Integrating Affective Responses and Gamification into Early Reading Acquisition Software Applications

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Abstract

Sisu is a gamified learning application designed to assist school-aged children who are struggling to read. Sisu utilizes readily-available technology to promote learning at home, with unique elements tied to the learning experience: (1) a spelling game with (2) an empathic agent, and (3) a mini-game. The empathic agent utilizes a facial action coding system (FACS) to recognize core expressions of the child user and respond to the child's affect in-game. We anticipate that Sisu's accessible and affective nature will not only support children's emotional needs, but the addition of gamified elements will motivate them to practice reading and assist them in their learning objectives.

Author Keywords

Intelligent agents; empathy; gamification; motivation; engagement; at-risk children; reading acquisition; education

ACM Classification Keywords

H.5.2 User interfaces: Graphical user interfaces; **I.2.11** Distributed artificial intelligence: Intelligent agents; **K.3.1** Computer uses in education: Computer-assisted instruction; **K.8.0** General: Games

Background

Learning disabilities inhibit the educational process for 3.2% of children in Canada [8]; many of these disabilities directly impact children's ability to read and write. Early reading interventions typically occur during school age [9], but only after children do not respond successfully to standard classroom reading interventions and before they are clinically diagnosed with a specific learning disability [20]. Several disabilities negatively affect reading and spelling, but dyslexia, a neurobiological disorder, is one of the more common diagnoses [9]. Children with dyslexia commonly lack phonological awareness, which is trouble identifying certain letter-sound associations in the context of spelling and reading [16,57]. Without proper instruction many children with reading difficulties, like dyslexia, experience symptoms of stress and depression, which affects their peer relationships during school and limits future career options as an adult [9,54]. Early reading acquisition has multiple approaches from sight reading a whole word to unpacking the word into its smallest units (i.e., phonological) [3]. While both sight-word and phonological approaches demonstrate learning gains in research studies for some readers [15,49], the phonological approach is the new standard as it provides early readers with long-term strategies for pronouncing new words, and addresses the core deficit in children with dyslexia [3,21,22]. Thus, reading instruction tools that begin at the phonemic level improve the ability to acquire sufficient reading skills throughout school [10]. However, recent findings suggest that reading difficulties may also be caused by visual stress and visual attention [5,6,30,38]. Visual stress is understood to be a visual processing disorder in the brain triggered by specific types of lighting, word crowding, and colour [52], while issues with visual attention span is understood to be an impairment to how visual information is processed, which limits the number of letters in a string that can be simultaneously held in memory [38]. The most common approach to address the variety of issues that impede reading progress in early readers is the Orton Gillingham (OG) method. OG uses multi-sensory techniques that engage different areas of the brain in learning letter-sound correspondences [12,16]; combining touch (e.g., tracing letters), sound (e.g., hearing individual phonemes), and associative visuals (e.g., pictures of objects/verbs) that provide both pronunciation strategies as well as associated meaning. Research results from studies using the OG method are inconsistent [49], potentially because of the variety of confounding variables; for instance, children may spend varying amounts of time practicing spelling or have different socio-emotional experiences with different teachers and tutors. The current design concept leverages the success of other software and tangible solutions that take phonological and visual deficits into account [24,25], and investigates the challenges of home-based early education software: motivating children to practice reading and proactively addressing the child's emotional experiences during the learning process.

Motivation and Engagement in E-Learning

Children who practice spelling for 20-minutes a day are more likely to demonstrate learning gains over the course of a few weeks [16]. Unfortunately some children who find reading effortful are not motivated to independently work on their reading skills [16], and may need tutors and teachers capable of engaging them in the learning process. One-on-one teaching, while extremely important, is not a practical solution for daily practice given teachers' workloads, parents' ability to pay for private tutors, or the family's location (e.g., rural). Moreover, software applications designed for children may require embedded incentives, such as video games, to motivate children to learn on their own at home. Children often want to play video games either for fun or to regulate emotions [44], and sometimes parents elect to use “screen time” as a bargaining tool [32]. However, not all children will be motivated by the same game and may be motivated by different interactive and design elements that can support motivation and promote learning [34]. One approach to motivate children to learn can occur using gamification strategies and unique elements that promote engagement in the learning activity [39]. Gamers typically fall under one of the four gamer archetypes: Achievers, Explorers, Socializers, and Killers [2]. Gamification strategies for the Achiever archetype comprise personal achievement measures, collections, badges, level indicators, and points [60]; Explorers are motivated by curiosity and extended worlds; Socializers enjoy communication channels, hints, easy-to-reach achievements, and amusing responses to their actions, and Killers tend to enjoy extensive leveling system, difficult achievements, and large puzzles that take a long time to complete [2]. While these archetypes were not designed for young children and it’s unclear whether or not children will fall into the same persona categories as adults. Furthermore, Dichev and Dicheva’s 2017 study indicates there is little empirical evidence published correlating specific gamified techniques with learning outcomes for elementary-aged children [19] and the gamification strategies used for this age group most often emphasized the Socializer archetype, which is often reliant on the presence of a teacher to organize and direct the learning activity [7,50,56]. Additionally, while gamified elements within learning applications is a growing trend, e-learning applications for children that integrate gamification strategies (e.g, points) within the learning application that directly translate into rewards within a video game has not been found. The integration of games and gamification may inspire children to return to the learning application and extend the duration of time spent practicing to spell and read outside of the classroom.

