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Do children with reading difficulties benefit from instructional game supports? Exploring children's attention and understanding of feedback

Asimina Vasalou[1] | **Laura Benton**[1] | **Seray Ibrahim**[1] | **Emma Sumner**[2] | **Nelly Joye**[3] | **Elisabeth Herbert**[2]

[1]UCL Knowledge Lab, UCL Institute of Education, University College London, London, UK

[2]Psychology and Human Development, UCL Institute of Education, University College London, London, UK

[3]School of Health and Social Care, University of Essex, Essex, UK

Correspondence
Asimina Vasalou, UCL Knowledge Lab, UCL Institute of Education, University College London, London, UK.
Email: a.vasalou@ucl.ac.uk

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Abstract

This paper examines how primary aged children with reading difficulties attend to, understand and act upon different types of feedback within a digital literacy game. A systematic and structured video analysis of twenty-six children's game play was carried out focussing on moments where children made an error and were followed by in-game feedback. Our findings show that children benefited from outcome feedback, which supported an accurate interpretation of their game performance and prompted children to try again. In contrast, though the elaborative feedback attracted similar levels of attention, children struggled to understand the content, resulting in a reliance on implicit knowledge to correct their next response. Alongside identifying a set of new questions for future research, the study contributes a number of intrinsic and extrinsic recommendations for ensuring children with reading difficulties attend to and comprehend games-based feedback.

KEYWORDS
children with reading difficulties, game feedback, games-based learning, instructional support

Practitioner notes

What is already known about this topic?
- Outcome and elaborative feedback provided in games can scaffold the learner to recognise errors and apply corrective strategies.
- Elaborative feedback, in particular, has been evidenced to support the learner's understanding and lead to learning gains, albeit with older populations.

What this paper adds?
- An empirical evaluation of how young children who struggle with reading attend to, understand, and respond to feedback in a digital literacy game.
- Demonstrates that children attend to the outcome and elaborative feedback to equal degrees, but struggle to understand and apply elaborative feedback due to its metalinguistic complexity.

Implications for practice and/or policy?
- Games that embed outcome feedback visually in the target response can enhance the child's attention to, and understanding of, their performance.
- Games that offer verbal elaborative feedback require additional instruction to maintain children's focus on the feedback and to support content understanding.

INTRODUCTION

Digital learning games are found in many formal education settings where teachers aim to strengthen mainstream provision and its focus on academic skills and knowledge, such as Maths or Literacy (All et al., 2016; Benton et al., 2018; Johnson et al., 2017; Moyer-Packenham et al., 2019). Games gradually introduce challenging content, scaffold learning through in-the-moment feedback, and can foster skills mastery through motivated repetition and practice (Clark et al., 2016; Ke, 2016). These characteristics can be particularly formative to the learning process of those who face difficulties in mastering a skill, such as children who struggle to learn to read. This group of children have reported enjoying literacy games and perceive the game tasks to stretch their abilities without negative judgement (Holmes, 2011). Moreover, other work has shown that games can benefit children with reading difficulties when played in groups whereby children rehearse and reflect on their understanding and learning strategies aloud (Vasalou et al., 2017). Government statistics from the UK revealed that 73% of children reached the expected standard in reading by the end of primary school in England (Department for Education, 2019), highlighting that just over a quarter of 11-year-olds are under-achieving in this respect and are leaving primary school without the necessary skills. Games can play an important role in supporting the progression of this group of struggling readers who are at risk of being left behind.

The present work investigates the question of whether, and the extent to which, feedback offered in learning games can support children with reading difficulties in their understanding of literacy, particularly when the child makes an error within the learning activity. By feedback, we refer to ‘information communicated to a learner that is intended to modify her

or his thinking or behaviour for the purposes of learning' (Shute, 2008). Past research has shown that feedback is one of the most significant instructional interventions for improving attainment (Hattie, 2008), a finding that also carries over to the digital environment (Johnson et al., 2017). In evaluating the impact of various instructional dimensions incorporated in digital games on learning outcomes, Wouters and Oostendorp (2013) found that feedback was amongst the most significant interventions for improving the acquisition of skills and knowledge, and to a lesser extent in-game performance, by focussing the learner on relevant information. The impact of feedback, whilst recognised to be critical to the learning of those who struggle to read (eg, Rose, 2009; Vaughn & Wanzek, 2014), has received limited attention in the context of games. The paper addresses this area through a qualitative research study in which we analysed the game play of children with reading difficulties, their interpretation and response to game feedback. In taking a qualitative approach that focuses on the process of game play, our study contributes an understanding of how this group of children process different aspects of game feedback, leading to new recommendations for the design of literacy games and future research in the area of digital games and feedback.

BACKGROUND

Feedback can support learning in a number of different ways. It can reduce cognitive load and bring attention to a key part of the task; it can signal a gap between performance and the learning aim; and may provide information for correcting inappropriate task strategies (Johnson et al., 2017; Shute, 2008). It has also been established that feedback can be delivered in different ways, and therefore the effectiveness of feedback in part depends on its design (Hattie & Timperley, 2007; Johnson et al., 2017; Narciss et al., 2014; Schrauben & Witmer, 2019; Shute, 2008). This has led to an effort to identify what makes feedback effective and a number of frameworks have been developed that seek to characterise it (Benton et al., 2018; Johnson et al., 2017; Narciss et al., 2014; Shute, 2008).

