A randomised controlled trial of a computerised intervention for children with social communication difficulties to support peer collaboration

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Abstract: An intervention aiming to support children with social communication difficulties was tested using a randomised controlled design. Children aged 5-6 years-old (n = 32) were tested and selected for participation on the basis of their scores on the Test of Pragmatic Skills (TPS) and were then randomly assigned to the intervention arm or to the delayed intervention control group. Following previous research which suggested that computer technology may be particularly useful for this group of children, the intervention included a collaborative computer game which the children played with an adult. Subsequently, children's performance as they played the game with a classmate was observed. Micro-analytic observational methods were used to analyse the audio-recorded interaction of the children as they played. Pre- and post-intervention measures comprised the Test of Pragmatic skills, children's performance on the computer game and verbal communication measures that the children used during the game.
This evaluation of the intervention shows promise. At post-test, the children who had received the intervention, by comparison to the control group who had not, showed significant gains in their scores on the Test of Pragmatic Skills ($p = .009$, effect size $r = -.42$), a significant improvement in their performance on the computer game ($p = .03$, $r = -.32$) and significantly greater use of high-quality questioning during collaboration ($p < .001$, $r = -.60$). Furthermore, the children who received the intervention made significantly more positive statements about the game and about their partners ($p = .02$, $r = -.34$) suggesting that the intervention increased their confidence and enjoyment.

Title: A Randomised Controlled Trial of a Computerised Intervention for Children with Social Communication Difficulties to Support Peer Collaboration.

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The above authors confirm that this manuscript has not been previously published and has not been submitted elsewhere

***Highlights (for review)**

- Children with social communicative disorders find peer collaborative activities a challenge
- The study reports an RCT to evaluate an intervention to aid these children to collaborate
- The intervention used a collaborative computer task to encourage perspective-taking
- Children receiving the intervention showed improved their pragmatic skills post-test

1. Introduction

Children who experience difficulties with social communication and language skills are known to have problematic peer relationships (Ellis Weismer, 2013). They are less well-accepted than typically-developing children (Laws et al., 2012) and can be at greater risk of bullying (Conti-Ramsden & Botting, 2004). Emerging evidence also suggests that they are less likely to be able to benefit from the collaborative activities with peers that are a common feature of educational settings (Brinton, Fujiki, Montague & Hanton, 2000; authors' own blinded reference 1). However, research into how to improve collaborative working for these children is scarce. We report here a randomised controlled trial of an intervention to support young children (ages 5-6 years-old) with social communication difficulties to participate in collaborative interaction to address this limited literature.

1.1 Characteristics of children with impairments in social communication

The difficulties experienced by children with social communication impairments include the use of linguistic context to comprehend a speaker's meaning (pragmatic language skill) and, more broadly, application of knowledge of conventional norms and expectations from the wider society in which the child lives to understand and relate to others (Norbury, 2014). For example, such children are likely to find it difficult to take turns during conversation, to maintain a topic of conversation appropriately, make inferences, understand non-literal language such as jokes or sarcasm, repair communication breakdowns and may often be non-responsive or respond irrelevantly to conversational partners.

Children with difficulties with the use of language in social communication are a heterogeneous group and encompass both clinical and non-clinical categories. Clinical groups include the categories of 'Language Impairment' (also commonly known as 'Specific Language Impairment'), 'Social (Pragmatic) Communication Disorder' and 'Autism Spectrum Disorders' defined in DSM V (Diagnostic and Statistical Manual of Mental

Disorders, American Psychiatric Association, 2013). Children experiencing difficulties with social communication are not limited to those covered by these DSM V diagnoses. Social communication and pragmatic language difficulties have also been shown to be associated with other clinical populations such as ADHD and conduct disorder (Norbury, 2014) and with non-clinical groups such as shy children (Coplan & Weeks, 2009, Mewhort-Buist & Nilsen, 2013). It has also been reported that social communication disorders are severely under-diagnosed, particularly in children of low socio-economic status (Bishop & McDonald 2009; Donno, Parker, Gilmour & Skuse, 2010). Although exact figures are sparse, it is estimated that approximately two-thirds of children with speech, language and communication needs do not seek help from services (Law, Reilly & Snow, 2013). In view of the overlapping conditions, co-morbidity, under-diagnosis and impact of societal factors in the area of language impairment, these authors have argued that there is a need to take a more inclusive approach that targets a broader spectrum of children, rather than limiting itself to diagnosed children in receipt of healthcare services and/or special educational provision.

