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INFRASTRUCTURE AND INTEGRATED TOOLS FOR PERSONALIZED LEARNING OF READING SKILL

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Table of Contents

1 EXECUTIVE SUMMARY

The iRead game task began with existing expertise on game activities for word level learning from a previous FP7 project, *iLearnRW*. Within the current project we based our initial approach on those activities (also referred to mini-games or puzzles) and subsequently extended them to support (*i*) the new areas of learning and (*ii*) the new languages included in iRead (German and Spanish). We have used a learner-centred design approach (LCD) in our design work. LCD recognises the important role of users (teachers and children) in informing digital technology design for education (Good & Robertson, 2006). It is also adaptable to the needs of different projects recognising the place for co-design activities where no technology exists, as well as the importance of user-centred design practices where a prototype exists. Given our point of departure, our own approach to LCD was in line with a user-centred view on design. Thus, in a first step we reviewed theories of reading and broader pedagogies for supporting learning. These theories were applied to the activity design of games, and led to a series of detailed games specifications contextualising theoretical concepts to the operations of our technology. Next, following an agile approach, each game was coded into a fully functional prototype and formative user-centred evaluations were carried out in schools with teachers and students.

The deliverable is structured as follows:

- In *Section 2* we detail our theoretical approach to reading fluency. We present a needs analysis on existing literacy games to identify both good practice in instructional game design and current gaps that our project can contribute to addressing. These two theories are translated into pedagogical recommendations, actionable decisions and inform the subsequent game specifications.

- In *Section 3* we briefly introduce our game concept, Navi-Go describing the game world the player comes into allowing the individual game activities to be woven into a broader context. We then present a series of 13 distinct game mechanics that can be used for word and/or sentence-level game activities.

- *Section 4* recounts the work that was done to link the theoretical findings from section 2 with the game mechanics in order to fully specify game activities to ensure the game addresses the various stages of reading fluency as well as provide pedagogically appropriate feedback.

- *Section 5* describes the support provided by WP8 'Software Infrastructure: Development, Integration, Refinement & Maintenance' to operationalize the games game specifications.

- *Section 6* details a series of formative evaluations carried out in schools to date reporting on the lessons learned through work with teachers and primary school children.

2 Theories Informing Game Design

2.1 Reading Fluency (Domain theory)

2.1.1 Review of the early reading and second language literature

Given iRead's focus on typical and atypical as well as second language learning, our domain theories of reading draw from, and consolidate views on second language learning and reading development research more broadly.

There are a number of conceptualisations of second language (L2) knowledge (R. M. DeKeyser, 2009) and of particular relevance to the present project is the distinction between *declarative* and *procedural* knowledge. The declarative-procedural dichotomy is related to second language acquisition (SLA) theories that regard adult language learning as similar to the acquisition of other complex cognitive skills (e.g., learning to drive or play the piano). In most models of skill acquisition, learning progresses in three consecutive stages (R. DeKeyser, 2007; VanPatten & Williams, 2014). First, learners acquire factual information (e.g., L2 rules) through verbal explanation and/or by observing and analysing the behaviour of others engaged in the target skill. The resulting declarative knowledge is conscious and generalisable, but since the processing costs of retrieving information from declarative memory are relatively high, performance utilising declarative knowledge tends to be slow. The second step involves the transformation of declarative knowledge (knowledge *that*) into procedural knowledge (knowledge *how*) by the process of proceduralisation. Unlike declarative knowledge that provides a routine for piecing together bits of information *in working memory*, procedural knowledge consists of ready-made chunks that can be accessed directly from procedural memory. As a result, procedural knowledge enables faster and more efficient performance, although with the disadvantage of being highly specific and hard to transfer. For example, there seems to be limited transfer between seemingly parallel production and comprehension skills such as writing and reading, and speaking and listening (R. M. DeKeyser, 1997). In the last stage, procedural knowledge is automatised via a large amount of practice, leading to the final outcome of *automatic procedural knowledge*, which allows for fluent, spontaneous, and effortless performance.

According to the skill acquisition approach, a key to achieving automaticity, the desired outcome of L2 learning, is to ensure that the learner has successfully undergone the declarative and procedural stages before moving onto the phase of automatization. In the absence of a well-established declarative base, effective proceduralisation is unlikely to occur, since it is declarative knowledge that drives the build-up of routines at the procedural stage. To give a concrete example, it would be unreasonable to expect learners to be able to proceduralise the past counterfactual construction (*if … had verb + past participle*) correctly before they have created a full and accurate declarative representation of its various components (*if*, *had, verb + past participle*) and their combination. In a similar vein, automatisation is unlikely to result in the automatic application of correct rule unless sufficient time has been allocated and appropriate conditions have been created for full proceduralisation to take place. If learners are pushed too early to use a rule fast and under time pressure before they have completely proceduralised the rule, they might easily automatise incorrect or partially correct form-meaning mappings, ultimately leading to fossilisation (Han, 2002). Getting back to the example of the past counterfactual, due to incomplete proceduralisation, inaccurate

forms such as *if … had verb* and *if … verb+past participle* might get automatised instead of the correct structure.

Becoming a skilled reader - being able to read with accuracy, fluency and comprehension - is dependent upon the development of the two key skills of decoding and language comprehension (see the Simple View of Reading; (Hoover & Gough, 1990)). Reading comprehension is heavily reliant upon successful decoding of words. The Dual Route Cascaded model of reading (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) highlights that words may be decoded via a lexical or non-lexical route, discussed previously in D7.1 iRead Reader app Interaction and Visual Design. Both routes essentially require that children master the alphabetic principle (Byrne, 2014) and the link between letters and sounds (grapheme-phoneme correspondence; GPC). Therefore, to develop *declarative knowledge*, children's starting point when teaching young children to read is to focus on their accuracy when producing and recognising letter forms; to ensure that children are able to successfully identify the letter sound (phoneme).

Once children can accurately identify the phoneme for a given letter (or combination of letters), the second stage is to move from this *declarative knowledge to procedural* knowledge. This is done by encouraging children to *blend* and segment phonemes to make whole words (procedural knowledge; i.e., developing phonemic awareness). Carroll and colleagues (2011) report findings that demonstrate the benefit of programmes focusing on a few key phonological skills (namely blending and segmenting) rather than a wider mixture of skills such as rhyming words, transposition and deletion tasks, and extensive work on syllable division. While the latter are useful for children to develop an awareness of sounds within words, blending and segmenting are crucial to decoding unfamiliar words. Randomised controlled trials (RCTs) of reading interventions that adopt this approach of combining teaching accuracy as well as using blending and segmenting activities to develop reading skills show fruitful results (e.g., the Phonology with Reading programme, (Carroll et al., 2011; Hatcher et al., 2006; Hatcher, Hulme, & Snowling, 2004). Further, there is a substantial body of evidence which has shown that early explicit teaching of phonemic awareness that sets the foundation for declarative knowledge is a foundational sub-skill for later efficient reading ((Gallagher, Frith, & Snowling, 2000), and for a meta-analysis see (Suggate, 2016)) and also spelling (Tainturier & Rapp, 2001). Engagement in different activities (i.e., accuracy and blending) to promote word knowledge links with Share's (1995) self-teaching hypothesis whereby opportunities for children to blend and segment, for example, the same vowel sounds in different contexts enables phonological recoding of information and thus children independently develop their lexicon through repeated exposure.

Many reading interventions incorporate blending and segmenting activities to promote fluency (e.g. Fuchs & Fuchs, 2005) and how quickly a child can read has consistently been shown to predict overall reading performance (accuracy and comprehension) in primary-aged children (see Geva & Yaghoub Zadeh, 2006). *Fluency* may, therefore, be seen as the end goal in decoding. Once children are proficient in being able to pronounce and blend phonemes to read a word, it is important that they can demonstrate efficient and effortless mapping, i.e., *automatisation*, of the grapheme-phoneme correspondences. Reading fluency is typically assessed using timed tasks and considers accuracy as well as speed of production.

The three stages that have been identified to support reading development (accuracy, blending, fluency) are notably applicable to reading regular words. For irregular words (sight words) (see D4.1), the blending stage is not suitable because these words cannot be easily decoded using the GPC. In the English language, in particular, there are a number of high frequency words (HFWs) that fall into this category. An early reading intervention study by Shapiro and Solity (2008) gave precedence to learning HFWs given the importance of fluent retrieval of these words in everyday reading and writing. Here we incorporate accuracy and automaticity activities to support the learning of such words.

The three stages of reading identified so far are applicable to both beginning readers and older learners with dyslexia. The teaching principles do not differ for the two target groups. Rose (2009) argues that developing readers and children with dyslexia both benefit from a systematic, cumulative approach to teaching reading skills. It is, however, likely that children with dyslexia need more exposure and practice which will be considered further as part of the Adaptivity component (Task 4.5).

2.1.2 From Theory to Game *Mechanics* Design

To summarise, we started from the position that learning to read is a gradual move from declarative to procedural knowledge and finally automatisation of this knowledge. To support these *reading fluency pedagogies* in the game activities designed, we defined three types of activities:

- **Accuracy (declarative knowledge):** In their early encounters with a language feature, children will be taught to understand and apply the correct linguistic rule. Within the iRead game children will start by playing accuracy-focused activities. These activities will work with whole words or sentences, typically involving multiple choice or matching mechanics, which do not have a time limit. In these activities children will focus on an individual language feature and rule.

- **Building and Manipulating (declarative/procedural knowledge):** Within the iRead game, children will use and combine different linguistic rules in their declarative knowledge, to bring together smaller units of words such as graphemes or morphemes to build a correct word (blending and segmenting) or rearrange/build meaningful sentences. Building and manipulating skills will begin to encourage the child's application of multiple linguistic rules in context to promote proceduralisation of the skills.

- **Automaticity (automisation):** Once children have developed their confidence to read words and sentences with a specific and group of features accurately they will then move on to practicing their automaticity skills so they can start to read in an automatic, quick and effortless way. Within the iRead game, automaticity activities will incorporate a timed element so children have to be able to read and understand words or sentences quickly as well as accurately.

We note that the progression between learning stages – i.e., from declarative to procedural and then automatisation – will be ensured by the Adaptivity component of the project (see Task 4.5) and it outside the scope of this deliverable.

Our first design goal was to ensure that the three game types we developed could support the stages of reading fluency for all of the domain model categories across the four languages included in iRead (e.g. GPC, prefixes - see D4.1, 4.2, 4.3). Our second goal was to maximise the use of the same game mechanics across the different languages. To achieve these complex requirements, two parallel processes took place:

(i) our games partner, FIAB, designed a wide range of initial game mechanic concepts to maximise the design space addressing reading fluency pedagogies and their application to the categories involved in the domain models

(ii) education partners defined an inclusive list of learning activities used to teach the reading fluency stages for each of the categories in their language domain models. For example, for the English language this led to a total of 105 proposed unique activities. In a final step, learning activities from (*ii*) were compared with the game mechanics concepts from (*i*) to find alignments. Where gaps existed new game mechanics were developed. This process led to a smaller set of game mechanics, which took into account the diversity of language characteristics across the four languages and fulfilled the pedagogical requirements.

At the time of the deliverable writing, 13 mechanics have been designed and developed (with an additional two mechanics under development), which are presented in Section 3. We then describe how we specified the pedagogical activities and linked this with these mechanics in Section 4.

2.2 Pedagogical Feedback[1]

The domain theories of reading presented above were instructive in identifying the learning stages our games should promote, but it is also important to provide the necessary support to enable students to progress onto the next learning stage through the provision of appropriate pedagogical feedback. We therefore sought to identify a systematic and theory-informed approach to designing this feedback.

Feedback plays a powerful role in raising achievement above and beyond other instructional interventions (J. Hattie, 2008). Previous research has begun to recognise the need to examine how feedback is designed in learning games (Gresalfi & Barnes, 2016). This work has often, however, treated feedback at a high-level, for instance simply identifying whether 'appropriate feedback' is present (Aleven, Myers, Easterday, & Ogan, 2010; Duysburgh, Slegers, Mouws, & Nouwen, 2015; Papadakis, Kalogiannakis, & Zaranis, 2017; Shoukry, Sturm, & Galal-Edeen, 2015), thus excluding a deeper analysis of *how* this feedback has been designed.

We thus set out to understand and evaluate how feedback is currently represented in learning games for early learners in the reading domain. We first reviewed the empirical

[1] The work reported in section 2.2 has been published at the ACM SIGCHI Conference – full reference Benton, L., Vasalou, A., Berkling, K., Barendregt, W. and Mavrikis, M. (2018) A Critical Examination of Feedback in Early Reading Games. *Proceedings of the 2018 annual conference on Human factors in computing systems* (in press). Montreal, Canada: ACM Press.

literature on feedback and learning games (Section 2.2.1) to inform a framework for content analysis capturing the main dimensions of feedback for games (Section 2.2.2.2). This was subsequently applied to five popular early learning games for reading (*Section 2.2.3*). Taking a theoretical and critical lens, we scrutinised the types of feedback present in these games helping us address two aims:

(1) Capture best practices that we could carry into the iRead game activities
(2) Identify new opportunities for game design and research that would guide our own efforts and those of others.

2.2.1 Review of the Literature

2.2.1.1 Dimensions of Feedback

Feedback has been defined as information given by an agent (human or digital) to inform learners about their performance and understanding. Feedback is most powerful when it is proceeded with instruction, and hence learners who lack the required knowledge will benefit more from instruction than feedback (2007). In their seminal paper reviewing the evidence of the impact of feedback on achievement, Hattie and Timperley (2007) set out four major levels for the focus of feedback. Below we introduce these levels and illustrate each level of feedback with examples from the domain of reading:

Task-level: corrective feedback or knowledge of results, provides information about how well the task has been performed. Intended to support surface-level learning in terms of the ability to acquire, store, reproduce and use knowledge. E.g. “Your answer is correct”.

Process-level: feedback related to underlying processes used in the task as well as relating/extending to other tasks. Intended to support deeper-level learning in understanding, enabling the identification of relationships and transfer of knowledge to other contexts. E.g. “Remember the same sound in English can be written in different ways”.

Self-regulation-level: feedback supporting self-evaluation, self-efficacy and self-beliefs. Enables students to become more effective learners through monitoring, directing and regulating their own learning strategies, for instance in addressing errors. E.g. “Try breaking down longer words into syllables to help you read the text more accurately”.

