Institution: University of Hertfordshire		
Unit of Assessment: 11 – Computer Science and Informatics		
Title of case study: Kaspar the social robot: supporting children with autism and increasing public acceptance of robot-assisted therapy		
Period when the underpinning research was undertaken: 2005 – 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Kerstin Dautenhahn	Professor of Artificial Intelligence	Apr 2000 – Aug 2020
Farshid Amirabdollahian	Professor of Human-Robot Interaction	Jan 2009 – present
Ben Robins	Senior Research Fellow	Sep 2002 – present
Luke Wood	Research Fellow	Oct 2010 – present
Period when the claimed impact occurred: 2014 – 31 December 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact (indicative maximum 100 words)

Human-robot interaction research by the Adaptive Systems Research Group at the University of Hertfordshire (UH) informed the design and development of patented humanoid robot Kaspar to provide therapy for children with autism. In schools, homes and hospitals, Kaspar provided one-to-one support to around 250 children over the impact period, benefitting parents, carers, teachers and practitioners in six countries. It demonstrated its effectiveness in the first clinical study of its kind in the NHS and, to meet the aim of making Kaspar available to anyone that would benefit, a licensing agreement was reached with a Canadian company to bring Kaspar to market in North America and Asia. Kaspar has played a high-profile role in stimulating debate in, and increasing public acceptance of, social robots as therapeutic interventions; it reached in excess of 10 million people through in-depth and sustained media coverage, including high-profile documentaries on national television in the UK, Australia and the Netherlands, and engaged half a million people at museum exhibitions around the world.

2. Underpinning research (indicative maximum 500 words)

Autism spectrum disorder (ASD) is a lifelong developmental disability that affects 700,000 people in the UK. Children with ASD experience persistent difficulties with communication and social interaction, and display restricted, repetitive patterns of behaviour that can impair daily life. Early and individualised interventions are considered crucial for children in increasing their everyday functioning. Wider research has shown that children with ASD enjoy interacting with computers and can respond especially well to interactive robots, finding the two-way communication less socially demanding and more predictable than human-led interventions.

In 2000, researchers led by Professor Kerstin Dautenhahn began investigating how robotic systems could be developed into social mediators, empowering children with disabilities to discover a range of play styles, from solitary to social and cooperative play. Under the EU FP6 IROMEC project [**G1**], robot-supported scenarios were created according to the cognitive needs of the children and were designed to meet educational and therapeutic objectives in five developmental areas: sensory development, communication and interaction, cognitive development, motor development and social and emotional development [**3.1**]. The most promising results came through the group's development of a minimally expressive, child-sized humanoid robot Kaspar that could be used to teach children with ASD social interaction and communication skills [**3.2**]. Researchers simplified Kaspar's features and expressions to appeal specifically to children with ASD by not overwhelming them with social cues. Kaspar sits on a table in front of the child. It can move its hands, arms, torso and head, display basic facial expressions (e.g. sad, happy) and can express pre-programmed words or sounds. The robot can be operated via remote control by a care professional that activates targeted interaction scenarios, or by children themselves while they learn collaborative play. The robot also responds autonomously to the activation of the sensors.

The EU FP7 RoboSKIN project [**G2**] enabled the research team to install patches of artificial 'skin' on the robot and embed tactile sensors. Children with ASD often experience difficulties with touch; novel algorithms underpinning these sensors allowed the robot to detect varying

types of touch and then encourage or discourage (e.g. in response to aggression) different approaches [**3.3**]. Subsequent studies showed that children performed more gentle touches on the robot as a result of triadic play sessions involving the child, the robot and a researcher [**3.4**]. Researchers applied the play scenarios from **G1** to trials of this next iteration of Kaspar and designed a novel experimental setup in which Kaspar and the children participated in a collaborative, dyadic video game. The children alternated between playing the game with an adult and the robot. Results showed that children found the activity to be more entertaining, appeared more engaged, and displayed better collaborative behaviours during the second session with the adult compared with the first session. This suggested that the intermediary play session with Kaspar had a positive impact on subsequent play [**3.5**]. Researchers then designed a triadic interaction where two children and the robot collaborated to play a video game. Results showed how this encouraged collaboration between the children and helped them to take the initiative.

