Robot Therapy: Promoting Communication Skills for Students with Autism Spectrum Disorders

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Abstract

Bill is an eight-year-old second grade student identified on the autism spectrum. Autism is his primary disability. He receives speech and language services to improve his joint attention and social engagement skills. His teacher, speech language pathologist, and mother report Bill spends much time "scripting" shows he has watched on TV. Other than repeating the TV scripts continually, he does not verbally respond to others' comments, nor is he able to initiate any conversations. It was decided to use "robot therapy" in an exploratory study during Bill's speech therapy sessions to facilitate communicating with Bill. The speech language pathologist recommended working on Bill's social engagement development as he felt this would improve Bill's communication abilities. This article reports on the procedures used during this exploratory action research study so that practitioners can use these procedures in schools. It also offers other ideas for robot use which can be utilized in educational settings as well as in future action research studies.

Autism Spectrum Disorder

The Diagnostic Criteria for Autism Spectrum Disorder (ASD), according to the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5), "include persistent deficits in social communication and social interaction, as manifested by deficits in social-emotional reciprocity, ranging, for example, from abnormal social approach and failure of normal back-and-forth conversations…to failure to initiate or respond to social interactions" (Messent, 2013, p. 479). Initiating and responding to social interactions are functions of social engagement, thus the speech language pathologist's emphasis on improving these skills. Research study results show a positive correlation between acquiring these skills and subsequent language development (Charron, Lewis, & Craig, 2017; Mundy, Sigman, & Kasari, 1990).

Joint Attention Skills

Typically developing children learn to identify, use, and follow non-verbal cues even before they learn to talk and communicate verbally (Owens, 2016). Joint attention is the ability to share a common focus on something (people, objects, a concept, an event, etc.) with someone else. It involves the ability to gain, maintain, and shift attention (Woods & Wetherby, 2003; Wong & Kasari, 2012). Skills such as pointing, looking where another individual is directing, as well as maintaining eye contact are all forms of nonverbal communication that are commonly learned and utilized before using speech to interact with others (Poon, Watson, Baranek, & Poe, 2012). These skills present in typically developing children at approximately 9 months of age. Children with ASD often have difficulty learning these joint attention skills (Dalton, 2011; Dawson et al., 2004; Leekam & Ramsden, 2006), because these skills involve not only being attentive to the gestures (physical and verbal) demonstrated by the other person, but also exhibiting an appropriate response. Since this ability facilitates language development and effective communication with others, it is important that students learn these skills (Warreyn & Roeyers, 2014; Owens, 2016). Joint attention skills are a prerequisite to social engagement and appropriate communication skill development. For example, the development of effective communication skills will facilitate collaboration with peers in a workplace environment as an adult.

Literature on using robots to scaffold communication and social competencies for students with Autism Spectrum Disorder (ASD) through developing joint attention and social engagement skills suggests promising outcomes (Charron et al., 2017; Srinivasan, Eigsti, Gifford, & Bhat, 2016; Huijnen, Lexis, Jansens, & Witte, 2016; Costescu, Vanderborght, & David, 2015; Paparella & Freeman, 2015; Warren et al., 2015). Like their more typically developing peers, many children with ASD are interested in electronic devices and are drawn to robots (Billard, Robins, Nadel, & Dautenhahn, 2007; Robins, Dautenhahn, Te Boekhorst, & Billard, 2005). The purpose of this article is to demonstrate how professionals might aid communication skill development through the use of a humanoid robot.

The Humanoid Robot

A review of the literature suggests using a robot is a viable option for improving joint attention and social engagement skills (Charron et al., 2017; Bekele, Crittendon, Swanson, Sarkar, & Warren, 2014; Billard et.al., 2007; Kim et al, 2013; Staudte & Crocker, 2011;

Severson, 2010; Kahn et al., 2012). An example of a robot that interacts well with children is the NAO humanoid in Figure 1 (“Softbank Robotics,” 2017). NAO is roughly two feet tall with facilities for speech recognition, object recognition, mobility, and gesturing. A useful feature of the NAO robot is its programmability. It comes off the shelf with several behaviors that can be used in human-robot interaction, and other behaviors can be programmed.

