# A feasibility study of using Kaspar, a humanoid robot for speech and language therapy for children with learning disabilities*

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*Abstract*— **The research presented in this paper investigates the feasibility of using humanoid robots like Kaspar as assistive tools in Speech, Language and Communication (SLC) therapy for children with learning disabilities. The study aims to answer two research questions: RQ1. Can a social robot be used to improve SLC skills of children with learning disabilities? RQ2. What is the measurable impact of interacting with a humanoid robot on children with learning disability and SLC needs? A co-creation approach was followed, three therapeutic educational games were developed and implemented on the Kaspar robot in collaboration with experienced SLC experts. Twenty children from two different special educational needs schools participated in the games in 9 sessions over a period of 3 weeks. Results showed significant improvement in participants' SLC skills – i.e. language comprehension and production skills – over the intervention. Findings of this research affirms feasibility, suggesting that this type of robotic interaction is the right path to follow to help the children improve their SLC skills.**

## I. Introduction

Approximately 5 million people in the United Kingdom (UK), including 286,000 children have a learning disability [1]. It is estimated that 89% of the learning disabled population need SLC therapy to help with their communication difficulties [2]. Whilst communication difficulties show a wide range and are different to every person, the following areas are commonly found to be of difficulty in the learning disabled population: (1) understanding speech, writing and symbols, (2) having a sufficient vocabulary to express a range of needs, emotions or ideas, (3) being able to construct a sentence, (4) maintaining focus and concentration in order to communicate, (5) fluency, (6) being able to articulate clearly which may be due to related physical factors, (7) social skills, a lack of which may prevent positive interactions with people [3]. The potentially extensive and long term effects of communication problems related to having a learning disability can have a very harmful effect on the people's health and social wellbeing if left without intervention [3]. If appropriate SLC support is not available it may lead to mental health problems, as well as to reduced learning opportunities and participation in employment, which in turn may lead to isolation, challenging behaviour, risk of harm or abuse, and failure to reach potential in life [3]. Hence, SLC therapy is absolutely crucial for children with learning disabilities. It promotes inclusive communication and accessible information for children with learning disabilities. It improves their quality of life, enabling them to build relationships and achieve their potential. Whilst a vast amount of research has investigated communication interventions and their impact on children with Speech Language and Communication Needs (SLCN), the possibility of using state of the art robotics technology, specifically focused on Speech Language and Communication (SLC) therapies has had very little investigation.

Research into the potential use of robotic technology for children began in the late 1990s, with Dautenhahn and Werry conducting some of the first studies in this area with Autism Spectrum Disorder (ASD) [4, 5]. Since then positive results in this domain have led to much more work being conducted into how robotic technology can be used as assistive tools for children with ASD [6]. Numerous reasons why social robots have an advantage include: their capacity to act as a playmate, their ability to display particular behaviours consistently and predictably and their ability to act as a social mediator. In addition, children often find robots less intimidating than humans because they may feel less judged by them [7]. Previous research investigating if humanoid robots could be used to interview children demonstrated that children are able and willing to interact with humanoid robots for information acquisition purposes, and that robots even provide advantages at interviewing children in challenging situations (e.g. interviews conducted by social services). [8, 9]. One of the particularly useful features of a robot that could be beneficial to SLC therapies is the capacity for consistent interaction that can be repeated for achieving sufficient exposure required for optimal learning. It is thought that children with SLCN can utilise implicit learning principles but with significant amount of input [10], which is possible via the robotic interaction. Based on literature suggesting that children with other disabilities respond well to social robots [7], it is likely that children with learning disabilities in need of SLC therapy could also benefit from robotic therapies via a series games that have purposeful goals [11]. To date, however, the work investigating the possibility of using robots to assist with SLC is relatively limited. Some of previous research focused on children with conditions such as ASD [12], or hearing

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impairments [13], while others focused on the early acquisition of language with young children [14]. A more recent exploratory study [15] investigated the potential use of a social robot (NAO) in speech therapy intervention for children with language disorders. Their findings indicated that NAO had potential to increase motivation, and readiness towards learning as well as to improve attention span of children. Another pilot study, using the RASA robot in speech therapy sessions for children with language disorders found further supporting evidence for the potential usability of robots in SLC therapy with children [16]. These studies, however, both presented preliminary exploratory findings with small number of participants.

