Effects of the Picture Exchange Communication System on Early Social-Communication Behaviors in Children with Autism Spectrum Disorders

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The Picture Exchange Communication System (PECS) is a common training choice for non-verbal children with autism spectrum disorders (ASD). Thus, this study investigated whether Phases 1–3 of the PECS (which are relatively easy for children to master) promote the development of early social-communication behaviors among children with ASD. We assigned 43 children (mean chronological age = 45.85 months) from the same child development support center into two groups: a PECS training group and a non-intervention (control) group. The training group received PECS (Phases 1–3) training once a week for 24 weeks at the university associated with the authors. Their early social-communication behaviors were evaluated by using behavioral observations and eye-tracking experiments during the pre- and post-training phases. Results showed that most of the early social-communication behaviors in the PECS training group were observed more frequently during the post-phase than the pre-phase, while the control group did not show any differences between the phases. These findings suggest that PECS training (Phases 1–3) can facilitate early social-communication behaviors in children with ASD.

Key Words: Autism Spectrum Disorder (ASD), Picture Exchange Communication System (PECS), early social-communication behaviors, joint attention, eye-tracking, generalized linear mixed model

Introduction

Autism spectrum disorders (ASD) are defined by the following DSM-5 diagnostic criteria (American Psychiatric Association, 2013): (1) persistent deficits in social-communication and social interaction across multiple contexts; (2) restricted, repetitive patterns of behavior, interests, or activities; (3) symptoms must be present in the early developmental period; and (4) symptoms that cause clinically significant impairments in social, occupational, or other important areas of current functioning. Administering a standardized ASD screening tool is recommended at 18 months of age (e.g., Dawson, Hill, Spencer, Galpert, & Watson, 1990; Kasari, Sigman, Mundy, & Yirmiya, 1990; Loveland & Landry, 1986; Mundy, Sigman, Ungerer, & Sherman, 1986; Phillips, Gómez, Baron-Cohen, Laá, & Rivière, 1995).

A recent study on the early symptoms of such deficits showed that at six months of age, the frequency of eye-contact and smiling among children with ASD was at the same level as that of typically developing children. However, they suddenly decreased at 12 months of age for children with ASD (Ozonoff, Iosif, Baguio, Cook, Hill, Hutman, Rogers, Rozga, Sangha, Sigman, Steinfeld, & Young, 2010). This indicates that initial social-communication behaviors become clearer by the child’s second year because the acquisition of joint attention occurs at a later stage. In this study, we defined the behaviors seen by the child’s second year (e.g., joint attention, request, eye-contact, and positive affect expression) as “early social-communication behaviors.”
Joint attention is the ability to coordinate attention between others and subjects in a social context (Bakeman & Adamson, 1984). In this regard, there are two forms of joint attention: initiation joint attention (IJA) and responsiveness to joint attention (RJA) (Mundy, Delgado, Block, Venezia, Hogan, & Seibert, 2003). Although IJA and RJA in typically developing children emerge around nine months of age, they have different functions: IJA is related to sharing positive affect (Bakeman & Adamson, 1984), while RJA pertains to attention regulation and inhibitory control (Vaughan Van Hecke, Mundy, Block, Delgado, Parlade, Pomares, & Hobson, 2012). Children with ASD show less IJA and RJA than those with developmental disorders without ASD (Loveland & Landry, 1986; Mundy et al., 1986). As for other aspects, the acquisition of IJA and the gaze-following aspect of RJA are more difficult than the point-following component of RJA (Beppu, 1996; Travis, Sigman, & Ruskin, 2001). Moreover, IJA can be classified into high-level IJA (IJA-HL; pointing and/or showing) and low-level IJA (IJA-LL; coordinated gaze shifts). A recent study showed that IJA-LL, IJA-HL, and the point-following of RJA are differentially related to measures of later social and language development in children with ASD (e.g., Pickard & Ingersoll, 2015). Although IJA-HL is a unique predictor of imitation, and point-following is the predictor of both imitation and language, IJA-LL is not related to later social-communication. Paparella, Goods, Freeman, and Kasari (2011) reported that the sequence of joint attention emergence in ASD differs from typical development, with the first joint attention emergence being IJA-LL. In this regard, all of the sub-divided joint attention behaviors are important contributors to social-communication development.