Emotion-Based Learning with Empathic Agents

Developing a positive relationship between children and digital agents is possible, as humans respond to computers (media) using the same social protocols enacted with other human beings [47]. Until recently the burden of interpretation was placed on the human: machines had capabilities for expression (e.g., Microsoft’s Clippy), and humans were responsible for decoding what the machine needed them to do; human emotional expressions were excluded from the communication context. New efforts are paving the way for a more symbiotic relationship between humans and computers using emotion detection, which uses a camera to detect changes in facial muscle movement. Ekman’s Facial Action Coding System (FACS) recognizes six universal facial expressions: happiness, surprise, fear, sadness, anger and disgust by identifying a muscle contraction (or release) and assigning it a numeric Action Unit (AU) [23]. Combinations of Action Units create a facial expression, which can be interpreted into an emotion. For example, when a person has a genuine smile, the corners of the mouth turns upward, and the cheek muscles raise creating wrinkles around the eyes, which FACS codes as AU6+12. Programs such as Affectiva[1] Affdex facial

[1] https://www.affectiva.com/

expression recognition software uses an ordinary digital camera, such as those embedded in laptops, to detect facial muscle movements, which are converted into Action Unit(s) from Ekman's FACS and refer to a specific emotional state. When combined with nonverbal and verbal programmed responses to the learner's emotional state, may result in a robust and useful tool in effortful learning scenarios, as the system can dynamically respond to the child's emotional state by addressing the emotion itself, or altering the content by decreasing or increasing its challenge level. The potential downside of facial emotion recognition engines is that, while they have been increasing in accuracy over the years (currently reporting 90% accuracy[2] in lab settings), emotion detection "in the wild" remains problematic [18,35]. However, computers may not be required to demonstrate 100% accuracy in their identification of emotional response as humans experience difficulty in accurately identifying emotions themselves [58]. Further, the literature on effective teaching methods suggest limiting the range of emotional responses, which if adapted by the system reduces the possibility for the digital agent to make a grievous error [45]. Emotion recognition and expression play an important role in contextualizing the opaque nature of human communication [45]; in e-learning software this contextualization may smooth human-computer interactions. In typical learning environments, emotionally intelligent human teachers learn to recognize children's facial expressions and use environmental cues to interpret their emotional state (e.g., boredom, frustration, etc.) [33] and limit their own range of expressed emotions during feedback steps to preserve each child's individual identity as an intelligent person, which orients the child towards mastering the learning task [27,28,36]. Empathic digital agents can mimic human teacher's behaviors and preserve students' self-image as competent and capable learners by using contextualized cues during the learning process as well as removing any displays of detectable negative emotions, like disgust or anger [45]. Digital agents that work to keep children's identity intact and maintain a positive mood during learning may facilitate creative ways of solving learning-based problems and provide positive self-talk [4,51].

Related Work

GAMIFICATION: No known research studies combine the effects of gamification principles and empathic agents in learning applications. While gamification design principles have received some attention, there is very little guidance on reconciling design principles to the desired learning outcomes, and very little research exists in the realm of elementary-aged children's learning applications in early reading acquisition.