Self-level: feedback directed at learner personal characteristics, such as praise used as a reinforcer/reward. It is differentiated from praise accompanied by task-focused information. E.g. “Well done, you are a good reader”.

At each level three key questions underpin the successful application of feedback (J. A. Hattie & Yates, 2014), which include:

- *Where am I going? (Feed Up)* Requires clear goals and success criteria to be defined.
- *How am I going? (Feed Back)* Requires the identification and communication of the learner’s current strengths and weaknesses in relation to the goal/success criteria they are trying to achieve.

- *Where to next? (Feed Forward)* Requires guidance and scaffolds to enable the learner to know what to do in the future.

Feedback is most effective when it aims to move learners between levels from task to process to self-regulation (J. Hattie & Timperley, 2007). However, a learner's level of knowledge impacts their feedback needs (J. A. Hattie & Yates, 2014). To our current interest, Hattie and Gan (2011) suggest task-level feedback is particularly powerful for novices who need feedback to acquire content knowledge. Shute (2008) explains task-level feedback "typically provides more specific and timely (often real time) information to the student about a particular response to a problem or task". Games are particularly suited to providing this form of feedback.

2.2.1.2 Feedback in Learning Games

Instructional design in games includes the provision of feedback, enabling connections between gameplay and initial instructional objectives [13, 17], and informing the learner about their next step [16]. Johnson et al. (2017) group the learning game feedback types into *outcome feedback* (relating to task-level feedback (van der Kleij, Eggen, Timmers, & Veldkamp, 2012)) and *elaborative* or *explanatory feedback*[2] (relating to all levels of feedback (van der Kleij et al., 2012)). Outcome feedback includes information about the response correctness, error location and performance measures (e.g. via a numerical scoring system). Elaborative feedback includes specific task/topic information, corrective strategies, why a response is (in)correct or hints/prompts. These feedback types are not mutually exclusive – e.g. a game score could be combined with guidance on how to improve that score next time (Johnson et al., 2017), but the specific use of elaborative feedback has been shown to be very effective in learning achievement (Johnson et al., 2017; Mayer, 2014; Shute, 2008).

In evaluating game feedback types, Moreno (2004) found that novice college students learned more (in the context of botany) when provided with outcome-elaborative feedback than just outcome feedback. Mayer and Johnson (2010) replicated these results in the context of electronic circuitry with the same profile of learners. Moreno (2004) suggests elaborative feedback may reduce novice learners' cognitive load as they do not then spend time searching for a plausible explanation for their result. However the existing literature does not clearly outline how these findings would apply to early learners, who are considered novice learners in a large number of domains (Blair, 2013). We suggest young children's elaborative feedback needs careful design to reflect their current levels of cognitive development and metacognitive capabilities within the specific domain.

2.2.2 Methodology

2.2.2.1 Game Selection

Five early reading games (comprising 35 mini games) were analysed. The games were identified in a series of interviews with eight primary school teachers (from four primary schools) in the UK (reported in D3.1). To select our participants, we had employed a maximum variation sampling strategy that sought to increase differences between schools to distil common patterns in games usage in the classroom (Patton,

[2] Referred Johnson et al. as *process* feedback, but we use the alternative names to prevent confusion with Hattie and Timperley's notion of process-level feedback.

1990). In this initial work we applied the following criteria to select a balanced representation: location (urban/rural), type (faith/state/independent), technology adoption (high/low) and socio-economic background (affluent/deprived).

During the interviews the teachers were asked about their current routine for teaching reading and what games they incorporated into this routine. This process led us to identify five commercial reading games used by the teachers (see Table 1). The selected games were designed to teach early reading skills to children aged 5 to 7 years, or to teach older children who are still struggling with acquiring these early reading skills. All of the games were available online, with two also available as apps. The games covered key reading areas aligning with those of the iRead project such as phonics, vocabulary, fluency and comprehension. All games had a substantial user base across UK schools as well as in some cases worldwide, reinforcing the relevance of these games within primary school classrooms more broadly.

Game (mini-games sampled)	Overall learning goal	Reading area(s) (no. of mini-games)	Gameplay description	User base
Teach Your Monster to Read (TYMTR) (11)	Letters, sounds and single sentences	Phonics (8) Sight words (2) Comprehension (2)*	Online/app-based world with three game levels each containing a sequence of mini-games (some playable standalone)	Used by over 500,000 children (Teach_Your_Monster_to_Read, 2017)
Busy Things (BT) (8)	English Curriculum objectives	Phonics (6) Morphology (1) Syntax (1)	Online learning portal with standalone mini-games organised by age/reading area	4000+ schools subscribe (Busy_Things, 2017)
Education City (EC) (5)	English Curriculum objectives	Phonics (3) Morphology (1) Comprehension (1)	Online learning portal with standalone mini-games organised by age/reading area	15,500+ schools, 70 countries (Education_City, 2017)
Nessy Reading and Spelling (7)	Fundamental reading skills (for struggling readers)	Phonics (3) Sight words (1) Syntax (1) Comprehension (2)	Online learning program with 100 sequenced learning lessons (split into 10 'islands') each including mini-games	10,000+ schools worldwide (Nessy, 2017)
Fonics (4)	44 initial sounds (phonemes)	Phonics (4)	Online/app-based mini-games which can be played in sequence or standalone	1,750+ schools, 72 countries (Fonics, 2017)

Table 1. Overview of sampled games (*one mini-game covers two different areas)

Each game comprised a series of learning activities, i.e. *mini-games*, but due to large numbers (100+) in some games it was not possible to include them all in the analysis. Therefore, we followed a maximum variation sampling approach deliberately maximising differences in both mechanics and reading areas (Patton, 1990) (see Table 1), with 35 mini-games selected. This approach to sampling allowed us to capture both variations in feedback design as well as shared patterns of game feedback across different games.

2.2.2.2 Content Analysis of Games

We employed a deductive content analysis approach (focused on the mini-games) similar to Roskos et al. (2017) who (in the context of e-books) drew on prior literature to first develop a content analysis framework and then used empirical data to guide the qualitative content analysis.

Framework development

The three broad dimensions proposed by Hattie and Timperley (2007), *Feed Up* (where am I going?), *Feed Back* (how am I going?) and *Feed Forward* (where to next?), initially directed the construction of an analytic framework. We subsequently excluded *Feed Forward* because it was missing completely from two games (the mini-games were standalone) and where it did exist the logic was not always transparent, i.e. it was often not possible to infer how gameplay performance drove *Feed Forward*, putting at risk the reliability of our analysis. Using the remaining two dimensions, we identified and combined three frameworks previously developed in learning sciences and learning games research (J. Hattie & Timperley, 2007; Johnson et al., 2017; H. Wang & Sun, 2011), each of which was informed by a thorough literature review on feedback. This combined approach provided us with a more comprehensive methodology to appraise how game feedback is designed.

Feed Up: *Feed Up* types were primarily informed by Hattie and Timperley (2007). In order for feedback to be effective first effective instruction needs to happen. We sought to establish whether this instruction occurred within the game - if it taught the literacy concept prior to gameplay and through what mode. Furthermore, to experience success within the game, the player also needs to learn the game play schema (including the games rules, underlying narrative and player interactions) (Lindley & Sennersten, 2006) to master how to play the game (M. J. Habgood & Ainsworth, 2011). We thus also examined the forms of support available for learning the game play mechanics. Next, we turned to how the games conveyed task expectations, identifying if the learning objective and success criteria for each mini-game were made explicit to the player (J. Hattie & Timperley, 2007).

Feed Back: *Feed Back* types were informed by the serious games framework set out by Johnson et al. (2017), which captured both outcome and elaborative types of feedback. Given our coding scope on mini-games, we excluded aspects of their framework that related to feedback given outside the mini-game (e.g. percent accuracy). Furthermore, it was deemed necessary to account for rewards in the *Feed Back* dimension. While game rewards are a motivational tool (H. Wang & Sun, 2011), by rewarding successes the learner also gains knowledge of their results (both at task-level and self-level), thus facilitating the learners' understanding of their strengths. Wang and Sun's game reward system framework was used (H. Wang & Sun, 2011), but being a consequence of play across mini-games 'plots' and 'unlocking content' were excluded.

Application of framework

Our analysis was iterative involving three phases. In phase one, the games were coded by two researchers with expertise in interaction design, reading and learning games. They divided the games between them and undertook the coding independently. They then discussed the coding outcome, highlighting representative examples of each code and adjusted the coding where there were application discrepancies to ensure consistent

coding of all games[3]. The reasons for these discrepancies included: coding errors; undecided or differently interpreted codes. In light of these discrepancies the definitions within the coding framework were updated and an illustrative example for each code from the data was added to enhance its interpretation.

In phase two, a third researcher with expertise in reading and learning games, independently coded a subset of the mini-games (30%), deemed sufficient in previous work (Lombard, Snyder-Duch, & Bracken, 2002). To establish inter-rater reliability (i.e. between the first/second coders and third coder – see Table 2) we used Cohen's Kappa which was κ=0.57 for this phase. This suggests a moderate agreement (Stemler, 2001), due to still many discrepancies in the coding. A discussion of the disagreements revealed the following issues (codes appear in bold): different definitions of the game scope e.g. coding errors; not coding for *optional* support for the **gameplay mechanics**; undecided or differently interpreted codes e.g. viewing the **response specific** code as a sub-code of **topic specific** rather than applying these codes separately. During this second coding phase we also inductively identified one feature refinement (**try again**) and one new feedback feature (**punishment**) that our coding framework did not address fully, leading us to revise the framework (see Table 2). We split **try again** into three sub-categories that recognised the variability in the mini-games e.g. content changes (**same mechanics, new content**) and number of attempts (**limited** and **unlimited**). Furthermore it was observed that some games included **punishments** for errors and therefore we added codes to recognise rewards that were **removed** or **lost**. After this final phase, the inter-rater reliability was recalculated using Cohen's Kappa, which was κ=0.75 (Table 2 shows updated reliability in brackets at code-level) suggesting a substantial agreement (Stemler, 2001).

	Type	Code	Description	Code Source	Inter-rater reliability κ
Feed Up	Learning Objective	Yes/No	Is the learning objective of the game clear?	(J. Hattie & Timperley, 2007)	1
	Success Criteria	Yes/No	Are the criteria that the player has to fulfil to achieve success clear?	(J. Hattie & Timperley, 2007)	0.5
	Learning Instruction	Visual/Verbal/ Model/None	Does the game introduce the learning concept prior to gameplay? In what mode(s)?	(J. Hattie & Timperley, 2007)	0.13 (0.64)
	Gameplay Mechanics	Visual/Verbal/ Model/None	Does the game provide any support for learning the gameplay mechanics? In what mode(s)?	(M. J. Habgood & Ainsworth, 2011; Lindley & Sennersten, 2006)	0.25 (1)
Feed Back	Outcome	Knowledge of Result	States that the answer is correct/incorrect	(Johnson et al., 2017; Shute, 2008)	0.67 (0.79)
		Knowledge of Correct Result*	Provides the correct answer	(Johnson et al., 2017; Shute, 2008)	0
		Try-Again (unlimited)*	Allows unlimited attempts with the same content	(Johnson et al., 2017; Shute, 2008) + inductive coding	1 (1)

[3] Note inter-rater reliability is not relevant here as the coders looked at different games

	Try-Again (limited)*	Allows limited attempts with the same content (in terms of options or time)	(Johnson et al., 2017; Shute, 2008) + inductive coding	1 (0.75)
	Try-Again (new content)*	Allows player to try again with same mechanics but different content	(Johnson et al., 2017; Shute, 2008) + inductive coding	1 (0.71)
	Error Flagging*	Highlights where the error was made	(Johnson et al., 2017)	0 (1)
Elaborative	Topic Specific	Provides additional information about specific literacy concept	(Johnson et al., 2017)	0.75
	Response Specific	Explains why answer is correct/incorrect	(Johnson et al., 2017)	1
	Informational*	Gives information about how to work out correct answer or advance general understanding	(Johnson et al., 2017)	1
	Hints, Prompts or Cues*	Guides player to correct answer (without providing answer)	(Johnson et al., 2017)	1
Rewards^	Score System	Uses numbers to represent performance	(F. Wang & Hannafin, 2005)	0.25
	Experience Points	Enhancement of player avatar abilities	(F. Wang & Hannafin, 2005)	1
	Item Granting System	Virtual items that can be used in the game	(F. Wang & Hannafin, 2005)	0.38 (0.58)
	Resources	Collectable valuables used in gameplay	(F. Wang & Hannafin, 2005)	1
	Achievement Systems	Collectable avatar/player titles	(F. Wang & Hannafin, 2005)	1
	Feedback Messages	Evoke praise through text, pictures, sound effects or video clips	(F. Wang & Hannafin, 2005)	0
Punishments*	Removal	Temporary removal of rewards (re-gainable through game play)	inductive coding	(0.33)
	Loss	Loss of lives/points (not re-gainable)	inductive coding	(0.33)

Table 2 - Final coding framework (*) applies to incorrect responses only (^) applies to correct responses only. Third coding phase inter-coder reliability in brackets

2.2.3 Results

In this section we present the numerical findings from our analysis, illustrated with examples from the mini-games. It should be noted that as we selected a diverse sample of games (with respect to domain and mechanics) rather than all mini-games from each game, the reported results are not absolute but rather a proportion of the sampled mini-games. Codes from the framework appear in bold text.

2.2.3.1 Feed Up (Where am I going?)

Table 3 summarises the outcomes of the *Feed Up* analysis. Our findings show that **learning objectives** were found in all games. However, some of the mini-games within TYMTR and Fonics did not present learning objectives, showing an inconsistency in design of mini-games within the same game. For example, within Fonics one mini-game explicitly highlighted the learning objective for a specific phoneme (/ll/) by

stating “Can you find the /ll/ sound”. By contrast, another mini-game simply asked the child to “Drag the words to the correct picture” without describing the objective (of reading comprehension).

Success criteria were included consistently in three of the five games. Within two of these (EC and Nessy) this criterion was made very clear, with the target number of successes displayed visibly on the screen. In addition, at the start of each Nessy mini-game the child was given the number of correct answers required to “pass”. Within BT the success criteria were more implicit – there were numbers of options present in the design, but the game did not present an explicit target (such as number of correct answers) and the child could typically try again an unlimited number of times. TYMTR and Fonics did not include success criteria consistently across mini-games. TYMTR mini-games contained a progress bar, but this did not express how many correct trials were required to be successful in the game. Similarly in the Fonics game only one mini-game indicated how many questions were required to be answered correctly.