Joint attention is also considered to be a pivotal skill in promoting later language and sociality (Mundy & Crowson, 1997), while the acquisition of joint attention is a priority in development support. Hence, various developmental support programs aimed at the acquisition of joint attention have been designed (e.g., ESDM: Roger & Dawson, 2010; SCERTS: Prizant, Wetherby, Rubin, Laurent, & Rydell, 2006; JASPER: Kasari, Gulsrud, Paparella, Hellemann, & Berry, 2015). Since children with ASD have difficulty displaying spontaneous request behaviors (Leekam & Ramsden, 2006), it is important for them to acquire joint attention and establish the spontaneous request method to substitute for language. Lerna, Esposito, Conson, Russo, and Massagli (2012) reported that the Picture Exchange Communication System (PECS: Frost & Bondy, 2002) collaterally promoted early social-communication behaviors (including joint attention) in children with ASD. In other words, the PECS can help children with ASD not only acquire a request method, but also early social-communication behaviors.

The PECS is a spontaneous and functional communication training system that uses picture exchange for non-verbal children with ASD (Bondy & Frost, 1994). PECS attracted attention as a support technique for children with ASD. Overall, PECS training is divided into six phases (Phases 1–6) in which children master the criteria in each phase and advance to the next stage (Bondy & Frost, 1994). Carr and Felce (2007) reported that Phases 1–3 of the PECS increased spontaneous communication in children with ASD, while Lerna et al. (2012) showed that Phases 1–4 of the PECS collaterally promoted social-communication skills such as request behaviors and IJA-LL.

In general, there are two schools of thought regarding the effect of the PECS on IJA. One is explanation by social motivation, while the other is explanation by social cognition. According to the social motivation theory to explain ASD symptoms (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012), social motivational disability causes children with ASD to decrease their interaction with others and inhibits the development of social-communication skills such as joint attention. In other words, since their requests are conveyed by the PECS, their social motivation increases, and joint attention behavior is promoted. From the viewpoint of social cognition, the PECS system visualizes communication exchange, such as a child-required item-communication partner via a picture card, and they detect “the joint attention frame” (Tomasello, 2003). In either case, joint attention behavior is promoted by communication exchange via picture cards.

The majority of previous research on the effect of the PECS only conducted Phases 1–3, since the acquisition of request skills is useful for children with ASD and their families. A related study found that it is easier to master such skills in Phases 1–3 than in Phase 4, while the latter may require clinical therapy for a longer time period (Fujino, 2009). Perhaps an
instruction program to promote the development of joint attention could be more effective if it was proven that IJA among children with ASD increases by acquiring the skills in Phases 1–3. However, previous studies have not concluded that IJA in children with ASD increases by acquiring the skills in these phases (e.g., Lerna et al., 2012). Thus, there is still room for consideration.

It is important to discuss how the PECS can improve early social-communication behaviors in children with ASD. Therefore, this study investigated whether Phases 1–3 of the PECS (which are relatively easier for children to master than Phase 4) promote the development of early social-communication behaviors in children with ASD. Since previous research did not indicate which joint attention behaviors (i.e., IJA-LL, IJA-HL, or RJA) are influenced by PECS training, we examined the effect of PECS training on each of the different joint attention behaviors. Moreover, since Phases 1–4 of the PECS collaterally promote IJA-LL (Lerna et al., 2012) and Phases 1–3 promote joint attention behavior through communication exchange via picture cards, this study makes the following hypothesis: The shorter phase of the PECS promotes the development of at least IJA-LL in children with ASD because the first joint attention behavior that emerged was IJA-LL (Paparella et al., 2011). Additionally, previous studies have not shown the PECS effect on eye-contact and positive affect expression. Therefore, as an exploratory analysis, we examined the effect of PECS training on the development of early social-communication behaviors in children with ASD, aside from joint attention.

Methods

Participants

Forty-three children with ASD participated in this study, the majority of whom were unable to use two-word sentences. Their mean chronological age (CA) was 45.85±10.72 (26–69) months, while their mean developmental age (DA), as assessed by the Kyoto Scale of Psychological Development 2001 (Ikuzawa, Matsushita, & Nakase, 2002), was 18.99±4.63 (11.18–31.20) months. Twenty-nine children were diagnosed with ASD (including autism and pervasive development disorder not otherwise specified, PDD-NOS) by medical doctors in accordance with the DSM-IV-TR (American Psychiatric Association, 2000) or DSM-5 (American Psychiatric Association, 2013) criteria. The remaining 14 children did not receive a medical diagnosis of ASD. Instead, we used the Social Communication Questionnaire (SCQ; Kuroda, Inada, & Uchiyama, 2013), which is an effective screening tool for supporting the clinical diagnosis of ASD. All 43 children scored higher than or equal to the SCQ cutoff value (15 points). According to the t-test analysis, the effect was not statistically significant for the SCQ (with diagnosis 23.90±4.49; without diagnosis 22.79±5.04; t(41)=0.73, p=0.47). Thus, we considered a child scoring higher than or equal to the SCQ cutoff value as a child with ASD.