EMPATHIC AGENTS: There is no known comprehensive literature review to base the design of empathic agents, but studies are beginning to demonstrate the potential use for the inclusion of empathic agents and social robots for use with children. Empathic agents are based on the evidence that computers are social actors [47] as well as the growing knowledge about the role of emotions during the learning process [28]. However, studies that implemented empathic agents and social robots often do not demonstrate significant differences between groups [11,37,46]; and only one research team who collected biometric readings demonstrated a significant reduction in stress in the empathic condition

[2] http://discuss.affectiva.com/t/determining-accuracy/48

[46]. The case for inclusion of emotion recognition is based on recent work that correlated learning gains with the expressiveness of a social robot [59] as well as increased engagement and enjoyment with an embodied social robot [29]. The inconsistency of results in previous studies may be due to the variety in approaches and measures used in studies and the absence of more advanced technologies and algorithms (e.g., AI) used to contextualize emotional responses and expressions from social robots and digital agents. The incremental benefits found in the affective computing domain gives emotion-based applications a potential place in service of early education.

FACIAL EXPRESSION RECOGNITION IN CHILDREN: The decision to incorporate facial expression recognition software was due to its non-invasiveness. Unlike other forms of automated sensing, such as physiological (bio)sensors, facial recognition software only requires standard computer equipment rather than wearables, making it relatively simple to deploy at scale. Facial expressions can be detected in children as young as 2 years of age [59] and the expressivity of children tends to increase when they are in a home environment [53]. When exploring previous studies on facial expression recognition for children, one industry concept using the Affectiva Affdex called 'Little Dragon' integrates emotion-based learning and a reading application, but no known publications have determined whether or not it's effective for early readers. Additionally, in a study with children comparing an affect-aware system to a non-affect aware system, participants' experienced significantly more enjoyment and excitement in the affect-aware system based on the facial expressions data that was directly input to the game logic [42], giving it potential as a new communication method between humans and computers. The core challenge in the creation of affect-aware educational software is to ensure that the experiential measures (e.g., engagement and enjoyment) and correlated with learning gains.

Design Concept

1- The Spelling Game

The spelling game is the educational aspect of the application and is designed to help children in elementary school learn to read and spell (Fig-1). It adapts the basic structure of a GUI in an existing tangible spelling application that implemented features like audio repetition, hint functions, phonological breakdown of words, and dynamic colour cues that call attention to immediate changes to the sound of the letter and letter combinations and have been validated in two studies [1,14,24,25]. The letter box area includes extra-large letter spacing and a cream background[3]; a design decision that directly supports children with dyslexia [41,61]. A Helvetica font was selected for the main letters based on a recent fixation and readability study [48].

GAMIFICATION

The gamification elements within the spelling game stem from recent gaming studies optimized for visual selective attention, dyslexia, and motivation [17,26,31] and include a gamified "correct-word counter", a "bonus counter", and a count-down timer (Fig-1). The "correct-word counter" tracks the number of correctly spelled words in each session and stores the points for later use as food "treats" for sea creatures in the mini-game.

[3] https://www.w3.org/WAI/RD/2012/text-customization/r11

Figure 2 - Emotional expressions from empathic agent @Amelia W. Cole

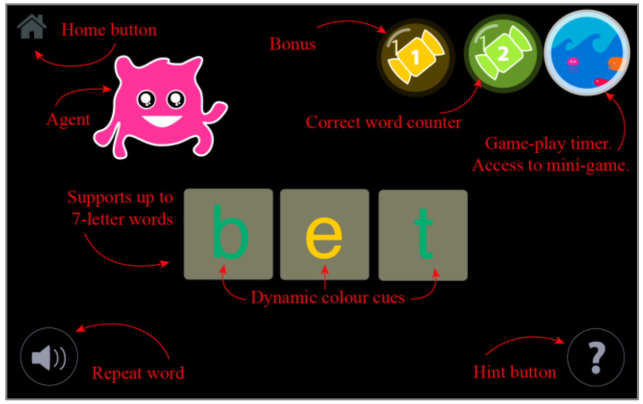

Figure 1 - Spelling game annotated with overlaid explanation. The learning objective is for children to identify phonemic sounds and associated rules to spell words correctly.

A gold treat counter acts a bonus mechanism and stores the number of times a child has correctly spelled five words in a row, upon which a “medicine" will be created, and can be used to restore the health of sea creatures in the mini-game (see Fig-3). The count-down timer resets daily to twenty-minutes and was selected because of the correlation between time and learning (i.e., brain plasticity) [16]. Once twenty-minutes of spelling play is complete, a random number of green “treats” and gold “medicine” are added to the reward counters, and the mini-game becomes accessible for play. Emphasizing time spent in the spelling game over accuracy increases the possibility that children will feel more encouraged to practice, and worry less about spelling each word correctly to gain access to the rewarding mini-game. The words in the spelling queue are categorized by English language phonological spelling rules (e.g., consonant-vowel-consonant) and the default words within each rule are based on Milne’s recommended list of beginner words for children with dyslexia, emphasizing high frequency or common words [40].

