An Interactive Game-based Learning Framework with a Social Robot to Promote Well-being of Dyslexic Children

Shyamli Suneesh[1]*, Devasena Pasupuleti[2] and Virginia Ruiz Garate[3]*

Abstract— **This paper presents the preliminary design and development of a generalized Child-Robot-Interaction framework involving interactive game-play between the socially assistive robot NAO and children with varying types of dyslexia. Our framework aims to enhance the learning and overall development of dyslexic children by integrating four vital modalities - auditory, visual and bodily kinaesthetic, reading and writing styles together into a set of four interactive games. These games, namely - Picture Memory (P), Sound and Read (S), Spelling (S) and Spatial (S) abbreviated as PSSS focus on aiding dyslexic children with their language skill sets such as reading, speaking, writing and listening, with the future goal being improving their mental well-being. Each of the games starts with the robot providing a set of instructions regarding the game to the child followed by the child playing the game with the robot. The PSSS games have been designed by taking prior literature and scientific data on child psychology, special education pedagogical methods, and linguistic studies into consideration. This research provides detailed experimental demonstrations of the design and working of the proposed framework. In the future, we intend to integrate the framework into real-time Human-Robot-Interaction studies to help children with special needs improve their mental health, confidence and ability to learn better.**

I. INTRODUCTION

The younger population, especially children, with learning difficulties, are more likely to experience feelings of anxiety, depression, low confidence and low self-esteem [1]. According to statistical data provided by the World Health Organization (WHO), 10% of the world's population, especially children, have learning disabilities among which a majority of the population is situated in Europe (18%) and the US (14%) [2]. Over the years different terms such as "intellectual disabilities" and "learning disabilities" have been used interchangeably to define learning difficulties in various countries. In this article, the authors refer to learning difficulties as "learning disabilities". Among the various kinds of learning disabilities that exist, such as dyslexia, dyscalculia, dysgraphia, Attention Deficit Disorder (ADHD), etc, the authors have chosen to concentrate on "dyslexia" as statistics show that 1 in every 10 children in the world suffers from dyslexia, making it vital to address the growing problem [3].

[1]Shyamli Suneesh is with The University of Bristol, Bristol, UK shyamli.suneesh@gmail.com

[2]Devasena Pasupuleti is with Amrita Vishwa Vidyapeetham, Amritapuri, India pdevasena835@gmail.com

[3]Virginia Ruiz Garate is with Mondragon Unibertsitatea, Bilbao, Spain vruizg@mondragon.edu

*Shyamli Suneesh and Virginia Ruiz Garate are also associated with The University of the West of England, Bristol, UK

The term "dyslexia" is defined as a learning disability caused due to limitations in the development of the brain and is often characterised by difficulties in reading, writing, word formation and visual notations, which can lead to low self-confidence, depression and anxiety in individuals [4]. The degree of dyslexia varies from person to person. Some may find it difficult to associate certain sounds with certain letters, some may find it hard to differentiate between different directions (left and right) whereas some may experience a combination of two or more such types of dyslexia [2]. While an ordinary individual tends to use his/her left brain more actively, dyslexic individuals tend to make use of their right brain more [5]. Since the active usage of the right side of the brain has been associated with creative and out-of-the-box thinking, devising pedagogical methodologies involving vivid colours and gameplay would help dyslexic children enhance their learning abilities with enjoyable outcomes.

In this article, we present an in-depth look into the working of four different interactive games that can be played by children aged 5 to 10 years, and which have been designed to address four modalities - auditory, visual and bodily kinaesthetic, reading and writing. The design of the games is based on prior research and scientific data on child psychology, special education pedagogical methods, and linguistic studies. In future work, we will conduct a user study with dyslexic children to evaluate and improve upon the proposed framework and study the correlation between our framework and the mental well-being of dyslexic children.

II. Background and Related Work

Children with dyslexia have decreased socio-emotional experiences such as declined mental health, anxiety and aggression when compared to normal children [1]. Improving upon their school-connectedness, through proper pedagogical methods can help dyslexic children form better friendships and improve their mental well-being [6].

A. *Pedagogical Lesson Planning for Dyslexic Children*

Designing activities around phonological processing (usage of sounds to process spoken and written forms of language), working memory (amount of information that can be retained in memory whilst performing an activity) and processing speed (the pace at which a child can absorb the information, understand it and respond) are key points in pedagogical lesson planning for special needs education [7]. According to Cambridge English, providing multi-sensory approach activities allows children to explore their different senses, which in turn helps them realise what would be the ideal learning technique for them [8], [9]. Such activities are not limited to but include games that involve a combination of touch, gestures, reading and speaking. Studies that experimented with socially engaging games with both ordinary and autistic children noticed a good and steady improvement in the cognitive, learning and social abilities of the children [10], [11]. Games that provide the opportunity to recap and recall also help in converting short-term memory into long-term memory in the brain [12], [13]. Prior research demonstrates that verbal-visual association exercises, in which a child hears a sound and sees a word in front of them to pair the two, much like learning a new word and connecting it to a visual aid like a picture, have also been successful [14], [15], [16].

Educational psychologist Walter Burke Barbe and his colleagues proposed that there are three "modalities" of learning, namely - Visual, Auditory, and Kinaesthetic, with every individual having their strengths, weaknesses and preferences in each of them. He further states that the most effective learning takes place when all three modalities are used in combination [17]. The VARK model of learning styles, designed by Neil Fleming in 1987, displays four basic styles of learning - Auditory, Visual, Kinaesthetic, and Reading/Writing. This model is a well-known educational and psychological concept that specifies how individuals exhibit retention of material and the best of their learning potential [18]. By understanding the theory of learning styles, researchers can develop innovative teaching styles to help teachers and educators cater to the diverse requirements of special needs students, thus creating an inclusive learning environment for all [18], [19]. Hence, by integrating all the above said four modalities into a funnel, as mentioned in Fig.1, we can develop the correct approach to building game-based frameworks for children with special needs.