All of the children attended the same child development support center five days a week and received common group therapy. We recruited the participants who received individual developmental support at the university (including PECS training). Based on their parents’ consent, the recruited participants were divided into two groups: a PECS training group (n=19) and a non-intervention (control) group (n=24). Table 1 shows the participants’ characteristics for both the PECS training group and the control group during the pre-training period. According to the t-test analysis, the group effect was not statistically significant for CA, DA, and the SCQ (t(41)=0.53, p=0.60; t(41)=0.59, p=0.56; t(41)=0.14, p=0.89).

This research project was conducted over a span of four years, and it recruited participants at the same...
time each year in a similar manner. Specifically, in the first year, six children were assigned to the PECS group, while eight were assigned to the control group. In the second year, seven children were assigned to the PECS group, while five were assigned to the control group. In the third year, no children were assigned to the PECS group, while six were assigned to the control group. In the fourth year, six children were assigned to the PECS group, while five were assigned to the control group. Only the first-year data of those who participated in this research project for more two years was used for analysis.

**Procedure**

We evaluated early social-communication behaviors via behavioral observations and an eye-tracking experiment during both the pre- and post-training phases of the PECS in order to determine if any changes following PECS therapy were significant (Table 2). Each year, the pre-training phase occurred from April through May, the intervention phase was from May through October, and the post-training phase was from October through November.

**Outcome Measures**

**Behavioral observation measures in free-play situations.** In both the pre- and post-phases, we conducted behavioral observations during free-play situations in a playroom at the child developmental support center, similar to those performed in the research by Nagai, Hinobayashi, and Kanazawa (2017a). The free-play situations occurred for approximately 90 minutes per day. The door to the playroom remained locked during these sessions to ensure the safety of the children and to prevent any of them from unexpectedly leaving the room. The play equipment included a trampoline, slide, bead cushion, mat, wall bars, and rope swing. In addition, various toys, such as mini-cars, blocks, housekeeping sets, and picture books, were prepared by the nursery staff. It should be noted that the communication book for the PECS was not provided, since the children in either group participated together during the observation situations.

Video recording was also conducted when more than five children and two nursery staff were in the room. The combination of children and nursery staff was decided according to the activities in the center. The nursery staff having played with the children knew whether each child belonged to either group, but no particular changed to their method of engagement. The first author, who had previously established a good rapport with the children and staff members at the center, conducted all of the observations alone, in order to avoid any disturbance effect that could have been caused by the presence of multiple observers. Using a hand-held recorder, all of the observations focused on the front side of the target child to enable the observer to capture and evaluate his/her gaze direction and expressions. The observer also used a five-minute focal sampling method (Martin & Bateson, 2007), in random order using Microsoft Excel’s RAND function. We recorded the behaviors of the 43 individuals four times in each phase, with 40 minutes of video recording per individual. The total recording time was 1,720 minutes, recorded over 160 days in the four-year period.

We coded the occurrences of early social-communication behaviors in the video recordings according to their operational definitions (Table 3). Each category was based on the study by Nagai et al. (2017a). We also calculated the frequency of requests and IJA in 20-minute segments as well as the ratio of eye-contact and positive affect expression. In order to assess the coding reliability, the first author and a well-trained research assistant independently coded a randomly selected portion of the video data (approximately 20%, n=9 of 43). Cohen’s kappa for each category was calculated by the interrater agreement of each behavior, recorded per second. Table 3 presents Cohen’s kappa in this study (κ=0.78–1.00).

**Eye-tracking measures: To measure gaze behav-

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### Table 2 Within Group and Between Groups Observation and Eye-tracking Experiment Schedule

| Group             | Pre Phase (5 weeks)                  | Intervention (24 weeks)                     | Post Phase (5 weeks)                       |
|-------------------|--------------------------------------|--------------------------------------------|-------------------------------------------|
| PECS training     | Behavior observation and Eye-tracking experiment | Individual therapy for PECS training (Phases 1–3) and Group therapy | Behavior observation and Eye-tracking experiment |
| Control           |                                       | Group therapy                               |                                           |

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During both the pre- and post-phases, we used a corneal reflection technique (TobiiT60XL; Tobii Technology Japan) to record the gaze of both eyes from the reflection of near-infrared light on the cornea and pupil. The frequency of the recordings by this system was 60 Hz and the visual angles were precision to 0.5° and accurate to 0.22°. An integrated 24-inch computer display (1,920×1,200 pixels) presented the stimuli movie in a darkened room by means of a computer with Tobii Studio software, Version 2.1.15 (Tobii Technology Japan), while the ClearView Fixation Filter was set to define the gaze fixation. The distance from the monitor to the participants was approximately 60 cm. The participants were permitted to move their heads throughout the experiment, but were instructed to remain seated in the chair, since the data had to be collected inside the parameters of head movement space for accurate recordings, which was 40×20×27 cm. A five-point calibration was administered.