2- Empathic Agent

Most importantly, this spelling game implements an empathic digital agent that uses contextualized affective responses to help children cope with the frustration of learning a new skill [33,36]. We used an abstract representation of the empathic agent as people require very few cues to respond socially to media [47] and its flexible shape allows for exaggerated expressions of emotion in both the face and body. The system uses the Affectiva Affdex to interpret the emotional state through a child’s facial expression and uses pre-programmed, context-based verbal and nonverbal behaviours in response to their expressions. In all four contextual scenarios described below, the system will recognize happiness, surprise, fear, sadness, anger and disgust per Ekman’s range of potential facial expressions [23]. The emotions displayed by the digital agent are based on the descriptions provided by Ekman and are limited to neutral, happy, fearful, and sad (Fig-2). Anger and disgust have been excluded from the digital agent’s range of emotion as they are typically viewed as negative expressions in the teaching environment.

CONTEXT-BASED SCENARIOS

Repeated mistakes

If the child is making repeated mistakes and gets three incorrect answers in a row, then the agent provides appropriate nonverbal signals (such as emotional expressions) and supportive verbal responses in a female child’s voice based on the affective state of the child. If a neutral or happy child who has made several errors in a row and continues to practice their spelling may feel supported if they receive short encouraging verbal messages from the empathic agent, like "*I know you can do it. Try again!"*. If the child expresses sadness, then the agent interprets this to mean the child is experiencing difficulty, and offers support by saying, "*This one is really hard. Let's figure it out together.*" Disgust from a child, while rare, will signal the software to automatically change to a new word, and the empathic agent will say, "*Let's try a different word!"* Anger expressed from a child making repeated mistakes will result in the empathic agent showing encouragement to take a break and come back later, *"Sometimes learning new things is hard. We can take a break and try again later."*

Struggling while spelling a word

If a child is struggling to spell a word and is spending more than a minute in-between letter placements and the affective state of the child moves away from neutral or happy, then the empathic agent displays appropriate non-verbal signals. For example, if the system detects fear, the agent will use eye gaze to direct the child to an incorrect letter. Sadness or disgust in the child will trigger a non-verbal response from the agent of tilting its head. Finally, anger elicits a 2-second fear response from the agent and it runs off screen with intermittent peeking out from the edges to pretend to check if the child has returned to a non-angry state.

Distraction and inattention to the spelling game

After five minutes of non-use, the system will stop the timer and the agent will progressively inquire if the child will return to gameplay. After 21 minutes, the game moves to an inactive state.

Highly attentive

A child's continued neutral or joyful state will be met with the agent taking a neutral or relaxed position, with small animations, such as eye blinking, to maintain a sense of presence and support. While one study has suggested that animation is distracting [11], it is hypothesized that children with dyslexia are significantly less sensitive to motion [13] and may not be distracted by the subtle animations of the agent in the background, thereby reducing disruptions to perceived flow.

3- The Mini-Game

The purpose of the mini-game is to provide additional motivation to learn to spell. Simple embedded gamification techniques inside the spelling game transfer into elements for use within the mini-game. As described in the Spelling Game above, the green earned points from correctly spelled words translate into available food "treats" for sea creatures. The gold "medicine" obtained from correctly spelling 5 words consecutively help cure sick sea creatures. A timer based on the accumulated time spent playing the spelling game will unlock new sea creatures at increasingly longer time intervals (20 minutes, 50 minutes, 110 minutes). The sea creatures themselves become badges, as each one represents the accumulated length of time a child has played the game. The ocean theme was selected to inspire curiosity and balance novelty with familiarity; elements often associated in engagement research [43]. The game is designed to elicit caring behaviour through the "feeding" and "curing" actions, which is reminiscent of games like Tamagotchi[4] and Fantasy Forest[5]. Each sea

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[4] http://us.tamagotchifriends.com/

creature has a defined set of behaviours, e.g., differences in speed and movement, that helps the creatures reach the treats or medicine, and encourages children to think strategically about treat or medicine placement on the screen.

