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Using the humanoid robot Kaspar in a Greek school environment to support children with Autism Spectrum Condition

Abstract: Previous studies conducted with the humanoid robot Kaspar in the UK have yielded many encouraging results. This paper examines the influence of conducting play sessions with Kaspar on the social and communication skills of children diagnosed with Autism Spectrum Condition (ASC) and suggests possible ways for using the robot as a (therapeutic) tool in a Greek school for children with special needs. Over a period of 10 weeks 7 children took part in a total of 111 individual play sessions with the Kaspar robot. Each child participated in between 12 and 18 sessions with the robot. The results from this study indicate that the play sessions with Kaspar appear to have positively influenced the behaviours of some of the children in specific domains such as communication and interaction, prompted speech, unprompted imitation and focus/attention. Furthermore, the children's teachers expressed positive views regarding the impact of the play sessions on the children and offered interesting suggestions about the ways in which the robot could potentially be used in everyday teaching tasks and were eager to obtain a Kaspar for their classroom activities.

Keywords: Autism Spectrum Condition, Kaspar robot, social and communication skills, therapeutic tool

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1 Introduction

Autism Spectrum Condition (ASC) is a developmental condition that is becoming increasingly prevalent, possibly due to increased awareness of the condition and changes in the diagnostic criteria [1, 2][1]. ASC is a spectrum of conditions that appears in many different forms and varies in its degrees of severity from severe low functioning autism, to high functioning and Asperger's syndrome [3]. A key characteristic of ASC is impairment of social communication and interaction [3–6]. Children with ASC often find it difficult to engage in social or collaborative play activities with other children and can be quite solitary [7] which can adversely affect their development. In recent years the field of socially assistive robots for children with ASC has become an increasingly popular field of research with a range of robotic platforms being utilised for this application [8–10]. Projects such as AuRoRa [11], IROMEC [12] and Baby-Robot [13], have been investigating how robots can be employed as 'social mediators' [14] to assist in facilitating and promoting social communication and interaction amongst children with ASC, with some promising results.

A humanoid robot that has been used widely to work with children with ASC is the Kaspar robot [15, 16]. Since its initial creation in 2005 the Kaspar robot has been used in a number of long-term case-study evaluations with over 170 children that are affected by ASC [17, 18]. To date, all of the studies carried out with the Kaspar robot in a school setting have been conducted in UK schools. Given that ASC is not restricted to a particular country, it is important to examine the possible influence of play sessions with Kaspar in a different cultural/educational setting. The study outlined in this paper details the findings of a study with

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[1] We prefer using the term Autism Spectrum Condition (ASC) instead of Autism Spectrum Disorder (ASD) since it is less stigmatising, see L. Hull et al., Putting on My Best Normal: Social camouflaging in adults with Autism Spectrum Conditions, Journal of Autism and Developmental Disorders, 2017, 47(8), 2519-2534, DOI: 10.1007/s10803-017-3166-5.

Kaspar that was conducted in a Greek school environment to support the social and communication skills of children with ASC and examine how teachers/professionals based in a different cultural environment could use Kaspar as a (therapeutic) tool in the classroom. Note, our intention was to investigate whether Kaspar would also benefit children in those different settings; we did not study cultural factors per se which would go beyond the scope of this article.

In section 2 we explore the domain of social robotics and its connections with the diagnosis and therapy of children with ASC, while an overview of some of the most widely known robotic models used for therapeutic purposes is provided. Following on from this, we then introduce the Kaspar robot, along with evidence from previous studies conducted with Kaspar in the UK. The aims of the study and research questions conclude section 2. Section 3 describes the sample, the setting of the study, the procedure followed in the play sessions with the robot as well as the range of measurements used. Section 4 then describes in detail the data analysis which is discussed in section 5 where we examine how the findings of the study relate to the existing evidence in this field, including studies conducted with different robotic models. Concluding this article section 6 outlines the findings of the study alongside a discussion of the limitations of the study.

2 Background

2.1 Social robotics therapy and ASC

In recent years the use of social robots for the diagnosis and therapeutic assistance of children and young people with ASC has received an increasing amount of attention [19–22]. Although to date, research conducted on the diagnostic use/utility of robots is quite limited [23, 24], a growing number of studies have examined the use of robots as mediators in the therapy of children with ASC, primarily focusing on the areas of: children's eye contact, self-initiated interactions, collaboration, verbal communication, turn-taking, imitation, triadic interactions, emotion recognition and joint attention [25–28].

Research suggests that very often children with ASC proactively initiate interactions with social robots [29]. Studies from Duquette et al. [30] and Francois et al. [31] highlighted the role of robots in assisting children to initiate social interactions by creating a predictable environment in which they feel it is safe to play. Kozima et al. [32] reported that pre-school children with ASC were en-

gaged in spontaneous dyadic interactions with the robot, and later in triadic interactions, the children shared their pleasure from interacting with the robot with their parents/caregivers and other children. Findings from studies of Lee et al. [33], Shamsuddin et al. [34] and Wainer et al. [18] highlighted children's higher scores in robotic therapy sessions in eye contact and facial expression related behaviours. Tapus et al. [35] revealed that pre-school children with ASC showed increased levels of eye gaze (the duration the child gazed at the interaction partner's face or arms) and smile/laughter behaviours when interacting with the robot rather than when interacting with a human. In addition, Simut et al. [36] reported that children with ASC showed increased eye contact with the social robot compared to the human partner during a play task.

Further positive effects have been shown in children's language and communication skills [37]. Research by Kim et al. [38] indicated that children who interacted with a social robot produced more speech, while their speech was directed not only towards the robot but also towards the adult partner. Further evidence in this field has shown some positive effects in terms of turn-taking for children with ASC via play tasks facilitated by a robot [15, 39]. Additionally, findings from Kaboski et al. [40] revealed that social interactions with robots significantly decreased social anxiety in children with ASC.

In addition, robots that produce repetitive behaviours appear to stimulate children's imitation skills and assist their understanding of social behaviours. Boccanfuso and O'Kane [41] highlighted that children with ASC would imitate the pose of the robot despite its simplistic appearance. Earlier evidence from the AuRoRa project and specifically from Davis et al. [42] reported that children with ASC imitated the Robota robot's movements (movement of body parts, such as arms), while Duquette et al. [43] showed that children would very often imitate the robot's facial expressions rather than the human partner involved in the experiment.

2.2 Robotic models for ASC therapy

To date, various robotic platforms with different appearances, features and functions, have been developed by clinicians and researchers who share knowledge from areas such as clinical psychology and engineering [44]. Very often each study investigating the use of robots for children with ASC focuses on developing a specific aspect of the Human-Robot Interaction (HRI) support and improve specific skills of the children interacting with the robot such as:

- Emotion recognition
- Turn taking skills
- Collaboration
- Imitation skills
- Tactile interaction

Research in robotic therapy for children with ASC seems to suggest that some children do respond well to various kinds of robots, from doll like robots to mobile robots [45, 46]. The AuRoRa project utilised different mobile and humanoid robots (e.g. Labo-1, Robota doll, Kaspar) which engaged children with ASC in interactive play tasks and social interactions [45, 47]. Various studies have explored the use of social robots with different appearances, for example a cartoonish appearance, such as Tito [30] and Keepon [32, 48], an animal form, such as PABI [49, 50], Probo [51] or Pleo [38] or a humanoid form, such as Nao [40, 52] or Zeno [53] when developing therapies that encourage communication skills and interactions in children with ASC. Findings from Ricks and Colton [54] revealed that a humanoid robot can elicit better engagement during a therapy session and generalisation of the skills learned by a child than a non-humanoid robot. An earlier study by Dautenhahn and Werry [20] reported individual differences in terms of the preferences of children with ASC between robots and non-robotic toys. Evidence from Robins et al. [55] showed that a humanoid robot with a simplistic appearance can increase children's interaction and highlighted the potential benefits of using robots with a simple appearance for therapeutic sessions. Studies by Bird et al. [56] and Pierno et al. [57] revealed that children with ASC showed a faster response when cued by the robot's movement rather than a human, while Lee et al. [33] demonstrated that facial expression of the robots elicited a better response compared to prompting by humans.