The study presented in this paper aims to investigate further the feasibility of using humanoid robots as assistive tools in SLC therapy for children with learning disabilities. It used the humanoid robot, Kaspar, originally developed in 2005 at the University of Hertfordshire for children with ASD [17]. Over the years, Kaspar has been used to work with more than 500 children in various settings [18], proven to be successful for a wide range of therapeutic and educational purposes both in schools and at homes, in addition to clinical settings [19, 20, 21, 22]. Recent case studies focusing on developing communicational skills in clinical settings of a children's hospital in Skopje, Macedonia with children with severe autism showed that sessions with Kaspar helped the children to learn basic social communication skills for the first time, and that these skills were then successfully generalised and used in their daily lives [23].

The current study aims to answer the following research questions (RQ):

RQ1. Can humanoid robots be used to improve SLC skills of children with learning disabilities?

RQ2. What is the measurable impact of interacting with a humanoid robot on children with learning disability and SLC needs?

## II. METHOD

This research was approved by the University of Hertfordshire's ethics committee for studies involving human participants, protocol number: aSPECS/SF/UH/04944(1). Informed consent was obtained in writing from all parents of the children participating in the study.

### *A. Participants*

Twenty children from two different special education schools (10 children from a primary school and 10 children from a secondary school) took part in the study after getting the written and signed consent of their parents or legal guardians. Their mean age was *M* = 10.76 (*SD* = 2.43) ranging from 6 to 14 years old. Three of them were female and 17 were male. Their diagnosis included ASD (11 children), Down Syndrome (2 children), Speech and Language Difficulties (all participants independent of their other diagnosis), Attention Deficit Hyperactivity Disorder (3 children), Global Developmental Delay (1 child), Cardiofaciocutaneous (CFC) syndrome (1 child), and Hypotonia - Gross Motor and Fine Motor Developmental Delay (1 child).

### *B. Educational Target analysis*

Using a co-creation method, professional guidance from experienced SLC experts was considered to develop the therapeutic educational games for this study. Our partner special needs school provided information about the SLC objectives that are important to the education journey of the pupils. They also provided us with a breakdown of targets set against interactions with children at varying levels of complexity. This included a pool of exemplar targets for fifty-five individual pupils (fully anonymised), featuring different objectives for various learning styles. This provided the co-creation input with a series of rows and columns of information per pupil (three main SLC targets for each pupil according to their SLC skills and their learning style).

TABLE I. SLC development target classifications and the frequency of their occurrence.

| **SLC Target Classifications** | |
|---|---|
| **Code** | **References** |
| Language production\Active or production verbs and derivative words | 57 |
| Language production\Production of phrases, grammatical structures or other objects | 38 |
| Bidirectional social interaction\Interaction partners | 33 |
| Games and activities | 26 |
| Language comprehension\Phrases or concepts to understand | 24 |
| Degree of independence\Use of aiding tools and toys | 19 |
| Degree of independence\Increasing independence | 16 |
| Bidirectional social interaction\Socially engaging verbs and derivative words | 14 |
| Desired success rate or frequency | 14 |
| Language comprehension\Comprehension verbs and derivative words | 12 |
| Language production\Production of phonemes or sound | 11 |
| Non-verbal communication | 10 |

A frequency analysis was carried out in order to know which type of SLC targets were the most common in interacting with the children with special needs. The different phrases in the list of targets for individual pupils were coded and classified into different categories related to SLC skills such as language comprehension, production, or interaction. In addition to the main coder, who coded 100% of the targets, a second coder coded 20% of the targets and Cohen's Kappa was run to determine if there was agreement between the two coders on the classification of the phrases. There was a substantial agreement between the two coders ($\kappa = 0.75$).