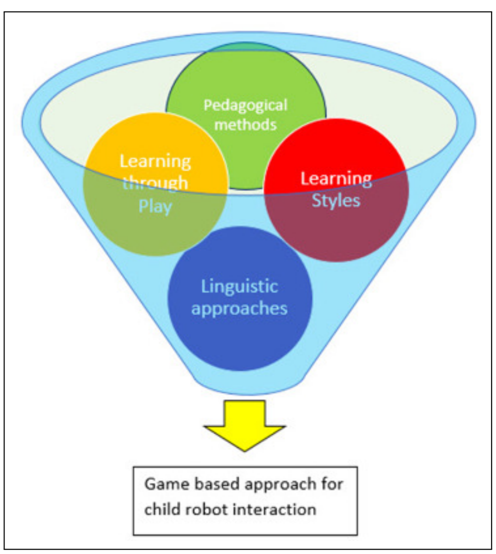

Fig. 1. The funnel showing the different ingredients required for a CRI framework game

B. The Role of Socially Assistive Robots in Special Needs Education

Socially Assistive Robotics (SAR) is a field of robotics that utilizes social robots to assist individuals by interacting with them through social cues such as conversation, eye contact, etc. Prior literature demonstrates that socially assistive robots have been used in various applications such as health-care, education, services, and entertainment [7]. Among these applications, socially assistive robots for healthcare and well-being (SARs) have proved to have a significantly positive impact in assisting people with neurodevelopmental disorders and learning disabilities [20], [21], [22]. Social robots such as PARO, NAO, KASPAR and KEEPON [23], [24], [25], [26] have been used in research as assistants to therapists and caretakers, where activities are charted by the therapist or caretaker for the robot to perform in collaboration with the child [27], [28], [29]. Socially assistive robots with anthropomorphic child-like features are generally used to develop social interactions with children of age groups 5 to 15 years old [21]. These robots have also taken the role of a companion to children where working in teams with each other to solve certain games and puzzles resulted in children experiencing a sense of belonging which in turn led to an improvement in their social skills [30], [31], [32], [33].

In this way, socially assistive robots have proven to play a vital role in aiding children with learning disabilities, along with providing the added advantage of not experiencing fatigue and being able to provide timely and consistent repetitions, which are all advantageous for facilitating long-term interactions and learning with children [34].

C. Use of Socially Assistive Robots in improving the Mental Well-being of Children with Special Needs

Children with neurodevelopmental disorders such as dyslexia, autism and ADHD struggle to form strong social bonds with their peers. This in turn leads to decreased confidence, low self-esteem and depression, ultimately leading to reduced quality of life in the future [35]. Socially assistive robots have proven to help children with special needs maintain positive social lives by helping them positively perceive themselves, enhancing their social connectedness with peers, ultimately leading to improved confidence [35]. In one such study, called the DREAM project, the robots NAO and Probo were used to study clinically relevant interactive capacities for social robots that could operate autonomously to assess ASD children's behaviour. The authors found that these robots helped stimulate daily interactions between children with ASD, thus reducing their stress levels and encouraging them to participate in therapeutic activities arranged by their care-takers [36], [37]

Prior research mainly focuses on SARs that help elevate the mental well-being of autistic children. Studies involving SARs and dyslexic children mostly focused on addressing the domains - communication and interaction, joint attention, learning by imitation, and skills' performance [37]. To the best of our knowledge, detailed and long-term studies on the use of SARs to improve various categories of mental well-being of children with special needs, especially dyslexia, are yet to be conducted. Therefore the authors hypothesize that there will be a positive correlation between learning through play and the mental well-being of children (namely - confidence, self-esteem and social connectedness) by using the proposed framework.

III. Methodology

The proposed Child-Robot-Interaction framework is an integration of different exercises based on comprehensive reading, visual-spatial understanding and didactic games. In the following sections, the authors explain the design of a game-play framework involving a socially assistive robot, that effectively combines the above-mentioned pedagogical methods to provide enhanced learning experiences for dyslexic children.

A. Hardware - The NAO Robot

In recent years, there has been a steady increase in the number of humanoid robots being used in educational settings to promote enhanced teaching and increased interest among students. Findings from prior research have shown that using humanoid robots in the domain of education has made a positive impact on students, with them receiving the robot positively well [38]. Amongst the various socially assistive humanoid robots that exist, NAO has been popularly and widely used with children and for special needs education [39], [40]. The physical attributes of NAO such as height, physique, voice and gestures are suitable for a younger age group. NAO's voice can be modulated and paced according to the need of the experiment making it highly flexible. NAO provides the added advantage of being able to sit and stand flexibly, along with not having a tablet on its chest, which can help encourage children to reduce screen time and in turn increase the direct face-to-face interaction time with the robot. Many studies in the past have used NAO to motivate children to learn arithmetic, to promote positive reading habits in children and in game-based approaches to assess speaking and listening skills for children who use a hearing aid with all these experiments resulting in positive outcomes [41], [42], [38]. Hence, we use NAO proposed Child-Robot-Interaction framework (CRI).