A University fundraising campaign (2012-2015) secured £570,000 from international foundations, charities and individuals. This allowed researchers to make Kaspar more robust and versatile. It was fitted with radio-frequency identification (RFID) technology to make it easier for carers to operate the robot and it was given new abilities, including being able to hold a comb, toothbrush or spoon. Under Horizon 2020 project BabyRobot [**G3**], Kaspar was developed further into a semi-autonomous system, whereby object recognition, localisation and decision-making are automated, while still allowing the supervising adult to be in control of the interaction and respond to children's needs. This included the first study into whether Visual Perspective Taking (VPT) skills – the ability to see the world from another person's perspective – could be improved in children with autism through playing specifically designed game scenarios and interacting with a humanoid robot. It found statistically significant evidence that games with Kaspar can have a beneficial effect on VPT skills [**3.6**].

3. References to the research (indicative maximum of six references)

3.1 Robins B, Dautenhahn K, Ferrari E, Kronreif G, Prazak-Aram B, Marti P et al. Scenarios of robot-assisted play for children with cognitive and physical disabilities. Interaction Studies. 2012;13(2):189-234. https://doi.org/10.1075/is.13.2.03rob
3.2 Dautenhahn K, Nehaniv CL, Walters ML, Robins B, Kose-Bagci H, Mirza NA et al. KASPAR - a minimally expressive humanoid robot for human-robot interaction research. Applied Bionics and Biomechanics. 2009;6(3-4):369-397. https://doi.org/10.1080/11762320903123567
3.3 Robins B, Dautenhahn K. Tactile Interactions with a Humanoid Robot: Novel Play Scenario Implementations with Children with Autism. International Journal of Social Robotics. 2014 Aug 1;6(3):397-415. https://doi.org/10.1007/s12369-014-0228-0
3.4 Costa S, Lehmann H, Dautenhahn K, Robins B, Soares F. Using a Humanoid Robot to Elicit Body Awareness and Appropriate Physical Interaction in Children with Autism. International Journal of Social Robotics. 2015 Apr 1;7(2):265-278. https://doi.org/10.1007/s12369-014-0250-2
3.5 Wainer J, Dautenhahn K, Robins B, Amirabdollahian F. A Pilot Study with a Novel Setup for Collaborative Play of the Humanoid Robot KASPAR with children with autism. International Journal of Social Robotics. 2014 Jan;6(1):45-65. https://doi.org/10.1007/s12369-013-0195-x
3.6 Wood L, Robins B, Lakatos G, Syrdal DS, Zaraki A, Dautenhahn K. Developing a protocol and experimental setup for using a humanoid robot to assist children with autism to develop visual perspective taking skills. PALADYN: Journal of Behavioural Robotics. 2019 Mar 26;10(1):167-179. https://doi.org/10.1515/pjbr-2019-0013

Key underpinning grants
G1 IROMEC, EU FP6, €2,145,000 (£442,700 to UH), 2006-2009.
G2 RoboSKIN, EU FP7, €3,557,139 (£411,772 to UH), 2008-2012.
G3 BabyRobot, HORIZON 2020, € 3,995,741 (£501,878 to UH), 2016-2019.

4. Details of the impact (indicative maximum 750 words)

The research team built 20 of the redesigned Kaspars between 2014 and 2017. This allowed researchers to work with more children and families, schools and care professionals simultaneously, with increased feedback facilitating further technological advances. Through

being loaned, free of charge and with specialist support from Robins, to schools, homes, hospitals and museums, Kaspar has: supported the development of social skills in children with ASD; shown its efficacy in a clinical environment; established a route to commercialisation through a patent and a licensing deal; and raised the public profile of the use of social robots for therapy.