Across these frameworks a distinction is made between feedback that informs the learner about the correctness of their response, that is *outcome feedback,* and feedback that aims to evolve the learner's understanding, that is *elaborative feedback*.[1] Within games, outcome and elaborative feedback can be presented together (Johnson et al., 2017); however, it is elaborative feedback that has been evidenced to support the learner's understanding and lead to learning gains (Attali & van der Kleij, 2017; Hattie & Timperley, 2007; Johnson et al., 2017; Schrauben & Witmer, 2019). Elaborative feedback seeks to scaffold the learner's thinking and influences further responses by providing additional information (Attali & van der Kleij, 2017); whilst outcome feedback is chiefly corrective. There are three key characteristics to how elaborative feedback is designed:

- **Content** captures the level of information in the elaborative feedback, how complex and specific it is (Johnson et al., 2017; Narcis, 2008; Shute, 2008). Feedback has been shown to be more effective when it is specific rather than vague, and less complex and lengthy (Shute, 2008). The information embedded in the feedback can vary. It can include support to understand the task, knowledge about the concepts covered in the task, flagging up specific errors, providing strategies to process the task, and/or giving support in developing meta-cognitive skills (Benton et al., 2018; Hattie & Timperley, 2007; Narciss, 2008).
- **Timing** reflects when the elaborative feedback is presented. Immediate feedback follows directly after an item response and delayed feedback comes at the end of a task (Johnson et al., 2017; Kleij et al., 2012).
- **Modality** captures whether the elaborative feedback is verbal or visual, building on multimedia theory's proposition that learning is an active process and people learn visually

and aurally (Johnson et al., 2017; Mayer & Moreno, 2003). Johnson et al. (2017) draw on past research to argue that in primarily visual tasks, such as games, feedback presented verbally may be better processed (also Mayer & Moreno, 2003).

In parallel to the recognition that elaborative feedback can be delivered in different ways, the design and impact of feedback also depend on who the learner is, their profile and needs (Attali & van der Kleij, 2017; Johnson et al., 2017; Narciss et al., 2014). For example, while delayed timing can benefit higher ability learners, in the case of lower ability and novice learners, immediate feedback is more likely to be remembered and is thus more effective (Attali & van der Kleij, 2017). However, as Johnson et al. (2017) argue 'the interaction between feedback strategies and characteristics of the individual learner is not well known'. This is particularly the case with novice learners, including young learners and learners who may struggle with a particular domain (Benton et al., 2018, 2019). Benton et al. (2018) observed that most of the research involving digital tools and their delivery of feedback has been carried out with university students (eg, Attali & van der Kleij, 2017; Johnson et al., 2017; Shute, 2008). This knowledge gap is evidenced in the design of learning games for primary school children's literacy learning, which have tended to prioritise outcome feedback more so than elaborative feedback (Benton et al., 2018). The lack of available games for young children incorporating elaborative feedback can in turn limit the opportunities for empirically investigating the impact of elaborative feedback on children's learning.

STUDY MOTIVATION AND RESEARCH QUESTIONS

The present paper seeks to develop a theoretical understanding of how outcome and elaborative game feedback presented in tandem supports the learning of primary school children who experience difficulties within the domain of reading. Children with reading difficulties have been previously identified as a group that can particularly benefit from the use of learning games (eg, Holmes, 2011; Vasalou et al., 2017). In seeking to better understand the relationship between game design and learner, we refer to past research which has predominantly focussed on children with dyslexia with this subgroup forming a substantive percentage of children with reading difficulties. Children with dyslexia are known to present with poor verbal working memory (Swanson et al., 2009); and auditory processing problems have been cited for some, although the research evidence remains inconsistent (see Witton & Talcott, 2018). By extension, difficulties with processing verbal stimuli (or feedback) may thus be hypothesised for this group. Moreover, visuospatial attention has been reported to be poorer for readers with dyslexia; although again the findings in the literature are mixed (see Goswami, 2015) and the implications for learning are unknown. Considering the profile of these learners poses questions about the presentation of feedback and the way it may be interpreted by individuals, such as, for example, the extent to which feedback introduces difficulties with cognitive load. Thus, though feedback is an important instructional element of games, to date, little is known about the way in which children with reading difficulties—including children with dyslexia—interact with game feedback.

