the first attempt.

	Outcome: Proportion of correct responses on first attempt											
	Noun suffixes (with instruction)						Adjective suffixes (no instruction)					
	pseudo R^2	*B*	*SE*	χ^2	*df*	*p*	pseudo R^2	*B*	*SE*	χ^2	*df*	*p*
Constant		0.15	0.29	0.53		0.59		0.18	0.42	0.42		0.67
Pretest score		1.55	0.57	2.71		0.006**		0.94	0.67	1.40		0.16
Model	0.19			12.38	3	<0.001	0.09			47.01	3	>0.05

** indicates $p < .05$.

TABLE 5 Regression model assessing the impact of prior knowledge on the recovery after hint.

	Outcome: Proportion of correct responses after feedback hint (second attempt only)											
	Noun suffixes (with instruction)						Adjective suffixes (no instruction)					
	pseudo R^2	*B*	*SE*	χ^2	*df*	*p*	pseudo R^2	*B*	*SE*	χ^2	*df*	*p*
Constant		0.26	0.39	0.66		0.51		0.74	0.46	1.60		0.011
Pretest score		0.06	0.88	0.07		0.94		−3.53	1.01	−3.51		<0.001***
Model	0.0003			27.76	3		0.40			9.17	3	

*** indicates $p < .001$.

knowledge on the responses of primary children with reading difficulties to literacy game feedback, in two conditions: with or without pre-training. Here we note that the findings should be considered exploratory in nature, given the small sample size. Below we summarise the findings and discuss possible implications for literacy game design.

Summary of the results

Regressions were used to assess the impact of prior knowledge on (1) accuracy rates (proportion of correct responses on the first attempt) and (2) recovery rates (proportion of correct responses after receiving elaborative feedback). Two conditions were explored, one whereby the children received teaching instruction on the target feature before playing the game (noun suffixes) and the other where children did not receive any instruction (adjective suffixes). For the feature that received pre-training, prior knowledge of the target was a predictor of performance, but only on the child's first attempt of a trial (ie, when success was achieved on the first attempt at the item within the game). This pattern of relationship between prior knowledge and performance disappeared in second attempts (error correction after receiving the hint). However, for the feature that did not receive pre-training, prior knowledge of the target was a predictor of performance, but only *after* the hint was given to aid error correction, and this relationship was negative: those children with better knowledge of the target feature made fewer recoveries after the feedback hint than those with less knowledge.

Teaching instruction as a knowledge enhancer but elaborative feedback as a knowledge equaliser?

First, we consider why prior knowledge predicted children's game performance in their first attempt on the taught feature (ie, the one linked to the pre-training), but not for the untaught feature, given the two features were similar in terms of focus and difficulty level. It is possible that the additional teaching instruction may have *acted as a knowledge enhancer, prompting children to access their existing prior knowledge around noun suffixes or suffixes more generally*. In this rich multimedia environment, children were presented instructions both verbally and visually situated within an interactive animated game world. It is possible that children may have been more likely to experience cognitive overload with respect to the untaught feature, where they had not received additional support to access their existing knowledge (ie, through pre-training; Mayer & Pilegard, 2014). Furthermore, research has shown that for students with dyslexia who have a core reading difficulty, additional auditory information in multimedia environments impacts learning negatively, which has been linked to cognitive overload in a group of students that typically present with poor working memory (Harrar et al., 2014; Knoop-van Campen et al., 2018). Similarities could be drawn with the present sample of children that present with reading difficulties.

However, prior knowledge of the taught feature (ie, noun suffixes) did not predict the likelihood of recovery from an error within the game, with the subsequent game performance of children who made an error more homogenous. This suggests that *the provision of elaborated feedback in the form of a hint potentially acted as a knowledge equaliser by enabling a broader range of children, regardless of their prior knowledge, to access the knowledge provided through the pre-training*. This preliminary finding contrasts with previous findings that suggest elaborated feedback is more beneficial for children with less prior knowledge (Attali & van der Kleij, 2017; Johnson et al., 2017; Smits et al., 2008) and that perhaps the direct connection between the elaborative feedback and the pre-training is key. Thus, instructional supports may only be beneficial when they are clearly connected to the targeted learning objective (Clark et al., 2016). Furthermore, it is worth considering the type of elaborative feedback within the Navigo game, which was in the form of a verbal hint. This elaborative feedback hint could be viewed as a 'knowledge prompt' (Law & Chen, 2016) since it focuses on corrective action and prompting the correct conceptual knowledge and does not offer an explicit explanation on why the selected answer was incorrect.