Figure 1. The NAO Robot **(**photo credit, Lewis**)**

The speech language pathologist used the below 7-step model presented by the Autism Speaks Organization for developing Bill’s communication skills (Mohr & Christensen, n.d.).

- Set Goal (teacher): Choose and clearly define a manageable social skills goal.
- Teach (teacher and/or robot): Explain what behavior looks like and why behavior is important.
- Model (robot): Demonstrate the desired social behavior.
- Practice (robot): Role-play the desired behavior.
- Prompt (robot): Prompt for a natural display of desired behavior.
- Reinforce (robot and/or teacher**)**: Reinforce after he/she demonstrates desired behavior.
- Generalize (teacher directed): Encourage practice of the behavior in all settings.

Bill’s Program

Once and sometimes twice-weekly twenty-minute speech pathology therapy sessions over an eight-month period with Bill were videotaped and later used for data collection, documenting social engagement development. Bill’s mother, the speech language pathologist

(SLP), and the special educator all reported that "he likes to talk about the robot" and that "he gets bored with teachers, but doesn't get bored with the robot." The speech language pathologist also reported increased verbal production when Bill's therapy was robot based as opposed to working with the speech language pathologist alone. Improvements were seen in Bill's response to directives, initiating social engagement with others, and communicating while needing increasingly fewer prompts from the speech language pathologist.

Introduction to the Robot

Practitioners should consider limiting the first few therapy sessions to five to ten minutes of hearing the robot make generic statements and watching the robot move. Bill's name was programmed into the robot's voice so Bill felt less intimidated, slightly more comfortable, and more involved. The robot said, "Hello Bill. I am happy to meet you." The robot yawned and said, "I'm tired, so I am going to sit down," and then moved to a sitting position. The robot then said, "I think I will lie down now," and then laid down on the table. The robot followed with, "OK, time to get up." The robot stood, waved, and said "Goodbye, Bill." Beginning sessions were short and simple. After a few sessions, once Bill had acclimated to the robot, activities were designed to develop "following directive" skills.

Response to Directives

Joint attention was developed by having the student respond to directives. Responding to directives was developed through Bill following the robot's commands. Anyone can learn to program the robot; it is programmed by stringing pictures together to form a sequence of actions and comments (DiMaria, 2016). The speech language pathologist determined what activities would best facilitate Bill's communication development. Another individual operated the robot during the speech language pathologist sessions. Directives were designed to incorporate Bill's specific interests. Incorporating Bill's interests ensured he would be engaged in the task. Bill was passionate about trucks. Thus the robot was programmed to say, "Look at the truck." Once Bill demonstrated that he was willing and able to look in the direction indicated by the robot, the interaction evolved to where the robot provided directives to Bill which he followed. The robot said "Put the truck in the box" or "Put the truck under the table." Eventually, Bill interacted directly with the robot, such as when the robot asked Bill to give him something in response to his request. The robot said, "Give me the dump truck," or "Give me the blue truck." Language was developed using Bill's current communication level. Practitioners should be aware that students on the autism spectrum have a wide range of abilities. Some students may be able to play games such as Simon Says with the robot immediately after being introduced to it, while this type of activity may take others months or even longer to master. The robot may be programmed to use each individual student's social engagement level and interests. It can tirelessly make the same requests of the student until a level of comfort is achieved. Table 1 provides a list of possible activities.

Table 1. *Possible Activities*

Level 1: Requiring Minimal Support

<table>
<tr><td colspan="2">These activities can take place as small group activities utilizing students’ specific interests and language development needs. Groups may consist of students with autism or other disabilities, as well as typically developing peers.</td></tr>
<tr><td colspan="2">Level 2: Requiring Substantial Support

These activities initially may take place in an individual setting with the teacher, the robot operator, and the student or a small group setting with two or three students. Response to directives are mastered first. After these are mastered, initiating social engagement skills may be worked on. Larger group work may take place after skills are mastered in order to reinforce concepts and provide practice. Groups may consist of students with autism, other disabilities, as well as typically developing peers.</td></tr>
<tr><td colspan="2">Level 3: Requiring Very Substantial Support

These activities initially take place in an individual setting with the teacher, the robot operator, and the student. Response to directives are mastered first. After these are mastered, initiating social engagement skills may be worked on. Small group work may take place after skills are mastered in order to reinforce concepts and provide practice. Groups may consist of students with autism, other disabilities, as well as typically developing peers.</td></tr>
<tr><th>Possible <u>Response</u> to Directives – The robot tells the student what to do.</th><th>Possible <u>Initiating</u> Social Engagement – The student tells the robot what to do.</th></tr>
<tr><td>Language expansion activities: The robot says: “Look at the block”

“Put the block”
● Under the table
● On the table
● By the window
● Behind the curtain
● Beneath the clock
● Inside the doll house
● Near the door
● Far away from the door
● Underneath the flag

Play Simon Says with the robot playing the role of Simon. Use the vocabulary students need to learn.