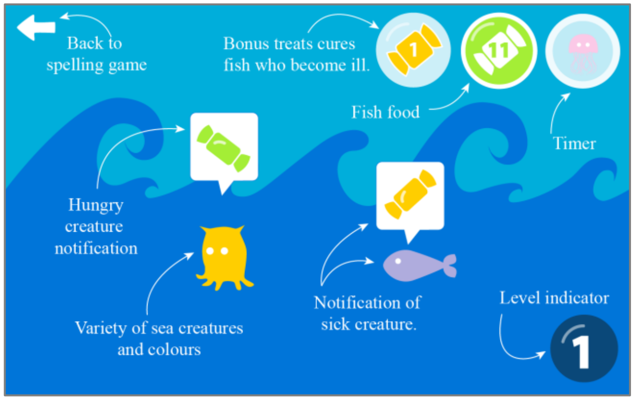

Figure 3 - Mini-Game screen annotated with overlaid explanation @Amelia W. Cole

Future research plan

Research Question

Does a home-based spelling application with affective and gamified elements (RQ1) improve spelling accuracy, (RQ2) increase the duration of time spent in the spelling game, (RQ3) increase number of sessions of game play per week, and (RQ4) increase levels of enjoyment of children aged 7-8 who are struggling to read?

Methods

As emotion-based integrated learning is a relatively unexplored area, we will use a mixed methodological approach to determine if Sisu's gamification and affective elements support learning gains. A comparative quasi-experimental independent measures study will be conducted with an Orton-Gillingham (OG) trained home tutor, who will install the game on child participants' home computers and meet once a week for regularly scheduled thirty-minute sessions in addition to homework assigned using the Sisu application. This will ensure each child receives the same amount of instruction and no child is placed at risk of falling behind if the system does not work. 12-15 children aged 7-8 will be recruited from the OG tutor's network of existing clients. Each child will be randomly allocated to one of three conditions: (1) spelling app with the mini-game, (2) a spelling app with the empathic agent, and (3) the spelling app with both the mini-game and empathic agent. Each week the tutor will teach each child two new spelling rules and six new words. At home, the child will continue to have access to the previously trained (learned) words and 12 additional untrained (new) words, and no restrictions will be set on the child regarding number of words or game play time. Parents or guardians will be asked to remind children to practice their spelling homework, but not to pressure or force learning sessions. Children will be asked to take a written spelling test at the beginning of the study with new words, at the end of the study with both learned and new words, as well as four weeks after the end of the study to make sure they have learned and retained the spelling rules. Data collection and analysis will quantitatively compare the spelling accuracy, duration of time spent in the spelling game, and document the categories of emotional responses.

[5] http://www.storm8.com/game/fantasy-forest-2/

Instances of facial expressions will be numerically logged, and the valence and arousal data from the Affectiva Affdex will be mapped against the time variable to understand emotional changes during the learning process. Parents will be asked to report how often and how they encouraged their children to practice (if at all) to account for variances in parenting styles. This process ensures the use of Evidence-Based Design (EBD), a method of utilizing multiple forms of evidence such as study data, prior literature, and expert opinions to inform the design process [55].

Discussion

Our mission is to create a low-cost solution that can be broadly distributed to a large group of English-language learners in elementary school who are struggling to read. We do not intend to replace tutors, rather to reduce the time children need to spend with tutors and increase the likelihood that they will continue to practice to spell at home. We chose a laptop with a keyboard as a primary hardware because it doesn't require any unique equipment; this reduces the expense for parents who may already be burdened with paying outside tutors. Affectiva Affdex was selected because it's non-invasive and only requires an integrated or external web camera. As Affectiva's emotion recognition system becomes more sophisticated, our application can adapt as it uses Affectiva's API as well as a common development platform, Unity3D. The empathic agent is fairly basic at the outset of this learning game and has limited dialogic capabilities, but future iterations of this system would grow the agent's vocabulary and research ways to enhance the natural interactions experienced between the child and its digital agent. The animations for the digital agent is another opportunity for improvement, as more sophisticated expressions and subtle cues like gaze direction may be helpful in supporting the child as they learn to read. Limitations also exist in the spelling rules and word opportunities. At the moment only the simple consonant-vowel-consonant rule (e.g., bet) is active, and many additional rules need to be added for the learning program to be effective. Additionally, some words (e.g., though) in the English language still require memorization as the sounds in the letters don't adhere to the 44-phonetic sound rules in the English language, which will not be addressed in this spelling program. Finally, recent studies have investigated the effects of video game play on the attentional abilities and spelling accuracy of children with dyslexia and found that 12-hours of action video game play improved children's spelling. If the mini-game does not motivate children to practice daily, changing the type of game to an action-video game may demonstrate more motivational results.