A possible implication of these findings for literacy game design for children with reading difficulties may be for pre-training (ie, instruction) within the context of literacy game learning to highlight key features of the learning content and explicitly make connections with the target learning objective, as well as elaborative feedback. Yet, further research is needed to understand how to best position the nature and content of error feedback. For instance, what is the impact of a knowledge prompt in combination with an elaborated explanation of the selected incorrect answer, and is this beneficial for children with both high and low prior literacy knowledge?

Supporting learning strategy preferences through feedback design

Next, we focus on the finding that, *in the untaught condition, the level of children's prior knowledge did not predict initial success and subsequently impacted their performance negatively after they received a feedback hint*. In the case of the untaught feature, the children were required to possess a certain level of linguistic awareness to succeed within the game. However, is it possible this could be at an implicit level. For example, children may be able to complete a sentence by choosing the correct adjective without an awareness that it is an adjective. Whereas in the taught condition the pre-training and feedback hint both explicitly drew children's attention to the target concept, that is, part-of-speech—foregrounding this concept within the game. In another literacy game study, children reported using correction strategies such as trying out 'the word options mentally in order to make sense of the sentence they produced' (Vasalou et al., 2021). This indicates that some children were choosing an alternative strategy to that suggested in the hint (ie, to ‘look for an adjective’). Therefore, providing a hint that does not align with a child's preferred strategy (ie, on a metalinguistic rather than epilinguistic level, eg, explicit knowledge of linguistic units vs. implicit ability to manipulate linguistic units) may have caused additional confusion and contributed to additional cognitive load, hindering children with more prior knowledge in recovering from an error.

Previous research has shown that French children with dyslexia can produce morphologically complex words in a sentence completion task but cannot segment the same morphemes within a word explicitly (Casalis et al., 2004). It was hypothesised that the poorer phonological skills of this population impaired their ability to explicitly segment words into morphemes, while their ability to use the same morphemes in context was intact. Although the hints in our game did not require phonological manipulation, they required a high level of language processing (eg, thinking of the parts of speech, noun vs. adjective, then thinking of the type of suffix this might include, before then checking it against the given options). With the population of struggling readers as a whole likely to experience difficulties not only with phonological processing but also with broader language skills and working memory (Gray et al., 2019), it is possible that using an explicit hint might not have been the most appropriate type of support.

A further point of note is that the feedback was automatically presented within the game—the children had no choice in whether to receive it or not, although they could continue to play the game while it was read aloud. It was also spoken directly after the child made the error when they may have already started considering their own correction strategy. This could have impacted their ability to attend to and/or process the hint. Therefore, similar to Grawemeyer et al. (2015), a higher interruptive form of feedback may have better helped those children who perhaps missed the feedback altogether due to their higher cognitive load.

In line with recommendations from the game literature (Johnson et al., 2017), the feedback hint within the Navigo game was verbal only. However, problems with verbal working memory and/or auditory processing are often reported in children with reading difficulties (Rose, 2009; Swanson et al., 2009; Witton & Talcott, 2018) which could have impacted their processing of the verbal feedback within the game. The opportunity to move on without listening could have further encouraged some children to avoid processing the hint. This raises points for reflection about the presentation of feedback as discussed below.

These preliminary findings suggest that literacy game designers may want to consider combining pre-training with different types of in-game feedback for different types of learners (eg, level of prior knowledge) or depending on the type of knowledge that designers want to build (eg, metalinguistic vs. epilinguistic). The findings also point towards the need to carefully consider the modality, content and timing of feedback in relation to the specific needs of the intended target audience and the primary goal of the game. Further research should seek to understand how feedback can be successfully combined with pre-training and matched to a child's learning approach (ie, using implicit strategies that rely on procedural knowledge vs. explicit feedback that refers to declarative knowledge), for example, through personalisation. Furthermore, the use of verbal and visual feedback may be considered. The visual presentation could reinforce the verbal pictorially rather than simply be presented as text. Additionally, high-interruptive feedback may be beneficial to encourage children to attend to the feedback, rather than continuing with the game.