We based our use of stimuli movies (Fig. 1) and RJA evaluation on a previous study, which found that eye-tracking provides a useful measure of RJA (Nagai, Hinobayashi, & Kanazawa, 2017b). Each stimulus began with a scene of a female model sitting behind a table and facing the camera. Two toy objects were placed on the table, one on each side of the model. The videos consisted of three steps. The first step was the baseline (Fig. 1, left), in which the model remained still for 3.0 seconds. In the second step, the model turned her head with/without pointing toward one of the two objects (1.2 seconds). The third step was the gaze-following condition (Fig. 1, center) or the point-following condition (Fig. 1, right), fixating on the object for 2.8 seconds. In total, four trials (gaze-following or point-following condition, left or right) were presented to each child.

After the recording, a gaze-replay movie file showing the exact location of each child’s gaze was exported. The principal measurement of gaze-following determined whether the first eye-movement saccade from the head toward an object during the gaze-following condition step or the point-following condition step moved toward the object at which the model looked at (correct responsiveness) or toward the other object (incorrect responsiveness). We then analyzed the gaze behaviors by using both an “area of interest (AOI)” setting and a “gaze plot” function to judge whether the participants’ gaze fixation moved from the model (RJA cue) to the toy (object of the

Table 3 Operational Definitions and Inter-Observer Reliabilities for Behaviors Observed in a Free-Play Situation

| Behavior Category | κ   | Definition                                                                 |
|-------------------|-----|---------------------------------------------------------------------------|
| Request           | 0.87| Verbal requests, gesturing (pointing for request, reaching for an object), and using an adult's hand as an instrument (crane behavior) |
| Eye-Contact       | 0.79| Looking at communication partner’s face with spontaneous request           |
| IJA-LL            | 0.84| The child makes eye-contact with others while manipulating or touching a toy. The child alternates looking between an object and the other's eyes. |
| IJA-HL            | 1.00| With a clear articulation of the index finger the child points to an object. The child raises a toy upward toward the other's face while looking at the other. |
| Positive affect expression | 0.78| Smiling or positive affect expression with looking at communication partner’s face while request and IJA |

Fig. 1 An Example of Series of Eye-tracking Stimuli
Left: baseline, center: gaze-following condition, right: point-following condition.
RJA target). Figure 2 shows the AOI setting and visual angle for each condition, following Nagai, Hinobayashi, and Kanazawa, (2017b). We also used AOI analysis tools to calculate where and for how long the participants fixed their eye gaze in each step. Overall, three AOIs were defined to analyze each video: the overall, the RJA cue, and the RJA target (Fig. 2). Three steps were also defined for each video: the baseline (3.0 seconds), turning toward the target object (1.2 seconds), and the fixation on the target object (2.8 seconds). Thus, we reported the fixation time for each step and AOI during the gaze-following or point-following conditions.

**Treatment**

The children with ASD received PECS training during the individual developmental support program in a visually structured room at the university associated with the authors. Specifically, each child received PECS training (Phases 1–3) during the 10-minute snack time of the 50-minute individual therapy sessions that were conducted once a week for 24 weeks. The average number of times that they participated in the program was 15.42±2.73 times (10–19 times), due to the parents' availability and the children's physical conditions. The standard schedule of one developmental support session was as follows: free-play with the therapists and parents (20 minutes); independent task activity (5 minutes); free-play with the parents (15 minutes); and snack time (10 minutes).

It should be noted that we conducted Phases 1–3 of the PECS training based on Frost and Bondy's methodology (2002). We also continued support until a planned endpoint, even if each child completed Phase 3. In the remaining period, we utilized the PECS during the free-play sessions in order to generalize the PECS strategies in the children's home lives, but we did not begin Phase 4. In order to enable the children to transfer the PECS into their home lives, we required the parents to participate in the training and provided them with appropriate advice. In particular, the therapists advised the parents to immediately offer extravagant praise when their children gave them a picture card. As for the therapists, they previously attended a workshop on PECS training provided by an expert consultant from Pyramid Educational Consultants Japan, after which they received a certificate of completion. The first author was in charge of all of the main therapists in this program to avoid any disturbance effect that could have been caused by the presence of multiple therapists.