2.3 Kaspar the social robot

The Adaptive Systems Research Group at the University of Hertfordshire has developed a child-sized, interactive and expressive humanoid robot called Kaspar. Kaspar can move its arms, head and torso, blink, make facial expressions (e.g. smile when 'happy') and vocalise pre-programmed sounds and words, sentences or words by using a neutral human voice. Note, for the purpose of this study all of Kaspar's speech was translated into Greek. In the ROBOSKIN project, the development of robotic skin for tactile feedback was added to Kaspar in order to support and improve HRI's in the domain of robot-assisted play [17, 58]. Alongside, tactile play scenarios were developed [59].

Kaspar has the capacity to operate in a semi-autonomous manner when the professional/therapist or the child controls the robot via a wireless keypad to perform various pre-programmed actions that can be performed by Kaspar (e.g. sad expression). Other actions are triggered when the robot's tactile sensors placed on different parts of its body are activated (e.g. when touching or tickling hands or feet). The Kaspar robot used in the study described in this paper was operated in a semi-autonomous manner and was the most recent developed version of the robot created by the research team. The robot was equipped with 22 Degrees Of Freedom (DOF) and 15 pressures sensors placed around the body of the robot. Further details of Kaspar can be found in previous publications [15, 16].

The Kaspar robot has been used successfully in many studies to improve the development of communication and social skills in children with ASC. To date, Kaspar has been used in turn-taking and imitation games with children diagnosed with ASC [15], capturing temporal and spatial features of tactile interactions [58], examining dyadic interactions [28] and as a mediator in interviews with children [60, 61]. Earlier findings by Robins et al. [10] demonstrated how Kaspar had been used in long-term studies and one off trials, to support children with autism, focusing particularly on three cases. The paper illustrates how some children with ASC are willing to interact with humanoid robots such as Kaspar, and that robots can be used to encourage social interaction and communication. A later study by Wainer et al. [18] designed and tested a collaborative triadic interaction game using the Kaspar robot. In this long-term study which involved 23 sessions for each child, the games were designed to have in the intervention phase pairs of children with ASC playing games with Kaspar, each participant (including the robot) was an equal player in the game. In the study Kaspar operated fully autonomously, and used information on the state of the game and behaviour of the children to engage, motivate, encourage and advise pairs of children playing an imitation game. The study demonstrates how a humanoid robot can be used to foster and support collaborative play among children with ASC. Detailed observational analyses of the children's behaviours indicated that different pairs of children with autism showed improved social and communicative behaviours in playing with each other after they played as pairs with the robot Kaspar compared to before they did so.

Taking into consideration the promising results from studies conducted with the robot Kaspar in UK schools, the

study outlined in this paper aimed to examine if these results can be replicated in a different cultural environment. Specifically, the study explored how Kaspar can be used in a Greek school setting to support the development of the social and communication skills of children with ASC and how teachers/professionals based in the Greek school environment believe Kaspar could be used as a (therapeutic) tool in the classroom in order to support children's communication skills and social engagement.

2.4 Aims and design of the study

The aims of the study outlined in this paper were as follows:

1. Examine the impact of play sessions with Kaspar on children's communication and social skills in a Greek setting.
2. Explore the possible ways that Kaspar can be used as a (therapeutic) tool for teachers/professionals in the classroom in order to efficiently support children's communication and social skills in a Greek setting.

In order to evaluate the impact that the sessions with the robot had on children, the mixed-method design of the study incorporated a range of measures that were used to elicit several perspectives (more details are included in section 2.4 below). Pre- and post- evaluation questionnaires were completed by the children's teachers before and after the study had taken place to establish if the teachers had noticed any differences in the children after they had completed the sessions with the robot. The school's psychologist and teachers of the children who participated were interviewed after the study to identify if the interactions with the robot had an effect on children's communication and social skills, as well as the possible ways that Kaspar could be used as a (therapeutic) tool for teachers/professionals in the classroom in order to support these skills. Moreover, behavioural coding and analysis of the video-recorded sessions with the children interacting with Kaspar were performed for all sessions, in order to examine the children's interactions and engagement with the robot.

3 Methods

3.1 Participants

The study was conducted in a special primary school funded by the Greek state and located in the West district of Athens. The school offered educational provision only to children diagnosed with ASC and Cognitive Disabilities.

The sample of the study consisted of 7 children, 5 boys and 2 girls, aged from 7 to 11 years old, diagnosed with ASC by the Greek public health services and KEDDY (Centres for Differential Diagnosis, Diagnosis and Support), based on DSM-IV-TR criteria [62]. The severity of the children's disorder ranged from high to low functioning Autism. In addition, one of the children had severe language difficulties, while another child was non-verbal.

The children's teachers (5 teachers in total) did not take part in all the play sessions with the robot but they were asked to attend one of them. However, the school's psychologist attended the children's first two play sessions (with the exception of P03 where the psychologist attended the first 5 sessions because this child was low functioning and non-verbal) as a non-participant observer in order to assist with their familiarisation with Kaspar and the researcher.

In addition to voluntary consent given by the head teacher, psychologist, teachers and parents, prior to the first play session it was explained to the children, with the school's staff assistance, that they were going to spend some time playing with a robot. At the beginning of every play session children were asked if they wanted to play with Kaspar. Children who were non-verbal or had severe language problems were able to signal a wish for non-participation or withdrawal at any time during the study, for example by showing signs of discomfort or pointing the exit door when in the play session room. However, this did not happen in any play session, as they were always willing to play with Kaspar.

3.2 Setting

The play sessions with the robot took place in a quiet room in the school and were conducted by the researcher (first author of this article). By running the study in the children's school we minimised any anxiety issues that could have arisen if the location was unfamiliar to the children. Additionally, this ensured the study's ecological validity and may have assisted with the generalisation of any effects of the interactions with the robot.

The room was minimally furnished so as to minimise children's distractions during the play sessions. Kaspar was placed on a table where the child would sit facing the robot, whilst the researcher was sitting next to the table, near the child. Two video cameras were placed in the play sessions room: one camera was placed close to the robot facing the child in order to capture the facial expressions of the child and one was placed lateral to the scene in order to record a wider view of the interactions between the child, Kaspar and the researcher (Figure 1).
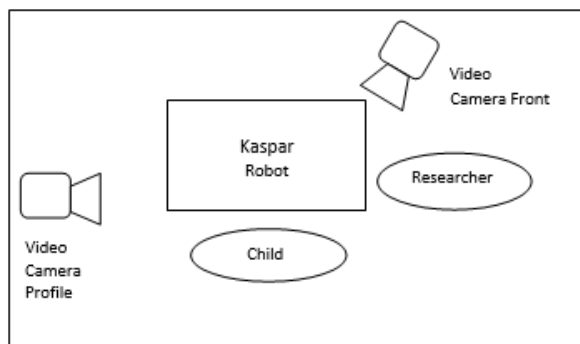

Figure 1: The play session setting.