B. Software Architecture

NAO can be programmed using Choregraphe which is an IDE created by Softbank Robotics, ROS, Gazebo, Webots, Matlab and Python SDKs [43]. Since the primary focus of our research is to design a CRI framework for children, the focus was on the social interaction between the robot and the child, hence Choreographe was preferred by the authors. The Choreographe graphical interface consists of box libraries, which are a list of behaviours that can be implemented in the robot [39]. The list of key box libraries used in our research are - Say, Vision Recognition, Speech Recognition, Switch Case, Counter, Text Edit, Tactile Sensors, Delay, Play Sound, Timeline, and Diagram Box [39]. As this framework is still nascent, NAO was teleoperated by one of the researchers while another researcher interacted with the robot while testing this framework. In the future too, when conducting real-time user studies, we intend to tele-operate NAO to avoid any technical difficulties.

C. Dialogue Structure

The proper choice and usage of sounds and gestures by the robot help significantly enhance the social interaction between the child and the robot. Hence, repeated dialogue prompts were not used to avoid children feeling a sense of monotonous dialogue delivery ultimately leading to boredom and loss of interest in the game. For instance, when the child answers a question incorrectly and the robot keeps uttering "try again" continuously, it becomes monotonous and boring for the child. Hence, various dialogue prompts were used which were triggered randomly each time. Verbal praises and words of positive affirmation by teachers at regular intervals led to dyslexic children understanding and retaining classroom concepts significantly well. It also led to an increase in the levels of self-esteem among the children [44], [45]. Hence we designed the responses of NAO to avoid using negative phrases and instead use timely positive affirmations.

When the child gives an incorrect answer, the robot responds to the child with one of the following responses: *"Please try again", "It's alright you got this", "Just do one more attempt", "I know you have got this"*. In this case, special care was taken to not use dialogues such as *"You are wrong"*, directly to the child, as it would tend to create an atmosphere of low self-esteem. Upon reaching the counter limit (the maximum number of times the child is allowed to answer incorrectly or does not understand the instructions) the robot responds with one of the following responses: *"Don't worry, take a deep breath", "relax", and "try again slowly"*. And finally, When the child answers correctly or completes the game successfully, the robot responds by saying one of the following responses: *"Very good", "Well done", "Wow", "Superb", "That's amazing", "Excellent work", "Congratulations, I am so proud of you"*.

D. Child-Robot-Interaction Framework

As discussed in the previous sections, every child has a different degree of dyslexia which means that every child requires a different approach to learning styles. A tailored and personalized learning framework that can be used by children requiring different learning styles is the best approach to the existing problem. However, it is generally difficult to perform this regularly. Hence, to accommodate different learning styles within the same classroom, the authors used a multi-sensory approach (Fig.2) in the design of each of the games [46].

Learning through play has proven to be an entertaining way of understanding concepts as it makes the existing lessons more interesting for the children [47]. Moreover, when games are tailored to target children's needs, they have an intrinsic motivation to overcome their learning difficulties

TABLE I
CHILD-ROBOT-INTERACTION FRAMEWORK ARCHITECTURE - GAME DESIGN

Game	Association	Items Used	NAO Algorithms
PICTURE MEMORY	Visual-Audio Association	Picture Flashcards	Vision Recognition
SOUND AND READ	Word-Sound Association	Flashcards and Story sheet	Speech and Vision Recognition
SPELLING	Bodily Kinaesthetic Approach	Magnetic board with Magnetic Letters	Vision Recognition
SPATIAL	Sense of Direction	Play Map of a Farmland with Animals	Touch Sensing

TABLE II
CHILD-ROBOT-INTERACTION FRAMEWORK ARCHITECTURE - SKILLS ACQUIRED

Game	Primary Skills	Secondary skills	Learning Styles
PICTURE MEMORY	Listening, Visual	Memory	Visual
SOUND AND READ	Reading, Listening, Speaking	Memory	Reading, Auditory
SPELLING	Spelling, Vision, Writing	Motor Control, Spatial, Memory, Reading	Visual, Bodily Kinaesthetic
SPATIAL	Spatial, Motor Control	Memory, Social	Bodily Kinaesthetic

to win or complete the game. In this article, we present the design of our Child-Robot-Interaction framework that consists of four games (PSSS), namely - “Picture Memory” (P), “Sound and Read” (S), “Spelling” (S), and “Spatial” (S) [34]. Different linguistic approaches and pedagogical methodologies have been evaluated and taken into consideration while designing these four games to learn how teachers approach dyslexic children in a conventional classroom setting with an intent to focus on developing a dyslexic child’s language skills - reading, writing, speaking and listening [48], [8]. The overall setup of the framework is presented in Tables I and II.

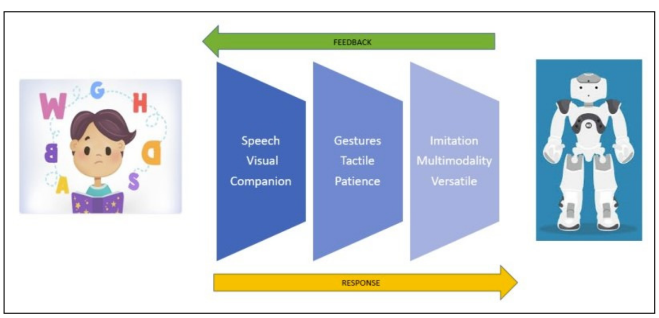

Fig. 2. Modalities addressed through the proposed framework

IV. Design and Development of the Interactive Games

We will now discuss the design and development of each of the games in detail in the following paragraphs.