1.2 Benefits of collaborative working

Collaborative work is generally viewed by educators as a valuable activity for children that supports learning and development as well as being a preparation for working cooperatively in the adult world (Fawcett & Garton 2005; Joiner, Faulkner, Littleton & Miell, 2000). A number of collaborative activities between children (such as collaborative learning, cooperative learning or peer tutoring) now commonly take place in classrooms and have generally been judged to be beneficial in terms of improved learning (e.g., Azmitia, 1998; Johnson & Johnson, 2009; Tolmie et al., 2010). As well as educational benefits, collaborative working has been claimed to improve peer relations and facilitate children's feelings of belonging (Johnson-Pynn & Nisbet, 2002; Tolmie et al., 2010). However, group and/or dyadic work is not invariably useful, only collaborations where children are actively engaged and that are characterised by high-quality questioning, explanation, clarification of ideas, discussion and generally positive affect have been found to be productive (Howe, 2010). Thus, it would appear that children with social communicative impairments would find such activities challenging but potentially would have much to gain from opportunities to collaborate, if these can be designed to cater for their needs. This is especially true bearing in mind the negative long-term impact into adulthood of such impairments on academic achievement, social relationships and mental health (Whitehouse, Watt, Line & Bishop, 2009).

1.3 Social communication difficulties and collaborative work

One would anticipate that children with social communication difficulties would find it particularly challenging to participate in collaborative activities with their peers. Little is known about the precise ways in which social communication difficulties impact on collaborative contexts for young children (aged 3-7) although a few initial studies have begun to explore this question (Brinton et al., 2000; Kimhi & Bauminger-Zviely, 2012; authors' own blinded reference 1).

Brinton et al., (2000) examined collaboration between language-impaired children (ages 6 – 7 years-old) in triads with two typically-developing classmates. The triads were asked to collaborate on activities such as the construction of a toy vehicle, and production of a collage and a cardboard model. Although this was a preliminary study (only n=6 language-impaired children), the authors reported that four of the language-impaired children presented a challenge to cooperative work, displaying either aggressive or withdrawn behaviours in this context. They noted that the social demands of the task limited the children's inclusion and participation as much as the linguistic demands.

Kimhi & Bauminger-Zviely (2012) investigated collaborative problem-solving in children aged 3 to 6 years-old and compared high-functioning children with autism spectrum disorders (n = 28) with age-matched typically-developing children (n = 30). Children were observed whilst solving balance scale problems working in pairs. The authors found that the children with autism spectrum disorders were slower to solve the problems, showed more irrelevant behaviours and shared less, by comparison to the typically-developing children.

(Authors' own blinded reference1) compared 24 dyads comprising two typically-developing children with 32 dyads consisting of one typically-developing child and one child scoring low on a test of pragmatic language skills (ages 5 – 6 years-old). During a collaborative task, the low-scoring children frequently ignored their partners' questions and requests, used high-quality clarification questions less often and gave poorer directions than the typically-developing children. They also made fewer positive statements about the game or their partners.

In summary, these studies illustrate that children with social communication difficulties behave differently during collaboration than do their typically-developing peers and, in particular, are less likely to demonstrate some of the behaviours associated with successful collaborative learning such as sharing of information and effective questioning and responding. As well as demonstrating limitations in communication, problems with the social aspect of tasks are also evident such as aggression, withdrawal and less overall enjoyment.

1.4 Interventions for children with social communicative disorders

It is possible that these children could be aided by clinical and educational interventions; however, research is largely at early stages. Interventions for children with social communication difficulties encompass those for children with high-functioning autism spectrum disorders, others aimed at children with language impairments in social interaction but who do not meet the criteria for autism spectrum disorders and school-based interventions that will include (but not specifically target) children with social communication difficulties because they are universal interventions.