Improving social interaction and communication skills in children with ASD

Over the impact period, as the technology evolved in response to study outcomes, Kaspar was used in eight schools and specialist centres in six countries, in the homes of 10 families in the UK and in an NHS Trust. It supported the development of communication skills in 243 children with ASD, benefitting families and carers, teachers and ASD practitioners, and clinicians. The number of sessions for each child ranged from 14 to 25; close collaboration between UH researchers and carers ensured the sessions were adapted to individual therapeutic needs. An independent validation of Kaspar as a beneficial intervention came through a 2016 study by academics in the Netherlands into the effectiveness of Kaspar in supporting children with ASD [**5.1**]. Through interviews with 54 experienced ASD practitioners, the study found that 98% of practitioners said Kaspar has a role in improving the communication skills of children with ASD and 96% said Kaspar has a role in improving social interactions and relations. It concluded: "*Professionals are convinced that Kaspar can be useful in interventions for a broad range of therapy and education goals for children with autism spectrum disorder*." A study by the Australian e-Health Research Centre and University of New South Wales (UNSW) used Kaspar to develop a framework that helped autistic children to recognise the emotions behind different facial expressions [**5.1**].

Qualitative data from parents and teachers has shown that Kaspar can have a positive effect on behaviour, helping children with ASD acquire social skills that improve school and family life. Captured in BBC 2 documentary Six Robots & Us [**5.2**], Kaspar spent five weeks in the home of the Doherty family to support four-year-old Ethan, who has ASD. Midway through Kaspar's stay, Ethan, for the first time, communicated with his mother about his school day, showing her a picture of a fish he had drawn. His mother told the interviewer: "*It was like it was made of gold. It really is like a … I'm going to try not to cry … just a really exciting moment. I suppose it just gives you hope. I think for us it just gives you those moments that everyone else gets and takes for granted. Really special*." Observing interactions with Kaspar via video link, psychologist Dr Caroline Jay said: "*This is a real breakthrough. Ethan hasn't done this before and he's been able to communicate with her in a way that he has typically found really difficult*." Also observing, Professor Jonathan Rossiter, of Bristol Robotics Laboratory, said: "*What's remarkable about this is that we are seeing a real result with a real child with a real robot and that's heartwarming, but it's also incredibly valuable for research*." By the end of the five weeks, Ethan's parents described Kaspar as "*definitely beneficial*", noting that their son appeared "*as happy and social as he had been for a while*", more willing to try new food, more open to sharing and turn taking, and more inclined to play with his sister. They asked to keep Kaspar for another five months.

TRACKS, a specialist early years centre for children with ASD, reported positive outcomes from working with Kaspar from 2015 onwards. The deputy head told Reuters in 2017 [**5.3**] about a case involving a child who was previously unable to eat with his classmates due to anxiety. She said: "*We started doing it with Kaspar and he really, really enjoyed feeding Kaspar, making him eat when he was hungry, things like that. Now he's started to integrate into the classroom and eat alongside his peers. So things like that are just a massive progression*." The TRACKS head teacher also told daynurseries.co.uk in 2016 [**5.3**] that Kaspar was "*a good tool for teaching emotions*", helping one child to understand why it was wrong to hit other children. In another case, a period of interacting with Kaspar helped one child indicate to teachers when he had calmed down during a tantrum, which enabled staff to know when to cease restraint. From 2018, Kaspar was used in a specialist primary school in Athens. Teachers' comments included [**5.4**]: '*Kaspar contributes in a positive way to the…social development of the child*'; '*She works more positively and the robot supports her focus*'; '*In terms of communication I can say that I see a difference*'.