Conclusion

The purpose for developing Sisu is to increase the accessibility of learning applications and provide struggling readers with the emotional and motivational support they need to overcome the hurdle of learning to spell and read. We aim to discover design and implementation guidelines for affective computing and gamified elements in early childhood learning, as the open question is not whether or not empathic agents and gamification will be useful, but rather how to implement these elements effectively to make applications engaging, reduce negative emotions *and* enhance learning outcomes. We hypothesize that combining affective and gamified elements may increase the duration of time spent learning (e.g., engagement) and improve spelling accuracy, which may result in fewer hours required with tutors, and expand the reach of specialized educational programs to more rural areas. Furthermore, if these elements are beneficial in early learning applications, essential design and implementation guidelines will be produced and may extend to other early educational programs.

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Works Cited

1. Alissa N. Antle, Min Fan, and Emily S. Cramer. 2015. PhonoBlocks: A Tangible System for Supporting Dyslexic Children Learning to Read. ACM Press, 533–538.
2. Richard Bartle. 1996. Hearts, clubs, diamonds, spades: Players who suit MUDs. *Journal of MUD research* 1, 1: 19.
3. Virginia W. Berninger. 1996. *Reading And Writing Acquisition: A Developmental Neuropsychological Perspective*. Westview Press, Boulder (Colo.).
4. Herbert Bless, Gerald L. Clore, Norbert Schwarz, Verena Golisano, Christina Rabe, and Marcus Wölk. 1996. Mood and the use of scripts: Does a happy mood really lead to mindlessness? *Journal of personality and social psychology* 71, 4: 665.
5. Marie-Line Bosse, Marie Josèphe Tainturier, and Sylviane Valdois. 2007. Developmental dyslexia: The visual attention span deficit hypothesis. *Cognition* 104, 2: 198–230.
6. Marie-Line Bosse and Sylviane Valdois. 2009. Influence of the visual attention span on child reading performance: a cross-sectional study. *Journal of Research in Reading* 32, 2: 230–253.
7. Ivica Boticki, Jelena Baksa, Peter Seow, and Chee-Kit Looi. 2015. Usage of a mobile social learning platform with virtual badges in a primary school. *Computers & Education* 86: 120–136.
8. Shannon Brennan. 2009. *Participation and Activity Limitation Survey 2006: facts on learning limitations*. Statistics Canada, Ottawa.
9. Canadian Dyslexia Association. n.d. Voices of Dyslexia: Tragedies & Triumphs. Retrieved from http://www.dyslexiaassociation.ca/english/files/voices.pdf.
10. Karyn L. Carson, Gail T. Gillon, and Therese M. Boustead. 2013. Classroom Phonological Awareness Instruction and Literacy Outcomes in the First Year of School. *Language Speech and Hearing Services in Schools* 44, 2: 147.
11. Gwo-Dong Chen, Jih-Hsien Lee, Chin-Yeh Wang, Po-Yao Chao, Liang-Yi Li, and Tzung-Yi Lee. 2012. An empathic avatar in a computer-aided learning program to encourage and persuade learners. *Journal of Educational Technology & Society* 15, 2: 62.
12. James M. Clark and Allan Paivio. 1991. Dual Coding Theory and Education. *Educational Psychology Review* 3, 3: 149–210.
13. Piers Cornelissen, Alex Richardson, Alexandra Mason, Sue Fowler, and John Stein. 1995. Contrast sensitivity and coherent motion detection measured at photopic luminance levels in dyslexics and controls. *Vision Research* 35, 10: 1483–1494.
14. Emily Sarah Cramer. 2015. A Code of Many Colours: Rationale, Validation and Requirements for a Sound-Based Letter Colour-Code that Might Support Some Children with Dyslexia in Spelling Certain Words.

Master's Thesis. Simon Fraser University, Vancouver, Canada.

15. Ronald D. Davis and Eldon M. Braun. 2010. *The Gift of Dyslexia: Why Some of the Smartest People Can't Read and How They Can Learn*. Penguin Books, New York, NY.

16. Stanislas Dehaene. 2010. *Reading in the Brain: The New Science of How We Read*. Penguin Books, New York, NY, USA.

17. Sebastian Deterding. 2012. Gamification: Designing for Motivation. *interactions* 19, 4: 14–17.

18. Abhinav Dhall, Roland Goecke, Jyoti Joshi, Karan Sikka, and Tom Gedeon. 2014. Emotion Recognition In The Wild Challenge 2014: Baseline, Data and Protocol. *Proceedings of the 16th International Conference on Multimodal Interaction*, ACM, 461–466.

19. Christo Dichev and Darina Dicheva. 2017. Gamifying education: what is known, what is believed and what remains uncertain: a critical review. *International Journal of Educational Technology in Higher Education* 14, 1: 9.