Previous research investigating feedback in games and digital technology has been often driven by a 'cognitive consequence' lens that seeks to quantify learning gains resulting from the use of games, or a 'value-added approach' where specific game feedback characteristics are varied to then measure their impact on learning and performance (Johnson et al., 2017). Given the dearth of research in this area, in our work, we take an alternative approach by examining children's unfolding information processing during a learning episode. We define a 'learning episode' to be an event triggered by an error and that is subsequently followed by feedback within the game. Given that learning games, most often, will inform the player

about their performance, we consider the concurrent information processing of outcome and elaborative feedback presented when children make an error. We follow the information processing view by Mayer and Moreno (2003) who claim processing to 'include paying attention to the presented material, mentally organizing the presented material into a coherent structure, and integrating the presented material with existing knowledge'. In this process, the participant is active in selecting, evaluating and applying the information in a learning episode and integrating it with long-term prior knowledge (Johnson et al., 2017). In the domain of reading, this long-term knowledge would relate to declarative and procedural reading skills the child has been previously taught and acquired through practice. To understand children's information processing we employ a structured qualitative research design. In contrast to quantitative research that often seeks to generalise to a population or setting, we engage in 'analytic generalisation' (Yin, 2018) informing a theoretical understanding about the relationship between children with reading difficulties and the design of game feedback.

In summary, the aim of our research is to understand how primary school children with reading difficulties attend to, understand and act upon a combination of outcome and elaborative feedback in a literacy learning game. This goal was pursued through two research questions (RQ):

- **RQ1:** Following an error, do children with reading difficulties attend equally to *outcome* and *elaborative* feedback? Does one attract more attention over the other?
- **RQ2:** When children with reading difficulties attend to *elaborative* feedback, do they accurately process it and act on it?

METHODOLOGY

Participants and context

The research study was carried out in England and the study participants were primary school aged children with reading difficulties. In England, educational policy stipulates that children will receive targeted support in reading where further support than that provided by universal teaching approaches is required; and a formal diagnosis such as dyslexia is not a formal requirement to access targeted support (Department for Education, 2015; Rose, 2009). Twenty-six children in Years 4, 5 and 6 participated in this study (17 male; aged 8–11 years old) across four different mainstream urban primary schools. At the time of the study, none of the participants had received a formal diagnosis of dyslexia or had another diagnosis (eg, ASD, ADHD). All were identified as children with reading difficulties by their school special education needs coordinator (SENCo) and received additional targeted literacy support in small groups. We focussed on this age range to rule out the possibility that children were still in the initial stages of learning to read (new to reading instruction). By this point in their education, children in the UK will have been in formal schooling for at least 3 years (and for the older participants up to 6 years). Therefore, reading difficulties identified by teachers or SENCos at this age are likely to be persistent and not due to lack of instruction. In summary, our sampling approach reflects the characteristics of children with reading difficulties that SENCos support in the context of group literacy sessions.

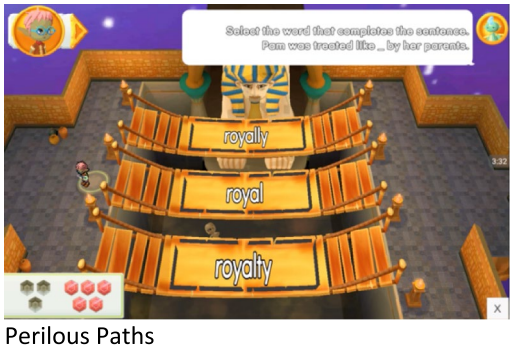
To identify a literacy area that posed difficulty for this cohort we consulted their teachers (two literacy leads and two SENCos who supported the children). Teachers were prompted to identify language areas and learning objectives that were known to cause some difficulty to the children involved. These consultations allowed us to isolate the language area of 'morphology', which refers to the process of analysing the structure of a word and recognising units that can be added to a base (root) word to change the meaning. Within morphology

five different prefix and suffix language features were chosen, which children of this age group would have been previously exposed to in the classroom: (a) Prefixes: negatives non, de; (b) Derivational noun suffixes: -ent/-ence, etc.; (c) Suffix -ing with a change of letter; (d) Adverb Suffix: ly and (e) Superlative adjectives: est. We also verified the relevance of these features through a bespoke morphological task to assess children's knowledge of the target morphemes ahead of the game. These consisted in tasks of prefix identification (eg, Circle the prefix in 'unhappy'), sentence completion (eg, (paint) Picasso was a great sculptor and … 'painter'), or sentence building (eg, City, town, village (big): 'A city is the biggest. A town is bigger than a village.'), which children completed on paper, as a group. Their scores on these tasks ranged from 22% to 88%, with a mean of 58% and a SD of 27%. This established that all children made at least one error in the task and therefore it was likely children would make an error within the game.

Literacy game and feedback design

An earlier review of the current literacy games landscape showed that only a minority of games include elaborative feedback, and those that do often apply inconsistent design principles (Benton et al., 2018). The Navigo literacy game[2] was used in the present study, which was designed to include elaborative feedback in each game activity. Navigo is a game that supports the acquisition of reading skills in primary school children including novice learners and children with reading difficulties. Navigo has 16 game mechanics used across 900 literacy game activities.[3] From the subset of 16 game mechanics, two multiple-choice game mechanics were identified that covered the focal morphology features whilst also providing both outcome and elaborative feedback in the event of a player error. The mechanics, *Crocotiles* and *Perilous Paths*, are presented in Figure 1.