Demonstrating viability of using social robots to treat autism in clinical settings

In December 2016, computer science and clinical psychology researchers at UH, together with clinicians at Hertfordshire Community NHS Trust, secured a £250,000 grant from the National Institute for Health Research (NIHR) to carry out the first clinical feasibility study of the use of a robot within the NHS to treat children with ASD. Responding to the announcement, the then Minister for Public Health and Innovation said: '*This innovative approach is an excellent example of our researchers pushing boundaries to improve lives*' [**5.5**]. The study involved 38 children aged 5-10. It compared the social skills of those children who interacted with Kaspar and a therapist, and those who interacted with a therapist only. The study concluded that the outcome measures '*suggest a potential effect of the intervention to be explored in a large-scale trial*' and that '*qualitative interviews with parents, children and clinicians all found the study to be acceptable and felt that such an intervention could be delivered in an NHS setting*' [**5.6**]. Semi-structured interviews with six health professionals at the Trust showed they felt that Kaspar '*would be a beneficial intervention for children with autism*', while interviews with 18 families '*showed that parents think it is important that the NHS offers this type of intervention*' [**5.6**]. NHS Improvement highlighted the trial on its website as one of four case studies on '*using innovation to help improve patient experience* [**5.7**]. In December 2020, the UH team submitted a £1m bid to the NIHR to conduct a large-scale randomised controlled trial involving 500 children at ASD diagnostic clinics across NHS eight trusts.

Beginning in 2016, a children's hospital in Skopje, Macedonia explored the use of Kaspar for children with severe forms of autism. Results of year-long case studies show that children learnt basic social communication and emotion recognition skills for the first time and that these were successfully generalised and used in daily life [**5.8**]. The clinicians have continued to use Kaspar.

Increasing public awareness, understanding and acceptance of the role that social robotics can play in treating children with ASD

Kaspar was the subject of sustained, in-depth media coverage during the impact period, reaching a global audience in excess of 10 million people and featuring positive outcomes from interactions with children [**5.3**]. In July 2016 Dautenhahn was invited to take Kaspar into the studio of Radio 4's Today Programme (around 7m listeners a week) for an item on robots providing humans with one-to-one care. A Mail on Sunday feature in December 2016 quoted the original founder of TRACKS school as saying: "*We have had a lot of wow moments since Kaspar became a permanent part of our school*." [**5.3**] In addition to BBC 2's Six Robots & Us, Kaspar was featured on ABC Television's (Australia) weekly news documentary programme Compass. The episode *My Best Friend Is A Robot*, broadcast in August 2019, highlighted the joint studies by the Australian e-Health Research Centre and UNSW Sydney. It showed the robot interacting with four brothers who have ASD; the occupational therapist leading the therapy sessions said to camera: "*I feel Kaspar can alleviate a lot of anxiety that a child might feel with another person or another child themselves* [**5.3**]." In April 2018, Kaspar featured in an hour-long documentary on national television in the Netherlands, which followed an eight-year-old boy with ASD for a year. The boy responded well to his sessions with Kaspar, with the lead researcher commenting that the programme led to multiple inquiries from professionals and parents on participating in studies or purchasing a Kaspar [**5.3**].

The Kaspar team used the event of the clinical feasibility study being funded to engage the media during Autism Week in 2017. A video and news article published by Reuters was reproduced widely, for example receiving 1.1m views in 10 days through the Business Insider UK Facebook page. It quoted the director of the National Autistic Society's Centre for Autism as saying Kaspar "*is one of a number of emerging technologies which have the potential to make a huge difference to people on the autism spectrum*." Further coverage followed in the Daily Mail, The Independent, The Mirror, Fox News and AOL [**5.3**].

Some of the feature articles addressed the ethical implications of social robots, drawing positive conclusions on the use of Kaspar for therapy. An article in Slate read: '*A robot (Kaspar) designed to assist children with autism is a glimmer of the best possible future for social A.I.*' The article was an edited extract from a book *Living With Robots*, published by Harvard University Press. It said: '*The KASPAR model's undoubted successes exposes* [sic] *the shortcomings of most current ethical thinking about the use of robots in educational institutions, hospitals, and specialized*

centers … Robotic interaction partners such as KASPAR do not replace human beings. They only support them in providing aid and treatment.' A *Newsweek* piece acknowledged ethical considerations but used the headline: '*Robots could be key to teaching autistic children social skills*.' A three-page feature on Kaspar in *Autism Eye* in 2017 reported favourably on the use of the robot [**5.3**].