A. *Picture Memory Game*

In this game (refer to figures 3 and 4), NAO tells a word to the child and the child then has to pick up a flashcard from

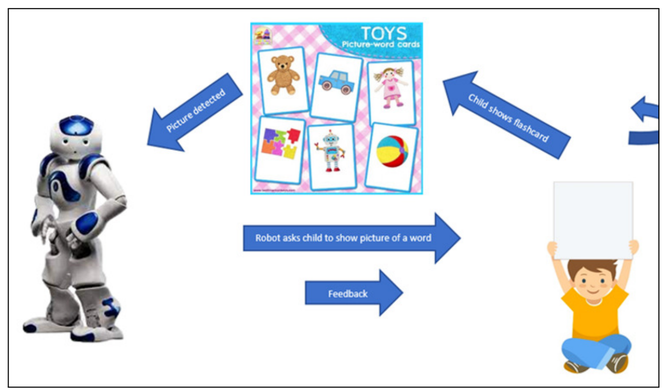

Fig. 3. An overview of the “Picture Memory” game

the tray placed in front that shows the picture associated with the word by raising the flashcard to the eyes of NAO. The setup is in such a way that the distance between NAO and the flashcard held by the child is in the range of 12cm to 35cm from NAO’s head. This enables the robot to identify the images correctly. The technique of this game has certain similarities with the “Spelling” game, as in both scenarios the input to the robot is an image that has to be identified using a label. In this game, NAO’s vision recognition box library is used, where the flashcard images are compared to the images present in its vision recognition database. The following set of words was extracted and stored in the database using respective labels - “pie”, “cake”, “dog”, “toy” and “fish”. The game progresses forward till all the questions have been answered correctly by the child.

Prior literature has shown that dyslexic children enjoy colours, art and visual aids. Hence associating a picture with

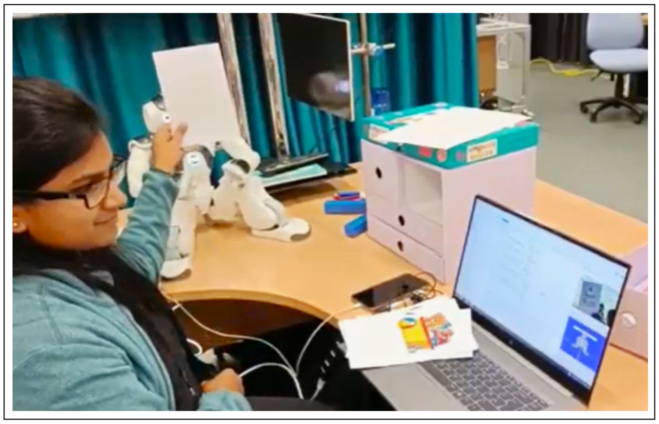

Fig. 4. A researcher playing the "Picture Memory" game with NAO

a newly learnt word helps them in retaining their memory in the long term [49]. For both the "Spelling" game as well as this game, the images when being learnt by NAO are cropped by edge points on the vision screen where one can comprehend how NAO sees the view in front of it. It was observed that NAO was quick in recognizing the pictures on the flashcards in contrast to the letters placed on the magnetic board. This is potentially due to the pixels being steady in the flashcard picture compared to individual letters placed together slightly differently each time changing the pixel resolution for every new input.

B. Sound and Read Game

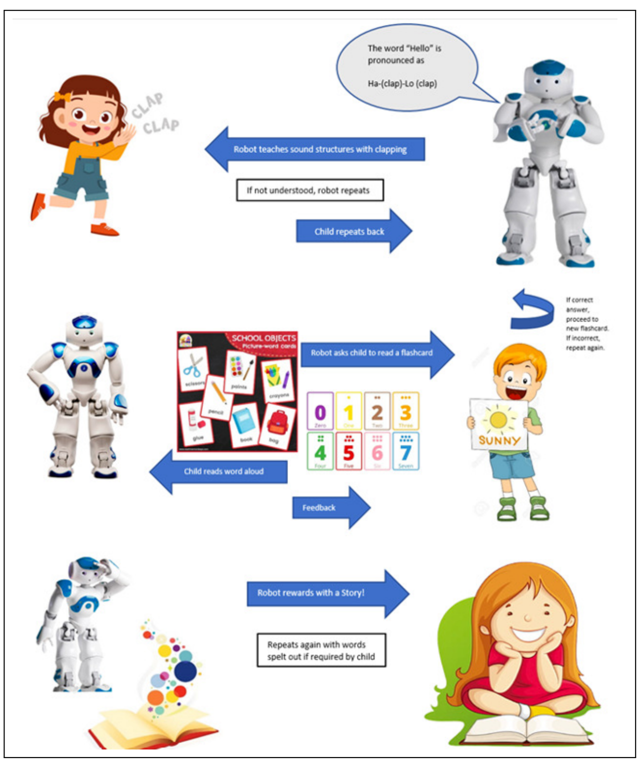

Fig. 5. An overview of the "Sound and Read" game

The "Sound and Read" game starts with NAO explaining the instructions of the game to the child, followed by assuring whether the child understood the instructions clearly or not. If the child has not understood the instructions clearly, the robot then repeats the instructions. If the child has understood the instructions clearly and responds to the robot accordingly, the game then starts. If the child does not understand the instructions of the game even after NAO repeats them 3 times, for which a counter has been input within the robot, the game ends instantly bringing the child to the notice of the educator or the therapist present nearby, to help the child with any difficulties.