20. Katherine A. Dougherty Stahl. 2016. Response to Intervention. *The Reading Teacher* 69, 6: 659–663.

21. Linnea C. Ehri. 1987. Learning to read and spell words. *Journal of Literacy Research* 19, 1: 5–31.

22. Linnea C. Ehri. 2014. Orthographic Mapping in the Acquisition of Sight Word Reading, Spelling Memory, and Vocabulary Learning. *Scientific Studies of Reading* 18, 1: 5–21.

23. Paul Ekman and Erika L. Rosenberg, eds. 2005. *What the Face Reveals: Basic and Applied Studies of Spontaneous Expression Using the Facial Action Coding System*. Oxford University Press, Oxford ; New York.

24. Min Fan. 2017. Exploring the Design of a Tangible System Supported for Learning to Read in Children At-risk for Reading Difficulties. Ph.D. Dissertation. Simon Fraser University, Vancouver, Canada.

25. Min Fan, Alissa N. Antle, Maureen Hoskyn, Carman Neustaedter, and Emily S. Cramer. 2017. Why Tangibility Matters: A Design Case Study of At-Risk Children Learning to Read and Spell. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, ACM, 1805–1816.

26. Sandro Franceschini, Simone Gori, Milena Ruffino, Simona Viola, Massimo Molteni, and Andrea Facoetti. 2013. Action Video Games Make Dyslexic Children Read Better. *Current Biology* 23, 6: 462–466.

27. Tove Gerholm. 2011. Children's development of facework practices—An emotional endeavor. *Journal of Pragmatics* 43, 13: 3099–3110.

28. Erving Goffman. 1995. On Face-Work: An Analysis of Ritual Elements in Social Interaction. In B.G. Blount, ed., *Language, Culture, and Society: A Book of Readings*. Waveland Press, Long Grove, Illinois, 222–247.

29. Goren Gordon, Samuel Spaulding, Jacqueline Kory Westlund, et al. 2016. Affective Personalization of a Social Robot Tutor for Children's Second Language Skills. *Proceedings of the Thirtieth AAAI Conference on Artificial Intelligence*, AAAI Press, 3951–3957.

30. Usha Goswami. 2015. Visual attention span deficits and assessing causality in developmental dyslexia. *Nature Reviews Neuroscience* 16, 225–225.

31. C. Shawn Green and Daphne Bavelier. 2003. Action video game modifies visual selective attention. *Nature* 423, 6939: 534–537.

32. Alexis Hiniker, Hyewon Suh, Sabina Cao, and Julie A. Kientz. 2016. Screen Time Tantrums: How Families Manage Screen Media Experiences for Toddlers and Preschoolers. *Proceedings of the 2016 CHI*

Conference on Human Factors in Computing Systems, ACM, 648–660.

33. Ashish Kapoor and Rosalind W. Picard. 2005. Multimodal Affect Recognition in Learning Environments. *Proceedings of the 13th Annual ACM International Conference on Multimedia*, ACM, 677–682.

34. Karl M. Kapp. 2012. *Wiley: The Gamification of Learning and Instruction: Game-based Methods and Strategies for Training and Education*. Pfieffer: An Imprint of John Wiley & Sons, New York, NY.

35. Heysem Kaya, Furkan Gürpinar, Sadaf Afshar, and Albert Ali Salah. 2015. Contrasting and Combining Least Squares Based Learners for Emotion Recognition in the Wild. *Proceedings of the 2015 ACM on International Conference on Multimodal Interaction*, ACM, 459–466.

36. Jeff Kerssen-Griep, Jon A. Hess, and April R. Trees. 2003. Sustaining the desire to learn: Dimensions of perceived instructional facework related to student involvement and motivation to learn. *Western Journal of Communication* 67, 4: 357–381.

37. Jacqueline M. Kory Westlund, Marayna Martinez, Maryam Archie, Madhurima Das, and Cynthia Breazeal. 2016. A Study to Measure the Effect of Framing a Robot as a Social Agent or as a Machine on Children's Social Behavior. *The Eleventh ACM/IEEE International Conference on Human Robot Interaction*, IEEE Press, 459–460.

38. Muriel Lobier, Rachel Zoubrinetzky, and Sylviane Valdois. 2012. The visual attention span deficit in dyslexia is visual and not verbal. *Cortex* 48, 6: 768–773.

39. Marianne Martens. 2015. Reading and "Gamification": Joining Guilds, Earning Badges, and Leveling Up. *Children and Libraries* 12, 4: 19–25.