Recent reviews have examined social skills interventions for children with high-functioning autism spectrum disorders (Cappadocia & Weiss, 2011; Rao, Beidel, & Murray, 2008) and treatments for disorders of language use in social interactions excluding children with autism spectrum disorders (Gerber, Brice, Capone, Fujiki & Timler, 2012). Reviewed interventions used a variety of training techniques such as direct instruction (e.g., learning what a friend is, how to recognise facial expressions), modelling (watching an adult or peer demonstrate an 'ideal' behaviour), role-playing (acting out a particular role or behaviour in a simulated context), feedback and reinforcement (rewards such as snacks or treats) or cognitive-behavioural therapy techniques such as identifying feelings and practicing self-evaluation. Some interventions were more specifically aimed at producing changes in language use such as increases in initiation of conversation, topic maintenance and making relevant responses.

Few of the reviewed evaluations used comparison groups or randomised controlled trial methods and sample sizes were generally small making assessment of their efficacy difficult (however, for a recent exception, see Adams et al., 2012). Cappadocia & Weiss (2011) highlight a particular issue in this area, namely, that most studies evaluated entire intervention packages, rather than the techniques above (modelling, role-playing etc..) individually, thus rendering the possibility of isolating the particular 'active ingredient' in the intervention problematic. Whilst many of the interventions used group collaborative *activities* as situations in which to practise newly-learned social skills, only one recent study focused on collaborative *working* with peers (Bauminger-Zviely, Eden, Zancanaro, Weiss, & Gal, 2013). These authors included participation in collaborative computer games as one of the components in a cognitive-behavioural therapy intervention package. Other components of the package included direct instruction on conversation skills and social problem-solving using vignettes. Pre- and post-test analyses demonstrated some improvement for the package as a whole on measures of cooperative behaviour and social engagement, suggesting that this may be a useful approach, but the study was limited by lack of a control group.

Universal school-based interventions have been reported to improve collaborative learning in schools, including some for young children (e.g., Kutnick, Ota & Berdondini, 2008, children ages 5 – 7 years-old). However, whilst these universal interventions appear to benefit children in a class as a whole, it is acknowledged that there is wide variation from child to child (Tolmie et al., 2010), and the exploratory studies that have taken place so far (Brinton et al., 2000; Kimhi & Bauminger-Zviely, 2012; authors' own blinded reference 1) suggest that children with poorer social communication skills may need more support and training to participate effectively.

1.5 Design of collaborative tasks

Task design is recognised as one of the most challenging aspects of fostering constructive collaborative activity for children (Baines, Blatchford, Kutnick, Chowne, Ota & Berdondini, 2009). Generally, tasks that are stimulating, open-ended and high in ambiguity provide the right context for encouraging discussion and exchange of ideas (Baines et al., 2009, Howe et al., 2007). However, it is precisely in these unstructured, spontaneous, unrestricted situations that children with social communicative difficulties perform worst (Bishop & Adams, 1991) and may resort to aggressive or withdrawn behaviours (Brinton et al., 2000). Therefore, a careful balance needs to be reached on tasks between providing enough challenge and novelty to stimulate interest, versus incorporating some support in the form of constraints on the interaction so that children whose interactional skills are weak are able to contribute. A frequently-encountered problem in studies of collaborative learning is that the children do not, in fact, collaborate. Tasks typically used, such as jigsaw puzzles, balance beam, Lego® modelling and paper and pencil tasks often result in one child completing the task alone with the other children excluded from participation (Howe, 2010, Wegerif & Scrimshaw, 1997). One solution to this problem is to use the flexibility afforded by computer-assisted technology so that structured game formats can be designed that oblige each child to contribute equitably to a joint goal. This feature of computer technology has been exploited by Bauminger-Zviely et al. (2013) and Holt and Yuill (2014) to design collaborative tasks for children with autism. These authors were able, by using carefully tailored support to constrain and structure the social demands of the tasks, to elicit and develop specific contingent behaviours important to peer collaboration. These two studies suggest that computerised presentation of collaborative tasks may yield favourable results; however, this is still a novel approach, these pioneering studies are limited due to their lack of control groups and small sample sizes. We wished in the present study to use technology in order to manage the children's contributions to the task to avoid exclusion or domination.