In both games, the child played three separate rounds in which three possible options were presented to complete a sentence. There was no pre-teaching instruction in either game, or the opportunity to practice before starting a round. When the child provided a correct response, the game presented outcome feedback in the visual mode. If the child made an error within a round, the game provided immediate *outcome feedback* to inform the player about the correctness of their response. In addition to this, the game offered immediate *elaborative feedback* giving the child a hint on how to work out the correct answer from the remaining options. The timing was in alignment with the view that feedback presented immediately is particularly important to low ability learners (Johnson et al., 2017).



Perilous Paths

Crocotiles

FIGURE 1 Game mechanics used in the study

TABLE 1 Analysis of game feedback for Perilous paths and Crocotiles

Game	Language features	Elaborative feedback (per feature)	Outcome feedback (for all features)
Perilous Paths	• *Prefixes negatives*: non, de	• Game reads out incorrect answer	Bridge breaks
Total cues: 7	Example word: deconstruct	Hint: 'These prefixes are all related to negatives or opposites. Think of how the prefix will change the meaning of the word you are trying to complete'	Bridge border appears in red
	• *Derivational noun suffixes*: -ent/-ence/-ty/-ity/-ness	• Game reads out incorrect answer	Red gems lost
	Example word: royalty	Hint: 'Look for a noun'	Sphynx moves
	• *ing with a change of letter*	• Game reads out incorrect answer	Player is thrown back to starting position
	Example word: lie > lying	Hint: 'Think about when the events of the sentence took place'	**Total: 5 visual cues**
		Total: 2 verbal cues	
Crocotiles	• *Adverb suffix*: -ly	• Hint: 'Look for an adverb'	Word selected appears in red
Total cues: 5	Example word: more slowly	• Hint: 'Consider the structure of the sentence and think of whether we compare one or two things'	Word disappears
	• *Superlative adjectives*: -est	**Total: 1 verbal cues**	Sound effect
	Example word: the fastest		Red gems lost
			Total: 4 visual/verbal cues

The outcome feedback was offered in a visual mode, whereas the elaborative feedback was verbal in line with Johnson et al. (2017) who propose that in primarily visual tasks, such as games, elaborative feedback presented verbally may be better processed. Table 1 illustrates how both games provided outcome and elaborative feedback. It is noted that *Crocotiles* offered fewer visual and verbal cues in its feedback.

Across the two game mechanics, the elaborative feedback presented conceptual knowledge by prompting the child to apply a metalinguistic rule to the morphology learning task. Schneider and Crombie (2003) suggest that children with reading difficulties should be encouraged to reflect on the language and to engage in analysis, creating deeper learning. For instance, providing linguistic terminology (eg, 'look for a noun') encourages the child to think about word class function and effect, and to analyse the items in this way. Gombert (1992) termed this 'linguistic decision-making' in his model of metalinguistic awareness and argued that this process was crucial when learning to read. Given the child's age and the curriculum they had encountered, children had been previously taught these metalinguistic concepts. In addition to this, *Perilous Paths* provided information about the error by reading out the incorrect answer, aiming to support the child to detect the incongruency within their response. Table 1 summarises the feedback design elements presented within each game mechanic.

Study procedure

All of the children were familiar with the game mechanics chosen through their participation in a previous phase of the research. This ensured that errors in the game were not mechanical and due to usability issues with the two game mechanics. Each child played two games in total, thus encountering two morphological features during a single session (from those identified with the teachers).

The researcher worked with each child on a one-to-one basis, in a quiet room within their school. The researcher introduced the format of the session explaining to the children that they would be playing two separate games. In order to investigate their information processing, an *active intervention approach* was used, detailed by van Kerseren et al. (2003). Active intervention involves asking children about preceding plans, actions and evaluations during interaction with technology. Compared to other verbal interventions such as retrospection, van Kerseren et al. found that active intervention led to a higher number of verbalisations. When the child selected either a correct or incorrect answer, the researcher intervened with questions 1 and 2. In the event of an incorrect response, after the child made an attempt to correct their response, question 3 was additionally presented (parenthesis indicate what each question prompt intended to measure):

1. *Did you get that answer correct or incorrect?* (to identify if the child was made aware of their error)
2. *How do you know?* (to identify if the child noticed particular visual aspects of outcome feedback)
3. *How did you choose your answer?* [if child does not mention the hint] *Did you hear the hint and did it help you? If yes, how?* (to identify if the elaborative feedback was noticed and the child's understanding).

Data collection and analysis

The child's game play session was recorded using screen recording software installed on each tablet and an audio recorder was used to record verbal utterances. This resulted in 26 videos in total, one per child, capturing interactions within each of the two games. The focus of our study was to explore how children attend to, and understand, feedback following an error in the literacy game task. Of a total of 26 children, 6 children did not make an error in the games and therefore will not be considered in the subsequent analysis since they did not receive error feedback. Of the remaining 20 children, all made at least one error (with five participants making two errors). The game play videos of these 20 children forms the main focus of our analysis. In total 25 game errors were analysed.