As Table I demonstrates, the most common targets were related to language production and comprehension, the interaction between peers, and the engagement in activities and games.

### *C. Games*

Three games were designed taking the above SLC development targets into consideration: one of each targeting either production, comprehension, or interactive goals.

Once, the games were developed, children in each school participated in 9 sessions over a period of three weeks, each session consisting of three games.

*1) Game 1: Feeding Kaspar*

In this game six different plastic food items are used with Kaspar. Each item was split into two parts and attached with a Velcro tape. During the game Kaspar asks the child to cut a piece of food and place it close to Kaspar's mouth. This is repeated six times until the child used all the food items. Experimental setup is shown on Fig. 1, while a detailed flow-chart demonstrating the interaction design for the game is presented in Fig. 2.

The following specific SLC goals were targeted in this game related to comprehension:

a) Responding to simple questions when in a familiar context with a special person (e.g. parent or teacher);
b) Understanding of single words in context, e.g. cup, milk, daddy;
c) Selecting familiar objects by name and find objects when asked, or identify objects from a group;
d) Understanding simple sentences (e.g. Throw the ball);
e) Identifying action words by following simple instructions, e.g. Cut the banana;
f) Beginning to understand more complex sentences, e.g. Put your toys away and then sit on the carpet;
g) Being able to follow directions;
h) Understanding use of objects (e.g. Which one do we cut with?);
i) Responding to instructions with complex elements, e.g. Cut the fruit and put it closer to my mouth.

Figure 1. Experimental setup of Game 1: Feeding Kaspar.

*2) Game 2: Pointing with Kaspar*

In this game 3 different animal pictures are placed in the room, one to the left, one to the right and one in front of the robot (Fig. 3). In the first part of the game, Kaspar asks the child to point at a specific animal. For example, Kaspar says "Can you point at the elephant, please?". Once that child has done that, they receive positive reinforcement from Kaspar. After that, in the second part of the game, the child is instructed to ask Kaspar to point at one of the animals. Once they have done it, Kaspar then points at the animal and makes the animal sound. In this game, part one and part two are both repeated three times.

The following specific SLC goals were targeted in this game:

Related to interaction:

a) Turn-taking;
b) Joint attention by pointing to share an interest.

Related to comprehension:

c) Understanding of single words in context is developing, e.g. cup, milk, daddy;
d) Following directions.

Related to production:

e) Using of single words or full sentences (depending on the developmental stage of the child);
f) Making requests.

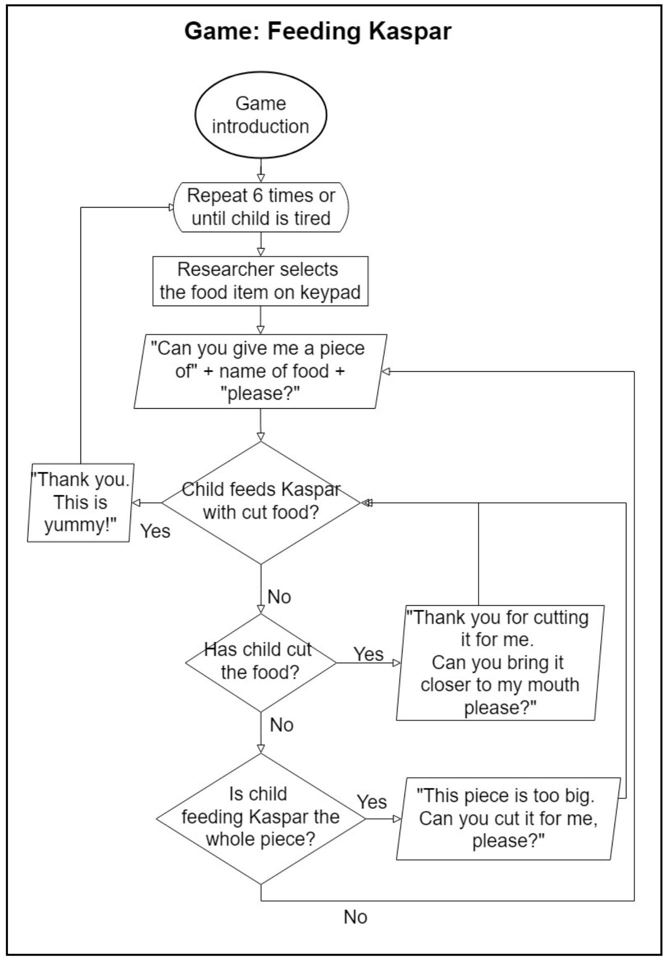


Figure 2. Flow-chart demonstrating the interaction design used in Game 1: Feeding Kaspar.