A further advantage of the design flexibility available with computer technology is that it can be used to manipulate a game environment to create imaginative scenarios providing multiple instances requiring perspective-taking of one's own and another's point of view. Farrant, Fletcher & Maybery, 2006 have indicated that the impairments of children with language disorders impact on visual perspective-taking abilities. Therefore, we aimed to target the intervention effectively at perspective-taking and communication as these skills reciprocally influence each other.

The modelling approach to instruction (Palincsar & Brown, 1984) is based on a social, collaborative approach whereby an 'expert' initially demonstrates a particular skill and the 'novice' learns initially by observation and later by performing the skill themselves with support, encouragement and feedback from the expert. This approach is well-suited for training children with language impairments in the skills needed for collaborative work with peers, being based on a social approach and on observation rather than on an exclusively verbal approach.

1.6 Aims of the present study

Our aim was to trial an intervention to support children with social communicative difficulties to participate more effectively in peer collaborative work. Following the recommendations of Law et al., (2013) we recruited a mainstream school sample of children with social communication difficulties to include, but not be limited to, those with clinical diagnoses, selection was therefore based on a test of pragmatic language skills and a communication checklist.

In a previous study (authors' blinded reference 1) children taking part in a collaborative task who had scored low on a pragmatic skills test were observed and revealed clear differences on particular communications by comparison to high-scorers. Therefore, the intervention reported below targeted these specific verbal communication skills (i.e., giving appropriate directions, requesting clarification, information-seeking). These communications are also among those which previous research has identified as being associated with successful collaboration (Howe, 2010; Kruger, 1993).

The intervention described here adds to previous research in this area by (a) focusing specifically on improving children's collaborative working, (b) targeting a small number of selected discrete communicative skills rather than implementing the broad approach adopted by most previous studies (c) using modelling as a training technique in isolation rather than evaluating a package of training techniques and (d) using a randomised controlled trial design to assess changes in the children's language scores and behaviours.

The intervention that the children received was based on a dyadic computer task requiring substantial high-level collaboration and perspective-taking. The computer task was designed to frame and guide the interaction such that the purposes and consequences of social communication are made more salient and contingent than in typical conversations. A modelling training approach was used with the computer task as this was the most appropriate in this context where observation and awareness of the game partner's actions were important aspects for success. There were two groups; (a) the Intervention Group (IG) who received the intervention at Time 1 (b) the Delayed Intervention Group (DIG) who received the intervention later, at Time 2.

1.7. Hypotheses

1. The children in the Intervention Group (IG) will show superior performance on the computer game to children in the Delayed Intervention Group (DIG) immediately following the intervention administered at Time 1, as measured by the number of game rewards that they manage to score.

2. The children in the IG will show improved pragmatic language skills from baseline by comparison to children in the DIG as measured by the Test of Pragmatic Skills immediately following Time 1.

3. The children in the IG will show greater use of communication features associated with successful collaboration (e.g., questions, directives, clarifications) from baseline compared to children in the DIG immediately following Time 1.

2. Method

2.1. Overview of Study Method

Children were identified as high-pragmatic-language-skilled (HP) or low-pragmatic-language-skilled (LP) by means of the Test of Pragmatic Skills (TPS, Shulman, 1986). A pool of 201 children from mainstream schools was tested using the TPS, and from this, a sample comprising the highest- and lowest-scoring children were selected for the study; 32 children were identified as low-scoring.

Before the intervention was administered, each LP child was paired with an HP partner and the children's verbal communications were audio-recorded whilst they played the Maze Task computer game together. Baseline measures were taken; these were (a) the dyads' performance on the Maze Task (b) analysis of each member of the dyads' verbal communication and (c) TPS scores of the LP children.