This game consists of three levels as displayed in Fig.5. The first level starts with NAO teaching the child a set of words using the "clapping technique" [50]. The clapping technique is a learning approach where words are separated by syllables with claps introduced in between them to separate the different sound structures. Prior research proves that dyslexic students learn better with tapping and sound strategies [50]. After NAO has uttered a new word, it asks the child to repeat the same word. The robot's speech recognition algorithm is activated at this point to identify the child's vocal response. The words to be identified have been embedded into the vocabulary of the speech recognition box library as a list of words before the study. NAO then verifies whether the answer given by the child is correct or incorrect. If the answer is incorrect, it repeats the clapping technique and asks the child to respond again. In this way, if the child gives an incorrect answer 4 times in a row, for which a counter has been set within the robot, then NAO asks the child to relax, slow down and think clearly. This process continues till the child responds to NAO correctly, after which it proceeds to teach the next new word to the child. If the child answers correctly, the robot congratulates and encourages the child with positive verbal reinforcements. This first level ends with the child learning all the words correctly. This level was designed using behaviour layers within the robot's timeline that contained an mp3 file of the clapping sound that produces a combined clapping motion by the robot when played together. NAO's speech recognition algorithm was used for identifying the words when the child responds, with the words embedded into its vocabulary.

The second level starts with NAO asking the child to pick up a flashcard numbered between 1 to 9 from the tray placed in front of the child, after which the child has to read that word aloud to the robot. These flashcards have pictures and their corresponding labels written below them. Most of the words on the flashcards are from the first level. NAO then gives feedback to the child depending on whether the pronunciation of the word is correct or incorrect. The process of reassuring the child of the instructions of this level and the counter phenomenon is the same as level one. Taking lessons from syllable structure, this level focuses on practising reading. This level was designed using NAO's speech recognition algorithm, where the robot compares the word read aloud by the child with the words embedded into its vocabulary. The list of words written on flashcards 1 to 9 is - "baby", "cat", "egg", "sun", "leaf", "bee", "joy", "bowl" and "soup" respectively.

The third level consists of NAO assuming the role of a storytelling buddy who narrates a story twice to the child using sentences formed with the newly learnt words from levels one and two. Throughout the narration, NAO uses a slow, modulated and pleasing tone which children find appealing. During the first time, NAO narrates the story in one stretch and during the second time, NAO stops in between to spell out the words learnt whenever their usage arises all while narrating the same story. In this level, a story sheet is given to the child so that they can follow the lines carefully and read along with the robot. This level was designed using NAO's gesture algorithm and its "say" boxes. Completion of these three levels leads to the end of the "Sound and Read" game.

Syllable separation, clapping technique, repetition and practice are some of the most vital steps to help dyslexic children learn better [50]. Each of these three levels has been designed to strengthen children's reading skills ranging from the application of phonological awareness through syllable division to phonemic awareness through practising reading with speech and to phonics where the child views the words and sentences in front of them whilst relating to the story narration being heard, hence paving way for the word-sound association.

C. Spelling Game

Fig. 6. An overview of the "Spelling" game

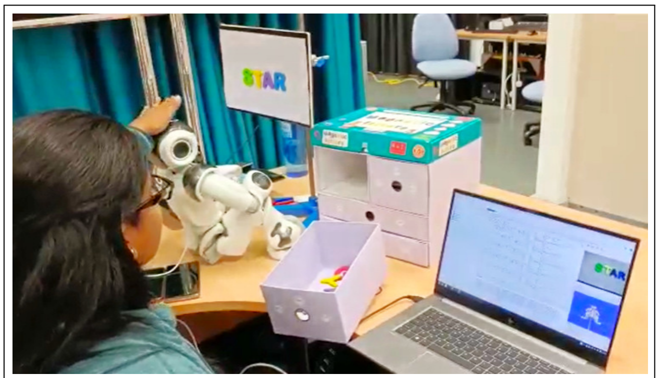

Fig. 7. A researcher playing the "Spelling" game with NAO

In this game, the setup consists of a black magnetic board bolted onto a stand next to the robot. The game starts with NAO instructing the child on what has to be done, followed by making sure that the child has understood the instructions. If not, the robot follows the same reassuring and counter technique as explained in the previous section. Once the child has understood the instructions clearly, NAO asks the child to spell out words using colourful magnetic letters on the board in front of the child. An overview of this game is displayed in Fig.6 and Fig.7. The words to be spelt out are uttered by NAO. Once the child has spelt out the word, NAO activates its vision recognition algorithm and compares the image of the whole word on the magnetic board, to the image of the words present in its vision recognition database. The robot has been programmed in such a way that only when the child taps the head of the robot (activating its tactile sensor), will the robot understand that the child has finished spelling the word and goes ahead to verify. This technique grants children the space and time to learn according to their own pace [9], [51]. The vision recognition database has ".vrd" files that consist of learnt images of a list of words that have been prepared for the child in advance. Then, depending on whether the answer is correct or incorrect, NAO gives appropriate feedback to the child. Once all the words have been spelt, the game ends with NAO uttering words of appreciation to the child. It was observed that using yellow-coloured letters on the black surface of the magnetic board was a good choice as the letters were easily identified by the robot. On the contrary, using colours such as blue, violet and red on the black surface were not identified by NAO's camera. To overcome this problem, we used white paper as a background for different coloured letters.

When one attempts to touch physically present alphabets and spell them out, they are engaging in bodily kinaesthetic learning. Teaching spellings to children using a magnetic board and associating letters with colours that help with visual distinction, are some of the primary pedagogical methods used by special education teachers [52]. The list of words in this game was chosen considering phonemic awareness, with special attention to essential sound structures involving vowels and consonants. The order of words spelt progressed from 3 letter words to 4 letter words along with the inclusion of grammatically sound categories that fall under phonemic awareness which include - similar sounding words, short vowels, long vowels, consonants, digraphs and diphthongs.