3.3 Procedure

Each child received 10 to 15 minutes of individual play sessions with Kaspar and the researcher, two or three times a week (depending on the child's school timetable) for 10 weeks (Table 1). Additionally, 2 of the children who took part in the study, co-attended 3 sessions with the robot and worked as a pair (i.e. child P04 and child P06). In total 111 sessions were run during the study period.

Apart from the first two play sessions, where the school's psychologist was also present in order to familiarise the children with the sessions' context, and one 'informative' session that each teacher had been asked to attend in order to be introduced to the sessions' framework, the interactions involved only the children, Kaspar and the researcher (Figure 2).

Before the sessions, Kaspar was placed on a table and connected to a laptop. The robot was operated remotely via a wireless keypad (specially programmed) either by the researcher or by the child, depending on the play scenario and the child's ability.

It is noteworthy to mention that prior to the beginning of the children's first session, the researcher introduced Kaspar explicitly as a robot by pointing out specific

Figure 2: Play sessions with Kaspar involving children with ASC.

features, such as the robotic parts visible in the neck etc. The researcher then asked the children if they could identify any other robotic parts, and with some of the children this raised further comments and questions by them (e.g. 'The robot wears trousers like I do' or 'Does Kaspar have teeth?').

The sessions were based on pre-programmed play scenarios that have been developed and used successfully in previous studies with Kaspar [59]. The play scenarios, which were based on specific therapeutic or educational objectives (i.e. Cause and Effect, Imitation and Turntaking² see below), involved different modalities of interactions and engagement, and aimed to provide a starting point for the interaction, as the researcher was not expected to follow them slavishly, but to build upon them. In addition, the play scenarios gradually increased in complexity between sessions, from very simple interactions to more complex interactions.

Firstly every session started with Kaspar saying 'Hello' to the child with the aim of getting the child to respond back to Kaspar, which very often they did. This was followed by a short familiarisation/repetition, for example the 'Cause and Effect' game, where the child explored briefly the various robot reactions to tactile interaction. During the session, the child could play the 'Imitation' game by exploring the effect of pressing the keys on the keypad, identifying (naming) and copying Kaspar's postures or imitating Kaspar's songs by singing along. The researcher ensured that each session finished on a 'happy

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2 The play scenarios included: (a) Cause and Effect games that require an awareness of one's own body; (b) Imitation games that require the ability to recognize and imitate partial or complete sequences of movements; and (c) Turn taking games based on dyadic or triadic interactions defined as collaboration and exchange.

Table 1: Number of play sessions with Kaspar per child.

Child ID	Number of individual sessions	Number of pair sessions	Total number of sessions
Child P01	18	0	18
Child P02	17	0	17
Child P03	12	0	12
Child P04	12	3	15
Child P05	18	0	18
Child P06	12	3	15
Child P07	16	0	16

note' by providing the activity or robot behaviour that each child enjoyed most. Similarly, during the play sessions when the children got distracted the researcher encouraged them to take an active part by providing their most liked 'fun' activity. Nevertheless, when the children did not respond to an activity or could not understand what they have been asked to do, the researcher encouraged them either by repeating the activity or by guiding them on how to do it.

3.4 Measures

A range of methods were used in order to identify the impact of the play sessions with Kaspar on children's social and communication skills, and to investigate how Kaspar can be used as a (therapeutic) tool for teachers/professionals in the classroom in order to support these skills.

Pre-Post Evaluation Questionnaire: The Evaluation Questionnaire that was used was developed as a tool for evaluating the potential improvements of children who interacted with the robot, through the detailed assessment of their competences in the following five developmental areas: Sensory (14 items), Communication and Interaction (54 items), Social and Emotional (17 items), Cognitive (32 items) and Motor (5 items). It is based on a review of a variety of standardized diagnostic assessment tools, such as the Vineland Scale of Adaptive Behaviour [63], Communication and Symbolic Behaviour Scales Development Profile [64] and Peabody Picture Vocabulary Test [65].

The questionnaire (available from the Kaspar research team), included aspects that were both positive and negative indicators (contra-indications), while each item was rated on a 5-point scale, ranging from 'Never' 1 to 'Always' 5. Given that the questionnaire was administered to Greek teachers, it was translated into Greek by a bilingual expert in the field of Special Education Needs (SEN) and back into

English, while the phrase-conceptual differences were resolved by consensus. It was provided to the teachers at the beginning (1st week) and at the end (10th week) of the study, in order to identify any improvements of the children's sensory, communication and interaction, social and emotional, cognitive and motor skills after the interactions with Kaspar.

Video-recording of the play sessions: Each play session with the robot lasted 10 to 15 minutes and was video-recorded in order to examine the children's interactions and engagement with Kaspar, and to identify if the therapeutic or educational objectives were met in the sessions.

Interviews with the school's psychologist and teachers: Using semi structured, face-to-face, individual interviews of the school's psychologist and the teachers of children who attended the play sessions with Kaspar, enabled the selection of essential data. Specifically, the interviews focused on identifying the influence of the interactions with the robot on children's communication and social skills, as well as the possible ways that Kaspar can be used as a (therapeutic) tool for teachers/professionals in the classroom in order to support these skills. Additional information about further improvements or suggestions for Kaspar were also sought by the interviewer.

The interviews (6 in total) took place in the play session room, at a time convenient to the teachers' school timetable, while their duration was approximately 20 to 25 minutes. They were audio recorded, and only one teacher requested to keep her responses in the form of field notes.

3.5 Ethics

This study received ethical approval by the Faculty of Science and Technology Ethics Committee of the University of Hertfordshire (Ethics Reference Number aCOM/PG/UH/00061) and the Greek Ministry of Education, Research and Religious Affairs. Fully informed, vol-

untary consent was obtained by the school's head teacher, the school's psychologist, teachers and parents. Prior to beginning of the study, the children were asked if they wanted to play with Kaspar, explaining to them what their participation would entail. At the beginning of every play session children were also asked if they want to play with Kaspar. Children who were non-verbal or had severe language problems were able to signal a wish for non-participation or withdrawal at any time during the study. In addition, personal information such as children's or teachers' names were replaced by pseudonyms to ensure participants' anonymity and confidentiality of responses.

4 Data analysis and results

4.1 Analysis approach

Both the evaluation questionnaires and the behavioural measurements output were analysed to consider whether or not there was a marked change in the behaviours of the children in the study.

The evaluation questionnaires were examined by attempting to establish whether or not there was a difference in how the teachers viewed the behaviours of the child between the beginning and the end of the study. This was assessed using a non-parametric Wilcoxon-signed-rank test.

The behavioural data was also examined in terms of change between the first and the last session, using signed-rank tests. In addition, the analysis also addressed whether or not such differences were due to an overall trend of change between all the sessions as well, to ensure that specific effects related to the first and/or last session were not the sole cause for such differences. The measure for these trends was the Mann-Kendall tau-coefficient for monotonic trends [66]. All analysis was performed in R [67] with the additional package Kendall [68].

Children with Autism are a heterogenous group, and the role of idiosyncratic factors on any intervention effects are often noted in the literature; children with autism are often more vulnerable to situational stressors, both in terms of frequency and magnitude, than typically developing children [69]. This makes it difficult to generalise about changes in the behaviour of one child between sessions, let alone across a group of children. Often this type of noise is controlled by classical power analysis [70] and including a (usually larger) number of cases to account for this noise.