The majority of the games appeared to be consistently providing **learning instruction** for the concept that the mini-game was focused upon. These games used a variety of modes, often in combination, mirroring existing pedagogies such as multisensory learning (Rose, 2009). However, there were some games (BT and Fonics) that did not include these teaching elements consistently or at all, suggesting their value would be predominantly for practicing familiar concepts. The results also revealed that one game, TYMTR, took a different approach, incorporating a combination of both teaching and practice-focused mini-games.

		TYMTR (11)	BT (8)	EC (5)	Nessy (7)	Fonics (4)
Learning Objective		82%	100%	100%	100%	75%
Success Criteria		18%	100%	100%	100%	25%
Learning Instruction	*Visual*	45%	13%	80%	86%	-
	Verbal	64%	13%	80%	86%	-
	Model	64%	13%	80%	86%	-
	None	36%	88%	20%	14%	100%
Gameplay Mechanics	*Visual*	-	-	80%	100%	-
	Verbal	91%	100%	80%	100%	50%
	Model	-	-	-	100%	-
	None	9%	-	20%	0%	50%

Table 3. Summary of Feed Up coding (mini games coded)

The majority of the mini-games reviewed provided support for the **gameplay mechanics**. Two games, EC and Nessy, used a combination of different modes to achieve this with other games relying solely on the verbal mode (which was also re-playable if the child wanted to repeat the instructions). From these, Nessy taught the mini-game mechanics the most consistently and comprehensively by providing a tutorial video for each mini-game. This explained the game mechanics whilst demonstrating the mini-game being played. However, the child was required to explicitly select this and had the option to go straight to playing the game. Despite the inclusion of some game play support in all games, three games (TYMTR, BT, Fonics) featured a subset of mini-games that required the use of intuition to work out how to play. Many mini-games reinforced the overall gameplay schema through following a common narrative (e.g. helping a monster with a specific task) or consistent interactions

(e.g. tapping on one of four options), which once learned could be applied to subsequent mini-games.

2.2.3.2 Feed Back (How am I going?) – Correct Response

Table 4 provides the results of the *Feed Back* coding for a correct response. These results highlight that in all cases there was **knowledge of result** feedback if the child got a correct response, which was communicated in several ways: sound effects, colour changes, and variety of rewards. **Topic specific** feedback was also found in all games, but was used inconsistently across the individual mini-games within a given game. Fonics was the exception, consistently highlighting, sounding out phonemes and (where relevant) reading aloud the whole word for correct responses, which in turn reinforced the letter-sound mappings within words.

Looking across all games, we found that the EC mini-games incorporated the most varied and detailed feedback for correct responses. Not only did it provide the most comprehensive feedback regarding the topic going beyond simply reading aloud and highlighting, but also some mini-games provided more information about the specific sound being focused on and included illustrative images within the feedback. Furthermore, EC was the only game that included **response specific** feedback explaining why the response was correct, e.g. "Words like 'surprise' help us to imagine how someone may have felt".

As described earlier, game rewards are an alternative expression of **knowledge of result**. The most common form was the use of praise through **feedback messages**. This included phrases like "Well Done" or cheering, positive sound effects/music and animated celebrations from game characters. Two games incorporated a **score-based** reward system, which in Nessy subsequently translated into earning a certain number of 'nuggets'. Some TYMTR mini-games provided a chance to collect **items** by cashing in stars earned when making good progress.

		TYMTR (11)	BT (8)	EC (5)	Nessy (7)	Fonics (4)
Correct Feedback	*Knowledge of Result*	100%	100%	100%	100%	100%
	Topic Specific	9%	25%	60%	57%	100%
	Response Specific	-	-	40%	-	-
Knowledge of Results: Rewards	*Score System*	-	13%	100%	100%	-
	Item Granting	55%	-	-	100%	-
	Achievement Systems	9%	-	-	14%	-
	Feedback Messages	91%	100%	100%	100%	100%
	None	-	-	-	-	-

Table 4. Summary of Feed Back coding for correct response

2.2.3.3 Feed Back (How am I going?) – Incorrect Response

In contrast to the correct responses, there was significantly less consistency in how feedback was designed for incorrect answers (see Table 5). Compared to how **knowledge of result** was designed for correct responses, there was also less prominence given to this for incorrect answers. The child was made aware of an error more implicitly through the game being reset and being required to **try again**. Various manifestations of **try again** were identified across the games and also within the mini-games, although each game tended to favour a particular type. TYMTR allowed **unlimited attempts** to try again for incorrect answers, as did many of the BT mini-

games, whereas the EC mini-games typically gave a **limited number** of attempts before providing the correct answer (**knowledge of correct results**). Fonics also provided a **limited number** of attempts before the game was over, but did not inform the child of the correct response. Nessy used an alternative strategy, providing the correct answer each time and letting the child try again with **new content** but using the same game mechanic. Nessy was therefore the only game that explicitly discouraged a trial and error approach.

In probing whether the games provided elaborative feedback about the error, we found there was a relatively low number of mini-games that supported the child to understand the particular error made. Some of the Nessy mini-games provided **topic specific** feedback such as showing the word within the sentence, providing the context of use, or reading aloud the target sound and word it was used within, reinforcing the individual sound and how it is blended into a word. Similar to our observations about its feedback design for correct responses, EC mini-games also provided the most varied feedback for incorrect responses, incorporating **topic specific** feedback **(**e.g. reminding the purpose of apostrophes) and providing **hints, cues or prompts** (e.g. giving a strategy for choosing the correct answer/highlighting the sentence part to focus on).

As with the reinforcing role of rewards in **knowledge of results** for correct responses, punishments are an alternative way of expressing **knowledge of results** during errors. Punishments were generally avoided in three games. However, within Nessy giving incorrect answers **lost** the child the possibility of gaining a nugget, and too many incorrect answers meant insufficient nuggets were available to pass the level. Within Fonics each incorrect answer resulted in the **removal** of a life (if three lives are lost the game is over), but there was an opportunity to regain these lives by answering correctly.

		TYMTR (11)	BT (8)	EC (5)	Nessy (7)	Fonics (4)
Incorrect Response	*Knowledge of Results*	45%	88%	80%	86%	25%
	Knowledge of Correct Results	-	25%	80%	86%	-
	Try-Again (Limited Attempts)	-	25%	80%	-	75%
	Try-Again (Unlimited Attempts)	100%	63%	20%	14%	-
	Try-Again (New Content)	-	13%	-	86%	25%
	Error Reporting	-	13%	20%	-	-
	Topic Specific	-	-	40%	43%	-
	Response Specific	9%	-	-	-	-
	Hints, Cues or Prompts	9%	-	60%	-	-
Knowledge of Results: Punishments	*Removal*	-	13%	-	-	100%
	Loss	-	-	-	100%	-
	None	100%	88%	100%	-	-

Table 5. Summary of Feed Back coding for incorrect response

2.2.4 From Theory to Game Activity Design

This research set out to specifically examine *what dimensions of feedback early learning games for reading promote and exclude* in order to unpick these design decisions critically. To achieve this, we iteratively designed a new analytic framework for the content analysis of learning game feedback, informed by feedback theory and improved through our reflexive use of the framework on a sample of five games (comprising 35 mini-games). Below we discuss the design and research implications

from the analysis undertaken, highlighting the specific implications for the design of the iRead game activities.

Broadly our analysis highlighted the presence of two types of games, *learning* and *practice* games. Feedback is powerful only when it builds on prior instruction (J. Hattie & Timperley, 2007), however two of the five games were predominantly or completely missing the teaching of the learning concept. We would thus characterise these two games as practice games that assume concepts have been introduced *prior* to game play. The relationship between learning and practice was best reflected in TYMTR where learning games were followed by games that practiced the skills taught earlier. This finding broadly suggests that teachers using practice games in the classroom must ensure their students have already been taught the appropriate concepts. Yet, the two practice games included in the analysis were identified as 'games for learning' by the primary school teachers interviewed in the research, potentially questioning their scrutiny for how these games were designed and used with their students.

2.2.4.1 Promoted Feedback Dimensions

Theory-led Game Design Exemplars

Previous work in the domain of learning games has sought to develop design patterns that can marry game mechanics with evidence-based instruction (Kelle, Klemke, & Specht, 2011). Taking a theory driven perspective in our analysis of the five games, we identify three new exemplars of game feedback shown in past work to increase learning and achievement.

Echoing the importance of setting the child's learning expectations to know where they are going (J. Hattie & Timperley, 2007), most games posed a clear goal. Learning objectives were introduced by referring to the literacy objective contextualised in the task mechanics (e.g. 'put all in the sheep in the /s/ pen'). Further enhancing the *Feed Up* dimension, three games included criteria that clearly showed what a child needed to achieve to be successful in the game. Criteria for success were either implicit in the task (e.g. by posing one game round with a clear set of options), or on screen through a quantified target (e.g. a set number of stars that needed to be acquired). With the exception of the two practice games, *Feed Up* was also proceeded by first introducing and teaching the key literacy concept addressed in the game. Reflecting a multisensory approach to reading instruction, all the analysed games used in tandem visual, verbal, and modelling modes for instruction (Rose, 2009) reinforcing sounds, letters and meaning.

iRead Implication: iRead game activities will include clear learning aims and success criteria. When the student is first introduced to a language feature they will receive a brief learning instruction that teaches them the language rule (note: the delivery of this instruction forms part of the Adaptivity component (Task 4.5).

2.2.4.2 Excluded Feedback Dimensions

Alongside identifying the strong congruence between theory and game design, our analysis also found gaps in game feedback design. In analysing current game design limitations, we have identified three design and research opportunities in the space of games for early learning.

Need to Support Learning Mechanics as well as Content

In contrast to the uniform inclusion of effective teaching principles for reading in all of the games, with the exception of Nessy, the remaining four games reflected less effort in supporting learning of the game mechanics. Typically in games the player develops an understanding of the game play schema through experiencing failures at various points in the game and then trying again (Plass, Homer, Kinzer, Frye, & Perlin, 2011). However, within learning games it is difficult to separate failure due to the game mechanic or failure due to a gap in understanding the learning content. Previous work has shown when children experience breakdowns during learning games they may need support with both the learning content and with working out the game mechanics (Vasalou, Khaled, Holmes, & Gooch, 2017). This need for support has been found to increase in pace with the complexity of game mechanics (M. P. J. Habgood, 2007; Linehan, Kirman, Lawson, & Chan, 2011). Plass et al. (2011) recommend in learning game design the choice of game mechanics should not introduce these unnecessary confounds. Whilst the reviewed games mainly utilised more familiar multiple choice mechanics, given the young learner group we argue that they will still need opportunities to become familiar with the broader game play schema prior to focusing on new learning content. The most appropriate form for this support remains an open research question.

iRead Implication: we will consider providing children with a familiar or easy activity when they encounter a new language feature (note: the delivery of this instruction forms part of the Adaptivity component (Task 4.5).

Deep Learning Comes from Elaborative Feedback

All the games reviewed partially included the *Feed Back* phase by communicating the child's strengths and weaknesses in relation to the learning goal (J. Hattie & Timperley, 2007). During *successful* game performance, this was primarily achieved through a clear indication that the correct option was chosen using sound and colour to indicate success.

However, while knowledge of one's performance is a critical part of feedback, feedback is most effective when it is elaborated (Mayer & Johnson, 2010), for instance, by reinforcing attributes of the target concept or building upon topic specific feedback to explain why it is correct (Johnson et al., 2017; Mayer & Johnson, 2010; Moreno, 2004; Shute, 2008). The games we analysed presented some topic specific feedback for successful game performance, albeit not consistently across all mini-games. Additionally, only one game presented response specific feedback. In further probing the games, elaborative feedback was technically attainable within some of the domain areas they covered. For instance, TYMTR and the other phonics-focused mini-games reviewed used narration to introduce letters and words at the start of each mini-game. Thus, the mechanics of highlighting letter/word attributes to deliver topic specific feedback were within existing technical capabilities (Prensky, 2001). Although designers should keep in mind *Feed Back* needs careful integration to ensure it does not interfere with game play (Adams & Clark, 2014).

Turning our attention to game feedback during *unsuccessful* game performance, our research showed a clear and consistent gap in game design practice. An incorrect response was often communicated implicitly by asking a child to try again, indicating that their previous attempt was not correct. While try again was the primary response to

error, its role in learning was not clear. Most of the games allowed a child to repeatedly make the same mistake (although within some games the number of attempts was limited e.g. in Fonics the player has a set number of lives) without providing them with elaborative feedback or even the correct answer to allow them to learn from these failures, mirroring findings by Blair (2013) in maths games for young children. Moreover, very few of the games included elaborative feedback to support the child to understand their error. One exception and exemplar of good practice on both try again and elaborative feedback was Nessy: upon an error the correct answer was immediately explained giving the child a chance to apply this knowledge in the same context, but with new content.

In summary, our findings highlight a broad orientation in the games toward informing the child's understanding of their current performance, and providing opportunities to correct an error. These games did not capitalise on the value of feedback for deep learning by supporting the child to understand why they did well or did not succeed. This uncovers an opportunity for further design work to enable young children to build on successes and learn from errors through elaborative feedback targeted at their cognitive development and metacognitive capabilities.

iRead Implication: games will always provide performance feedback. Where technically possible we will provide elaborative feedback through hints (visual or textual/verbal) to help the child diagnose their error or provide them with a strategy to use.

3 Game Mechanics Design

Having set our theoretical foundation, this section describes the overall concept for the game and then details the 13 existing mechanics that have been developed to date – these game mechanics have been developed to support both word-level (supporting Phonology, Orthography, Word recognition and Morphology levels in the domain models) and/or sentence-level activities (supporting Syntax and Morphosyntax levels in the domain models) which are stated in brackets. Below we describe the concept/objective, player interaction, aesthetics/user interface (UI) design as well as the game-related feedback (which would occur alongside the pedagogical feedback described above) for each of the activities.

3.1 Navi-Go Game Concept

The iRead game activities have been themed to instil a sense of adventure and excitement in learners; helping to maintain their interest and motivation levels. The setting was inspired by commercial video games like the Legend of Zelda series and films like Indiana Jones and National Treasure. The Ancient Egyptian theme was chosen because of its association with archaeological adventure, the discovery of ancient treasures and the decryption of languages. This provided the perfect setting for the puzzle game mechanics allowing the game activities to have a consistent theme that provides a narrative around the player's quest to understand the language they are learning.