D. Spatial Game

This game (refer to figures 8 and 9) focuses on Spatial Dyslexia which refers to a certain type of dyslexia where a person's visual-spatial ability is disrupted causing them problems in identifying their sense of direction [53]. This game helps spatially dyslexic children practice their sense of direction - left, right and middle. The "Spatial" game starts with NAO providing instructions to the child on how to play the game. The robot follows the same reassuring and counter technique while explaining the instructions to the children as discussed in the previous sections. A map showing a farmland is placed in front of the child. The farmland consists

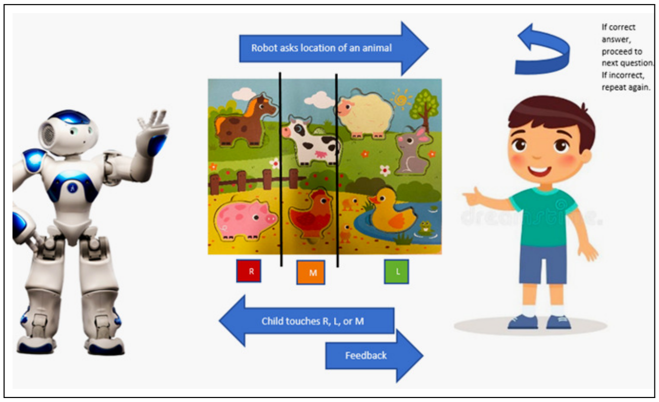

Fig. 8. An overview of the "Spatial" game

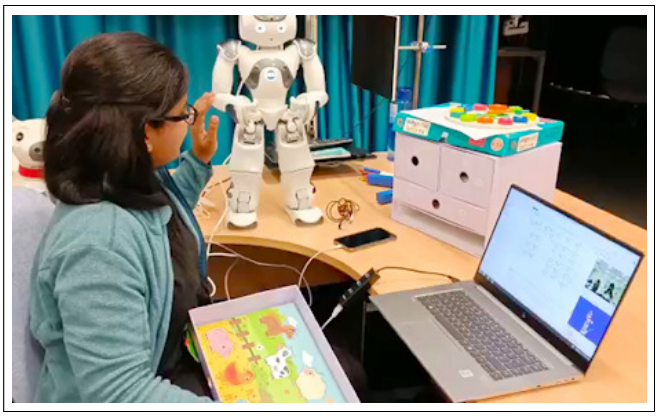

Fig. 9. A researcher playing the "Spatial" game with NAO

of seven animals, namely - a horse, cow, sheep, rabbit, duck, hen and pig. NAO then asks the child where a particular animal is placed in the farmland. The child is supposed to tap the right arm of the robot, if the prompted animal is on the right, tap the left arm of the robot if the prompted animal is on the left and if the prompted animal is in the middle, the child has to tap the robot's head. Incorrect answers by the child lead to the repetition of the same question up until the child answers correctly, and by correctly answering all the questions, the game is completed.

NAO's tactile sensors on its hands and head have been programmed accordingly in the design of this game. To let the child know where the sensors are located, NAO reaches out its right hand to indicate the "right" direction, its left hand to indicate "left" and wiggles its head to indicate the "middle" direction before the game starts. This game has been programmed using diagram boxes where actions can be exclusively differentiated as individual entities.

V. Conclusion and Future Work

The main aim of this article is to present the design of a generalized Child-Robot-Interaction framework involving interactive game-play between the socially assistive robot NAO and dyslexic children that can be used by children with varying degrees of dyslexia for their overall well-being and development. The framework consists of NAO, the social robot, that has been programmed using Choreographe and a set of four games (PSSS) namely "Picture Memory" (P), "Sound and Read" (S), "Spelling" (S), and "Spatial" (S), that have been designed taking into consideration various sound theoretical ideologies such as child psychology, learning styles, linguistic studies, pedagogical methods and learning through play. Factors influencing social engagement such as repeatability, verbal expression, dialogue management and gestures have also been taken into account while designing the framework. Each of these games addresses the primary and secondary skills that they target, the learning styles involved and the type of association it belongs to. Designing such games that are cognitively challenging and well rewarding can both, motivate children to learn positively at a significantly higher pace and provide them with an exciting experience.

Further development of the presented framework would be needed before real-world experiments can be carried out with children, to eliminate potential technical challenges that could arise. This would improve the chances of NAO identifying different coloured letters with clear-cut edge detection. We also aim to design a larger set of gestures using behaviour layers in timelines to match almost every action word in the sentences that NAO speaks. This would help project NAO as a more realistic interaction partner. Finally, as our end goal, we aim to conduct long-term participatory design studies with a large population of children of varying degrees of dyslexia to evaluate and improve upon the efficiency of our framework, and to study the correlation of our framework with the mental well-being of dyslexic children.

References

[1] B. D. Association, "Anxiety and mental health," Online. [Online]. Available: https://www.bdadyslexia.org.uk/dyslexia/neurodiversity-and-co-occurring-differences/anxiety-and-mental-health

[2] K. Hamdan, A. Amorri, and F. Hamdan, "Robot technology impact on dyslexic students' english learning," *International Journal of Educational and Pedagogical Sciences*, vol. 11, no. 7, pp. 1949–1954, 2017.

[3] H. Butcher, "The dyslexic statistic," Online, 2020. [Online]. Available: https://blog.dyslexia.com/the-dyslexic-statistic/

[4] L. S. Siegel, "Perspectives on dyslexia," *Paediatrics & child health*, vol. 11, no. 9, pp. 581–587, 2006.