However, in studies such as this, this is not usually possible. Participant numbers are often restricted due to the amount of time and resources required to obtain data

from one case. As classical power analysis becomes difficult to utilise, inferential statistics likewise become less useful for the reader and other researchers in the field, and over-reliance on inferential statistics in such cases is, by some, considered to be one of the causes of the so-called "reproducibility crisis" [71], and can be mitigated by more rigorous attention to descriptive statistics and effect sizes. Because of this, the primary emphasis in the behavioural analysis lies in reporting effect sizes in a standardised fashion. In addition, the dual focus on relative change from the first to the last session, and the consistency of such trends, allows for a more robust examination of these changes than focusing on either. For the results relying on Mann-Kendall's tau, we have used the method proposed by [72] for calculating Cohen's d, using the suggested correction for small sample sizes, while for the Wilcoxon-tests we have computed the effect size measure based on the Z-statistic of the test as suggested by Cohen [70]. Effect sizes have been categorised into "small", "medium" and "large" as per Cohen [70] (Table 2).

4.2 Results from the evaluation questionnaires

This analysis shows the changes in responses to the assessment questionnaires for each child in the study. These questionnaires, as previously discussed, consisted of 123 items regarding 5 domains:
1. Sensory Development
2. Communication & Interaction
3. Cognitive Development
4. Social & Emotional Development
5. Psychomotor Development

The responses were condensed into 5 scales, one for each domain, and the analysis was conducted on these scales. The heterogeneous nature of Autism Spectrum Conditions and the small size of the sample suggested that the use of very broad categories was considered appropriate.
The results can be found in Table 2 and Figure 3.

Both Table 2 and Figure 3 suggest small changes with regards to these domain scales with moderate effect sizes to the Communication and the Psychomotor Function domains. The improvement in the Communication domain approached significance.

Table 2: Changes across the developmental domains across the study.

	Median	Min	Max	P	Cohen's d	Effect size
Sensory Development	-0.14	-1.14	0.50	0.58	0.21	Small
Communication	0.44	-0.22	1.09	0.08	0.67	Moderate
Cognitive Development	0.31	-0.72	0.50	0.93	0.03	Small
Social and Emotional	0.18	-0.71	0.59	0.55	0.22	Small
Psychomotor	0.20	0.00	1.00	0.05	0.73	Moderate
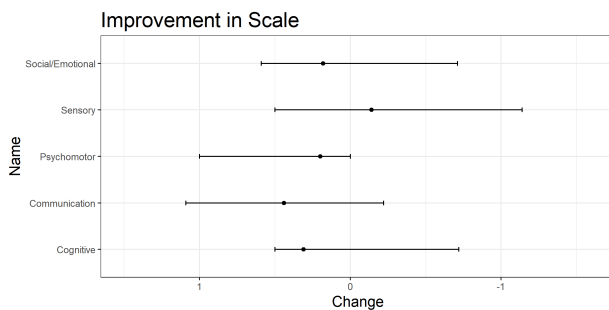
Figure 3: Improvement across the 5 developmental domains (points represent the median whilst bars represent the range).

4.3 Behaviour data

4.3.1 Overview of the data

The Data consists of output from 111 sessions, of these sessions 6 were joint and will not be considered here. There were 7 participants interacting individually with the robot. Throughout these sessions a set of behaviours were coded in terms of occurrences (number of instances where this behaviour was displayed) and the duration of these occurrence (how long in total these behaviours occur for).
The coded behaviours are detailed below. For a brief description of the coding for each behaviour please refer to the appendix.

1. Eye Gaze
2. Focus – Attention
3. Gesture recognition
4. Imitation Prompted
5. Imitation Unprompted
6. Initiating – Seeking affection
7. Seeking a response
8. Self-initiated play
9. Speech Prompted
10. Speech Unprompted

The analysis of the *video footage* from the play sessions aimed to examine the children's interactions and engagement with Kaspar, and to identify the therapeutic or edu-

cational objectives met in the sessions, which was based on established methods used in studies within the field of social robotics for the analysis of video recordings [12, 73]. Specifically, the 111 videos were analysed via the Observer XT 10.5 software [74].

Because there is the possibility that observations made from the video footage are subjective and the observer may portray their own perceptions, an inter-rater reliability analysis of video data (10% of randomly selected video footage) was carried out using a 10 millisecond tolerance window comparing all events. Independent ratings and coding was conducted by an observer/coder who was not involved in the study, was not part of the research team and did not meet any of the participants. The analysis, via The Observer XT software revealed that the overall Cohen's Kappa Measure of Agreement value was .81, showing very good agreement and consistency among observational ratings provided by both coders [75]. The Observer XT software compares the start/stop times of the events for each coder and if these events are within the 10 millisecond window of each other agreement has been achieved, if not this is considered to be a disagreement. Details of the inter-rater reliability agreement for each of the coded videos can be seen in Table 3 below.

4.3.2 Overall change across study

Table 4 below shows the overall changes between the first and last session per behaviour observed. This suggests that there was moderate effect for the Focus – Attention, and the Seeking a response behaviours in that they increased in relative duration. These moderate effects were not significant.

In addition, there was tendency which suggested an increase in the duration of Prompted Speech, this effect was approaching significance. There were large effects for Self-initiated play and Unprompted Speech. These suggested an overall decrease in the relative duration of these behaviours, and it was significant for Unprompted Speech, and approaching significance for Self-initiated play.

Table 3: Inter-Rater Reliability analysis of the video footage data.

Summed statistics	P02-S07	P02-S05	P03-S11	P04-S08	P04-S14	P05-S13	P05-S15	P06-S04	P06-S08	P07-S11	P07-S13	P01-S13	P01-S16	P03-S04	Overall
Agreements	102	127	36	162	216	146	200	136	118	248	255	203	225	85	2259
Disagreements	10	27	21	30	26	36	19	26	23	45	76	73	15	10	437
Proportion of agreements	0.91	0.82	0.63	0.84	0.89	0.8	0.91	0.84	0.84	0.85	0.77	0.74	0.94	0.89	0.83
Kappa	0.9	0.81	0.51	0.83	0.88	0.78	0.91	0.82	0.82	0.83	0.74	0.71	0.93	0.86	0.81
Rho	0.99	0.97	0.94	0.99	0.99	0.99	0.97	0.93	0.97	1	0.99	0.99	1	0.98	0.98

Table 4: Median changes in duration between first and last session behaviour observed.

	Median	p.value	N	Cohen's d	Effect size
Eye Gaze	0	>.99	2	0	Small
Focus – Attention	0.06	0.156	6	0.58	Moderate
Gesture recognition	0.13	0.312	5	0.45	Small
Imitation Prompted	-0.01	0.812	5	0.11	Small
Imitation Unprompted	0.06	0.312	5	0.45	Small
Initiating – Seeking affection	-0.01	>.99	2	0	Small
Seeking a response	0.02	0.219	6	0.5	Moderate
Self-initiated play	-0.06	0.031*	6	0.88	Large
Speech Prompted	0.03	0.062	5	0.83	Large
Speech Unprompted	-0.03	0.062	5	0.83	Large

4.3.3 Consistent trends across the study

Table 5 shows the consistency of trends across the study. There were large effects for Unprompted Imitation and Prompted Speech, suggesting that these behaviours increased consistently between sessions, these effects were significant. There was a moderate effect for the Gesture recognition, suggesting a consistent increase in the relative duration of this behaviour as well. This effect was significant. There was a small, yet significant result for Self-initiated play, suggesting that there was a consistent decrease in this behaviour across the sessions.