In "Navi-Go: Pyramid of the Lost Words" the player takes on the role of an archaeological adventurer, intent on unlocking the secrets hidden within an ancient and

mysterious pyramid. At the start of the game, the player arrives at an oasis at the base of the enormous pyramid. A camp has grown around the oasis made up of an array of colourful tents. This will be the player's basecamp, where they will return between adventures into the pyramid. In the camp, the player will be able to customise their character and review their progress as well as setting off for adventures in the pyramid.

The pyramid is not for the faint of heart. Its catacombs seem to constantly shift and change, adapting to the player's actions and presenting them with new challenges. Each time the player journeys into the pyramid, its rooms have changed and its puzzles have reset. However, the player is not alone in their adventure. On entering the pyramid, they encounter a tiny magical creature, known as Bat. Bat is a benevolent sprite, intent on helping the player solve the mysteries of the pyramid.

Bat will highlight points of interest in the environment and help to guide the player through the puzzles. With each adventure the player's knowledge of the pyramid grows, as does their understanding of the language puzzles they must master to unlock the pyramid's secrets. Each successful adventure will reward the player with new knowledge, treasures and equipment, which they can use to customise their avatar. Customisation will be a prevalent theme throughout the game. The player can customise their character's name, face and hair, equip different outfits to their character (Figure 1) and even make some customisations to the oasis and camp (Figure 2). This level of customisation is key to allowing the player to feel like their adventure is their own and encourage player-to-player discussion. Further work is planned on fleshing out the game narrative and establishing how it will be intrinsically woven into the learning and game mechanics (which are introduced below).

Figure 1 - Character Customiser

Figure 2 - Oasis Map Mock-Up

3.2 Game Mechanics

HEAROGLYPHS (Word-level game activity)

Hearoglyphs acts as a way for users to link an audio clip to a word. The gameplay is similar to that of the Cleomatchra mechanic, but here the player must find both the audio and written representations of a word.

Upon entering the room, the player must tap on the interactive puzzle plaque to trigger the game. At this point the Hearoglyphs UI will appear and we go to our split camera view, this view shows the puzzle across the left 75% of the screen and a context camera on the final 25% (see Figure 3). The player will see a puzzle board containing multiple audio buttons along with their paired words, arranged around in groups. The audio button and tiles will rotate to reveal their icon and word and begin to flash indicating the player should tap them. The player should tap both an audio button and a tile to select a pair.

As the player does well or badly, the context camera will display relevant feedback such as character reactions, environment changes such as a door raising, water level lowering, lights turning on and more to keep the player motivated. The player must continue until all pairs have been made at which point the way forward will be open allowing them to continue through the ruin.

Figure 3 - Hearoglyphs Gameplay Prototype

ANUBRICK (Sentence-level game activity)

Anubrick tasks the player with selecting specific words from a phrase or sentence. The aim of the game is to select the words from multiple sentences correctly, answering multiple questions to remove the walls and reach the end of the room.

Upon entering the room, the player is presented with a wall composed of the words of a sentence, with each word having its own brick (see Figure 4). Each of these bricks can be selected by the player to answer the question by tapping (toggled on). A brick can be deselected by tapping again (toggled off). Another variant of this puzzle places two sentences on a single wall. The first sentence will have certain words highlighted and the player must select corresponding words in second sentence.

Once the correct brick(s) is selected, the wall will disappear into the floor to allow the player to progress to the next wall of words.

Figure 4 - Anubrick Gameplay Prototype

PERILOUS PATHS (Word and Sentence-level game activity)

Perilous Paths presents the player with a maze-like room layout built up of several branching points that present a multiple-choice question for the player to establish which path is safe and which will lead to disaster.

The activity uses our typical camera view style as the player tries to navigate through the maze . At each branch the player taps on the bridge showing the correct answer to select the path to take (see Figure 5). Tapping beyond the answers of a question will find the quickest route to the next branch, *not* choose the correct answer.

At each multiple-choice question branch, if the incorrect path is chosen a classic trap will be triggered causing that path to be blocked and the player to be re-spawned back at the point the paths branch. If correct, they will progress forwards without difficulty.

Figure 5 - Perilous Paths Gameplay Prototype

CLEOMATCHRA (Word-level game activity)

A simple game of pairs but with a twist, instead of matching the same picture or word as in typical pairs, the player must match the corresponding words (accuracy) or word segments (building and manipulating).

Upon entering the room, the player must tap on the interactive puzzle plaque to trigger the game activity. At this point the pairs UI will appear and we go to our split camera view, this view shows the puzzle across the left 75% of the screen and a context camera on the final 25% (see Figure 6). As the puzzle appears, all tiles turn around to reveal their word segments. The tiles are arranged in two columns, the player must select two matching word segments (one from each column) by tapping on the tiles.

As the player does well or badly, the context camera will display relevant feedback such as character reactions, environment changes such as a door raising, water level lowering, lights turning on and more to keep the player motivated. The player will continue until all pairs have been formed and the way forward is opened.

Figure 6 - Cleomatchra Gameplay Prototype

REMOVE THE RUNES (Word-level game activity)

A simple game requiring the player to select *all* the tiles that display a correct answer to the question.

Upon entering the room, the player must tap on the interactive puzzle plaque to trigger the game. At this point the runes UI will appear and we go to our split camera view, this view shows the puzzle across the left 75% of the screen and a context camera on the final 25% (see Figure 7). When a tile is tapped it will read the word aloud alongside the highlight of the word being toggled on or off.

As the player does well or badly, the context camera will display relevant feedback such as character reactions, environment changes such as a door raising, water level lowering, lights turning on and more to keep the player motivated and understanding on what they are achieving. Once all of the correct tiles are highlighted (i.e. toggled on), the way forwards will open.

Figure 7 - Remove the Rules Gameplay Prototype

Walk like an Egyptian! (Word-level game activity)

In Watch like an Egyptian! the player enters a room covered with hexagonal floor tiles each represented with a word/segment. The only safe way across is to move from hexagon to hexagon along tiles displaying the correct answer to a given question.

The activity takes place solely in this room, as the player tries to navigate the path. Once the player has tapped a hexagon to begin on, the camera will shift into a bird's eye view and the potential hexagons to move to next will flash awaiting the player to tap their choice. When chosen, the player will hop onto the relevant hexagon and the cycle continues (see Figure 8).

If the player selects on a correct hexagon, they move forward and the next step begins. If the player chooses an incorrect hexagon a dangerous trap will be triggered, the player will jump backwards out of its way just in time and the hexagon will be destroyed to prevent the player making the same mistake. The player must then try that step again and select a hexagon from those that remain. Provided they make the correct answers, they will reach the other side safely and be able to continue through the door to the next puzzle.

Figure 8 - Walk like an Egyptian! Gameplay Prototype

BRIDGYPTIAN (Word-level game activity)

Bridgyptian sees the player solving word puzzles in order to create a bridge over a chasm of lava and progress to the next room.

As the player approaches the puzzle, the character will automatically progress up to the platform to the left of the chasm. The character will then be able to use their magic powers to move pillars around the chasm of lava to solve the word puzzle. Some pillars will be correctly placed into the pedestal already (see Figure 9) and the player must move the correct pillars from the remaining selection to correctly solve the puzzle by dragging the pillars to the middle of the screen and released them to place them on the pedestal. Once a question has been answered correctly, all of pillars will descend into the pedestals and be replaced with a new question. Once the player has correctly answered three questions, the pillars will remain in the pedestal and a bridge will emerge between the two platforms, supported by the pillars. The player will then be able to cross the bridge to reach the next room.

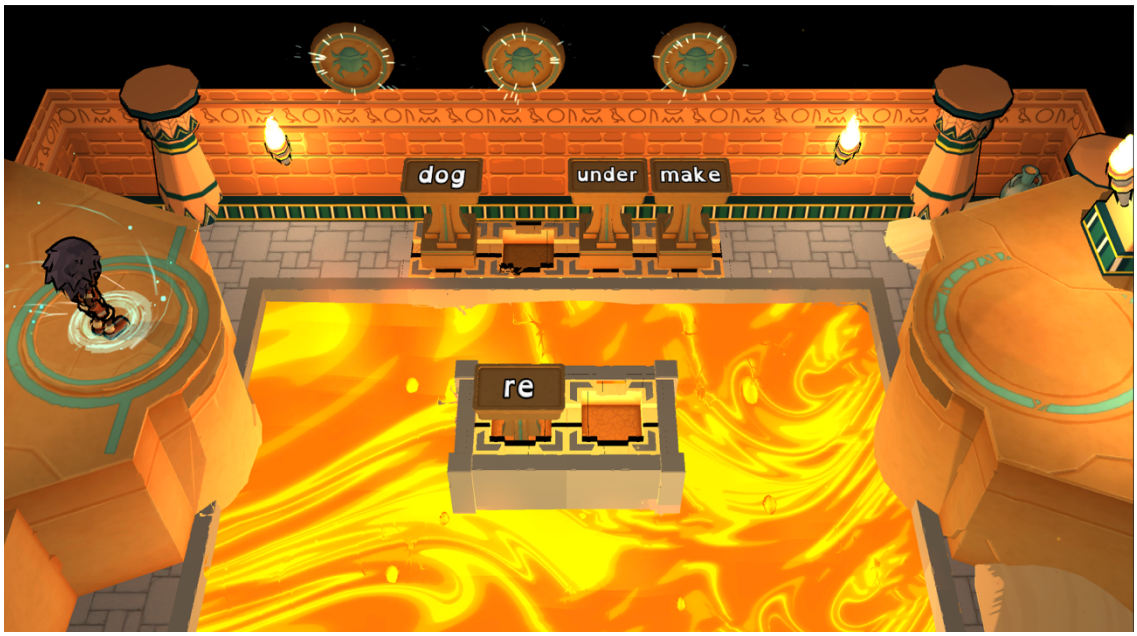

Figure 9 - Bridgyptian Gameplay Prototype

SLICECOPHAGUS (Word-level game activity)

Slicecophagus tasks the player with slicing the word at the appropriate location based on a rule. The aim of the game is to split all of the words correctly which will allow the laser to reach the bottom of the board opening the route forwards.

Upon entering the room, the player must tap on the interactive puzzle plaque to trigger the game. At this point the Slicecophagus UI will appear and we go to our split camera view, this view shows the puzzle across the left 75% of the screen and a context camera on the final 25%. The player will see a puzzle board containing a number of words, arranged vertically (see Figure 10). The player must drag each word back and forth to ensure that the laser will split each word in the correct position. The player must then tap the cut button at the bottom of the board.

As the player does well or badly, the context camera will display relevant feedback such as character reactions, environment changes such as a door raising, water level lowering, lights turning on and more to keep the player motivated. If the word is correct the tile will be split in two. If the tile is incorrect the laser will stop cutting ready for the player to move the remaining words again. The player must continue until all words have been cut in the correct position, allowing the laser to reach the bottom of the board. This will open the door in the room and allow the player to progress.

Figure 10 - Slicecophagus Gameplay Prototype

CART-ASTROPHE (Word-level game activity)

In Cart-Astrophe the player acts as a mine cart track controller trying to direct the cart, collecting rewards and linking the track together correctly to prevent our the cart plummeting into the abyss. The game activity is built up of three parts, initially the player will enter a typical ruin room with a minecart and track in place, the player climbs in and the minecart lurches forward through a door.

Next from a distant side view of the track, the player speeds along the winding mine track. The player is able to jump to grab collectibles scattered along the track by tapping the cart. Periodically, the camera will move ahead revealing a gap between the three tracks (see Figure 11). The player must place the joining track in the correct place by dragging it down to the matching track to continue on their journey.

If done correctly the minecart will roll into view, cross the track and progress further on to the next question. If answered incorrectly, the player will cross the incorrect track falling down a gap in the track ahead and land on a new track which presents a new question. If the player is successful the interface reverts back to our typical ruin room style, the minecart comes to a rough halt and the player climbs out allowing them to walk through the already open door ahead and enter their next game activity.

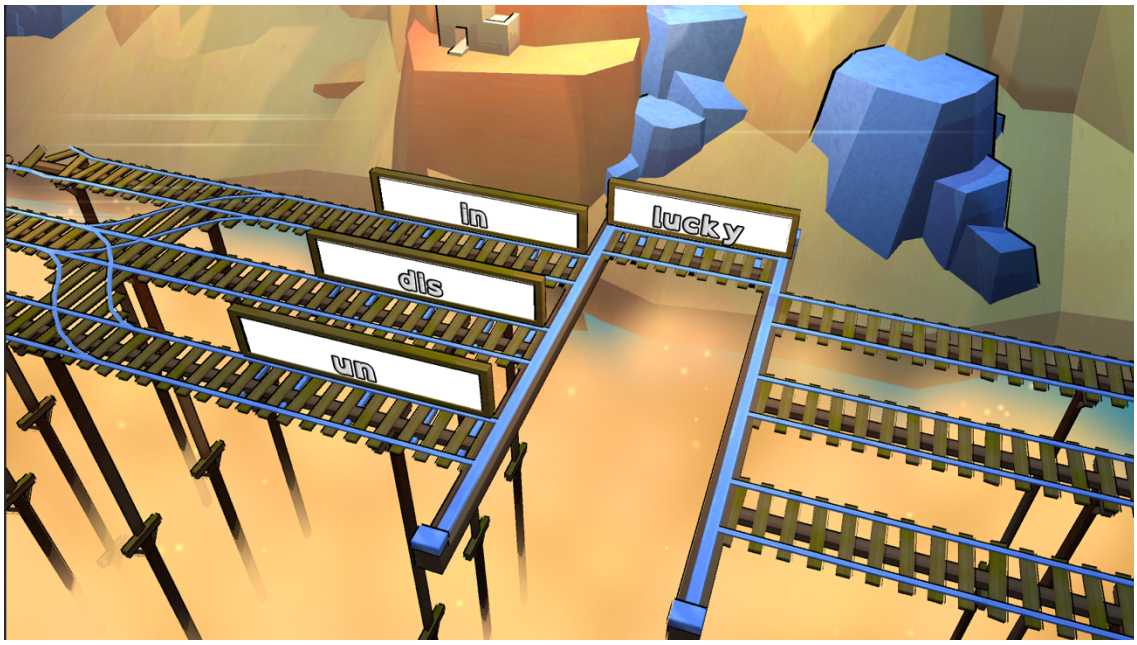

Figure 11 - Cartastrophe Gameplay Prototype

PILLAR PUSHER (*Building and Manipulating Game Activity*)

In Pillar Pusher the player enters a room with several pillars dotted around the environment displaying a word segment. The player's task is to use their levitation spell to move these pillars around the area placing the correct ones into the correct positions.