*3) Game 3: Tenses with Kaspar*

In this game several different images are used, shown on a tablet, portraying people doing daily activities (e.g. walking the dog, eating, cleaning, etc.). The researcher shows the child one of the pictures and Kaspar asks "What is my friend doing today?". The child then has to respond using either the tense of simple present or present continuous. After 3 pictures, the child is shown a new picture and Kaspar says "This is a picture of my friend yesterday. What did my friend do yesterday?". To which the child then should answer using any form of past tense. This is repeated with 3 different pictures, following which, a new picture is shown again, and Kaspar says “This is what my friend will do tomorrow. What will my friend do tomorrow?”. The child then should answer the question using a future tense. This is repeated with 3 different pictures. Experimental setup is shown on Fig. 4.

The specific SLC goals targeted in this game were the following:

Related to interaction:

a) Turn-taking.

Related to comprehension:

b) Responding to simple questions;
c) Understanding a range of complex sentence structures including tense markers.

Related to production:

d) Using different types of everyday words (nouns, verbs and adjectives, e.g. boy, go, drink);
e) Putting words together in full sentences;
f) Talking about people and things that are not present;
g) Using talk to explain what is happening, what happened and anticipating what will happen next;
h) Using a range of tenses (e.g. play, playing, will play, played).

The flow-chart on Fig. 5 shows the detailed interaction design used for the game.

A playlist of videos showing the interaction can be found on YouTube.

Figure 3. Experimental setup of Game 2: Pointing with Kaspar.

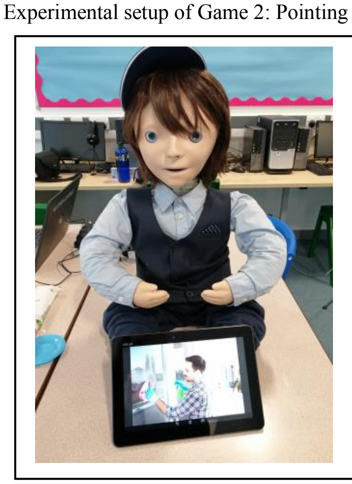

Figure 4. Experimental setup of Game 3: Tenses with Kaspar.

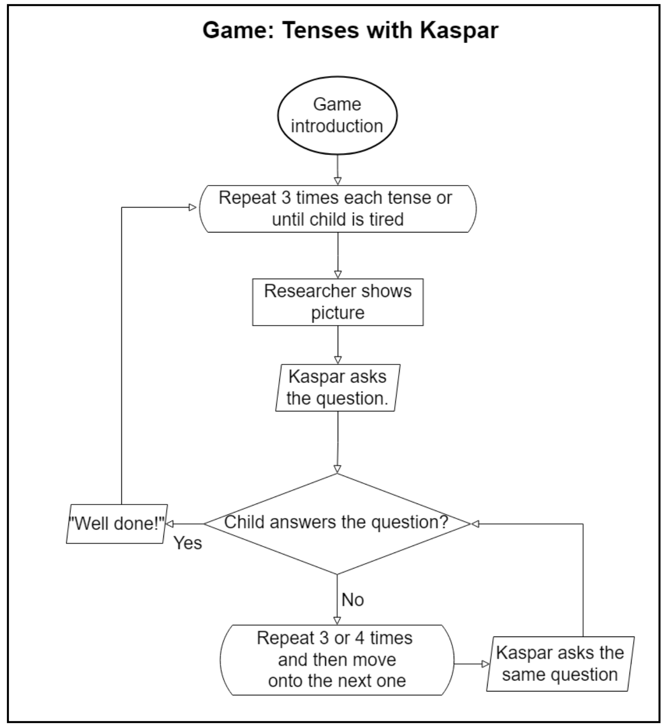


Figure 5. Flow-chart demonstrating the interaction design used in Game 3: Tenses with Kaspar.