4.3.4 Individual results

The above results, however, did not take into account the heterogeneous nature of the sample as illustrated by the graphs below. Because of this, we further investigated the trends for the individual children for the behaviours that showed a consistent trend throughout the study. Table 6 shows that the trends varied quite dramatically by behaviour and child. The most telling trend was that for unprompted imitation. All of the children showed a positive trend for increase, this effect was large for two of the children, and moderate for one child. Similarly for un-

prompted speech, while 3 of the 6 children exhibiting this behaviour showed a *significantly* consistent increase, the -coefficients for all of the children were positive. This suggests that these effects were consistent across the children.

4.3.5 Gesture recognition

Four of the six children displayed a consistent positive change in Gesture recognition, with a large effect size in the relative durations of engaging in this game. One of the children P02, however, had a small negative for this behaviour (Figure 4).
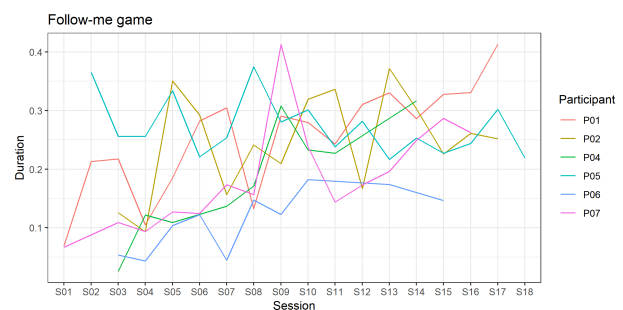

Figure 4: Gesture recognition changes for children across the play sessions.

Table 5: Consistency of trends.

Behaviour	tau	p.value	Cohens d	Effect size
Eye Gaze	NA	NA	NA	NA
Focus – Attention	0.26	0.150	0.30	Small
Gesture recognition	0.40	0.023*	0.51	Moderate
Imitation Prompted	0.24	0.172	0.28	Small
Imitation Unprompted	0.60	0.001*	0.96	Large
Initiating – Seeking affection	0.17	0.443	0.19	Small
Seeking a response	0.07	0.705	0.08	Small
Self-initiated play	-0.39	0.028	-0.49	Small
Speech Prompted	0.69	0.001*	1.32	Large
Speech Unprompted	-0.24	0.173	-0.28	Small

Table 6: Trends for Follow-me, Unprompted Imitation, Self-initiated play and Prompted Speech.

Participant	Follow-me				Unprompted Imitation			
	tau	d	Effect size	Valid sessions	tau	d	Effect size	Valid sessions
P01	0.676	.84	Large	17	0.059	.04	Small	17
P02	-0.309	.25	Small	17	0.059	.04	Small	17
P03	NA	NA	NA		0.758	1.39	Large	12
P04	0.676	.84	Large	17	0.758	1.39	Large	12
P05	0.676	.84	Large	17	0.373	.30	Small	18
P06	0.219	.18	Small	15	0.448	.42	Small	15
P07	0.676	.89	Large	15	0.567	.60	Moderate	16

Participant	Self-initiated Play				Prompted Speech			
	tau	d	Effect size	Valid sessions	tau	d	Effect size	Valid sessions
P01	-0.500	.48	Small	16	0.397	.34	Small	17
P02	-0.538	.57	Moderate	14	0.426	.38	Small	17
P03	NA	NA	NA	NA	NA	NA	NA	NA
P04	-0.545	.64	Moderate	12	0.273	.25	Small	12
P05	-0.206	.16	Small	17	0.216	.16	Small	18
P06	-0.333	.32	Small	12	0.303	.28	Small	12
P07	0.150	.12	Small	16	0.417	.36	Small	16

4.3.6 Unprompted Imitation

Five of the children showed a consistent positive change in terms of Unprompted Imitation across the study, while two of the children (P01 and P02) did not (Figure 5). This effect was large for two of the children, and moderate for one child.

4.3.7 Self-initiated play

All of the children show a decrease in the self-initiated play behaviour, and this was a moderate effect for two, but small for the rest of the sample (Figure 6).

4.3.8 Prompted Speech

Three of the 6 children who displayed the Prompted Speech behaviour in more than one session, exhibited a small, yet positive trend in terms of relative durations for this behaviour (Figure 7).

4.4 Interview findings

Thematic analysis was selected as the most appropriate method for analysing the data from interviews. Considering that it is a widely applied method for identifying, analysing and reporting themes within data [76], in this
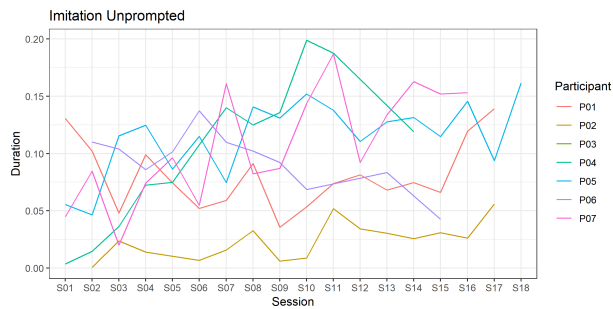
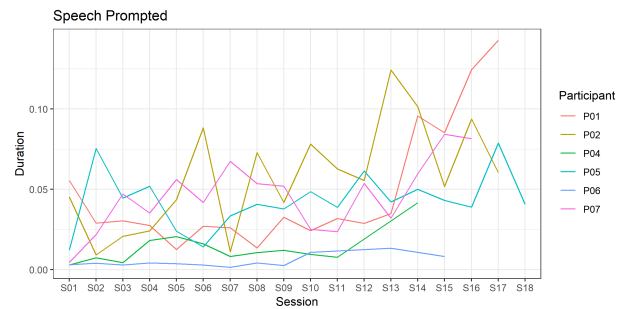**Figure 5:** Unprompted Imitation changes for children across the play sessions.

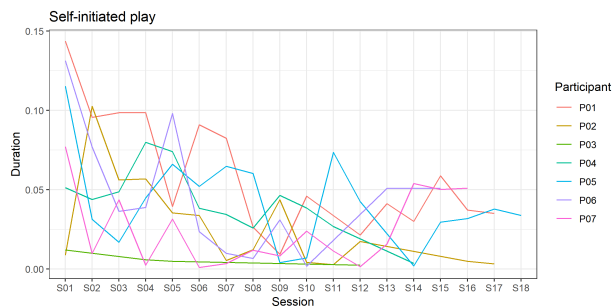**Figure 7:** Prompted Speech changes for children across the play sessions.

Figure 6: Self-initiated play changes for children across the play sessions.

particular study thematic analysis enabled us to explore (i) the impact of children's play sessions with Kaspar on their communication and social skills, and (ii) the ways that Kaspar can be used as a (therapeutic) tool for teachers/professionals in the classroom context in order to efficiently support these skills. The data from the school's psychologist and the teachers' interviews (6 interviews in total) were translated and transcribed, entered into a word file and analysed based on the above two main themes/points (i.e. impact of sessions on children's social and communication skills – possible ways for using Kaspar as a (therapeutic) tool in the classroom context for supporting children's skills).