Upon entering the centre of the room, the camera will shift upwards providing a more birds-eye view of the puzzle. The player will then be able to drag and drop the pillars around the pillar tracks until they have reached the solution. Often in this style of puzzle, part of the challenge is how to move the pillars to the desired outcome without blocking the required movement of the other pillars. In our case, to ensure learning is the core focus this element is only be used very lightly and the levitation spell will be used to speed up moving the pillars around (see Figure 12).

Once all pillars have been placed the word is checked. If a pillar is placed in the correct position the outline changes to green, but if a pillar is placed incorrectly the outline changes to red. The player can then reposition the pillars. When completed successfully a short cut-scene will play showing the environment reacting such as the door opening or a bridge being raised to open the way ahead.

Figure 12 - Pillar Pusher Gameplay Prototype

COGELISK (Sentence-level game activity)

Cogelisk tasks the player with rotating a set of wheels filled with words to create a meaningful sentence.

To begin the game the player interacts with the puzzle plaque which instigates our split screen view. In this view 75% of the screen will be filled with the interactive puzzle UI whilst the remaining 25% displays our context camera. Within the puzzle UI the player will be shown multiple layered wheels, each of these layers will have multiple words inset into the stone. The player must drag each layer of the wheel to align the solution. Note that the ring will snap into the nearest relevant position if let go unaligned. In further variations, there may be multiple wheels (see Figure 13), or even interlocked wheels.

The context camera will show positive and negative actions depending on how the player does, these vary from the player's reactions to environmental reactions such as a door opening or bridge raising. Once the solution is found, the way forwards will open and we return to our typical camera view.

Figure 13 - Cogelisk Gameplay Prototype

CROCO-TILES (Sentence-level game activity)

Croco-tiles sees the player solving word puzzles in order to create a bridge over a body of water and progress to the next room.

As the player approaches the puzzle, the character will automatically progress up to the platform to the left of the chasm. The character will then be able to use their magic staff to move pillars around the chasm to solve the word puzzle. Some pillars will be correctly placed into the pedestal already (see Figure 14) and the player must move the correct pillars from the remaining selection by dragging them and releasing them over the correct pedestal to solve the puzzle. The gameplay is similar to Bridgyptian, but presents questions based on a sentence-level rather than word-level.

Once a question has been answered correctly, all of pillars will descend into the pedestals and be replaced with a new question. Once the player has correctly answered the required number of questions, the pillars will remain in the pedestal and a bridge will emerge between the two platforms, supported by the pillars. The player will then be able to cross the bridge to reach the next room.

Figure 14 - Croco-Tiles Gameplay Prototype

RAFT RAPID FIRE (Word-level game activity)

Raft Rapid Fire places the player on a raft heading down a deep cavern river, where they must use their magic to destroy obstacles quickly as they pop out of the water to prevent their raft becoming damaged and falling into the water.

The game activity is built up of three parts, initially the player will enter a typical ruin room with a river and a docked raft in place, the player climbs on board, releases the rope and the raft begins flowing downstream toward the centre of the ruins. Next from a back view of the character (see Figure 15), the player must launch magical orbs at the various targets, made up of barrels that burst out of the water and signposts appearing from the stream banks, in quick succession by tapping them.

Shooting correct targets will cause the obstacle to no longer obstruct the raft, however shooting an incorrect target will cause ancient evil magic to rise from the crate damaging the raft. Failing to shoot a correct one will cause the obstacle to remain, crashing into the raft leaving some damage. Surviving the puzzle will see the player's raft float into a dark tunnel entering the final part of the activity which reverts back to our typical view, the raft slows to a half and the player jumps to shore allowing them to walk through the door ahead and enter their next puzzle.

Figure 15 - Raft Rapid Fire Game Prototype

4 Pedagogical Design Specification

In Section 2 we introduced our domain theories for reading and our broader theory for feedback. Section 3 focused on game design to describe the game world and game mechanics developed to date. The goal of this section is to present specific pedagogical game design decisions that bridge theory and creative game desogn:

(i) We show how the game mechanics reported in Section 3 are specified into *full game activities*, i.e. activities that offer instruction for the skills being practiced.
(ii) We define game rules for delivering feedback to avoid trial and error engagements with our games.

4.1 Game Activity Specification

Given the implications identified in Sections 2.1.2 'From theory to game mechanics design' and 2.2.4 'From theory to game activity design', each game activity will include the following parameters:

1. *Learning activity:* Defines the reading fluency type (Accuracy, Building and Manipulating, Automaticity) through a unique ID as well as the underlying mechanics of the learning activity. The learning activity impacts the choice of game mechanic (bullet 4).
2. *Instruction type*: Defines which features of a domain model should be taught together/in a similar way and sets their values as reflected in the domain model. The instruction type impacts the choice of teaching instruction (bullet 3), game mechanic (bullet 4) as well as the selection of distractors (bullet 6).
3. *Teaching instruction*: Defines a short animated sequence (visual and verbal) that appears at the start of the game activity (for accuracy games only) to introduce a

language concept and its rules the first time it is played. This would be also accessible to replay if the player chooses to do so as a reminder at a later point.
4. *Game mechanic:* Specifies one or more appropriate Navi-go game mechanics mapping to accuracy, building and manipulating or automaticity, and its underlying logic.
5. *Learning objective:* Is a short verbal narration of the learning objective related to the feature being played in the game mechanic it is embedded in and forms part of the game activity instruction.
6. *Distractors:* Defines the distractors for the game, if relevant in the context of the activity.
7. *Feedback correct:* Specifies any deviations from the generic correct feedback rule (see next Section 4.2) for a correct response within a game activity.
8. *Feedback error:* Specifies any deviations from the generic incorrect feedback rule for an incorrect response within a game activity.

Table 6, Table 7 and Table 8 reify these 8 dimensions in three example game activities – one for each reading fluency stage.

In the accuracy example below (Table 6), the game is teaching the child the principle that different letter consonants can have the same sound. The player is presented with words that include the graphemes *c* and *ck* and are both presented with the sound */k/*. The child's task is to match the words presented with the target audio of the word.

Pedagogical dimension	**Definition**
Learning Activity	ID: Ac7c; Accuracy – match word and audio
Instruction Type	Same sound different letters. Domain Model Features practiced from GPC category: (1) /k/ k, (2) /k/ ck
Teaching instruction	k = ck (visual). These letters make the same sound /k/ (verbal). For example, **k**it and du**ck** (visual and verbal).
Learning objective	Match the word with the correct sound
Distractors	Not relevant in this activity
Feedback correct	Colour the target grapheme (response specific)
Feedback error	n/a

Table 6: Example specification of an accuracy game for English

In the building and manipulating example below (Table 7), the game is teaching the child how prefixes can be added to existing words to make new words. The child is presented with a root word and three prefix options. The child's task is to position the root word next to the correct prefix to make a new word.

Pedagogical dimension	**Definition**
Learning Activity	ID: B4a; Building and Manipulating – add word segment to make a new word
Instruction Type	Prefixes. Domain Model Features practiced from Morphology category: (1) pre-, post-, ex-
Teaching instruction	There are some useful beginning chunks of words to remember. They are called prefixes (verbal). A prefix helps you read and understand some long words (verbal). For example, preset (visual and verbal). Preset is a long word. But you can chunk it into <pre> and <set> (visual and verbal). Preset means you prepare something to start or stop at a later time

	(verbal).
Learning objective	Select the prefix that completes the word
Distractors	Other prefixes in same feature group
Feedback correct	Morphemes are read aloud individually and then whole word is read aloud (response specific)
Feedback error	n/a

Table 7: Example specification of a building and manipulating game for English

In the automaticity example below (Table 8), the game is providing the child an opportunity to practice the skills they have already learned – differentiating between words that start with visually similar letters –to help them read these words more quickly. The child is presented with multiple words one at a time (for a set period of time) and their task is to select only the words that start with the letter 'd' as quickly as they can, whilst avoiding those words that start with any other letter.

Pedagogical dimension	**Definition**
Learning Activity	ID: Au1; Automaticity – multiple choice selecting **all** correct words at speed
Instruction Type	Confusing initial letters. Domain Model Features practiced from Confusing letters Category: (1) d
Teaching instruction	n/a
Learning objective	Select the words that start with 'd'
Distractors	Words starting with b
Feedback correct	n/a
Feedback error	Word read aloud (response specific) Generic rules do not apply except for colour change/loss of life

Table 8: Example specification of an automaticity game for English

Using these parameters, education partners have created games specifications that produce game activities reflecting the following: (1) they practice the features from the domain models developed in WP4 and (2) they do so through the three stages of reading fluency presented in Section 2.1. These specifications have been carried out by four project teams (UCL for Beginner Readers/EFL/Dyslexia, DHBW for German Beginner Readers, UB for Spanish Beginner Readers/EFL, and UOI for Greek Beginner Readers/Dyslexia). UCL created an initial games specification template (see Appendix 7.1) and then coordinated and trained education partners to use it. Each team has had iterative consultations over a period of months with the lead game partner FIAB to ensure that the game mechanics chosen align with the learning aims expected. Additionally, given the wide scope of this work, English game specifications were developed first and transferred over where possible to the other languages – with approximately 100 game activity variations currently specified (note that a game specification often applies to multiple features in the domain model taught in the same way).

Finally, Table 9 summarises the 13 game mechanics developed in the project to date (see Section 3.2) including the name of the game activities and the reading fluency stage(s) addressed.

Game Activity name	Reading Fluency
Hearoglyphs	Accuracy
Anubrick	Accuracy
Perilous Paths	Accuracy/Building and Manipulating
Cleomatchra	Accuracy/Building and Manipulating
Remove the Runes	Accuracy/Building and Manipulating
Walk like an Egyptian!	Accuracy/Building and Manipulating
Bridgyptian	Building and Manipulating
Croco-tiles	Building and Manipulating
Slicecophagus	Building and Manipulating
Cart-Astrophe	Building and Manipulating
Pillar Pusher	Building and Manipulating
Cogelisk	Building and Manipulating
Raft Rapid Fire	Automaticity

Table 9 - Summary of Game Mechanics

4.2 Pedagogical Feedback Rules

Rules for delivering timely feedback will be in place in all games. Based on the feedback research we have undertaken, we have developed a set of generic rules that will apply across game activities for both correct and incorrect feedback. The aim of these rules will be to provide a consistent approach to feedback and to discourage the player from taking a trial and error approach to a given game activity. Note that it will be necessary to slightly tailor this feedback for some domain features (e.g. to highlight the feature with the word) or game mechanics (e.g. if the feedback will interrupt the game play such as when there is a timed element).

4.2.1 Correct Feedback – Generic Rule

When a player makes a correct response the following will happen (feedback code from Table 2 in brackets):

- Correct answer, i.e. word/sentence, changes colour to green (knowledge of result)
- One point added to score (knowledge of result)
- Word/sentence read aloud (response specific)

4.2.2 Incorrect Feedback – Generic Rule

When a player makes an incorrect response the following will happen (feedback code from Table 2 in brackets):

- Incorrect answer, i.e. word/sentence, changes to red (knowledge of result)
- If there are less than 3 possible solutions:
    - Display and read aloud feedback hint (hints, prompts or cues)
    - Else if first attempt:
        - Try again (try again – limited)
    - Else if second attempt:
        - Display and read aloud feedback hint (hints, prompts or cues)
    - Else:
        - Display correct answer and lose life (knowledge of correct result)

5 iRead Game and WP8

In this section we focus on the technical work carried out to support the interaction of the game activities with the iRead core-infrastructure. In a high-level description, a user logs in the game-application on their device. After successful login, gameplay is available. The system selects a language feature from the user's domain model and an appropriate activity. Once the activity starts, personalised content is delivered to the game. When the activity is over, the game sends log entries to the system reporting the user's progress. If necessary, the system updates the competence of the user on the targeted language feature. This process is repeated until the user quits playing.

5.1 API endpoints

The API endpoints used by the game-application for the login process and for logging the user's actions and data, are provided by the iRead core-infrastructure as described in deliverable D8.1 iRead Core Infrastructure API:

/auth/login	used for logging in the iRead system
/auth/token	used for retrieving the access token; the access token is used in all subsequent API calls
/log/actions	used for logging user's actions
/log/application	used for logging application messages

Table 10: iRead core infrastructure API endpoints

All other processes are supported by an additional component, referred to as the game's server. The game's server offers the following API endpoints that can be used directly by the game-application:

/game/get_activity	used for selecting a language feature and an appropriate activity
/game/content	used for getting personalised content for a given language feature and activity

Table 11: game's server API endpoints

In the following, we describe in detail how game activities are stored in the game's server and the logic applied for the game's server calls.

5.2 Game Activities stored in the server

Within the game's server each game activity has a unique identifier (integer id) and a unique name. Furthermore, each game activity has different parameters, such as *number-of-questions* (for example refer to cart-astrophe), *number-of-allowed-failures*, *number-of-words-displayed* (see sliceophagus for an example), etc. Hence, for each game activity a list of parameters is defined: *number-of-questions* and *number-of-allowed-failures* are common to all games, while additional parameters are defined per game. Each parameter is characterised by a minimum value, a maximum value and a default value.

For each game activity we store:

- its integer id
- its name
- the list of parameters with minimum/maximum/default values

5.3 The "Select next activity" API call (/game/get_activity)

As mentioned in Section 4, specifications are provided for mapping language features of each domain model in iRead, to appropriate game activities, targeting accuracy, building and manipulating, or automaticity. This information is stored in the game's server as a list of **activity-triplets**. An activity-triplet consists of

- a language feature (its integer id value defined in the corresponding domain model),
- an activity-type code (a convention name for representing accuracy, building and manipulating, or automaticity),
- the game for practicing (its integer id as stored in the game's server).