The study design was a randomised controlled trial. After baseline measures were taken, half of the 32 LP children individually received the intervention; the other half received no intervention at this time but instead received it later. Children were randomly assigned to the intervention group (IG) or delayed intervention (DIG) control group. The intervention comprised three sessions playing the computer Maze Task game with a researcher, who used modelling techniques to instruct the children in verbal communication skills such as asking questions and giving good directions. Post-intervention (Time 1), all 32 LP children again played the Maze Task with the same HP partners as before and were again audio-recorded. As at baseline, measures of the dyad's performance on the Maze Task, the dyad members' verbal communication and TPS scores for the LP children were taken. The audio-recorded interaction of the dyads was analysed with a micro-analytic verbal communication coding system devised specifically for this study by the authors which was used for communications such as directives, questions, clarifications and requests. Finally, the intervention was given to the 16 children in the DIG who had not received it previously and the same measures as at Time 1 were again taken from all 32 children (Time 2).

2.2. Design

Measures were taken at baseline, Time1 and Time 2. The intervention was administered to the IG children between baseline and Time 1 and to the DIG children after Time 1 and before Time 2. We adopted a randomised controlled trial design; predictions were framed in relation to Time 1 results only. The crucial comparison was between the IG children and the DIG children at Time 1 when the IG children would have received the intervention but not the DIG children. We did however collect data at Time 2 as this provided an opportunity to carry out pre- and post-test analyses before and after the intervention for the DIG children. Although this comparison would not include a control group (the IG group having already received the intervention) it could potentially provide some indication of consistency with results obtained for the IG and DIG children at Time 1.

2.3. Participants

A total of 354 children from Year One classes in six U.K. schools were invited to participate. Letters were sent to parents explaining the study and written consent responses requested. Children's assent was also taken at the time that they were invited to participate in the interviews. Before study commencement, the full study protocol was examined by the University of (blinded) Ethics Committee and approval granted. A participation of rate of 61% was obtained, thus giving a total sample pool of 214 children (54% boys) of ages between 5 years 0 months and 6 years 5 months (*M* = 5 years 6 months, *SD* = 3.48 months). Demographic details of this sample pool have been given in a previous article (Authors' blinded reference 1).

2.4. Sampling Procedures

The sample of children who participated in the study was selected from the main pool of 214 children. Teachers were consulted about suitability; they recommended that 13 children did not take part due to English not being their first language and of an insufficiently high standard. All remaining 201 children were individually interviewed by the third author to administer the Test of Pragmatic Skills (TPS, Shulman, 1986) and the British Picture Vocabulary Scale (BPVS, Dunn, Dunn, Whetton, & Burley, 1997). Interviews took place in a quiet area of the school and lasted approximately 20 minutes. In addition to these measures, teachers were also asked to complete the Child Communication Checklist-2 (CCC-

2, Bishop, 2003) for all children scoring one standard deviation below the mean on the TPS i.e., for 32 children. All teachers had known the children for at least 3 months as recommended by the CCC-2 manual and the response rate was 100%.

2.5. Selection and Baseline Measures

Test of Pragmatic Skills.

The Test of Pragmatic Skills (TPS, Shulman, 1986) has been devised to give a measure of pragmatic skill in relation to developmental norms in typically-developing children ages three- to eight-years-old. The TPS has been standardised on 650 children in USA and test-retest reliability over 3 weeks was .96 and inter-rater reliability was .92. It is an elicitation test assessing the child's use of different communicative functions in a standardised but natural setting, where test questions are embedded within an on-going conversation with guided play between an adult tester and the child. It is designed to assess the extent to which children select an appropriate message or interpretation in relation to communicative contexts (e.g. greeting, requesting, informing, rejecting, reasoning, closing conversation). With our pool of 201children, the TPS produced a range of normally-distributed scores from 10 to 33 (M = 26.11; SD = 4.13). For our sample, Cronbach α = 0.79.

British Picture Vocabulary Scale (BPVS).

The British Picture Vocabulary Scale II (BPVS II; Dunn et al., 1997) is a norm-referenced, standardised assessment of receptive (spoken) vocabulary for Standard English for use with children 3- to 15-years-old and is normed at 100 with Cronbach α = 0.93, and median split-half = 0.86. For our pool of 201 children scores ranged from 56 to 128 (M = 99.85, SD = 11.61) with a normal distribution. Due to the method of test application (not all children attempt all items) it was not possible to apply a test of internal consistency for our sample.