## III. Results

### A. *Video coding*

All sessions with the children were video recorded. The first two sessions and the last two sessions were coded using nVivo 12 with the intention to assess the progress of the children. The videos were coded using a scheme that was specifically related to the games and both the production and comprehension of language. All videos were coded by a member of the research team and 20% of the videos were coded additionally by a different member of the team. There was a substantial agreement between the two coders ($\kappa = 0.76$, $p < .001$). Any disagreement was resolved through discussion. See Table II for the video coding scheme.

### A. *Impact of the intervention*

In order to compare the first sessions with the last sessions, a performance score $x$ was computed for each game. First, a specific value was assigned to each behaviour of the coding scheme as shown in Table II. It is important to note that Game 2 was related to both comprehension and production. So, both elements were evaluated and coded in this game.

TABLE II. Video coding scheme in Game 1, 2 and Game 3.

| **Behaviour** | **Value** |
|---|---|
| **Game 1 Food – Comprehension** | |
| Child does something unrelated to the task | 0 |
| Child uses the wrong food | 1 |
| Child just picks the right food item | 2 |
| Child only cuts food OR places whole food close to the mouth | 3 |
| Child cuts food and places it close to the robot but not the mouth | 4 |
| Child cuts food AND places food close to the mouth | 5 |
| Intentional mistake | N/A |
| **Game 2 Pointing - Comprehension, Production** | |
| **Comprehension** | |
| 0 Child does something unrelated to the task | 0 |
| 1 Child says the name of the wrong animal | 1 |
| 2 Child points at the wrong animal | 2 |
| 3 Child says the name of the right animal but does not point at it | 3 |
| 4 Child does not point at the animal but shows it in a different way | 4 |
| 5 Child points at the animal when K requests it | 5 |
| Intentional mistake | N/A |
| **Production** | |
| 0 Child does not produce any sound | 0 |
| 1 Child produces unintelligible sounds | 1 |
| 2 Child produces words with no meaning or with difficulty in the pronunciation | 2 |
| 3 Child produces a fragmented sentence including the animal | 3 |
| 4 Child produces a full sentence with grammatical or pronunciation mistakes | 4 |
| 5 Child makes a request without mistakes | 5 |
| Child repeats what they hear | N/A |
| Intentional mistake | N/A |
| **Game 3 Tenses - Production** | |
| 0 Child does not produce any sound | 0 |
| 1 Child produces unintelligible sounds | 1 |
| 2 Child produces words with no meaning or with difficulty in the pronunciation | 2 |
| 3 Child produces a fragmented sentence related to the picture | 3 |
| 4 Child produces a full sentence but the tense or the grammar is incorrect | 4 |
| 5 Child produces the right sentence using the right tense form | 5 |
| Child repeats what they hear | N/A |
| Intentional mistake | N/A |

After coding the videos, the score was computed following the formula below, in which $x$ is the child's performance score, $n$ is the number of times a child performs a specific behaviour and $k$ is the specific value assigned to this behaviour:

$$x = \frac{\sum(n * k)}{\sum n}$$

As an example, for the video coding presented in Table III,

TABLE III. Video coding example in Game 1 for calculating score x.

| **Game 1 Food - Comprehension** | ***k*** | ***n*** |
|---|---|---|
| Child does something unrelated to the task | 0 | 1 |
| Child uses the wrong food | 1 | 0 |
| Child just picks the right food item | 2 | 1 |
| Child only cuts food OR places whole food close to the mouth | 3 | 1 |
| Child cuts food and places it close to the robot but not the mouth | 4 | 3 |
| Child cuts food AND places food close to the mouth | 5 | 6 |
| Intentional mistake | N/A | 0 |

the formula and the score would be the following:

$$\frac{(1 * 0) + (0 * 1) + (1 * 2) + (1 * 3) + (3 * 4) + (6 * 5)}{12} = 3.92$$

This way, for each coded session, each participant had one score for Game 1 (comprehension), two scores for Game 2 (comprehension and production) and one score for Game 3 (production) making a total of 4 scores per session. The scores from the first two sessions were averaged as well as the scores from the last two sessions. Therefore, there were 4 scores for each child that corresponded to their behaviour at the beginning of the sessions and 4 scores for each child in the last sessions.