Selecting next activity is equivalent to selecting an appropriate activity-triplet. Firstly, the language feature for practicing is selected among the unlocked features of the user's domain model. The current implementation makes a random choice, as a more elaborated process is to be defined and implemented by the "adaptivity-component. Then, the list of activity-triplets that refer to the selected feature is retrieved, and an activity-triplet is selected randomly. Again, the adaptivity-component would take into account several parameters for making this choice.
More formally, we have the following:

Description	GET next activity-triplet	
Uri	/game/get_activity	
Method	POST	

Parameters	{
	"userId": [string],
	"modelId":[string]
	}
		
		The user's id
		The id of the domain model

Results	{
	"featureId" : [int],
	"activityType": [string],
	"gameId": [int]
	}
		
		The id of the target-feature
		The name of the activity-type code
		The id of the game for practicing

Table 12: Details on /game/get_activity API endpoint

5.4 The "Select content" API call (/game/content)

Once an activity-triplet is selected, input for the selected game needs to be prepared. Several things need to be decided in this process, such as the size of the content, target content and distractors.

The size of the content actually refers to the selected game activity's parameters. As already mentioned, each game has different parameters characterised by a minimum, a maximum and a default value. The current implementation uses default values for all parameters.

Regarding target content and distractors, we make a distinction depending on whether the content to be delivered contains sentences or not. In the first case, input is fully

specified in the corresponding resource that has been manually authored by the linguist partners. In particular, for each activity-triplet a list of sentences, along with distractors, is provided and stored within the game's server. The game's server, randomly selects sentences for the selected activity-triplet and uses a pre-specified format for the selected game. The game parameters specify the number of selected sentences.

The case where content is only related to word-elements (entire words or parts of words) is treated differently. In order to support dynamic creation of word-elements, we need to identify appropriate "functions" for selecting target content and distractor word-elements. This information is part of the specification for mapping the language features to activities provided by the linguist partners. The required additional information is stored in the game's server for each activity-triplet. In particular, for each activity-triplet we store:

- The name of an appropriate function for selecting target word-elements;
  the parameters required for the function (if any);
  additional restrictions for selecting target word-elements
- The name of an appropriate function for selecting distractor word-elements;
  the parameters required for the function (if any)
- Additional restrictions for selecting distractor word-elements.

Additional restrictions are defined for activity-triplets where word-elements are entire words. Restrictions refer to the number of syllables, position of a feature in selected words, and initial or ending letters of words.

5.4.1 Process for Selecting target word-elements

The functions implemented for selecting target word-elements are summarised in the following table. We give the name of the function, the type of word-elements it computes (i.e. entire words, prefixes, suffixes, graphemes) and the required parameters. Note that the number of target word-elements required is specified by the game activity's parameters.

function-name	word-elements	parameters
fromFeature	Entire words	None
fromGroup	Entire words	List of feature-ids
getGrapheme	A single grapheme of a primary word	None
getPrefix	Prefixes	List of feature-ids (optional)
getSuffix	Suffixes	List of feature-ids (optional)

Table 13: functions used for selecting target word-elements

fromFeature: Only words that contain the feature of the activity-triplet are selected. The current implementation makes a random choice, while more elaborated choices will be considered by the adaptivity-component.

fromGroup: Here, a group of features is considered. This group always contains the target-feature, i.e. the feature of the activity-triplet. We select half of the words to contain the target-feature and the remaining half of the words to contain other features from the group. Again the selection is made randomly.

getGrapheme: this function is only used when the target-feature belongs to the GPC language category. Initially one target word is selected and the grapheme of the GPC target-feature is the (only) correct word-element.

getPrefix/getSuffix: these functions are used only when the target-feature is related to prefixing and suffixing of words. A word that contains the target-feature is initially selected and split into the prefix (or suffix) and the base-word. Other valid prefixes (suffixes) than can be combined with the base-word are computed as the correct word-elements. If a list of features is provided as parameter, then only prefixes (or suffixes) of the given features are considered (the provided features are also related to prefixes or suffixes).

5.4.2 Process for selecting distractor word-elements

The functions used for selecting distractor word-elements are similar to those used for selecting target word-elements. Distractor word-elements are selected after the target word-elements are determined, and the number of distractor word-elements is determined by the game parameters.

In the case where distractor word-elements are entire words that contain a distractor feature, in the current implementation we consider the following filters (in the given order) for selecting distractors:

- same number of phonemes with at least one target word
- same cv-form with at least one target word
- same number of letters with at least one target word.

The number of phonemes and letters can be relaxed by +1 or -1 if no word satisfying these criteria is found. In the extreme case where this also fails, words that contain the distractor feature are selected randomly.

Also, when distractors are selected from a list of distractor features, it might be the case that some distractor features are locked in the user's domain model. We do not want to select all distractor content to be related to locked features, unless all of them are locked, hence we consider the following cases:

- If at least two distractor features are unlocked, then we consider only the unlocked features.
- If there is exactly one unlocked feature and at least one locked, then we select half words from the unique unlocked feature and the remaining from the locked features.
- If all features are locked, we select words from the locked features.

Note that in the final implementation, a more elaborated way to select target content and distractor word-elements may be implemented, which takes into account the user's domain model and previous user's game-playing (as recorded by the iRead infrastructure logger).

5.4.3 The content sent to the game-application and its format

The content delivered for an activity triplet is formatted using the json format. It contains the following information:

- **teaching instruction:** in the current implementation, teaching instruction is always part of the delivered content; a more elaborated process for deciding whether it should be included can be considered by the adaptivity-component.
- **game parameters:** the selected values for the available game parameters are given as part of the delivered content.
- **selected word-elements:** the actual structure of delivered word-elements depends on the selected game activity.
- **additional content information:** For each selected word delivered as content, we include its word-level information (stored in the dictionary resources of the iRead infrastructure). The same holds for sentences, if sentences are delivered as content. Word-level information includes phonetic transcription, syllabification, language feature occurrence, etc. Sentence information includes syntactic analysis and language feature occurrence.

In summary, we have the following:

Description	GET content for activity-triplet	
Uri	/game/content	
Method	POST	

Parameters	{
	"userId": [string],
	"modelId":[string]
	"featureId" : [int],
	"activityType": [string],
	"gameId": [int]
	}
		
		The user's id
		The id of the domain model
		The id of the target-feature
		The name of the activity-type code
		The id of the game activity for practicing

Results	{
	"teachingInstruction" : [string],
	"numberOfQuestions": [int],
	"fails":[int],
	…
	"data":{ .. },
	"data_info":{ .. }
	}
		
		The teaching instruction
		Values for the game activity parameters
		
		Selected content
		Word-level and sentence-level information

Table 14: Details on /game/content API endpoint

5.4.4 Feedback

Regarding support for game activity feedback, each activity is aware of the correctness/incorrectness of the delivered content (operationalising 'knowledge of results'). For word-level domain model categories, the available word-level information is provided in addition to an elaborative written feedback authored for each instruction type. Specifically, this information includes target feature position in a word, word GPC, syllable splits and morphemes. It can be used by the game, along with the target-feature's description and information, in order to decide how to present feedback based on the user's performance. For sentence or phrase level domain model categories, the

content sent to the game-application will just include written feedback authored by the pedagogical partners to support each domain model category.

6 Formative User Evaluations

Following our LCD approach we employed an agile process which included iterative rounds of prototype evaluation with both teachers and students. After each round a series of recommendations were made for improvements to the prototype that were subsequently implemented in existing game activities and also used to guide future development work. To date this work has only been undertaken in the UK context but we plan to continue this in the other countries in coming months. Furthermore, due to the lack of content integration at this stage our goals were to evaluate usability as well as children's engagement with the games.

Figure 16 provides an overview of the process to date, we have worked with five teachers from two schools and 32 students from the beginner reader group across three schools (see Table 15 and Table 16 for detailed breakdown). The teacher sessions focused on both pedagogical and game mechanic design, with the student sessions solely focused on the game mechanics. After the content integration is complete we plan to shift our focus back to the pedagogical design, and include further teachers as well as students from the other learner groups (dyslexia and EFL) and languages.

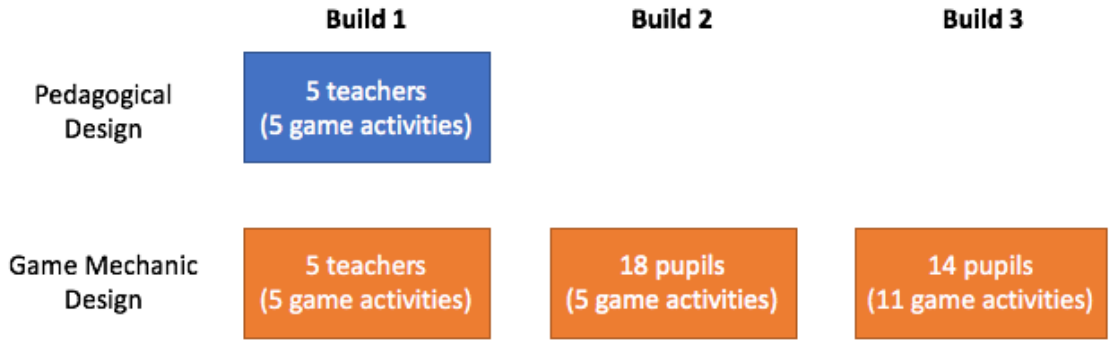

Figure 16 - Overview of Game Prototype Evaluation Process

During the sessions with both teachers and students researchers took written notes as well as audio recordings of the discussions. At the start of each session following our informed consent procedures set out in D10.1 (which included gaining prior parental consent for all children), we firstly explained the project in language appropriate to the participant group as well as what participation in the session(s) would involve. Participants were then asked to explicitly give consent for both participation in the session as well as to be audio recorded. We also ensured that we remained sensitive to any non-verbal cues that a child might not want to participate such as hesitance to complete the form and these children were given the option to go straight back to class (which a small number chose to). We also verbally confirmed consent at the start of each subsequent session.

School A	Urban, state primary, mixed, low SES, high EAL
School B	Suburban, fee-paying non-selective primary, girls, high SES, low EAL
School C	Urban, primary academy, mixed, average SES, high EAL

Table 15 - Overview of Design Schools involved in Formative Evaluation

Session Focus	Game activities tested	Participants
Pedagogical Design (classroom use) Game Mechanic Design (suitability for students)	Cleomatchra Walk like an Egyptian Rule-ing the Runes (now cut) Pillar Pusher Perilous Paths	School A: 3 teachers (Y1-3) School B: 2 teachers (head of Key Stage 1 and SEN coordinator)
Game Mechanic Design (student engagement and general usability)	Cleomatchra Bridgyptian Raft Rapid Fire Hear-oglyphs Cartastrophe	School A: 8 students (4 boys, 4 girls, age 7-8 years) School B: 10 students (all girls, age 6-8 years)
Game Mechanic Design (specific usability)	Character Creation tool Cleomatchra Bridgyptian Raft Rapid Fire Pillar Pusher Walk like an Egyptian Remove the Runes Slice-cophagus Anubrick CrocoTiles Perilous Paths Cogelisk	School C: 8 students (5 boys, 3 girls, age 6-7 years) School A: 6 students (3 boys, 3 girls, age 7-8 years)

Table 16 – Game Formative Evaluation Overview

6.1 Teacher Formative Evaluation

Early versions of five game activities were shown to two groups of teachers by a UCL researcher (total 5 teachers – see Table 16). The teachers played five prototype game activities and then were asked a series of questions about what and how the games could be used to teach specific reading skills as well as how usable the games would be for their students to play and what additional support they might require. Teachers were also asked for their ideas about how the game would fit into their classroom context and for any ideas for further development. Each formative evaluation session took 40-50 minutes and was audio recorded, then transcribed within the feedback form (see Appendix 9.1.1).

Below we discuss the main themes identified during these sessions both in terms of the pedagogical design but also the game mechanics.

6.1.1 Pedagogical Design Themes

- Pre-Play
    - Important to include an explanation of the language feature/rule and an example of how to play or an initial warm task to build up confidence of students who are nervous of getting the wrong answer
    - A teacher version of the game that enables them to model a particular game to the whole class on the whiteboard before students' play

iRead Implication: teaching instructions will be presented each time a child encounters a new language feature as well as a game tutorial each time they encounter a new game mechanic. Wherever possible a child will not encounter a new feature and game mechanic at the same time. Furthermore teachers will have direct access to play specific language feature/game combinations.

- Instructions
    - Short, precise and clear instructions that are read aloud
    - Use of symbols to represent some instructions/concepts would be useful for children who struggle with reading
    - Option to repeat words/instructions during game as reminder

iRead Implication: teaching instructions will be kept as simple as possible, with text kept to a minimum and instructions read aloud. There will be an option to listen again to both teaching and game instructions during game play.

- Feedback
    - Provide an overview of progress and goal so students know where they are heading
    - Feedback should be immediate so students understand what it is referring to and subtle so it does not disrupt the gameplay
    - Word-level feedback should reinforce completed word - word parts should be positioned so they can be read from left to right/form word after it has been built
    - Teacher want to access overall results to monitor progress e.g. lists of words, score, speed, accuracy
    - Positive feedback, teaching tips and alternative ways to practice the same thing if a child is struggling

iRead Implication: a 'score' will be visible in each game so children are aware of the game activity success criteria (i.e. number of correct responses made and required). Feedback will be given directly after a child has given a response unless this disrupts gameplay e.g. in automaticity activities. In building and manipulating activities word segments will be positioned so they can be read from left to right. Teacher reports will be available through the learning analytics component. Additional materials will be provided as part of the professional development component to help teachers support children who are struggling.

- Context of Use
    - Should be designed to be used independently, for instance as a 'guided reading' activity
    - Should be designed for short game play sessions (10-20 minutes maximum play) and the non-learning time in game, e.g. getting between activities, should be minimised

iRead Implication: during independent 'free' play children will be presented with a game play session containing a sequence of game activities that is appropriate to their experience and level. There will also be additional functionality so that teachers will be

able to create 'missions' that include a sequence of game activities specifically tailored for their lesson focus and format.

6.1.2 Game Mechanic Themes

- Cognition
  - Children struggle to understand the concept of a word/sentence 'not' having a particular language feature so this type of instruction should be avoided
  - Younger and struggling readers can become overwhelmed by lots of words presented on a screen at once

iRead Implication: game mechanics will focus on requiring the child to identify words/features containing a feature rather than those that do not contain a feature. Only the current selectable options will be visible on the screen.

- Interaction
  - Building/manipulation interaction should be simplified to accommodate children's limited motor skills and ensure simple game play
  - All relevant game components remain on-screen during activity

iRead Implication: interaction will be kept as simple as possible to ensure it does not disrupt the learning for instance by using drag/drop over multiple taps. The screen will not be scrollable during the game play.