40. Duncan Milne. 2005. *Teaching the brain to read*. SK Publishing, Artarmon, N.S.W.; Auckland, N.Z.

41. Elisabeth Moores, Rizan Cassim, and Joel B. Talcott. 2011. Adults with dyslexia exhibit large effects of crowding, increased dependence on cues, and detrimental effects of distractors in visual search tasks. *Neuropsychologia* 49, 14: 3881–3890.

42. Mohammad Obaid, Charles Han, and Mark Billinghurst. 2008. "Feed the Fish": An Affect-aware Game. *Proceedings of the 5th Australasian Conference on Interactive Entertainment*, ACM, 6:1–6:6.

43. Heather O'Brien and Paul Cairns, eds. 2016. *Why Engagement Matters: Cross-Disciplinary Perspectives of User Engagement in Digital Media*. Springer.

44. Cheryl K. Olson. 2010. Children's motivations for video game play in the context of normal development. *Review of General Psychology* 14, 2: 180–187.

45. R.W. Picard. 1997. *Affective Computing*. MIT Press, Cambridge, Massachusetts.

46. Helmut Prendinger and Mitsuru Ishizuka. 2005. The Empathic Companion: A Character-Based Interface That Addresses Users' Affective States. *Applied Artificial Intelligence* 19, 3–4: 267–285.

47. Byron Reeves and Clifford Nass. 1996. *The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places*. CSLI Publications.

48. Luz Rello and Ricardo Baeza-Yates. 2013. Good fonts for dyslexia. *ASSETS'13*, ACM.

49. Kristen D. Ritchey and Jennifer L. Goeke. 2006. Orton-Gillingham and Orton-Gillingham–Based Reading Instruction: A Review of the Literature. *The Journal of Special Education* 40, 3: 171–183.

50. Jorges Simoes, Rebeca P. Díaz Redondo, and Ana Fernández Vilas. 2015. An Experiment to Assess Students' Engagement in a Gamified Social Learning Environment. *eLearning Papers*.

51. Elly Singer. 2008. Coping with academic failure, a study of Dutch children with dyslexia. *Dyslexia* 14, 4: 314–333.

52. Liane Smith and Arnold Wilkins. 2007. How many colours are necessary to increase the reading speed of children with visual stress? A comparison of two systems. *Journal of Research in Reading* 30, 3: 332–343.

53. Samuel Spaulding, Goren Gordon, and Cynthia Breazeal. 2016. Affect-Aware Student Models for Robot Tutors. *Proceedings of the 2016 International Conference on Autonomous Agents & Multiagent Systems*, International Foundation for Autonomous Agents and Multiagent Systems, 864–872.

54. Statistics Canada. 2012. Learning disabilities among Canadians aged 15 years and older. *Statistics Canada*. Retrieved from Available: http://www.statcan.gc.ca/pub/89-654-x/89-654-x2014003-eng.htm.

55. Jaynelle F. Stichler. 2016. Research, Research-Informed Design, Evidence-Based Design: What Is the Difference and Does It Matter? *HERD: Health Environments Research & Design Journal* 10, 1: 7–12.

56. C-H. Su and C-H. Cheng. 2015. A mobile gamification learning system for improving the learning motivation and achievements. *Journal of Computer Assisted Learning* 31, 3: 268–286.

57. P. F. Vadasy, J. R. Jenkins, and K. Pool. 2000. Effects of Tutoring in Phonological and Early Reading Skills on Students at Risk for Reading Disabilities. *Journal of Learning Disabilities* 33, 6: 579–590.

58. Laura Jean Wells, Steven Mark Gillespie, and Pia Rotshtein. 2016. Identification of Emotional Facial Expressions: Effects of Expression, Intensity, and Sex on Eye Gaze. *PLoS ONE* 11, 12.

59. Kory Westlund, Jacqueline M, Sooyeon Jeong, et al. 2017. Flat vs. Expressive Storytelling: Young Children's Learning and Retention of a Social Robot's Narrative. *Frontiers in Human Neuroscience* 11.

60. Dmitri Williams, Nick Yee, and Scott E. Caplan. 2008. Who plays, how much, and why? Debunking the stereotypical gamer profile. *Journal of Computer-Mediated Communication* 13, 4: 993–1018.

61. Marco Zorzi, Chiara Barbiero, Andrea Facoetti, et al. 2012. Extra-large letter spacing improves reading in dyslexia. *Proceedings of the National Academy of Sciences* 109, 28: 11455–11459.