The robot says, “Simon says”
● Quack like a duck
● Run in place
● Skip around the room

Songs: The robot sings “Old MacDonald had a ______. Use any song the students like and have them fill in the blank.</td><td>Language expansion activities: The student says:
● “Look at the ceiling”
● “Quack like a duck”
● “Lie down”
● “Please give me a cookie”

Play Simon Says with the student playing the role of Simon. The student says, “Simon Says”

● Sit down
● Stand on one foot
● Touch your nose

The student sings a song or says a nursery rhyme and leaves a word out for the group (including the robot) to complete.

● Baa Baa Black Sheep have you any _______?
● If you’re happy and you know it clap your ______.</td></tr>
</table>

Initiating Social Engagement

Practitioners need to be aware that just as all children are individuals, students identified as having ASD vary widely in their demonstration of communication and social skills, as well as in their repetitive behaviors and intense interests (Hallahan, Kauffman, & Pullen, 2015). Therefore, a therapeutic intervention which can be uniquely tailored to each student is more likely to be successful. Some students may be able to further develop their social engagement skills spontaneously after joint attention skills have been established. However, many students will develop skills in responding to directives long before they are ready to initiate social engagement (Kasari, Gulsrud, Freeman, Paparella, & Hellemann, 2012). Once students are ready to work on their initiation of social engagement, the students can tell the robot what to do. Relatively simple commands such as “stand up, sit down, lie down, wave, sing, dance” all invite immediate response from the robot. There are numerous possibilities, and commands should be based on the student’s language level and interests. A student can practice these skills directly with the robot using physical, verbal, and/or visual prompts provided by the teacher during speech therapy sessions to aid the student’s understanding as necessary. Figure 2 provides an example of a visual prompt.

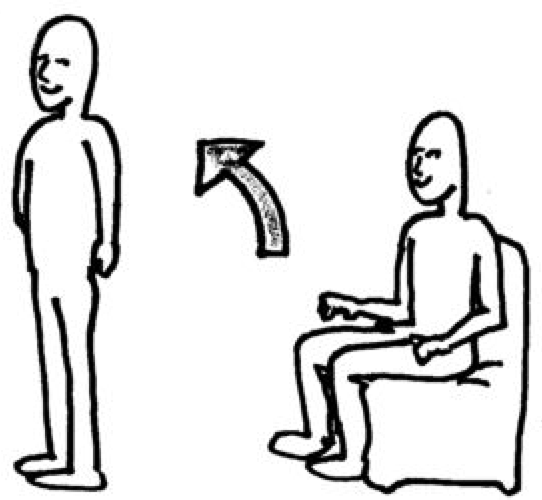

*Figure 2***.** Visual Prompt (wikispaces.com)

Using Prompts

Prompts should be gradually decreased until the student is providing voice commands to the robot without accompanying prompts. Data should be collected to monitor and document student progress in developing social engagement skills. Table 2 shows a simple progress chart to identify how many times the student responds to the robot’s directives with and without prompting. A more specific chart could be developed identifying the specific type of prompt the student required in order to respond appropriately. Did the student require a physical prompt, e.g., being physically guided to respond appropriately such as through a touch to the arm or guiding the student “hand-over-hand”? Did the student require a verbal prompt from the speech language pathologist? “Bill, look at the robot.” Did the student require a visual prompt with the speech language pathologist holding up a picture card?
Table 2

Example of Recording Directive Responses Chart

	Total Directives From Robot	No Respons e From Student	Correct Response without Prompting	Correct Response with Prompting
Date 1	105	4	64	37
Date 2	96	7	60	29
Date 3	138	11	95	32

There are numerous computer programs and apps available to professionals for producing visuals to support verbal communication. Mayer-Johnson's Boardmaker® is just one example of a popular software used for this purpose. The Autism Speaks website offers numerous other visual support options ("Autism speaks," 2017).