To address the RQs, each video was coded using a deductive analytic framework that we developed. The framework presented in Table 2 was used to categorise children's self-reports in relation to whether they noticed the game feedback (C2, C3), the dimensions (C5) and percentage of game feedback cues they noticed (C4), their awareness of having made an error in the game (C1), their understanding of elaborative feedback (C6) as well as their subsequent in-game performance in a further attempt (C7). When children shared their understanding of elaborative feedback, an inductive approach was additionally taken resulting in a set of codes capturing children's processing and integration of the conceptual knowledge presented in the feedback. Table 2 summarises these codes and shows their alignment with the two RQs.

To ensure the coding approach was systematically applied, two of the authors collaboratively developed the initial coding framework and applied it to some of the videos.

TABLE 2 Coding framework

RQ1—Following an error, do children with reading difficulties attend equally to outcome and elaborative feedback? Does one attract more attention over the other?	
C1: Is the child aware of their error?	Yes–No
C2: Outcome feedback: Does the child notice it?	Yes–No
C3: Elaborative feedback: Does the child notice it?	Yes–No
C4: % of cues child notices from those available	Ranging from 0% to 100%
C5: Specific visual cues noticed	Open coding mapping to the visual cues identified in Table 1
RQ2—When children with reading difficulties attend to elaborative feedback, do they accurately process it and act on it?	
C6: Elaborative feedback—does the child understand it?	Yes–No Inductive coding of children's verbal responses to identify patterns that explain how they understood the feedback
C7: In-game performance following elaborative feedback	Correct-incorrect answer in the try following the error

Subsequently, the first author coded the remaining videos upon repeated observations of the video data to ascertain the credibility of the coding. If the application of a code was not clear, a collaborative coding process was followed whereby the author previously involved in designing the coding framework discussed and reconciled the application of the code.

FINDINGS

RQ1—Following an error, do children with reading difficulties attend equally to outcome and elaborative feedback? Does one attract more attention over the other?

After each error, children were prompted to explain whether they recognised making an error. This served as a proxy to understand if they attended to and also accurately interpreted the *outcome feedback* reflecting their performance. All 20 children verbally acknowledged making an error suggesting that the game design was effective in communicating the outcome of children's performance. When children were asked to share the specific visual cues that supported them in reaching this conclusion, in 60% of the errors coded (15 out of 25) the children were able to identify specific visual cues that supported this understanding. In the event of an error, *Crocotiles* presented children with two visual cues and one verbal cue for outcome feedback. However, children mainly noticed two of these visual cues; the word changing to red and the word disappearing. During an error, *Perilous Paths* presented children with five visual cues for outcome feedback. Children attended to the word border changing to red as much as they noticed the bridge breaking. Across both games, only one child identified that they had lost red gems. In the remaining ten errors, children either did not mention any cues, or when explicitly probed to explain the cues they encountered, they were not able to share more information. Therefore, even though there was evidence that the game design supported children's recognition that an error was made, children

did not always perceive or were able to articulate the cues they perceived to support their inferences.

In a similar pattern, in 60% of the errors coded (15 out of 25) children reported hearing the *elaborative feedback* presented in the games. In addition to the verbal hint, the *Perilous Paths* game in particular voiced out a target sentence with a missing word at the start of each game round, for example 'Sign language is __verbal'. The child's task was to fill in the gap by choosing one of three options. Upon the child's wrong choice selection (eg, 'de'), the game voiced the selection made, providing feedback that could be used by the child to infer that the resultant sentence did not make sense. None of the children, however, noticed this feedback. Moreover, while the elaborative feedback was being read aloud, two of the 20 children had already diverted their attention to selecting an alternative response.

In summary, outcome and elaborative feedback attracted children's attention equally, with some visual cues being more salient than others in the perception of the outcome feedback. On the whole, children perceived less than half of the visual and verbal cues available in *Perilous Paths* and *Crocotiles* corroborating the conclusion that children attended to a narrow set of the overall feedback cues presented.

RQ2—When children with reading difficulties attend to elaborative feedback, do they accurately process it and act on it?

We now focus on the 60% of the cases (a total of 15 errors) during which children reported attending to (hearing) the elaborative feedback given in the form of a verbal hint. When prompting children to explain the hint, there were 11 instances where the children struggled to recall, or accurately recall, what the feedback said though some of them claimed it was helpful. For example, in reference to *Crocotiles*, one of the children expressed her difficulty to recall the feedback: 'It said look for a verb, or adverb. I don't know, I forgot'. Moreover, in four instances children had not attended to the visual outcome feedback and in turn treated the elaborative verbal feedback as a cue that suggested their response was incorrect. As one child explained, the verbal hint gives a clue to 'just pick a different answer'. These children appeared to subvert the design of the elaborative feedback to inform their understanding of their performance in line with the function of outcome feedback. Therefore, though RQ1 identified evidence showing that children understood the outcome visual feedback, with respect to elaborative feedback the findings showed that children were not processing or integrating the elaborative feedback with their existing knowledge to correct their error. An exception to this prevalent trend were two children who explained how they used the linguistic concepts within the elaborative feedback to correct their next game response. As one child explained, 'It (the hint) tells you it has an adverb and I know that (the correct answer) was an adverb at the end and that's why I chose that one'.