The data revealed encouraging information about the impact of interactions with Kaspar on communication and social skills for some children. Specifically, the majority of the interviewees highlighted Kaspar's special and innovative role in encouraging the social and communication skills of children diagnosed with ASC ('*…I believe the interaction with the robot helped both children…the experience and the contact, question-response, movement, there is no case that it didn't help the children*' teacher of children P03 and P07 – '*In terms of communication I can say that I see a difference…*' teacher of child P05).

Further to this, Kaspar's positive influence on children's social and emotional development was underlined by another teacher (teacher of children P04 and P06 '*Kaspar contributes in a positive way to the development, the social development of the child, the aspect of psychomobility*').

The teachers also emphasised the benefits of the children imitating the robot's speech, especially for the children who experience severe language problems ('*I believe that the sessions will be important for children who have speech/language problems, as [she mentions the child's name] has, who although knows all the letters because of his speech and language problems it's very difficult for him to read. So, I believe that the interactions with Kaspar would help him more*' teacher of child P05). Additionally, two of the teachers underlined the influence of Kaspar's presence on children's focus/attention as based on their experience from attending one of the sessions, when the robot was able to capture and maintain children's attention during the play session (teacher of child P04 '*…from the interaction I saw between [name of the child] and Kaspar, she focused on the robot, there was a direct interaction with the robot, direct eye contact, watching the robot*' and teacher of child P04 '*she works more positively and the robot supports her focus*').

Regarding the ways that Kaspar can be used as a tool for teachers/professionals in the classroom in order to support children's social and communication skills, the interviewees provided some interesting suggestions. The play scenarios encouraging the expression of emotions and imitation of the robot's wording were highly inspiring for the teachers who suggested that in the classroom context Kaspar could assist children's learning via imitation, for example phonetics or social cues ('*…the child can repeat in this way to associate something that they see with something that they hear and to repeat by imitating Kaspar*' teacher of children P04 and P06). Further suggestions were made by another teacher who suggested that

Kaspar could also help children learn maths, while individualising the robot's programme based on children's needs, which could also have some positive effects on their learning (teacher of child P02 *'Maybe you could add something to teach maths, sums/subtractions. Maybe the robot's programme could be individualised based on each pupil's needs, difficulties, skills, this point could be added'*).

Although the majority of teachers and the psychologist highlighted the encouragement that Kaspar can provide on the children's social and communication skills, they suggested that additional play sessions with the robot could be more helpful for the children. Working with the robot in the classroom context would be an interesting task for them, as according to the school's psychologist *'we would like to have Kaspar and it could be included in the classroom's programme to attract children's attention to educational tasks'*. The interviewees expressed their eagerness to have Kaspar in their classroom and include the robot in their everyday tasks and activities, either in groups or individually, and if possible, to permanently obtain Kaspar in the near future (*'…what I would like ideally, is to have Kaspar in the school, to have Kaspar in the school permanently…'* teacher of child P05 – *'I'm sure that the robot could be part of a classroom, not could be, it should be, it's necessary, it's a pleasant way to teach something to the children'* teacher of child P01).

5 Discussion

In this current study we aimed to (1) Examine the impact of play sessions with Kaspar on children's communication and social skills and (2) Explore the possible ways that Kaspar can be used as a (therapeutic) tool for teachers/professionals in the classroom in order to efficiently support children's communication and social skills. To address these, various measures were used in order to explore different perspectives. Pre- and post- evaluation questionnaires completed by the children's teachers, enabled us to identify a marked improvement in the children's communication development throughout the period. Behavioural analysis of the 111 video recorded sessions with the robot enabled us to explore children's interactions and engagement with Kaspar over the many sessions, and added to the findings regarding the impact of these interactions on specific children. Parts of the findings from children's behaviour analysis are in agreement with teachers' ratings in the questionnaire, revealing improvements for specific children in certain areas, in particular communication and social development. In addi-

tion, the school's staff (i.e. psychologist and the children's teachers) interviews added to the above evidence, and offered important information about the possible ways that Kaspar can be used as a (therapeutic) tool for teachers/professionals in the classroom, in order to support children's communication and social skills.

Similar to previous studies conducted with Kaspar, that involved turn-taking and imitation games with children diagnosed with ASC [15, 58], this study used a number of play scenarios focusing on cause and effect, imitation and turn-taking games. Generally the severity of the children's condition did impact on the interactions with the robot which is to be expected. In the cases where the children were lower functioning the sessions were much more difficult to conduct and it took much longer to reach the goals of the games. This is in line with our experience in the UK. The gender of the children did not have an impact on the interactions in the sessions.

In particular P03 was reluctant to sit down for very long but as this child became more familiar with the robot he was keen to try out the keypad on his own whilst watching Kaspar's movements towards the later sessions. Another child P04 initially would not sit next to Kaspar, despite the prompts of the experimenter and the psychologist, but equally she did not want to leave the room either so initially she attended the sessions keeping a distance from the robot. However, during the 4th session after further prompting from the experimenter, she decided to sit down next to the robot and from that session forward she was always sitting down and was looking forward when attending the sessions.

Although one could argue that there were some discrepancies between teachers' responses regarding the impact of sessions with Kaspar for these children and their ratings in the Evaluation Questionnaire, which, for some children, evidenced no improvement, it should be highlighted that different social research methods are known to generate different responses (e.g. observations and closed-ended instruments). Following a mixed methods approach, which is an 'inclusive, pluralistic and complementary' form of research [77, p. 17], enabled us to explore the findings from behavioural analysis, teachers' interview responses and their ratings in the questionnaire, identify possible contradictions and get a more detailed overview of the impact of play sessions with the robot on children's social and communication skills.

The findings revealed that children's ability to imitate the robot's poses, sequence of movements and facial expressions improved slightly, which is consistent with the literature in this field. Robins et al. [55], who used a small humanoid doll robot called Robota and a life-sized 'The-

atrical Robot' and Boccanfuso and O'Kane [41] who used CHARLIE, a robot equipped with a head and two arms, showed that children with ASC imitated the robot's poses despite having a simplistic appearance.

In addition, the analysis of children's behaviour (from video footage) revealed a consistent positive change in the amount of unprompted imitation across the sessions with Kaspar for five out of seven children (P03, P04, P05, P06 and P07). Bird et al. [56] and Cook et al. [78] examined the imitation of non-intentional movements in adults with ASC and control groups whilst Pierno et al. [57] explored the imitation of goal-directed action (with children diagnosed with ASC and a control group) using a human or a robotic arm model, but these studies were limited in that they did not examine the imitation of facial expressions. Considering the importance of developing the ability to imitate facial expressions in ASC therapy this current study also explored this point. The above findings from the behaviour analysis revealed not only did the children's imitation of Kaspar's postures and sequence of movements improve, but children's unprompted imitation of the robot's facial expressions (e.g. 'happy' or 'sad') also increased. This is in line with the evidence from Duquette et al. [30], who used the robot Tito with a sample of four children diagnosed with low-functioning ASC and showed more imitations of facial expression of joy (i.e. smiling) for children with ASC who interacted with a robot compared to the children who interacted with the experimenter.