A Wilcoxon Signed Ranks test comparing the average scores from the first two and the last two sessions showed a significant improvement in Game 1 ($Z$ = -2.534, $p$ = .011), Game 2 (comprehension) ($Z$ = -2.371, $p$ = .018), Game 2 (production) ($Z$ = -3.583, $p$ < .001) and Game 3 ($Z$ = -3.061, $p$ = .002).

The impact of the intervention sessions can be observed as presented in Fig. 6.

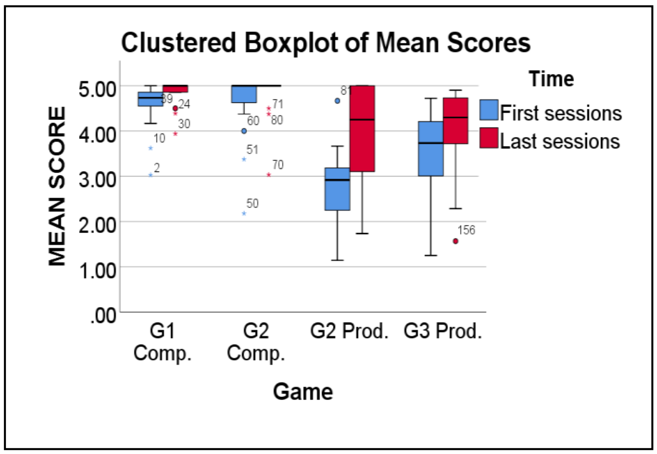


Figure 6. Differences in participants' mean scores in the first two and the last two sessions of Game 1, Game 2 and Game 3.

## IV. DISCUSSION

Results of the study suggests that there was significant improvement in the children's SLC skills from the first two sessions to the last two sessions. The findings further suggest that the area that was improved the most is the production of language in Games 2 and 3, indicating that most children ended the sessions making requests, and creating full sentences, explaining the actions of other people in the past, present and future.

Considering our research questions, results showed that the interactive games with Kaspar made significant improvement on the children's SLC skills, especially in the aspects of language production and comprehension (RQ1). Objective measurements using video coding analysis clearly demonstrated a measurable impact on their SLC skills (RQ2). This suggests that humanoid robots such as Kaspar can be used to help children with learning disabilities to improve their SLC skills, further supporting earlier findings of [15] and [16] with Nao and the Rasa robot. However, while these previous studies [15, 16] were descriptive and explorative, involving a very small number of participants (5 and 6 children per group respectively), the present study is the first providing statistical evidence of the feasibility of robot assisted SLC therapy. Furthermore, this study is the first that systematically analysed educational targets for children with SLCN to design the therapeutic games specifically targeting the needs of the participants.

Our future research plans involve further analysis of the data, including the analysis of pre- and post-intervention assessment questionnaires filled by the participants' teachers. This would provide further information on the effectiveness of the interventions, especially regarding the SLC goals related to interaction as well as comprehension and production - indicating whether teachers could see any improvements in the pupils' SLC skills.

## V. Conclusion

We embarked on this study to assess the feasibility of using the Kaspar robot for SLC therapy in the context of education for children with learning disabilities. Our results affirm feasibility, leading us to think that this type of robotic interaction is the right path to follow to help the children improve their communication skills. In addition, the results open new directions for our future research. Based on the findings of the current study we aim to investigate possibilities of robot-assisted therapy for SLC further by enabling longer-term use of our methods in special needs education.

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