The final part of our analysis focussed on whether elaborative feedback impacted on in-game performance. In analysing the 15 errors during which children had attended to the elaborative feedback, in ten cases (67%) the children recovered during their next attempt. To self-correct, however, most of the children reported relying on their own cognitive strategies—given the task at hand to construct a meaningful sentence, their main strategy was to try out the word options mentally in order to make sense of the sentence they produced. One of the participants mentioned 'knowing the correct answer as read it in my head and chose the one that made sense', *or* 'If you say "I can't say with certainly …" it just wouldn't make sense. I knew this one (target response: certainty) was right as it was meant to have "ty" at the end'.

DISCUSSION

The communicative function of visual cues in outcome feedback

Children playing both game mechanics reported attending to up to two visual cues (from the total of 4–5), namely the red *word colour* and the *disappearance of their word choice*, indicating that their attention was mostly focussed on cues associated with their target response in the middle part of the screen. These two cues were thus successful in signalling the gap between the child's performance and the learning aim. This suggests implications for how game designers may communicate outcome feedback to young children: visual cues indicating the player's performance are most salient when embedded within the focal learning content. In contrast, cues appearing in the edges of the game scene were not perceived by the children.

Surprisingly, given their prevalence in leisure games, only in two instances did children identify the loss of game rewards, signalled by collecting gems. This may have been because of the positioning of the rewards in the bottom left corner, suggesting that rewards should appear more prominently on screen. However, it is also possible that game rewards gain meaning and motivate children's behaviour during sustained, long-term use which was not possible to establish given the methodological approach taken in this study.

The observation that overall children attended to only part of the cues available could indicate that children experienced a high cognitive load when processing multiple visual cues. This is in line with Ke (2016) who argues that in-game learning supports, such as feedback, must be directly integrated into the game play to minimise cognitive demands. Nonetheless, in 40% of the errors coded, children had an accurate understanding of their performance, while at the same time they could not articulate how the game design contributed to this interpretation. Therefore, it is also possible that visual cues work to collectively inform the child's understanding of their performance, with on-task cues featuring centre screen, attracting attention and also conscious processing.

The impact of elaborative feedback on understanding and action

The present findings suggest that children who attended to the elaborative feedback improved their in-game performance using implicit procedural knowledge rather than relying on the declarative knowledge embedded in the elaborative feedback. In 67% of the errors children paused to reflect on and reconstruct the meaning of the sentences they were working towards without showing conscious awareness of the linguistic rules that applied. This enabled many of them to independently recover from their errors by identifying a correct response in their next try. This contrasts with Benton et al. (2019) whose empirical work with younger children (aged 6–8) showed that children were able to correct their error in a literacy game about 50% upon their next try. In contrast to the reflective strategies taken by participants in our study, these younger children relied on trial and error to explore all possible game options, or experimented with various game options to support or refute a direction. Thus, our findings show that this older group of children understood that the game was a learning activity that required their cognitive resources in order to progress. We now reflect on why the elaborative feedback was not understood by the majority of the children by considering the elaborative feedback design in relation to *content, modality* and *timing*.

The *content* of the elaborative feedback in the Navigo games was a metalinguistic verbal hint. The hint offered an explicit language rule that applied to the target game sentences. Previous research has suggested that length and complexity of elaborative feedback impact on its comprehension (Shute, 2008). Yet, these factors did not seem to affect children's

comprehension (see Table 1 for further details of the feedback design) as children struggled equally across the hints encountered. This was despite already encountering these rules in existing provision. That said, future research could examine whether the difficulties with utilising this feedback is associated with the level of explicitness or within-child characteristics (see below). Providing explicit pre-teaching instruction to introduce the linguistic terminology before gameplay may support children's ability to then use this information when prompted by the elaborative feedback to analyse word categories. We thus suggest that while elaborative feedback in games has been theorised to provide information for *independently* correcting inappropriate task strategies (Johnson et al., 2017; Shute, 2008), in the case of young children with reading difficulties, this kind of feedback may require explicit scaffolding by an adult prior to the presentation of the feedback.

In terms of the *modality* of the verbal elaborative feedback, Johnson et al. (2017) suggest balancing the verbal with the visual modality to avoid introducing too high a cognitive load. Learner characteristics could provide further guidance on which modality to emphasise. Children with reading difficulties often present as a heterogenous group and although verbal working memory difficulties are consistently reported (Rose, 2009; Swanson et al., 2009), additional problems with auditory processing may be present for some (Witton & Talcott, 2018) and thus may impact on the efficient processing of elaborative feedback. In our study children mostly engaged in the processing of the visual cues communicating outcome feedback and the small number of children, who did not attend to the visual modality, went on to extract meaning from the verbal hint managing its complexity by re-interpreting it as outcome feedback. Thus, it could be argued that complexity impacted on information processing more so than modality, though children's concurrent processing of visual and verbal cues may have introduced additional cognitive load due to the documented working memory difficulties of children with reading difficulties (Swanson et al., 2009). Whilst games designed for children with reading difficulties can be designed to offer a button to replay verbal hints, our study highlights that future empirical research is needed to identify what modality (or combination of modalities) is most appropriate for delivering more complex feedback such as metalinguistic rules.