[5] A. Marshall, "Brain scans show dyslexics read better with alternative strategies," Online, 2003. [Online]. Available: https://www.dyslexia.com/research/articles/alternative-brain-pathways/#˜ textĪn%20the%20right%20brain%20area,negatively%20 correlated%20to%20reading%20ability

[6] A. Wilmot, H. Pizzey, S. Leitão, P. Hasking, and M. Boyes, "Growing up with dyslexia: Child and parent perspectives on school struggles, self-esteem, and mental health," *Dyslexia*, vol. 29, no. 1, pp. 40–54, Feb. 2023.

[7] S. Suneesh, "Socially assistive robot to aid learning in dyslexic children," 2022.

[8] J. Blue, "10 ways to support learners with dyslexia: for pre a1 starters to b2 first for schools," Online, 2021. [Online]. Available: https://www.cambridgeenglish.org/blog/ten-ways-to-support-learners-with-dyslexia/

[9] I. D. Association, "Dyslexia in the classroom - what every teacher needs to know," Online, 2017. [Online]. Available: https://dyslexiaida.org/wp-content/uploads/2015/01/DITC-Handbook.pdf

[10] D. A. Lieberman, "What can we learn from playing interactive games," *Playing video games: Motives, responses, and consequences*, pp. 379–397, 2006.

[11] D. Pasupuleti, S. Sasidharan, R. Sharma, and G. Manikutty, "Exploring collaborative game play with robots to encourage good hand hygiene practises among children," in *2022 31st IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*, 2022, pp. 308–315.

[12] K. A. Ericsson and W. Kintsch, "Long-term working memory," *Psychol. Rev.*, vol. 102, no. 2, pp. 211–245, Apr. 1995.

[13] N. S. Rose, B. R. Buchsbaum, and F. I. M. Craik, "Short-term retention of a single word relies on retrieval from long-term memory when both rehearsal and refreshing are disrupted," *Mem. Cognit.*, vol. 42, no. 5, pp. 689–700, jul 2014.

[14] G. Hopkins and T. W. Bean, "Vocabulary learning with the verbal-visual word association strategy in a native american community," *J. Adolesc. Adult Lit.*, vol. 42, no. 4, pp. 274–281, 1998.

[15] T. Yang, Y. Cai, H. Liu, and X. Liu, "The nature of paired associate learning deficits in chinese children with developmental dyslexia," *Brain Sci.*, vol. 13, no. 2, Jan. 2023.

[16] E. C. Anyanwu, "Facilitated mental integration of repeated visio-auditory perception could improve knowledge acquisition and retention in dyslexia and learning disabilities," *Int. J. Disabil. Hum. Dev.*, vol. 6, no. 3, Jan. 2007.

[17] MindTools, "Learning styles," Online. [Online]. Available: https://www.mindtools.com/addwv9h/learning-styles

[18] P. Main, "Learning styles - classroom practice," Online, 2022. [Online]. Available: https://www.structural-learning.com/post/learning-styles

[19] D. M. Wiegand and E. S. Geller, "Connecting positive psychology and organizational behavior management: Achievement motivation and the power of positive reinforcement," *Journal of Organizational Behavior Management*, vol. 24, no. 1-2, pp. 3–25, 2005.

[20] S. Suneesh, "Review of socially assistive robots in special education," Online, 2022. [Online]. Available: https://bilt.online/student-research-journal-issue-3/

[21] M. Pivetti, S. Di Battista, F. Agatolio, B. Simaku, M. Moro, and E. Menegatti, "Educational robotics for children with neurodevelopmental disorders: A systematic review," *Heliyon*, vol. 6, no. 10, p. e05160, 2020.

[22] D. Karunarathne, Y. Morales, T. Nomura, T. Kanda, and H. Ishiguro, "Will older adults accept a humanoid robot as a walking partner?" *International Journal of Social Robotics*, vol. 11, no. 2, pp. 343–358, 2019.

[23] AIST, "Paro therapeutic robot," Online, 2014. [Online]. Available: http://www.parorobots.com/

[24] Aldebran, "Nao the humanoid and programmable robot," Online, 2022. [Online]. Available: https://www.aldebaran.com/en/nao

[25] U. of Hertfordshire, "Kaspar the social robot," Online. [Online]. Available: https://www.herts.ac.uk/kaspar/the-social-robot

[26] I. S. Robots, "Keepon," Online. [Online]. Available: https://robotsguide.com/robots/keepon

[27] F. Amato, M. Di Gregorio, C. Monaco, M. Sebillo, G. Tortora, and G. Vitiello, "The therapeutic use of humanoid robots for behavioral disorders," in *Proceedings of the International Conference on Advanced Visual Interfaces*, ser. AVI '20. New York, NY, USA: Association for Computing Machinery, 2020. [Online]. Available: https://doi.org/10.1145/3399715.3399960

[28] J. A. Buitrago, A. M. Bolaños, and E. Caicedo Bravo, "A motor learning therapeutic intervention for a child with cerebral palsy through a social assistive robot," *Disability and Rehabilitation: Assistive Technology*, vol. 15, no. 3, pp. 357–362, 2020.

[29] F. Amato, M. Di Gregorio, C. Monaco, M. Sebillo, G. Tortora, and G. Vitiello, "Socially assistive robotics combined with artificial intelligence for adhd," in *2021 IEEE 18th Annual Consumer Communications & Networking Conference (CCNC)*, 2021, pp. 1–6.