LIMITATIONS

The present study has shed light on the complex relationship between feedback, prior knowledge and instruction within literacy games, highlighting potential implications for learning game designers. However, limitations can be acknowledged. It is important to note that, due to the design constraints of the selected game, during the recovery condition the children were selecting their answer out of two possible options, which means there is a high element of chance that they might select the correct answer even if they were picking at random. Future studies could choose alternative game types with a higher number of response items or where the number of response options remains the same after feedback to further explore how children respond to game feedback and recover from errors. Furthermore, we presented a quasi-experimental study with a within-subject design and can acknowledge that the sample was relatively small. While this was an important first step, the findings are exploratory in nature. The study design did not allow us to compare the taught and untaught conditions systematically, as all children received teaching on the same feature (noun suffixes) and the sample size was too small to neutralise the two conditions needed for a multiple-regression analysis. Further studies should seek to replicate the findings with a larger sample size to confirm the findings presented and to develop specific recommendations for game designers. In future studies, different groups of children may be randomly selected to receive teaching instructions on different features to allow for the interactions between prior knowledge, *teaching* and feedback on game success to be tested.

CONCLUSION

This paper sought to establish the influence of prior knowledge and instruction on the response to elaborative feedback of children with reading difficulties within the context of a literacy game. This involved 36 children with reading difficulties playing a game focused on two particularly challenging language features—noun and adjective suffixes, but having received prior instruction (pre-training) for only one of these features. Findings revealed that the level of prior knowledge predicted initial success rates and performance after elaborative feedback (a verbal hint) differently for the two suffix types. For the taught feature (noun suffixes), prior knowledge *supported* success *before, but not after* a hint; while, for the feature where children did not receive any pre-training (adjective suffixes), prior knowledge *hindered* success *after, but not before* a hint. These results indicate that providing additional instruction (eg, pre-training) before playing a game may act as a knowledge enhancer, building on children's existing disciplinary expertise, whereas the inclusion of elaborative feedback (eg, a hint) could be seen as a knowledge equaliser, enabling children regardless of their prior knowledge to use the pre-training within their gameplay. It also suggests that taking into account children's preferred learning strategies within the design of pre-training and feedback could ensure children were helped rather than confused by the instructional support provided within the game. Children can experience difficulties with reading for a wide range of reasons and will often have had very varied educational experiences resulting in a diverse set of reading skills and knowledge gaps. Ke (2019, pp. 137–138) highlights that 'only when a support is context-aware and intrinsically integrated in the technical environment will the support be effective'. Therefore, literacy game designers should take this context into account through the provision of appropriately tailored and integrated instructional supports, such as pre-training and feedback.

ACKNOWLEDGEMENTS

We would like to thank Yvonne Vezzoli for contributing to the data collection and analysis. We also acknowledge the four schools and the children who participated in this research. This work was funded by iRead (project no: 731724) H2020 Innovation Action EU Project.

FUNDING INFORMATION

H2020 Leadership in Enabling and Industrial Technologies, Grant/Award Number: 731724.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest in relation to the research reported in this paper.

DATA AVAILABILITY STATEMENT

The data reported in this paper are not open access.

ETHICS STATEMENT

The BERA ethical guidelines were followed while conducting this research. The research team also obtained ethical approval from UCL IOE's research ethics committee prior to commencing the research.

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ENDNOTE

[1] https://iread-project.eu/game/

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How to cite this article: Benton, L., Joye, N., Sumner, E., Gauthier, A., Ibrahim, S., & Vasalou, A. (2023). Exploring how children with reading difficulties respond to instructional supports in literacy games and the role of prior knowledge. *British Journal of Educational Technology*, *00*, 1–18. https://doi.org/10.1111/bjet.13318