It has been suggested that *timely* feedback can support working memory for novice and struggling learners (Johnson et al., 2017). Our findings show that some children—though they represented a minority—moved on to the next try, while the feedback was still being presented, hence ignoring the feedback. This opportunity to move on without listening further encouraged the children to avoid processing the verbal hint. We thus further recommend that game design for children, who struggle with their learning, disables action when elaborative feedback is delivered and using visual cues as a way to bring children's attention to this moment.

Limitations

To investigate children's information processing, we used the active intervention method, which required us to interrupt children's game play at designated moments. This choice may have directed children's attention and processing on the game feedback, though our study showed that children did not notice the entirety of feedback cues, nor did many of them process the elaborative feedback. Despite this possible limitation, the active intervention method allowed us to overcome known limitations associated with other methods such as post-game interviews which would rely on children's memory, or the think-aloud method which would require children to process the game task and verbalise their actions at the same time. Moreover, our data set of game errors comprised 25 instances and could be deemed to be too small to inform a robust account of children's attention and understanding

of game feedback. However, the patterns of our qualitative findings were consistent across the participating children and saturation was reached after analysing half of the dataset, indicating that the size of the dataset was adequate. Finally, our study took place over a single session. It is possible that children with reading difficulties benefit from both types of feedback after repeated exposures to the game and its instructional supports.

CONCLUSION

This research aimed to reveal how primary aged children with reading difficulties attend to, understand and act upon different types of feedback within the Navigo digital literacy game. This research aim was achieved through an analysis of children's unfolding information processing while they played the game, allowing us to examine the effectiveness of different game design decisions. Falloon (2013) argues that children may not attend to design features in the way they were intended by the instructional designer. We found that the game design for visual outcome feedback was successful in communicating performance, namely by integrating a visual cue into the child's response. For practitioners, this suggests the importance of choosing learning games that offer outcome feedback intrinsic to the task content. In contrast, verbal elaborative feedback attracted equal levels of attention to the outcome feedback but was not understood by the majority of the children. We seek to disentangle the potential reasons for this and raise game design implications for drawing the child's attention to the feedback, namely by disabling player action when it is delivered and offering a replay button in case it is missed. Most importantly we suggest that practitioners may need to provide explicit instruction to introduce metalinguistic concepts prior to game play towards supporting children's comprehension of complex elaborative feedback.

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CONFLICT OF INTEREST
There is no conflict of interest that would lead to bias on the research report.

DATA AVAILABILITY STATEMENT
The data reported in this article is not open access.

ETHICS STATEMENT
The BERA ethics guidelines were followed. We obtained UCL IOE's ethical committee clearance prior to commencing the research.

ENDNOTES
[1] Outcome feedback can also be referred to as ‘summative’ and elaborative feedback as ‘formative’.

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

[3] For the purposes of this paper, a game mechanic affords certain interaction possibilities (eg, multiple choice available through dragging/dropping or tapping). A game activity utilises a game mechanic to support a particular learning aim. It includes instructional dimensions (eg, instructions, feedback) as well as the content.

REFERENCES

All, A., Nuñez Castellar, E. P., & Van Looy, J. (2016). Assessing the effectiveness of digital game-based learning: Best practices. *Computers & Education*, *92–93*, 90–103. https://doi.org/10.1016/j.compedu.2015.10.007

Attali, Y., & van der Kleij, F. (2017). Effects of feedback elaboration and feedback timing during computer-based practice in mathematics problem solving. *Computers & Education*, *110*, 154–169. https://doi.org/10.1016/j.compedu.2017.03.012

Benton, L., Vasalou, A., Barendregt, W., Bunting, L., & Révész, A. (2019). What's missing: The role of instructional design in children's games-based learning. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1–11). New York, NY: Association for Computing Machinery. https://doi.org/10.1145/3290605.3300812

Benton, L., Vasalou, A., Berkling, K., Barendregt, W., & Mavrikis, M. (2018). A critical examination of feedback in early reading games. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)* (pp. 1–12). New York, NY: Association for Computing Machinery. https://doi.org/10.1145/3173574.3173947

Clark, D. B., Tanner-Smith, E. E., & Killingsworth, S. S. (2016). Digital games, design, and learning: A systematic review and meta-analysis. *Review of Educational Research*, *86*(1), 79–122. https://doi.org/10.3102/0034654315582065

Department for Education [DfE]. (2015). *Special educational needs and disability code of practice: 0 to 25 years*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/398815/SEND_Code_of_Practice_January_2015.pdf

Department for Education [DfE]. (2019). *National curriculum assessments at Key Stage 2 in England*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/830285/KS2_Provisional_publication_text_2019.pdf

Falloon, G. (2013). Young students using iPads. *Computers & Education*, *68*(C), 505–521.

Gombert, J. E. (1992). *Metalinguistic development*. Harvester Wheatsheaf.