- Motivation
  - To maintain motivation if a child gets an incorrect answer this should result in a small step back rather than restarting the activity
  - Personalisation and rewards (gaining incentives rather than losing lives) are important for engagement

iRead Implication: children will have multiple attempts to get an answer correct as well as multiple lives. If they are unable to complete a game activity then they will be given the option to replay or move on. Children will be able to customise their character and they will be rewarded for successes within the game.

6.2 Student Formative Evaluation

Following on from the teacher formative evaluation two rounds of student formative evaluation were undertaken to inform the game mechanic design.

The first set of sessions was focused on **student engagement** with the games and involved 18 students from two schools (see Table 16). Each session involved two children, a researcher from UCL as well as a member of the FIAB team and lasted approximately 15-20 minutes. The sessions were audio recorded as well as documented via written notes. The children were asked to first attempt each of five prototype game activities without any assistance from the adults, if they became stuck they would be given gradually increasing levels of support that ranged from a hint to demonstration and verbal step-by-step instructions. At the end of each game activity the Problem

Identification Picture Cards (PIPC) method (Barendregt, Bekker, & Baauw, 2008) was used to elicit children's feedback on both the usability and fun (i.e. engagement) aspects of the activity. The full set of cards used can be found in the appendix - 9.1.2. The children were asked to select the cards that described their experience of the game activity and then they were asked to explain their selection. Table 17 provides a summary of the PIPC feedback, which showed that generally most of the children found all game activities fun but some were clearly much more straightforward to play than others.

Game Activity	PIPC card chosen	No. of pairs
Cleomatchra	Fun	9
	Easy	5
	Difficult	5
	Babyish	1
Bridgyptian	Fun	8
	Difficult	4
	Easy	2
	Frustrating	2
	Too Slow	1
	Scary	1
Raft Rapid Fire	Fun	8
	Easy	3
	Too Fast	3
	Too Short*	1
	Scary	1
	Difficult	1
Hear-oglyphs	Fun	7
	Easy	4
	Boring	1
	Babyish	1
	Too Short*	1
	Difficult	1
	Frustrating	1
Cartastrophe	Fun	7
	Difficult	4
	Easy	2
	Boring	1
	Scary	1
	Frustrating	1

Table 17 - Results from Student Formative Testing 1

The second set of sessions was focused on the **usability** of the game activities with a particular view to inform the design of the game play tutorials, and included a total of 11 games plus the character creation tool. These sessions involved 14 students in two schools (see Table 16). Each session involved two children, a researcher from UCL as well as a member of the FIAB team or second UCL researcher and lasted approximately 15-25 minutes. The sessions were audio recorded as well as documented via written notes. The children were asked to first attempt each four of the prototype game activities without any assistance from the adults, if they became stuck they would be given gradually increasing levels of support that ranged from a hint to demonstration and verbal step-by-step instructions. At the end of each game the children were asked a

series of questions to establish their understanding of the game and what they found difficult – these questions included:

- Can you explain the goal of the game?
- Did you find anything difficult?
- Do you have any ideas for how the game could help other children know how to play?

The findings from these sessions were then summarised and a series of recommendations for changes to the game activities as well as for the design of the game tutorials were made – this summary can be found in Appendix 9.1.3.

Below we discuss the main themes identified during the student formative evaluation both in terms of engagement and usability.

6.2.1 Engagement Themes

- Promoting engagement
    - Both easy and more challenging games were described as fun – getting things right was very motivating
    - Appealing graphics e.g. water, lava, sound effects and a fast pace
    - Mystery and opportunities to explore
    - Students were engaged with the learning as well as the game play
    - Feedback such as their raft breaking up (although in some games students were not aware if they had got the answer wrong or right).

iRead Implication: additional game mechanics and rewards will take into account the above motivating aspects

- Barriers to engagement
    - Not enough challenge
    - Not enough variation in game environment design
    - Difficult interaction e.g. dragging/dropping in some games
    - Not understanding how to start a game activity
    - Gameplay being too difficult e.g. too fast and not having time to read the words
    - Slow pace and having to wait
    - Concerns about failure e.g. a tile sinking in the lava or hitting the side with their raft

iRead Implication: the integration of suitable learning content will hopefully address to some extent the challenge/variation issues. The interaction in Pillar Pusher has been to make it easier to move the pillars around and in other games the target position for drag/drop will be made clearer. The addition of a 'helper' character will support the child with starting the game and game tutorials will provide further instruction about how to play the game to help build the child's confidence.

6.2.2 Usability Themes

- Learning
    - Learning goal can be confusing in matching activities if the selection sequence is not enforced (e.g. selecting a prefix and root word, selecting an audio clip and matching word in text form)
    - Allowing the same mistake to be made multiple can cause frustration
    - Some game elements such as background music can distract from learning
    - Audio clips played only once can be easily missed or forgotten
    - For automaticity games children do not read instructions if the game play starts immediately as this commands their attention. It can be challenging at the start if the game is too fast and the children are still learning how to play.

iRead Implication: for matching games initial segments of words/audio clips will be highlighted to guide the child towards selecting this first. Try again will be limited through the feedback logic, background music will be reduced during games. Also instructions will be read aloud before game play starts and accessible to play again during game play.

- Interface Design
    - Multiple and inconsistent colours can confuse the learning goal
    - Children need more guidance on where on the interface to place word parts/words when building words or sentences
    - Left or inconsistent alignment of multiple lines of one sentence and gaps between words can make it difficult for children to recognise this as a single sentence
    - Children were unaware that sometimes words were blocked by other interface elements

iRead Implication: variation in colours in some game activities will be reduced, targets for placing words will be made clearer and sentences will be aligned to be more readable. The camera angle for some game activities will be changed to ensure that all aspects of game play are visible.

- Game Play
    - It was challenging for children to know how to access a game or get to the next question within a game
    - Some interactions were more challenging or inconsistent within a game e.g. some children tried to tap rather than drag
    - Children sometimes missed key parts of the interface e.g. the button to 'check' their answer
    - In one game there was too much effort and not enough fun to navigating between learning tasks
    - In some games it is possible for children to become stuck if they get the wrong answer as they are not provided with feedback on how to recover

iRead Implication: the 'helper' character will support children to start playing the game as well as guiding them through the key aspects of the activity via a tutorial, additional game features will be added to game activities to ensure 'fun' is maintained and game

activity logic will be changed to reduce trial and error approaches by limiting attempts through lives and preventing children becoming 'stuck'.

7 CONCLUSIONS

This deliverable has detailed our process for undertaking the pedagogical design of the iRead games. Our work began with **reading fluency theories** that identified three types of activities for supporting reading fluency (Section 2.1). We then opened the scope of our theoretical engagement beyond domain theories to look at a critical dimension of instruction, **feedback** (Section 2.2). Through a content analysis of current games, we distilled seven instructional dimensions that must work in tandem to support learning. In parallel, a creative game concept was developed alongside with 13 different game mechanics (Section 3).

Game design and theory came together through a game specifications task that has been carried out across the four languages aligning theory, game mechanics and domain model to produce individual game specifications (Section 4). The technical requirements raised by these specifications have been catered for in WP8 'Software Infrastructure: Development, Integration, Refinement & Maintenance' (Section 5). Finally, games have been evaluated in a series of school visits in the UK. As this work continues to take place over the Spring and Summer of 2018 game mechanics and activities will be incrementally improved with input from more learner groups and teachers (Section 6).

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9 APPENDIX

9.1 User Testing

9.1.1 Teacher Formative Evaluation Example Output

Cleomatchra

What reading skills could this game be used to teach?	Types of word Chunking Suffixes Adverbs – ly words Prefixes Syllables
How would you want the learning objective to be introduced to students?	E.g. suffixes – you would need to understand how a suffix turns from a verb into an adverb or you might have to do a bit of grammar with them maybe you collect all the verbs and then add the suffix – might have to bring in types of words. Something I teach children who are already confident with their phonetic sounds. Start off with the general explanation because as a teacher the way we would use it is to have taught some of it at the board, talk about the word family or the word focus is, the rule that we are teaching them and then they would go off and do an activity with it. What we would need is for the interactive game to reiterate what we had just said – explaining the general rule and then having them do a warm-up activity and then do a matching game. Once you have taught the rule you want something really obvious for them to have a go at first because that's them thinking oh yeah now I know it. So they are really obviously noticing the components and then

	go on to let's find it now.
Would your students find this motivating?	
What problems might students have with the game mechanics/interaction?	
What in-game support might students require?	
What feedback would it be useful to have – for students? For you?	

Walk like an Egyptian

What reading skills could this game be used to teach?	
How would you want the learning objective to be introduced to students?	
Would your students find this motivating?	
What problems might students have with the game mechanics/interaction?	
What in-game support might students require?	This has gone straight into this, this is too much of a jump for year 1s in particular and rhyming is not a forte of our children (EAL?) would need an intro what do you mean by rhyme and there was perhaps a missing letter and they would have the 'at' all the way along and this would be further along because I think for some children it would be a bit daunting to look that many words. Would be fine for a Y3.
What feedback would it be useful to have – for students? For you?	

Remove the Runes

What reading skills could this game be used to teach?	
How would you want the learning objective to be introduced to students?	
Would your students find this motivating?	
What problems might students have with the game mechanics/interaction?	Teachers had difficulty.
What in-game support might students require?	Less daunting because there is less on the page. Some of my lower year 2s find the 'not' very difficult to comprehend. E.g. in guess who, you're looking for the ones that don't have something and that is tricky for them.
What feedback would it be useful to have – for students? For you?	

Pillar Pusher

What reading skills could this game be used to teach?	These sorts of activities that you are rearranging are particularly good for tricky

	words – so up to phase 6 there are lists of tricky words so those sorts of activities I do things like anagrams quite a lot with them to try and get them to remember the word order.
How would you want the learning objective to be introduced to students?	
Would your students find this motivating?	
What problems might students have with the game mechanics/interaction?	I would think about how he is being moved around because of motor skills – but might be good for them to practice. After all of this I would not know how to spell help.
What in-game support might students require?	Would the games show the phonics rules that we are teaching them – so the digraphs and trigraphs, if they were putting it together. If you were thinking of a word like 'chain' for instance I would want the 'ai' because it is one sound
What feedback would it be useful to have – for students? For you?	

Perilous Path

What reading skills could this game be used to teach?	Nice for initial sounds
How would you want the learning objective to be introduced to students?	
Would your students find this motivating?	Used to losing lives, but could take them back a step and rather than back to the beginning.
What problems might students have with the game mechanics/interaction?	
What in-game support might students require?	Instructions are long – the instructions need to be simplified and would need it to be read to them. Children wouldn't read the instructions they would just start the game.
What feedback would it be useful to have – for students? For you?	

Rule-ing the Ruins

What reading skills could this game be used to teach?	
How would you want the learning objective to be introduced to students?	
Would your students find this motivating?	
What problems might students have with the game mechanics/interaction?	Problems with seeing all four options
What in-game support might students require?	Symbol that you could show. Having an image for syllable symbol – we clap

	out syllables so maybe having a clap symbol come up and when they get it right having two claps because that's two syllables.
What feedback would it be useful to have – for students? For you?	

Rapid Raft Fire

What reading skills could this game be used to teach?	
How would you want the learning objective to be introduced to students?	
Would your students find this motivating?	
What problems might students have with the game mechanics/interaction?	
What in-game support might students require?	
What feedback would it be useful to have – for students? For you?	

Overall

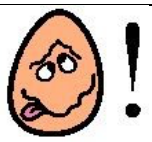
What do you like about the games?	Last one is quite nice, it applies pressure as it is moving and it will make them read quite quickly, for the children in my class that would be quite a good activity for them. I liked the perilous path game. I think sequencing the letters to make the words if you had that with the digraphs and the trigraphs in, that would be really good.
What are your concerns?	I wasn't sure about the watch your step game as I thought there were too many words. Use of joystick and lighting. Navigation is a bit challenging and lots of things go out of sight that you need to be able to see. Need to be careful of vocabulary used especially for EAL – short, precise and clear language. Visual as possible – e.g. use imprint where can write instructions and the visuals will pop up. I don't have concerns - we can all see this helping us as opposed to causing a problem.
How can you see this fitting into your current classroom context?	Definitely in guided reading, because there is always a group working independently and for 6 children every day to be having a chance. For me in Y3 in Autumn term that would be a

	perfect guided reading activity where they just need that revision of what they have learned. Would also be really useful when we don't all have an adult for every group when they split into their phonics groups then if you had another group in your classroom they could be practicing stuff at their own level. Whereas you're still teaching the others. Sometimes you have to do whole class and you have to pitch it midway which isn't useful for anyone. In Y3 (for phonics) we do it so majority are taught by the teacher and small group goes out with the TA, but we soon won't have that additional physical adult support and I would need something like this so you guys sit there and have a go with this. Would give flexibility when don't have enough adults or maybe within a group there is a child that is struggling within their own phase but they are too able for the group below they could have this as an additional thing to be practicing outside of phonics even – beginning/end of the day while take register. Something that is simple and easy as having an iPad there. 20 minutes maximum play.
Ideas for further development…	Audio with an example and now you have a go before they start the game. Especially if it is the first time they are playing it, so it is checking you know what to do before you go on to start the game. Could collect coins Symbol based language They like levels – so could see where their personal progress was and where they needed to get to, so they were working their way up You might want an aerial view of the ruins and have them complete different sections and see where they have been and what they have got left to do and then you might want some kind of bonus game activity that they can play at the end – a quick fire one Personalising avatar – adding features Something at each level that could be printed

	off – love certificates Feedback – if it's done in a game way they know which words they have got wrong don't they. I think it would need to be straight after the activity, so when we selected the ones that do rhyme and the ones that don't. E.g. telling you instantly by lighting green or red. It would be useful if a child was getting stuck at a level, would be good if the game gave them an alternative version of practicing that. I would want confirmation that they are working at the right phonics level within class and it would be quite nice to know where they are struggling with things within class, if they know the sequencing of the letters with the spelling. Knowing that it is consolidating your teaching – by saying yeah they are definitely working within phonics phase 2 or 3. But hang on they're doing all this stuff maybe they should be in phase 4 or 5. I suppose that would confirm teacher assessment. Would want a version that the teacher could use to model on the whiteboard. Because when you are introducing it to the class you might want to introduce the first couple of games and it saves that need for an adult to sit with each group. Introduce new things by putting it on the interactive whiteboard. Highlighting any particular sounds that they found difficult, you don't have time to go through individually and you don't always notice a child that has struggled with that sound and is repeatedly struggling with that sound every single day. Particularly with high frequency words to inform further activities.