Interviews with the school staff highlighted the importance of children's imitation of Kaspar's speech, considering the serious language problems that the children experience (Teacher of child P05 *'[she mentions the child's name] who although knows all the letters because of his speech and language problems it's very difficult for him to read. So, I believe that the interactions with Kaspar would help him more').* Additionally, in terms of children's improvement of speech/language skills, the behaviour analysis data revealed a positive trend in the amount of prompted speech across the sessions with Kaspar for three children (P01, P02 and P07). Similar to these findings aspects of the studies by Lee et al. [33] with the ifbot robot and Shamsuddin et al. [34] who used NAO, showed that participants achieved higher scores in robotic sessions with tasks including verbal response, while the evidence from Kim et al. [38], who used the socially expressive robot PLEO, revealed that 24 participants with ASC expressed more spontaneous utterances in the robot condition (RC) than in human condition (HC).

Although the evidence from studies in the domain of attention or joint attention is quite controversial, a number of studies have shown that children with ASC 'turn their at-

tention to the robot' [9, p. 175]. In the studies of Michaud et al. [79] and Duquette et al. [30], who used Roball and Tito respectively, despite their small number of participants and the non-statistically significant results, qualitative analysis revealed that participants with ASC directed their attention towards the robot. In line with these findings our study showed that Kaspar had a slight positive influence on focus/attention during the sessions for some of the children 9 (Table 5). In particular, part of the analysis from the pre- and post- evaluation questionnaire indicated that four children (P01, P02, P05 and P06) showed a slight improvement in their mean scores in the attention domain of the 'Cognitive Development' area. In addition, the data from the interviews with the school staff showed that two of the teachers highlighted the fact that the robot captured and maintained the children's focus/attention during the play sessions. Providing further evidence in terms of children's eye gaze/contact during interactions with a robot, Tapus et al. [35] and Simut et al. [36], using the NAO and Probo robots respectively, revealed that children with ASC had more eye contact with the robot during a play task rather than with a human. Nevertheless, given that the children's behaviour analysis did not reveal any changes for the majority of children in the duration of their focus/attention towards the robot during the play sessions (only child P04 showed a positive change), the above findings should be regarded and interpreted with careful consideration.

Drawing on the study of Lee and Obinata [80] who reported that the Parlo robot could be a more effective stimulus for children with ASC than a computer display or a parent, the evidence from the school's psychologist and some of the teachers in this current study, underlined the robot's role as a stimulus for children with ASC. Specifically, some of the interviewees highlighted Kaspar's role in attracting and maintaining children's attention, and suggested that this could be transferred to a classroom context, if Kaspar was part of everyday teaching (school's psychologist [Kaspar] *'...could be included in the classroom's programme to attract children's attention in educational tasks'* - teacher of child P01 *'I'm sure that the robot could be part of a classroom, not could be, it should be, it's necessary, it's a pleasant way to teach something to the children').*

In line with the study of Fridin and Belokopytov [81] which revealed preschool and elementary teachers' acceptance of socially assistive humanoid robots as interactive tools in the teaching of children with ASC; using the NAO robot, and further work highlighted the positive attitude towards the use of robots for therapeutic/educational purposes [82, 83]. Within this current study teachers provided interesting suggestions about the possible ways that Kas-

par can be used as a therapeutic tool in the classroom for supporting the development of children's social and communication skills. The findings revealed teachers' eagerness to use Kaspar in every day classroom activities in order to assist children's learning via imitation, including phonics, maths and social cues. Similar findings were highlighted by Huijnen et al. [84] who examined the ways that Kaspar can contribute to the therapy and/or educational goals of children with ASC. In focus groups with 54 ASC practitioners their study revealed that ASC practitioners expect Kaspar to provide assistance not only in domains such as communication, social/interpersonal interaction and relations, but also in preschool skills, which according to Huijnen et al. focus on 'objectives that enable the children to function in a school environment', such as 'train or practice skills' or 'execute a task' [84, p. 452].

In line with the point raised by Thill et al. [85] who emphasised that the next step in therapeutic scenarios for children with ASC is the development of more substantial levels of autonomy which will enable the robot to be adjusted to the individual needs of children over longer periods of time, the evidence from this current study also raised this issue. One of the teachers expressed her preference to tailor Kaspar's programme according to the children's individualised needs and skills in order to have a greater impact on children's development (teacher of child P02 '*Maybe the robot's programme could be individualised based on each pupil's needs, difficulties, skills, this point could be added*').

Overall, the findings revealed slight improvements in certain areas for some of the children and no improvements for other children after the play sessions with the robot. Considering the evidence from a whole range of different studies that highlight the diversity that surrounds the developmental/learning profiles of children with autism (i.e. some children will do well in some areas and not so well in others), the findings are in line with what we might expect from autistic children generally. As highlighted by Parsons [86], one of the key points about technology for autism more widely is that we need to understand much more about who the technology may 'work' for, under what circumstances and how, rather than assuming these are tools that will 'work' for all – and so we need to consider individual variability as an expected part of the process.

6 Conclusion

Considering the positive results of previous studies conducted with Kaspar in the UK, the aim of the study presented in this paper was to explore in a different cultural setting the impact of play sessions with the robot on ASC children's social and communication skills and possible ways for using Kaspar as a (therapeutic) tool in the classroom for supporting these skills. The evidence revealed a slightly positive influence of Kaspar's sessions for specific children in domains such as communication and interaction (e.g. 'Child's spontaneous speech is generally intelligible (speech clarity)'), social and emotional development (ability to '…join others in play with objects, toys or materials or other activities with a common goal or purpose'), sensory and motor development, unprompted imitation, prompted speech and focus/attention (i.e. 'The child is engaged when changes in elements in the environment occur').

In addition, teachers offered interesting suggestions about the ways that Kaspar could potentially be used in the classroom for supporting the learning of children with ASC. According to the teachers, the robot could be used on a daily basis for teaching tasks such as phonics, maths or social cues, while the fact that Kaspar appeared to attract and maintain children's attention could have a positive impact on children's learning in a class context. Additionally, programming the robot according to each child's individual needs could also have a positive impact on their development.

Overall, conducting the study in Greece enabled us to use Kaspar in a different cultural setting that lacks robotics intervention evidence for children with ASC. Although the small sample size of our study does not allow us to generalise or compare data directly with UK studies due to differences in the study design, there were no obvious cultural differences between our findings, previous results with Kaspar in the UK, and similar studies internationally. In addition, apart from the evidence regarding children's slight improvements in certain areas, this study highlighted teachers' (and the school's psychologist) positive attitudes towards using the robot as a therapeutic tool for supporting children with ASC in the classroom and their suggestions for possible ways to do this, adding to the body of studies conducted in this field.

Despite the above encouraging findings regarding the incremental benefit of using a robot for the support of ASC children's social and communication needs, these should be interpreted with careful consideration for the following reasons: (i) Although the study focused on a small num-

ber of case studies and individual data from children, the absence of comparison groups makes it difficult to determine whether there were any informative (group) patterns of change in children's behaviour and skills and (ii) the constraints of the study did not allow us to assess whether any of the improved behaviours/skills of children would have a lasting effect and could be generalised.

Nevertheless, this is a very promising area of research and considering the absence of studies within this field in the Greek context and the growing body of research internationally, the encouraging evidence of this paper highlights the need for further long-term research of robot assisted therapy for children with ASC in the classroom and home environment. Future research in this domain, with an extended time framework and control groups of children, would provide more detailed and rigorous data regarding the impact of sessions on children's social and communication skills. Additionally, enabling teachers to use robotic (humanoid) platforms, such as Kaspar, for ASC therapy in the classroom context for teaching different skills, and tailoring the functionality of the robot to children's individualised needs, could support children's learning and development.