**Analysis**

All of the statistical analyses were performed using SPSS Version 22 (IBM Japan, Ltd.). We used a pre-/post-phase paired generalized linear mixed model (GLMM; Schall, 1991) for the analysis, since it can handle non-normal data and contains random terms in its linear predictor. The objective variables were behavioral observations and eye-tracking measures. We supposed that the variables of the number of occurrences (request, IJA-LL, and IJA-HL) had a Poisson distribution and therefore used a log link. We also supposed that the variables of the ratio of occurrences (eye-contact, positive affect expression, and eye-tracking measures) had a binomial distribution and therefore used a logit link. Random terms were used to represent subject-specific random variation and account for repeated sampling within the same individuals. In our GLMM models, the identities of the participants were inserted as nested random effects to avoid the problem of non-independence that...
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might have occurred if different dyads were formed by the same individuals. The group (PECS training/control), phase (pre/post), interaction of group and phase, CA, DA, and SCQ scores of the participants were inserted as fixed effects. We then performed a post-hoc test to analyze the interaction between group and phase using Bonferroni correction.

**Ethical Considerations**

This study was approved by the Ethics Committee of the Behavioral Science/Graduate School of Human Sciences, Osaka University. The study purpose and methods were explained both orally and in writing to the participants’ caregivers, after which we obtained their informed consent.

**Results**

Table 4 presents the descriptive statistics of early social-communication behavior occurrences. The number of request behaviors was not significantly influenced by any fixed effects in our GLMM model, whereas the ratio of eye-contact to request behaviors (Table 5) was significantly influenced by the interaction with group and phase. According to the results of the post-hoc test, the post-phase for children in the PECS training group had a significantly higher mean than the pre-phase ($p<.01$), while the control group results were not significant. The number of IJA-LL behaviors (Table 5) was significantly influenced by the SCQ score. The ratio of positive affect expression to eye-contact or IJA (Table 5) was significantly influenced by the interaction with group as well as group and phase. According to the post-hoc test on the interaction between group and phase, the post-phase PECS training group showed significantly higher scores than the pre-phase group ($p < .01$), while the control group results were not significant.

**Discussion**

In this study, we investigated whether Phases 1–3 of PECS training, which children master easily, promoted the development of early social-communication behaviors in children with ASD.

| Variable                      | PECS Group | Control Group |
|-------------------------------|------------|---------------|
|                              | Pre Phase  | Post Phase    | Pre Phase | Post Phase |
|                              | Mean      | SE   | Mean      | SE     | Mean     | SE     |
| Request Number                | 4.63      | 1.02 | 8.03      | 1.53 | 3.11     | 0.69  |
| Eye-contact Ratio             | 0.17      | 0.05 | 0.37      | 0.07 | 0.17     | 0.05  |
| IJA-LL Number                 | 5.36      | 1.15 | 17.67     | 3.27 | 6.47     | 1.19  |
| IJA-HL Number                 | 0.58      | 0.55 | 1.68      | 0.83 | 0.92     | 0.49  |
| Positive affect expression    | 0.16      | 0.03 | 0.34      | 0.04 | 0.27     | 0.04  |
| RJA (Gaze-following) Ratio    | 0.08      | 0.05 | 0.17      | 0.08 | 0.17     | 0.06  |
| RJA (Point-following) Ratio   | 0.16      | 0.07 | 0.47      | 0.12 | 0.14     | 0.06  |

Table 4 Means and Standard Errors (SE) of Number or Ratio of Early Social-Communication Behaviors at Pre- and Post-Training Phases Shown Separately for the Two Groups
Table 5 Influence of Independent Factors on the Early Social-Communication Behaviors by Behavior Observation