Use of a robot to initiate social engagement helps students realize their own vocalizations have power. This capacity to influence the behavior of the robot provides the student with the knowledge that interaction with another can have powerful effects (Charron et al., 2017; Kasari et al., 2012; Paparella & Freeman, 2015). This may give students the motivation to use speech to affect change. For example, the student says, "Please give me a cookie," resulting in the student receiving a cookie. The goal is to generalize this skill from interactions with the robot to those with other humans. Table 3 shows a simple progress chart to identify how many times the student directed the robot with and without prompting.

Table 3. *Example of Initiating Social Engagement Responses Chart*

	Total Directives From Student	Directives From Student without Prompting	Directives From Student with Prompting
Date 1	103	78	25
Date 2	114	72	42
Date 3	70	56	14

Practitioners may note that interacting with the robot not only affords an opportunity to improve social engagement skills, but may also function as a motivator and an opportunity to work on genuine skills in authentic settings.

Robot Therapy as a Motivator

Students with ASD demonstrate a wide range of abilities and behaviors. Some students may use the robot for communication purposes to improve communication, others may use the robot as part of a reward system, and some may be able to use the robot for both. As robots can provide a partner to encourage interaction, they can also be used for motivation; many students enjoy working with technology (Billard et al., 2007; Cafiero, 2012; Chin, Hong, & Chen, 2014; Grynszpan, Weiss, Perez-Diaz, & Gal, 2014). For the child with ASD, a comfort level with the robot can lead to an interest in spending more time with it. Incentives such as permitting the student who has finished a difficult academic task to take the robot for a walk can motivate students to complete challenging tasks (Stanovich, 2004). Similarly, additional time with the robot can be a reward for appropriate behavior. Students who exhibit enjoyment with the workings of the robot may even be taught to program the robot for use with other students. For example, the simplest method of programming the NAO robot is through visual programming, which doesn't require coding. A student can be taught how to connect icons that represent base behaviors in order to produce more interesting and complex behaviors. With little instruction, a student could program the robot to stand, wave, and say "Hello, Everybody" in less than a minute. Or, the student could program the robot to react appropriately to verbal directives such as wave, sit, lay down, dance, or give a speech.

However, a current limitation of the robot in educational settings is the expense. In 2013 the robot retailed for $16,000 USD. In less than four years the price has gone down to $10,000 USD, and, like most new technologies, one would expect the price to decrease. School districts are advised to request a special quote from Aldebaran ("Softbank Robotics," 2017). Another possibility is a mutually beneficial partnership where a local university can purchase the robot and then have access to an authentic research site.

Generalization: Genuine Skills in Authentic Settings

While work with a robot may encourage a student to experiment with responding to directives and even initiating social engagement, the ultimate goal is for students to transfer these skills to real life settings. If a student's family frequently struggles with his conduct in public settings such as restaurants, a robot can be instrumental in practicing socially acceptable behavior. A menu secured from the restaurant can provide real world learning opportunities for the student as he can watch the robot hold the menu with one hand and point with the other while requesting a certain food item. The modeling provided by the robot may be easier and more engaging for the student than simply watching an adult demonstrate this behavior (Chaminade & Okka, 2013). Alternatively, the robot can play the role of the restaurant employee, and the student can practice requesting a favorite food item from him (Lewis, Charron, Clamp, & Craig, 2016a).

Joint Attention, Communication, and Social Skills

Practitioners have the responsibility to develop the communication skills, and subsequently social engagement, of all students. For those with ASD the world of social interaction can be challenging. Using a robot to initially teach, model, and practice these skills can be effective, motivating, and fun for students. Once these skills are developed, they can be generalized and practiced in other settings, ultimately the goal for all learning. Our hope is that this article encourages future action research in using robots to enhance communications skills with students on the autism spectrum.