[30] S. da Luz Schreider, J. A. C. Panceri, T. F. Bastos-Filho, É. V. da Silva Freitas, J. C. de Souza, and E. M. de Oliveira Caldeira, "Proposal of games for children and teenagers with down syndrome applied to a socially assistive robot," *balance*, vol. 7, p. 8, 2022.

[31] S. Gouraguine, M. Qbadou, and K. Mansouri, "Handwriting treatment and acquisition in dysgraphic children using a humanoid robot-assistant," in *2022 IEEE Global Engineering Education Conference (EDUCON)*. IEEE, 2022, pp. 1658–1663.

[32] S.-J. Cho and D. H. Ahn, "Socially assistive robotics in autism spectrum disorder," *Hanyang Medical Reviews*, vol. 36, no. 1, pp. 17–26, 2016.

[33] M. M. Blankenship and C. Bodine, "Socially assistive robots for children with cerebral palsy: a meta-analysis," *IEEE Transactions on Medical Robotics and Bionics*, vol. 3, no. 1, pp. 21–30, 2020.

[34] V. R. G. Shyamli Suneesh, Devasena Pasupuleti, "A socially assistive robot-play framework as an educational aid for dyslexic children," Robots for Learning Workshop - HRI 2023, 2023. [Online]. Available: https://robots4learning.files.wordpress.com/2023/03/cfp-r4l-hri2023-paper_7816-1.pdf

[35] M. Chita-Tegmark and M. Scheutz, "Assistive robots for the social management of health: A framework for robot design and human-robot interaction research," *Int. J. Soc. Robot.*, vol. 13, no. 2, pp. 197–217, 2021.

[36] DREAM, "Development of robot-enhanced therapy for children with autism spectrum disorders," Online, 2020. [Online]. Available: https://dream2020.github.io/DREAM/about

[37] R. van den Heuvel, R. Jansens, B. Littler, C. Huijnen, A. Di Nuovo, A. Bonarini, L. Desideri, P. Encarnação, A. Lekova, and L. de Witte, "The potential of robotics for the development and wellbeing of children with disabilities as we see it," *Technol. Disabil.*, vol. 34, no. 1, pp. 25–33, Mar. 2022.

[38] P. Polycarpou, A. Andreeva, A. Ioannou, and P. Zaphiris, "Don't read my lips: assessing listening and speaking skills through play with a humanoid robot," in *International Conference on Human-Computer Interaction*. Springer, 2016, pp. 255–260.

[39] Kai, M. Anter, J. Greiner, J. Vatter, and Weghake, "Nao6 - basics learn it," Online, 2019. [Online]. Available: https://www.eduporium.com/media/wysiwyg/PDF/The_Basics_Learn It_NAO__EN.pdf

[40] A. Subedi, D. Pandey, and D. Mishra, "Programming nao as an educational agent: A comparison between choregraphe and python sdk," in *The Proceedings of the International Conference on Smart City Applications*. Springer, 2021, pp. 367–377.

[41] J. B. Janssen, C. C. Wal, M. A. Neerincx, and R. Looije, "Motivating children to learn arithmetic with an adaptive robot game," in *International conference on social robotics*. Springer, 2011, pp. 153–162.

[42] W.-W. Shen and J.-M. Lin, "Robot assisted reading: a preliminary study on the robotic storytelling service to children in the library," in *International Conference on Innovative Technologies and Learning*. Springer, 2018, pp. 528–535.

[43] K. I. S. U. N. G. Seo and A. L. D. E. B. A. R. A. N. Robotics, "Using nao: introduction to interactive humanoid robots," *AldeBaran Robotics*, 2013.

[44] E. Leong, , S. Asjamiah, and A. Wang, "Exploring the classroom practices of the english exam skills programme for singaporean primary school children," *Asia Pacific Journal of Developmental Differences*, vol. 4, no. 2, pp. 167–194, July 2017.

[45] C. Miceli, *The Effects of Elementary School Teachers' Instructional Practices on the Self-Confidence of College Students with Dyslexia*, 2015.

[46] H. Pashler, M. McDaniel, D. Rohrer, and R. Bjork, "Learning styles: Concepts and evidence," *Psychological science in the public interest*, vol. 9, no. 3, pp. 105–119, 2008.

[47] M. Kangas, "Creative and playful learning: Learning through game co-creation and games in a playful learning environment," *Thinking skills and Creativity*, vol. 5, no. 1, pp. 1–15, 2010.

[48] ThisReadingMama, "Phonological awareness, phonemic awareness & phonics," Online. [Online]. Available: https://thisreadingmama.com/phonological-awareness-phonemic-awareness-phonics/

[49] R. Saengpakdeejit, "Awareness of vocabulary learning strategies among efl students in khon kaen university." *Theory & Practice in Language Studies*, vol. 4, no. 6, 2014.

[50] B. Balance, "Top teaching methods for dyslexic students," Online. [Online]. Available: https://www.brainbalancecenters.com/blog/top-teaching-methods-for-dyslexic-students

[51] B. Beamish, "8 signs of dyslexia," Online, 2021. [Online]. Available: https://dyslexiaoctopus.com/8-signs-of-dyslexia/

[52] D. Gold, "A teacher's guide to dyslexia," Online. [Online]. Available: https://dyslexiagold.co.uk/Dyslexia/TeachersGuide

[53] A. Facoetti, P. Paganoni, M. Turatto, V. Marzola, and G. G. Mascetti, "Visual-spatial attention in developmental dyslexia," *Cortex*, vol. 36, no. 1, pp. 109–123, 2000.