7 Limitations

Limitations of this study are as follows:

Questionnaire data: Regarding the questionnaire data there were two primary limitations:

– Whilst we used a questionnaire as pre- and post-measures these could have been biased by the examiner effect, where the teachers are trying to please the examiner and giving higher ratings in the post-test. However, these measures were also complemented by the objective behavioural coding measurements.

– Another limitation of this study relates to the generalizability of the tasks as the behavioural coding was only conducted for sessions with the robot; in future studies it would be useful to examine if the children are able to generalise to human-administered tasks. Further to this it would have been useful to have a control group in this study to measure the impact of the intervention on the children participating. However since we had very limited numbers in this study this was not possible.

Mood of the children: The mood of the children varied from day to day and undoubtedly impacted their interactions with the robot. Whilst these factors were not logged

in this study, in future studies it would be good to keep a record of such information in order to establish the impact this has on the interaction and with the children. We can state from previous work that very often children who we have been advised are "having a bad day" by teachers tend to improve in temperament after interactions with Kaspar, but this is anecdotal evidence which is not conclusive.

8 Ongoing and future work

This work has demonstrated that the approach towards robot-assisted therapy for children with autism with the Kaspar robot, which has been studies extensively in schools and family homes in the UK, can also be applied to educational settings in other countries. Since submitting this work we carried out a study of using Kaspar in a children's hospital in Macedonia, where a therapist programmed and operated the robot as part of intervention sessions for children with severe autism. Those encouraging findings suggest a direction for future work where researchers might explore a diversity of cultural settings for robot-assisted therapy and, in collaboration e.g. with educators, anthropologists, linguists and social scientists, might identify and study specifically the role of cultural factors in robot-assisted therapy.

Moreover, we also developed specific scenarios and an experimental protocol to teach children with autism visual perspective taking skills [13]. This line of investigation points towards the development and study of more diverse scenarios for robot-assisted therapy for children with autism, including those that are specifically targeting core aspects and mechanisms underlying mindreading and social behaviour.

In other work we developed a cognitive architecture and interfaces to run Kaspar in semi-autonomous mode, in order to reduce the cognitive load on the therapist/teacher/researchers or parent operating the robot [87]. In the present study it was a researcher operating the robot, but in future work therapists/teachers or parents will benefit from a reduced cognitive load. Generally, the issue on how much robot autonomy is feasible, desirable and beneficial, both to the children and their caregivers, is an open research problem.

Finally, we also developed an easy-to-use interface that will allow adults as well as children to more easily to program the robot and create more scenarios specifically adapted to individual children [88]. One cannot assume that a robot that will be delivered to end-users will already possess all the capabilities (e.g. games to play, speech,

gestures and other behaviours) needed for individual children, since their needs and preferences differ and educational/therapeutic goals relevant to them will change over time. Thus, allowing caregivers and professionals to program the robot easily could address this problem. Settings in different cultural environments, as reported in this article, would greatly benefit from an easy-to-programme interface, not only to allow the robot to easily change to different languages, but also to address e.g. different educational practises as well as different cultural norms and conventions (e.g. gestures and phrases used for greetings).

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A Appendix

Behaviours from videos – Coding scheme and notes

1.	Imitating Kaspar's movements after prompting (including hand movements, songs or expressions)	*Prompting*: the researcher encourages the child to imitate the robot's movements both verbally (e.g. singing) and physically (e.g. pointing the robot's arm or his/her own arm). This includes researcher's continuous prompting. Also singing is coded as imitation.
1.	Imitating Kaspar's movements without prompting (including hand movements, songs or expressions)	*Without prompting:* the child imitates the robot's movements both verbally (e.g. singing) and physically (e.g. pointing the robot's arm or his/her own arm) without any prompting from the researcher.
1.	*Prompted speech* (either involving Kaspar or researcher)	*Prompted speech*: the researcher encourages the child to express himself/herself verbally either in relation to the robot or the researcher (e.g. child's answer when the researcher asks something). Also repetition of Kaspar's or researcher's wording is coded as 'Prompted speech'
1.	*Unprompted / spontaneous - speech* (either involving Kaspar or researcher)	*Unprompted spontaneous speech*: spontaneous verbal initiations of the child either in relation to the robot or the researcher without any prompting from the researcher.
1.	Eye gaze	Child looks at researcher's eyes or face on own initiative *when trying to get the researcher's attention*. This means that the child leans towards the researcher in order to attract her attention and/or share the excitement.
1.	*Focus – attention* within the context of play session (standing /sitting close to the robot, looking at Kaspar or the researcher)	*Focus – attention*: the child stands/sits close to the robot, or in distance (the latter one applies only to one child), looking at Kaspar or the researcher.
1.	*Self-initiated* play	*Self-initiated play*: the child uses the keypad and presses buttons on his/her own initiative. When drumming and the researcher guides the child which buttons to press this is not considered 'self-initiated play'. However when the child knows which buttons to press for drumming without the researcher's guidance this behaviour is coded as 'self-initiated play'. When the child is asked to elicit a certain reaction from the robot (e.g. 'what do we have to press to make Kaspar happy?'), this is not considered 'self-initiated play'.
1.	*Seeking a response* from the robot (taking the initiative to get a response)	*Seeking a response*: the child takes the initiative in order to get a specific response from the robot (e.g. tickles the robot, touches the robot's arms or tummy so that to get a certain response) – tactile interaction (without using the keypad). When the researcher encourages the child to get a specific response from the robot (e.g. tickle the robot, touch the robot's arm/hand) this is not considered 'seeking a response'. When the child likes to keep his/her hands on Kaspar's feet then this is coded as 'seeking a response'.
1.	*Initiating – seeking affection*	*Initiating – seeking affection*: the child hugs or kisses Kaspar on his/her own initiative.
1.	*Gesture recognition* performance	How the child performed in each part of this game. For example when the child correctly identifies the behaviour of the robot. In most of the sessions the researcher had to repeat the robot's movements 2 or 3 times as the majority of children were not able to imitate Kaspar's body part movements from the first attempt. Each successful and unsuccessful attempt was recorded for this particular game. The behaviour's coding starts when Kaspar starts talking e.g. 'Now it is my turn, please look at me…' and it ends when the researcher turns towards the laptop and changes to another game.

Notes:

– When the researcher prompts the child to tickle or show/touch Kaspar's hands/arms this is not coded as 'Seeking a response'. Only when the child takes the initiative to do any of the above, then these behaviours are coded as 'Seeking a response'.

– 'Seeking a response': Sometimes when the child wants to touch Kaspar's arms/hands in order to get the response 'this is my arm/hand' and he/she can't find the exact spot with the sensor, the researcher shows the child where exactly the child must touch Kaspar's hand/arm in order to get the robot's response. This is still coded as 'Seeking a response'.

– 'Imitation': singing along while imitating Kaspar's movements in songs is coded as imitation (either prompted or unprompted). When the child only imitates the robot's movement (e.g. clap hands) without singing at the same time then the imitation is coded as started/stopped, but when the child sings along and imitates then the imitation is coded as ongoing.

– Tickling is coded as 'seeking a response' only when the child takes the initiative to tickle the robot and not when the researcher prompts the child to do so.

– 'Follow-me game': When the child imitates Kaspar's movements and names the body parts at the same time then the speech here is coded as 'Prompted speech'.

Drumming: When the researcher prompts the child to drum constantly then this behaviour is coded as 'Imitation prompted'. When the child though drums without the researcher's continuous prompting this is coded as 'Imitation unprompted'.