References

Autism Speaks. (2017). Retrieved from https://www.autismspeaks.org/family-services/resource-guide

Bekele, E., Crittendon, J. A., Swanson, A., Sarkar, N., & Warren, Z. E. (2014). Pilot clinical application of an adaptive robotic system for young children with autism. *Autism, 18*(5), 598-608. https://doi.org/10.1177/1362361313479454

Billard, A., Robins, B., Nadel, J., & Dautenhahn, K. (2007). Building Robota, a mini-humanoid robot for the rehabilitation of children with autism. *Assistive Technology, 19*(1). 37-49.

Cafiero, J. M. (2012). Technology supports for individuals with autism spectrum disorders. *Journal of Special Education Technology, 27*(1), 64-76. https://doi.org/10.1177/016264341202700106

Chaminade, T., & Okka, M. M. (2013). Comparing the effect of humanoid and human face for the spatial orientation of attention. *Frontiers in Neurorobotics, 7*, 12. https://doi.org/10.3389/fnbot.2013.00012

Charron, N., Lewis, L., & Craig, M. (2017 January 12). A robotic therapy case study: Developing joint attention skills with a student on the autism spectrum. *Journal of Educational Technology Systems.* https://doi.org/10.1177/0047239516687721

Chin, K., Hong, Z., & Chen, Y. (2014). Impact of using an educational robot-based learning system on students' motivation in elementary education. *IEEE Transactions On Learning Technologies*, *7*(4), 333-345. https://doi.org/10.1109/TLT.2014.2346756

Costescu, C., Vanderborght, B., & David, D. (2015). Reversal learning task in children with autism spectrum disorder: A robot-based approach. *Journal of Autism & Developmental Disorders*, *45*(11), 3715-3725. https://doi.org/10.1007/s10803-014-2319-z

Dalton, J. C. (2011). *Examination of joint attention and oromotor imitation in young children*. (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses database. (UMI No. 3509253)

Dawson, G., Toth, K., Abbott, R., Osterling, J., Munson, J., Estes, A., & Liaw, J. (2004). Early social attention impairments in autism: Social orienting, joint attention, and attention to distress. *Developmental Psychology, 40*(2) 271-283. https://doi.org/10.1037/0012-1649.40.2.271

DiMaria, F. (2016). Teaching STEM skills with NAO robots. Retrieved from https://thejournal.com/articles/2016/03/17/teaching-stem-skills-with-nao-robots.aspx

Grynszpan, O., Weiss, P. L., Perez-Diaz, F., & Gal, E. (2014). Innovative technology-based interventions for autism spectrum disorders: A meta-analysis. *Autism, 18*(4), 346-361. https://doi.org/10.1177/1362361313476767

Hallahan, D., Kauffman, J. M., & Pullen, P. C. (2015). *Exceptional learners: An introduction to special education*. Boston, MA: Pearson.

Huijnen, C., Lexis, M., Jansens, R., & Witte, L. (2016). Mapping robots to therapy and educational objectives for children with autism spectrum disorder. *Journal of Autism & Developmental Disorders*, *46*(6), 2100-2114. https://doi.org/10.1007/s10803-016-2740-6

Kahn, P. H., Kanda, T., Ishiguro, H., Freier, N. G., Severson, R. L., Gill, B. T., … Shen, S. (2012). “Robovie, you’ll have to go into the closet now”: Children’s social and moral relationships with a humanoid robot. *Developmental Psychology, 48*(2), 303-314.

Kasari, C., Gulsrud A., Freeman, S., Paparella, T., & Hellemann, G. (2012). Longitudinal follow-up of children with autism receiving targeted interventions on joint attention and play. *Journal of the American Academy of Child & Adolescent Psychiatry* 51(5):487-95. https://doi.org/10.1016/j.jaac.2012.02.019

Kim, E. S., Berkovits, L. D., Bernier, E. P., Leyzberg, D., Shic, F., Paul, R., & Scassellati, B. (2013). Social robots as embedded reinforcers of social behavior in children with autism. *Journal of Autism and Developmental Disorders, 43*, 1038-1049. https://doi.org/10.1007/s1083-012-1645-2

Leekam, S. R. & Ramsden, C. A. (2006). Dyadic orienting and joint attention in preschool children with autism. *Journal of Autism and Developmental Disabilities, 36*(2) 185-197. https://doi.org/10.1007/s10803-005-0054-1

Lewis, L., Charron, N., Clamp, C., & Craig, M. (2016a). Co-Robot therapy to foster social skills in special need learners: Three pilot studies. In M. Caporuscio, F. De la Prieta, T. Di Mascio, R. Gennari, J. Rodriguez, & P. Vittorini (Eds.) *Methodologies and intelligent systems for technology enhanced learning*, (pp. 131-141). Switzerland: Springer.