Goswami, U. (2015). Sensory theories of developmental dyslexia: Three challenges for research. *Nature Reviews. Neuroscience*, *16*(1), 43–54. https://doi.org/10.1038/nrn3836

Hattie, J. (2008). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Routledge. https://doi.org/10.4324/9780203887332

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, *77*(1), 81–112. https://doi.org/10.3102/003465430298487

Holmes, W. (2011). Using game-based learning to support struggling readers at home. *Learning, Media and Technology*, *36*(1), 5–19. https://doi.org/10.1080/17439884.2010.531023

Johnson, C. I., Bailey, S. K. T., & Van Buskirk, W. L. (2017). Designing effective feedback messages in serious games and simulations: A research review. In P. Wouters & H. van Oostendorp (Eds.), *Instructional techniques to facilitate learning and motivation of serious games, advances in game-based learning* (pp. 119–140). Springer International Publishing. https://doi.org/10.1007/978-3-319-39298-1_7

Ke, F. (2016). Designing and integrating purposeful learning in game play: A systematic review. *Educational Technology Research and Development*, *64*(2), 219–244. https://doi.org/10.1007/s11423-015-9418-1

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, *38*(1), 43–52. https://doi.org/10.1207/S15326985EP3801_6

Moyer-Packenham, P. S., Lommatsch, C. W., Litster, K., Ashby, J., Bullock, E. K., Roxburgh, A. L., Shumway, J. F., Speed, E., Covington, B., Hartmann, C., Clarke-Midura, J., Skaria, J., Westenskow, A., MacDonald, B., Symanzik, J., & Jordan, K. (2019). How design features in digital math games support learning and mathematics connections. *Computers in Human Behavior*, *91*, 316–332. https://doi.org/10.1016/j.chb.2018.09.036

Narciss, S. (2008). Feedback strategies for interactive learning tasks. In J. M. Spector, M. D. Merrill, J. G. van Merrienboer, & M. P. Driscoll (Eds.), *Handbook of research on educational communications and technology* (pp. 125–143). Lawrence Erlbaum Associates.

Narciss, S., Sosnovsky, S., Schnaubert, L., Andrès, E., Eichelmann, A., Goguadze, G., & Melis, E. (2014). Exploring feedback and student characteristics relevant for personalizing feedback strategies. *Computers & Education*, *71*, 56–76. https://doi.org/10.1016/j.compedu.2013.09.011

Rose, J. (2009). *Identifying and teaching children and young people with dyslexia and literacy difficulties: An independent report from Sir Jim Rose to the Secretary of State for Children, Schools and Families: June 2009*. DCSF Publications.

Schneider, E., & Crombie, M. (2003). *Dyslexia and foreign language learning* (1st ed.). David Fulton Publishers. https://doi.org/10.4324/9780203458709

Schrauben, K. S., & Witmer, S. E. (2019). Feedback provided within structured reading programs: A systematic review. *Reading & Writing Quarterly*, *36*(3), 193–210. https://doi.org/10.1080/10573569.2019.1627967

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research*, *78*(1), 153–189. https://doi.org/10.3102/0034654307313795

Swanson, H. L., Xinhua, Z., & Jerman, O. (2009). Working memory, short-term memory, and reading disabilities: A selective meta-analysis of the literature. *Journal of Learning Disabilities*, *42*(3), 260–287. https://doi.org/10.1177/0022219409331958

Van der Kleij, F. M., Feskens, R. C. W., & Eggen, T. J. H. M. (2012). Effects of feedback in a computer-based learning environment on students' learning outcomes: A meta-analysis. *Review of Educational Research*, *85*(4), 475–511. https://doi.org/10.3102/0034654314564881

van Kesteren, I. E. H., Bekker, M. M., Vermeeren, A. P. O. S., & Lloyd, P. A. (2003). Assessing usability evaluation methods on their effectiveness to elicit verbal comments from children subjects. In *Proceedings of the 2003 Conference on Interaction Design and Children (IDC '03)* (pp. 41–49). New York, NY: Association for Computing Machinery. https://doi.org/10.1145/953536.953544

Vasalou, A., Khaled, R., Holmes, W., & Gooch, D. (2017). Digital games-based learning for children with dyslexia: A social constructivist perspective on engagement and learning during group game-play. *Computers & Education*, *114*, 175–192. https://doi.org/10.1016/j.compedu.2017.06.009

Vaughn, S., & Wanzek, J. (2014). Intensive interventions in reading for students with reading disabilities: Meaningful impacts. *Learning Disabilities Research & Practice: A Publication of the Division for Learning Disabilities, Council for Exceptional Children*, *29*(2), 46–53. https://doi.org/10.1111/ldrp.12031

Witton, C., & Talcott, J. B. (2018). Auditory processing in developmental dyslexia: Some considerations and challenges. In T. Lachmann & T. Weis (Eds.), *Reading and dyslexia: From basic functions to higher order cognition* (pp. 135–146). Springer International Publishing. https://doi.org/10.1007/978-3-319-90805-2_7

Wouters, P., & van Oostendorp, H. (2013). A meta-analytic review of the role of instructional support in game-based learning. *Computers & Education*, *60*(1), 412–425. https://doi.org/10.1016/j.compedu.2012.07.018

Yin, R. (2018). *Case study research: Design and methods*. Sage.

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