Kaspar was displayed at the Science Museum for an exhibition called *Robots* from February to September 2017. It received 187,183 visitors; adult tickets were £15. Kaspar featured prominently in extensive media coverage of the exhibition, including BBC Radio 4, the Financial Times, the Guardian and The Telegraph. Kaspar went on tour with the exhibition to the Science and Industry Museum in Manchester (66,826 visitors), the Life Science Centre in Newcastle (98,232), National Museums Scotland (50,962), the National Museum of Science and Technology in Stockholm (290,955; a museum record) and the Hong Kong Science Museum (opened November 2020) [**5.9**].

Establishing a route to commercialisation to widen access to Kaspar

A combination of positive research outcomes, the clinical feasibility study and the widespread media exposure led to the University securing a licensing deal in 2019 with a Canadian technology company to bring Kaspar to market. Compusult, a distributor of several assistive technology products, set out to further reengineer Kaspar, which had been trademarked in the UK and EU in 2014 and 2016 respectively, into a robust and commercially viable robot that could be sold in North America and Asia. Compusult exhibited Kaspar at several trade events in 2019 and early 2020, including an assistive technology showcase at the United Nations in Geneva and the Assistive Technology Industry Association 2020 conference [**5.10**], although the marketing campaign was subsequently disrupted by the Covid-19 pandemic. A UK patent for Kaspar as 'an interactive humanoid robot using RFID tagged objects' was published in April 2020 under GB 2552981.

5. Sources to corroborate the impact (indicative maximum of 10 references)

5.1 Independent validations of the effectiveness of Kaspar as a therapeutic intervention.
a) Huijnen CAG, Lexis MAS, de Witte LP. Matching Robot KASPAR to Autism Spectrum Disorder (ASD) Therapy and Educational Goals. International Journal of Social Robotics. 2016 Aug;8:445-455. https://doi.org/10.1007/s12369-016-0369-4
b) Silvera-Tawil D, Brown SA. Cross-Collaborative Approach to Socially-Assistive Robotics: A Case Study of Humanoid Robots in a Therapeutic Intervention for Autistic Children. In: Korn O, ed. Social Robots: Technological, Societal and Ethical Aspects of Human-Robot Interaction. Human-Computer Interaction Series. Springer, Cham; 2019. https://doi.org/fscd
5.2 Six Robots & Us, Episode 2, BBC Two, December 2017: https://www.bbc.co.uk/programmes/b09l63pc Available to view via: https://www.dailymotion.com/video/x6csc18 (Key excerpts: 37m30s–39m32s; 55m43s–57m50s)
5.3 Compilation report of media coverage featuring Kaspar over the impact period.
5.4 Karakosta E, Dautenhahn K, Syrdal D, Wood L, Robins B. Using the humanoid robot Kaspar in a Greek school environment to support children with Autism Spectrum Condition. Paladyn, Journal of Behavioural Robotics. 2019;10(1):298-317.
5.5 NHS Herts Community Trust article corroborating the Minister's comments: https://www.hct.nhs.uk/news-and-events/kaspar-joins-hct/
5.6 NIHR Research for Patient Benefit: Final Report on the Kaspar RCT (PB-PG-0215-36122).
5.7 NHS Improvement: Using innovation to help improve patient experience, July 2017. https://improvement.nhs.uk/resources/using-technology-help-improve-patient-experience/ (copy available)
5.8 Zorcec T, Robins B, Dautenhahn K. Getting Engaged: Assisted Play with a Humanoid Robot Kaspar for Children with Severe Autism. In Kalajdziski S, Ackovska N, editors, ICT Innovations 2018. Engineering and Life Sciences: 10th International Conference, ICT Innovations 2018, Proceedings. Springer Verlag. 2018. p.198-207. https://doi.org/fscv
5.9 Corroborating emails from the Science Museum re visitor figures for the Robots exhibition.
5.10 Collection of weblinks that corroborates Compusult's commercialisation programme