Lewis, L., Charron, N., Clamp, C., & Craig, M. (2016b). *Soft Systems Methodology as a Tool to Aid a Pilot Study in Robot-Assisted Therapy*. Paper presented at the 11th ACM/IEEE International Conference on Human-Robot Interaction, Christchurch, New Zealand.

Messent, P. (2013). *DSM-5. Clinical Child Psychology and Psychiatry, 18*(4), 479.

Mohr, D. & Christensen, E. (2017). Retrieved from https://www.autismspeaks.org/sites/default/files/social_skills_training_groups_powerpoint.pdf

Mundy, P., Sigman, M., & Kasari, C. (1990). A longitudinal study of joint attention and language development in autistic children. *Journal of Autism and Developmental Disorders, 20*,(1), 115-128. https://doi.org/10.1007/BF02206861

Owens, R. E. (2016). *Language development* (9th ed.). Boston, MA: Pearson.

Paparella, T. & Freeman, S. F. (2015). Methods to improve joint attention in young children with autism: A review. *Pediatric Health, Medicine and Therapeutics,* https://doi.org/10.2147/PHMT.S41921

Poon, K. K., Watson, L. R., Baranek, G. T., & Poe, M. D. (2012). To what extent do joint attention, imitation, and object play behaviors in infancy predict later communication and intellectual functioning in ASD? *Journal of Autism and Developmental Disorders*, *42,* 1064-1074. https://doi.org/10.1007/s10803-011-1349-z

Robins, B., Dautenhahn, K., Te Boekhorst, R., & Billard, A. (2005). Robotic assistants in therapy and education of children with autism: Can a small humanoid robot help encourage social interaction skills? *Universal Access in the Information Society, 4,* 105-120. https://doi.org/10.1007/s10209-005-0116-3

Severson, R. L. (2010). *Thinking as or thinking as if: Children's and young adults' conceptions of a robot dinosaur in relation to natural and artifactual entities*. (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses database. (UMI No. 3406037)

Software Robotics, 2017. Retrieved from http://cloud.aldebaran-robotics.com/

Srinivasan, S. M., Eigsti, I., Gifford, T., & Bhat, A. N. (2016). The effects of embodied rhythm and robotic interventions on the spontaneous and responsive verbal communication skills of children with Autism Spectrum Disorder (ASD): A further outcome of a pilot randomized controlled trial. *Research in Autism Spectrum Disorders*, 2773-87. https://doi.org/10.1016/j.rasd.2016.04.001

Stanovich, K. E. (2004). *The robot's rebellion: Finding meaning in the age of Darwin*. Chicago, IL: University of Chicago Press.

Staudte, M. & Crocker, M.W. (2011). Investigating joint attention mechanisms through spoken human-robot interaction. *Cognition, 120*(2). 268-291. https://doi.org/10.1016/j.cognition.2011.05.005

Warren, Z., Zheng, Z., Swanson, A., Bekele, E., Zhang, L., Crittendon, J., & ... Sarkar, N. (2015). Can robotic interaction improve joint attention skills? *Journal of Autism & Developmental Disorders*, *45*(11), 3726-3734. https://doi.org/10.1007/s10803-013-1918-4

Warreyn, P., & Roeyers, H. (2014). See what I see, do as I do: Promoting joint attention and imitation in preschoolers with autism spectrum disorder. *Autism, 18*(6), 658-671. https://doi.org/10.1177/1362361313493834

Wong, C., & Kasari, C. (2012). Play and joint attention of children with autism in the preschool special education classroom. *Journal of Autism and Developmental Disorders, 42*(10), 2152-2161. https://doi.org/10.1007/s10803-012-1467-2

Woods, J. J., & Wetherby, A. M. (2003). Early identification of and intervention for infants and toddlers who are at risk for autism spectrum disorder. *Language, Speech, and Hearing Services in Schools, 34, 180-193.* https://doi.org/10.1044/0161-1461(2003/015)