| Variable               | Independent term      | Coef  | SE (coef) | t     | p (>|t|) |
|------------------------|-----------------------|-------|-----------|-------|-------|
|                        | Factor                | Level |           |       |       |
| Request                | Intercept             | 2.55  | 1.39      | 1.84  | 0.08  |
|                        | Group                 |       |           |       |       |
|                        | PECS training         | 0.36  | 0.30      | 1.21  | 0.23  |
|                        | Phase                 | 0.12  | 0.27      | 0.43  | 0.67  |
|                        | Group×Phase           | 0.44  | 0.35      | 1.26  | 0.21  |
|                        | CA                    | 0.01  | 0.01      | 0.59  | 0.56  |
|                        | DA                    | −0.02 | 0.04      | −0.52 | 0.61  |
|                        | SCQ                   | −0.06 | 0.03      | −1.77 | 0.09  |
| Eye-contact            | Intercept             |       |           | −2.96 | 0.20  |
|                        | Group                 |       |           | 0.22  | 0.69  |
|                        | PECS training         | 0.02  | 0.02      | 0.86  | 0.40  |
|                        | Phase                 | −0.03 | 0.46      | −0.06 | 0.95  |
|                        | Group×Phase           | 1.18  | 0.58      | 2.04  | <.05  |
|                        | CA                    | 0.02  | 0.02      | 0.88  | 0.38  |
|                        | DA                    | 0.05  | 0.06      | 0.79  | 0.43  |
|                        | SCQ                   | −0.02 | 0.05      | −0.45 | 0.66  |
| IJA-LL                 | Intercept             | 4.13  | 1.11      | 3.71  | <.01  |
|                        | Group                 |       |           | −0.26 | 0.32  |
|                        | PECS training         | 0.28  | 0.14      | 2.05  | <.05  |
|                        | Phase                 |       |           | 1.13  | 0.12  |
|                        | Group×Phase           | 0.91  | 0.21      | 4.38  | <.001 |
|                        | CA                    | 0.01  | 0.01      | 0.88  | 0.38  |
|                        | DA                    | −0.01 | 0.03      | −0.36 | 0.72  |
|                        | SCQ                   | −0.10 | 0.03      | −3.83 | <.01  |
| IJA-HL                 | Intercept             | 9.65  | 3.96      | 2.44  | <.05  |
|                        | Group                 |       |           | −0.45 | 0.62  |
|                        | PECS training         | 1.13  | 0.71      | 1.58  | 0.12  |
|                        | Phase                 |       |           | −0.03 | 0.98  |
|                        | Group×Phase           | 1.06  | 1.06      | −0.02 | 0.98  |
|                        | CA                    | 0.02  | 0.04      | 0.66  | 0.51  |
|                        | DA                    | −0.11 | 0.10      | −1.11 | 0.27  |
|                        | SCQ                   | −0.32 | 0.10      | −3.39 | <.01  |
| Positive affect        | Intercept             | −1.13 | 1.41      | −0.80 | 0.43  |
| expression             | Group                 |       |           | −0.76 | 0.50  |
|                        | PECS training         | −0.37 | 0.40      | −2.55 | <.05  |
|                        | Phase                 |       |           | 1.43  | 0.07  |
|                        | Group×Phase           | 0.31  | 4.63      | <.001 |
|                        | CA                    | 0.00  | 0.01      | 0.27  | 0.79  |
|                        | DA                    | 0.02  | 0.04      | 0.49  | 0.63  |
|                        | SCQ                   | −0.01 | 0.03      | −0.42 | 0.68  |

Note. The generalized linear mixed model with Poisson distribution was used in the analyses for request, IJA-LL, and IJA-HL. These generalized linear mixed model with binomial distribution was used in the analysis for eye-contact with request and positive affect expression with eye-contact with request or IJA. In these models, the identities of participants were inserted as nested random effects. In these models with categorical independent variables, one of the levels was treated as a criterion, and the parameters of the other levels were estimated as the difference from the criterion level. In these models, in the factor “group”, the level “control” was treated as a criterion, and the coefficient of “PECS training” was shown as the differences from the level of “control”, and in the factor “phase”, the level “pre” was treated as a criterion, and the coefficient of “post” was shown as the differences from the level of “pre”.

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The results showed that many kinds of early social-communication behaviors in the post-phase in children with ASD who had received PECS training had significantly improved, compared to those who had not received PECS training. In particular, the results showed that the frequency of IJA-LL in the children who had received PECS training significantly increased. This is consistent with previous work (Lerna et al., 2012), which indicated that Phases 1–4 of PECS training collaterally promote the development of IJA-LL. This study also showed that the three shorter phases of PECS training could also effectively promote the development of IJA-LL, thereby supporting our hypothesis. Children with ASD who had completed Phases 1–3 were able to acquire the tools of spontaneous request. Although some children with ASD tend to take more time to complete Phases 4–6, many children can complete Phases 1–3 in a relatively short time period (Fujino, 2009). Receiving a shortened PECS training that only covers Phases 1–3 includes the significant advantage of promoting joint attention development. However, PECS training has not been shown to increase IJA-HL, such as pointing and showing, in children with ASD. According to Pickard and Ingersoll (2015), IJA-HL is strongly related to imitation skills and language development, whereas IJA-LL is not. Many previous studies have reported that IJA-HL guarantees better social-communication development in children with ASD. The GLMM analysis showed that both IJA-LL and IJA-HL were influenced by ASD symptoms. Poor IJA is indicative of ASD core symptoms (Mundy et al., 2003), and furthermore, prior research has indicated that IJA-HL develops later than IJA-LL in children with ASD (Paparella et al., 2011). Thus, considering both prior research and the results of this study, PECS training can scaffold social-communication learning in children with ASD by teaching them to spontaneously share attention with others. Based on these findings, the PECS supports the development of IJA-LL in children with ASD, which typically precedes the development of IJA-HL, thereby laying the