9.1.2 PIPC Cards

			
Frustrating	**Difficult**	**Don't understand**	**Easy**

			
Boring	**Silly or Strange**	**Fun**	**Scary**

			
Takes too long	**Babyish**	**Too fast**	

9.1.3 Student Formative Evaluation Findings – Round Two

Age Group	Game	General Observations	Adult Intervention	Gameplay			Learning			Other Feedback	Recommended Changes	Notes on recommended changes
				Objective	Difficulties	Ideas	Objective	Difficulties	Ideas			
Group 1 - 2 boys, year 2	**Character creation**	Immediately understood UI Didn't scroll UI Didn't change any colours Didn't enter a name	No									
	Cleomatchra	Began walking with the joystick immediately	Teacher explains that they have to match the words	Understood how to answer the questions Aim was to open the door	Took a little time to discover they had to tap the table to start Trying to open the door was difficult		Understood the content of the questions Click the right words that make sense - similar to classroom activity		Instructions read aloud and explain that you have to select a word that makes sense	"Didn't know how to start the game" "a hint on how to start the game would have helped"	Explain the aim of the activity (perhaps through example) and read aloud Require prefix to be selected first	Mechanic change - prefix selection. Need to clarify if this is really required due to extra work
	Bridgyptian	Walked to the start of the game immediately		Understood they had to drag quite quickly Understood the aim of the game - get the right words so you could build the bridge and go through that door	Tried to just tap the pillars at first rather than dragging Struggled with removing wrong answers after getting it wrong A bit difficult to drag the words but got easier	Have vehicles	Clicking on the right word so you understand what they mean	Found repeated question confusing	Have different words If you get it wrong then you can't get it wrong again	"This is hard" bit difficult to drag "it would be better if questions didn't repeat" "should remove wrong answers after getting it wrong"	Highlight the need to drag rather than tap, make it harder for pillars to be accidentally dropped into the lava at the start Limit try agains - should only be able to use each pillar once, once it is established that the word is incorrect then this should be no longer enabled	Mechanic change - limit try agains. Need to clarify on the learning front what the pass criteria is. Could remove a scarab score when wrong answer given.
	Hear-oglyphs				Pressed words before pressing the audio buttons	Should make sounds associated with the words	Did not understand the game - thought you had to connect the word with the colour		Use colours to help you	"This is easy" "Should have a sound effect with the word" - e.g. dog goes woof "Matching colours would be good"	Require player to listen to audio first and then match to word - instructions to explain this sequence Improved sound would help Might be better to have the audio icons all the same colour, this seems to be causing some confusion	Will make all audio buttons one colour to begin with. MAke it so have to choose audio buttons first. Audio feedback for negative answer for example
	Raft rapid fire			Understood how to play immediately Were aware of the hearts and number of correct answers at the side and were monitoring this throughout the game	At the start pressed some of the barrels on the side Timing of shooting was difficult	Include a boat and more hearts Have the raft moving See where you are aiming for (e. g. see the door at the end) Customise boat	Didn't understand the question - just shot all barrels with words on Knew that you had to get 10 words and not run out of hearts in order to complete the game	Didn't know which one to shoot Didn't know where the end was		"too fast" "didn't know which to hit" "didn't know how long was left" "need more lives" "river should be wider" "can I move the raft myself" "can I customise the boat"	Make question clearer at start - e.g. read aloud, give example Repeat question after incorrect answers Progress bar rather than showing progress by numbers?	nothing shown in first few seconds and question is read out. player input to start the game - giving player time to read and confirm they want to start game. Slow down whole game to give more time to react after reading word. Needs to be modifiable - slower first time you play and gets faster as you play more/become better at it. - then adjust speed according to right and wrong answers. Question triggered again after 2 wrong answers in a row.
Group 2 - 1 boy, year 2 (other pupil didn't want to share feedback)	**Character creation**	Understood UI straight away Changed colours Didn't scroll UI										Amends as above
Favourite game: Raft rapid fire												
	Bridgyptian	user joystick movement immediately	Adam explains what to do to start and also how to correct a wrong answer	Aim to get across the bridge by putting pillars next to each other to support the bridge	Controls were difficult		It has to be an actual word with 're' at the start	The words were a bit difficult		"I think the aim is to cross the bridge" "Had to match the words up with re-" "controls are difficult"	Incorrect answer should be automatically removed and disabled	Amends as above
	Hear-oglyphs		Adam had to explain how to start the game by tapping the table Laura had to suggest which one to tap first and then they were able to quickly complete the game			Could have an arrow pointing at the table	To tap on one of the sounds and it tells you the word and then you need to press on the word that it says by reading the word	At the start it didn't really tell you what you had to do - wasn't clear enough		"didn't know how to play" "A hint on how to start would be good"	Indicate how to start the game by tapping on the table	Will be adding a highlighter/sparkle to podium to draw attention to start point
	Raft rapid fire		Explained how to play beforehand	Aware of the number of correct answers needed to complete the game	Bit fast		Aim was to read what it said, find out if it ends with a /s/ sound and shoot it by tapping			"too fast"		Amends as above

Age Group	Game	General Observations	Adult Intervention	Gameplay			Learning			Other Feedback	Recommended Changes	Notes on recommended changes
				Objective	Difficulties	Ideas	Objective	Difficulties	Ideas			
	Pillar pusher		Laura had to give guidance about where the word needed to be positioned	Understood how to play	Didn't understand where to place the correct word		Understood the aim of the game - one child suggests to read instruction To make the word in the right order and the right direction	Said the word at the start too quickly Word was a bit difficult		"when it said the word at the start it was too quick"	Make it clearer where the word has to be placed Say the word more slowly at start and provide option to repeat the word	TTS so can't say more slowly. But a repeat UI button will be added. Highlight where pilar needs to go to be covered by tutorial navi. Have the answer slots separate from question slots. Highlight the answer slots when a pilar is being levitated. Navi only needs to highlight the pilars you are going to pick up as an activity prompt.
Group 3 - 2 girls, year 2	Character creation	Understood UI Scrolled UI didn't change colour didn't enter name										Amends as above
Favourite game: Walk like an egyptian												
	Hear-oglyphs	Tapped to move	Adam had to explain how to start the game Adam had to suggest to press one of the audio buttons and explain they had to match it up with one of the words		Didn't know how to start the game		Aim was to press button and you had to listen to the word then you had to tap it on the screen			"It was a quiz, just had to match the words" "didn't know how to start the game"		Covered by tutorial navi hover over the plinth
	Raft rapid fire	Understood which answers were right, but were slow to react	Adam explained before starting	Understood how to play the game Piece of wood came off when didn't get the right one		Make it easier to go through the door and easier to steer the raft	To press all of the ones that end in s	Bit difficult with some of the long words		"The words were quite hard"		Content - no amends by FIAB
	Pillar pusher		Adam had to explain to move the pillars around to spell out word Had to be reminded of the word		Difficult to know to what to do - thought had to tap rather than drag		knew they had to spell the word		Give instruction at top - drag the letter	"didn't know how to play" "thought I just had to tap them in order" "should say how to play"	Highlight that the pillar needs to be dragged	Amends as above
	Walk like an egyptian	Hesitant to start the game and also during, seemed very worried about getting it wrong Mostly trial and error	Adam had to prompt them to start the game Adam had to explain the aim of the game and give an example Laura had to give encouragement to try	Had to choose from three or four words - if you were wrong you jumped back to the one you were already on but if you were right you would move forward	Didn't know you had to go onto the spinning thing - it looked like it could be a hole you could fall in to		Tried each word with 're' to see which one was a real word and tapped on that			"We had to pick the correct word to move forward" "Didn't know how to start" "Didn't want to step on the swirly thing at the start"	Change way the starting position is marked	Add a pair of footprints to indicate where to stand at start
Group 4 - 2 boys, year 2	Character creation	Understood UI Scrolled UI Changed colour										Amends as above
Favourite game: Walk like an egyptian												
	Pillar pusher			Understood how to play			Understood the question - had to make the word connect		Make the moving sound effect quieter	"We had to spell the right word" "The word was hard" "It was hard to drag" "The sound of the pillar moving is too loud"	Reduce sound effect on dragging movement	Amend sound
	Walk like an egyptian	Hesistant because of the peril		Understood how to play			Appeared to understand the game and completed without adult intervention however actually had been selecting words that 'er' could be added to the end of rather than the prefix 're'		Change last question so it is less obvious which tile to step on	"I was picking the word that could have 'er' on the end" "The words were too hard"		Also adding a safe fence / barrier along the edge of the starting platform
	Remove the runes	Understood how to start the game after a short while walking around Found this game very easy		Understood how to play the game			Explained the objective correctly		Include more words	"It would be better with more words" "I want to step up onto the stand from the side"		

Age Group	Game	General Observations	Adult Intervention	Gameplay			Learning			Other Feedback	Recommended Changes	Notes on recommended changes
				Objective	Difficulties	Ideas	Objective	Difficulties	Ideas			
Group 1 - 2 boys, year 3	Cogelisk	Found it difficult to know where to go and to get their character to the starting platform Ended up pressing the exit button During this process they ended up rotating the camera angle completely around			Where you had to go at the start	Make the map bigger Have an arrow to help you know where to move	Understood goal is to make a sentence using the words by swiping to change the words		Maybe it should stay like that / I liked it Could have a hint button with what you need to do e.g. "swipe down until you find the right word for the sentence"	It makes you think and have fun	Sort out camera angle change bug Indicate where character has to go to start the game or make it walk there automatically	Camera angle fixed Game indicator will be resolved with hints over sprints 31/32
	Perilous Paths			It has a question for you and you have to do what it says - you have to walk to that word	Hard to go from one bridge to another Didn't know what to do at beginning but once you play it is ok	Have a reward or see the perils Add some rules at the beginning to tell you what to do Add an arrow to show you where to go	Understood			Not difficult, but not much fun	Make going between the bridges more interesting or less effort Make interaction more consistent - either keep both or just one	Instructions to indicate where to tap
	Croco-Tiles		Laura had to intervene to show how to put the tiles in position		Hard to put the word in the right spot	Needs more hints or info - like the blue screen slot	Goal is to put in the missing word	Hard to know if it is one or sentences		Liked it because it was fun	Make gaps in sentence more obvious Align sentence so it is clearer that it is one sentence (could include a full stop?)	Fix the text sizes and make sure there is enough space between the words. Add full stop to last word.
	Anubrick		Laura had to show how to deselect a word Laura had to explain which was sentence 1 and which was sentence 2 Laura had to explain the word types in sentence 1			Add some more hints about where you need to go	Had to tap on the 2 nouns	They selected the 2 correct words and then one incorrect word and then nothing happened and they were confused about what they should do next Hard to know which is sentence 2	More explanations Slightly harder questions		Prevent children from getting into a stuck state - have a check button or give feedback after a set period of time to show the ones that are right/wrong Automatically walk the character towards the next wall or have a hint to walk forward	All being covered as part of 'navi' hints and inactivity prompts.
Group 2 - 1 boy, 1 girl, year 3	Cogelisk	Same problem as before - not knowing where to go to start the game		To find the place where to find the answer	To know where to go at the start	Include an arrow so you know where to go	Go through all the words and see what makes sense					
	Perilous Paths	Struggled to use their finger to move around - didn't know whether to press or drag character along			To get to the point where the instruction appeared Hard to know to tap the bridges and not drag the character across the bridge					Confusing to have line for prefix and stem on a different line It's nice - only some words other children might not know	Make the target position to receive the instruction clearer - could be a platform or something?	Being addressed
	Croco-Tiles	It seemed like they did not read the instructions	Laura has to show the spot where they put the word and it takes them a while to do this		Where the stairs were Where to put the word		You had to drag the word to complete the sentence	To see for the first one if you should carry on on the same line - i.e. to know where the gap is	A darker colour to show where the sentence goes		Same as for cogelisk - help the children know they have to get to the platform	Being addressed
	Anubrick	Instructions are very small Wall is small if character is far away			Depending on where the character is you cannot always see all the words		You had to find the words that the the same - you tap them and leave the others that are not nouns	Problem with comprehension of the task - because of the positioning of words thought the words were jumbled up and had to be tapped in order Knowing which word we had to tap on was hard	When all the words are tapped have an instruction that says		Don't have large gaps between words and align it across the wall so it looks less jumbled	Reducing or removing spacing between words - will review during next build (sprint 31)
Group 3 - 2 girls, year 3	Cogelisk	Game rotates around - seems to happen when both children are trying to control at once	Laura has to show how to get to platform		To know where to go (at the start)	Make it go back if you make an accident and have lava so you know where not to go (when starting the game)	Aim is to make the sentences make sense by finding the right word	Some words were a bit difficult			Obstacles could be used to make the path you have to walk towards the game clearer	Navi (guide) will address this
	Perilous Paths				Tries to drag character rather than press word Struggle to place the character in the right spot to trigger the instructions	It's a long course so would be nice to have something in the middle	Aim was to match the words that fit tog You have to try every one	It's difficult to know that you have to press but not drag	Some instructions at the beginning	It was a bit boring just to drag		
	Croco-Tiles	Seems to work - children start reading sentences for completing before reading instructions No feedback when word has been put on a space Children got a bit confused when they had the same sentence twice			Difficult to drag the tile in the right place Difficult to try and find a space for all the tiles in the sentence Were confused about the double block - thought it meant two words	Show how many blocks you need	Aim was to try to make sense				Make it less sensitive to the word having to be positioned in the correct place - snap it in position if it is partly over the space	Hit area to be revisited in sprint 31/32
	Anubrick	Unclear when response is good For the second game it was unclear what sentence they were supposed to be working on					Did not read the instructions and though to put the word into order Had to pick out the nouns by thinking if they were persons/name/thing	Difficult to get out when stuck - no feedback about what's been done Though they had to tap the words in order Confusing which words to use	Make the instruction clearer - e.g. "tap the nouns"		When there are two sentences make this distinction clearer e.g. label the sentences, only have the sentence you are supposed to be interacting with on the wall, don't have lots of colours on the first sentence	VFX have made distinction clearer during build 30 - there is a dividing line and colour changes