| Condition                  | Step                        | AOI                          | PECS Group | Control Group |
|----------------------------|-----------------------------|------------------------------|------------|---------------|
|                            |                             |                              | Pre Phase  | Post Phase    | Pre Phase  | Post Phase    |
|                            |                             |                              | Mean       | SE            | Mean       | SE            |
| Gaze-following             | Baseline                    | Overall                      | 1.76       | 0.20          | 1.80       | 0.26          |
|                            |                             | Cue                          | 0.71       | 0.14          | 1.07       | 0.26          |
|                            |                             | Target                       | 0.22       | 0.07          | 0.14       | 0.06          |
| Turning toward the target  | Baseline                    | Overall                      | 0.63       | 0.11          | 0.59       | 0.11          |
|                            |                             | Cue                          | 0.43       | 0.09          | 0.41       | 0.10          |
|                            |                             | Target                       | 0.04       | 0.02          | 0.03       | 0.02          |
| Fixation on the target     | Baseline                    | Overall                      | 1.20       | 0.22          | 1.19       | 0.27          |
|                            |                             | Cue                          | 0.42       | 0.13          | 0.76       | 0.25          |
|                            |                             | Target                       | 0.18       | 0.06          | 0.19       | 0.08          |
| Point-following            | Baseline                    | Overall                      | 1.48       | 0.20          | 1.18       | 0.20          |
|                            |                             | Cue                          | 1.22       | 0.19          | 0.95       | 0.19          |
|                            |                             | Target                       | 0.05       | 0.03          | 0.11       | 0.05          |
| Turning toward the target  | Baseline                    | Overall                      | 0.39       | 0.11          | 0.41       | 0.10          |
|                            |                             | Cue                          | 0.34       | 0.09          | 0.28       | 0.07          |
|                            |                             | Target                       | 0.08       | 0.05          | 0.09       | 0.04          |
| Fixation on the target     | Baseline                    | Overall                      | 1.19       | 0.26          | 1.25       | 0.28          |
|                            |                             | Cue                          | 0.77       | 0.20          | 0.80       | 0.17          |
|                            |                             | Target                       | 0.16       | 0.06          | 0.20       | 0.07          |
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Foundation for future learning.

The results of the eye-tracking experiment showed that the children with ASD who received PECS training could easily respond to the direction toward which others focused their attention; Nevertheless their fixation time did not change. Separating RJA into gaze-following and point-following, the results showed that their gaze-following did not change, but their point-following increased after PECS training. This is consistent with previous research showing that children with ASD have difficulty improving the gaze-following aspect of RJA, while easily acquiring point-following skills (Beppu, 1996; Travis et al., 2001; Paparella et al., 2011). Another study reported that point-following skills in children with ASD develop with an increase in mental development age (Mundy, Sigman, & Kasari, 1994). However, the results showed that only the interaction with group and phase significantly influenced point-following, even if DA was simultaneously inserted as a fixed effect. Hence, we believe that PECS training effectively contributes to the development of point-following and that the influence of DA is restrictive. The development of both IJA and RJA is also necessary to establish interactive communication using shared attention. Our results suggest that PECS training promotes the development of joint attention during the interactions between a child with ASD and a communication partner.

Although we incorporated request skills into our PECS therapy sessions, our results did not show that the frequency of request behaviors increased in children with ASD after receiving PECS training. This result is inconsistent with previous studies (Carr & Felce, 2007; Lerna et al., 2012). Lerna et al. (2012) reported that, when the PECS was introduced to the observation situation, the request behaviors in children with ASD increased after PECS training. Our results are inconsistent with this previous study because the PECS system was not introduced into our observation situation. However, we showed that other early social-communication behaviors, such as eye-contact during requests and positive affect expression in children with ASD, were promoted by PECS. There were also fewer of these behaviors in children with ASD than in typically developing children (Kasari et al., 1990; Phillip et al., 1995). This finding is in line with Ozonoff et al. (2010), who

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Table 7 Influence of Independent Factors on RJA by Eye-Tracking

| Variable                  | Independent term | Coef | SE (coef) | t     | p (>|t|) |
|---------------------------|------------------|------|-----------|-------|-------|
|                           | Factor           |      |           |       |       |
|                           | Level            |      |           |       |       |
| Point-following           | Intercept        | −3.97| 3.31      | −1.20 | 0.24  |
|                           | Group            | 0.01 | 0.72      | 0.02  | 0.99  |
|                           | Phase            | −0.35| 0.56      | −0.64 | 0.53  |
|                           | Group×Phase      | 1.94 | 0.80      | 2.43  | <0.05 |
|                           | CA               | −0.02| 0.03      | −0.55 | 0.59  |
|                           | DA               | 0.15 | 0.08      | 1.79  | 0.09  |
|                           | SCQ              | 0.01 | 0.08      | 0.05  | 0.96  |
| Gaze-following            | Intercept        | 3.81 | 3.00      | 1.29  | 0.20  |
|                           | Group            | −1.10| 0.76      | −1.45 | 0.16  |
|                           | Phase            | −1.37| 0.74      | −1.84 | 0.07  |
|                           | Group×Phase      | 2.17 | 1.12      | 1.94  | 0.06  |
|                           | CA               | 0.00 | 0.03      | 0.10  | 0.93  |
|                           | DA               | −0.02| 0.07      | −0.35 | 0.73  |
|                           | SCQ              | −0.21| 0.07      | −2.88 | <0.01 |

Note. The generalized linear mixed model with binomial distribution was used in the analysis for point-following and gaze-following. In these models, the identities of participants were inserted as nested random effects. In these models with categorical independent variables, one of the levels was treated as a criterion, and the parameters of the other levels were estimated as the difference from the criterion level. In these models, in the factor “group”, the level “control” was treated as a criterion, and the coefficient of “PECS training” was shown as the differences from the level of “control”, and in the factor “phase”, the level “pre” was treated as a criterion, and the coefficient of “post” was shown as the differences from the level of “pre”.
showed that the frequency of these behaviors in children with ASD suddenly decreases from six months to 12 months of age. Nevertheless, in our study, the PECS improved the early social-communication behaviors in the children with ASD. Children with ASD acquired the request method by receiving PECS training and experienced both the realization of their request and the subsequent praise. The children’s motivation for social engagement, attention sharing, and emotion sharing were also represented as joint attention behaviors (Bakeman & Adamson, 1984). Their experience through PECS training was their social reward, and their social motivation to attempt to request again and social engagement might increase. Since joint attention behaviors are a pivotal skill in promoting later language and sociality (Mundy & Crowson, 1997), joint attention and social motivation promoted by the PECS might increase other early social-communication behaviors. Charlop-Christy, Carpenter, LeBlanc, and Kellet (2002) reported that PECS training can improve maladaptive behaviors in children with ASD. Considering that positive affect expression combined with communication behaviors is a negative predictor of maladaptive behaviors in children with ASD (Nagai et al., 2017a), our results suggest that the PECS may provide the additional benefit of increased positive affect expression, such as reducing maladaptive behaviors.

In this study, we investigated whether Phases 1–3 of PECS training promoted the development of early social-communication behaviors in children with ASD. Previous empirical studies on PECS showed intervention effects, such as increased spontaneous communication (Carr & Felce, 2007), eye-contact during requests, and IJA-LL, during behavioral observations (Lerna et al., 2012). Based on the findings of previous studies, we used detailed behavioral observations and eye-tracking techniques to demonstrate that PECS training collaterally promotes early social-communication in children with ASD. Kanazawa and Nagai (2012) reported that a child with severe ASD independently applied the PECS to various request devices such as pointing and showing a letter. This collateral effect of the PECS suggests that children with ASD not only acquire the picture exchange skill and the general communication framework for requests, but they also spontaneously apply various devices in their communication. Overall, this study includes four limitations. First, it did not determine the mechanism in which the PECS promotes the development of joint attention. Future research should determine the mechanism in which social cognition and social motivation can promote joint attention in children with ASD. Second, since the participants received PECS training as a result of their parents’ initiative, future studies should adopt the design of randomized controlled trials for a more accurate investigation. In addition, they should examine whether parents’ engagement and approach at home influence the effects of PECS. Third, there were several methodological problems. For instance, several trials of the stimulus presentation were left incomplete in the measurement of RJA by eye-tracking. Fourth, this study did not investigate the long-term effect of PECS.

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