Child Communication Checklist-2 (CCC-2).

The Child Communication Checklist-2 (CCC-2, Bishop 2003) is designed to provide a measure of impairment in pragmatic language. This instrument is one of the most widely-used, standardized measures in research and clinical contexts (Norbury, 2014). Its primary purpose is to describe *patterns* of impairment as opposed to the TPS, which provides a measure of skill. It is not judged suitable for assessing variation among children who have average and above-average pragmatic skills (Bishop 2003) and was therefore not used for selecting the study sample. The CCC-2 was used here to provide information on the nature of impairment in the children who had received low scores on the TPS so that we may compare this to a clinically-recruited sample. The CCC-2 comprises 10 subscales and gives two composite scores; a General Communication Composite (GCC) identifying children likely to have significant overall communication problems and a Social Interaction Deviance Composite (SIDC) indicating children with disproportionate pragmatic difficulties relative to their other language skills. As a guideline, Bishop (2003) suggests that scores at or above the 15th percentile (GCC score $\geq$ 60) should be regarded as within normal limits, whilst scores on two or more of the subscales below the 5th percentile suggest that the child has communicative problems of clinical significance. Also, a SIDC score of −15 or less is an indicator of an autism spectrum disorder even when a child has a GCC score within normal limits. It is recommended that the CCC-2 should be used to indicate aspects of communication that may need further investigation, rather than providing a definitive diagnosis (Bishop, 2003). The CCC-2 has been validated on 542 children in UK, 111 children in Australia, plus clinical samples. The manual gives Cronbach α ranging from 0.66 to 0.80 for the ten subscales. For our sample, Cronbach α ranged from 0.64 to 0.85 for the subscales.

2.6. Selection Procedures

Children were selected for participation in the intervention on the basis of their TPS scores at baseline. We needed to select a group of ‘pragmatic skill test low-scoring’ children

(LP children) to undergo the intervention and a group of 'pragmatic skill test high-scoring' children (HP children) to partner these children to play the pre- and post-intervention Maze Task game.

Selection of pragmatic skill test low-scoring (LP) children.

According to the TPS manual, the expected score for children between 5 and 6 years of age is 28; the mean for our sample of 201 children was slightly lower than this at 26.11. There were 32 children whose scores fell one standard deviation below our sample mean of 26.11 and these were selected to receive the intervention. These 32 children were then rated by teachers using the CCC-2.

Selection of pragmatic skill test high-scoring (HP) children.

The BPVS was used as an additional selection screen for the children scoring over 28 on the TPS to exclude children who may have impairments with aspects of receptive verbal ability. Hence children were only selected from the initial pool of 201 as 'high-scoring' if they achieved (a) a score of 28 or over on the TPS and also (b) did not score lower than one standard deviation below the mean on the BPVS. High- scoring same-gender children were selected as partners to work on the computer task with the LP children. All dyads consisted of children who were classmates.

2.7. Computer Task

The 'Maze Task' used in the present study was developed specifically by the authors to observe the behaviour and communication of 5-6 year-olds in collaboration. The Maze Task aims to highlight the different visual perspectives that different people may have. The Maze Task is a dyadic computer task in which one child directs another child through a maze with features such as houses, trees and ponds. The maze includes obstacles (such as fallen trees, animals) to be negotiated and the aim is to find 'hidden treasures' such as coins, magic wands and stars which, once won, are then displayed in a visual hoard of 'prizes' or rewards on the screen for both children to see. The task is arranged over two inter-communicating laptop computers opposite each other, with each child using one laptop. The screen for each laptop gives a view of the maze and is not visible to the other child. The views on each laptop differ slightly from each other; the view on one laptop shows a map of the maze with the starting point, the available paths through the maze and the end point. The child seeing this view (the driver) will 'drive' a car through the maze using the keyboard arrow keys to move the car in steps. The view on the second laptop is identical to the first except that some additional privileged information is available i.e., the location of the hidden treasures and obstacles. The child with the second laptop (the navigator) directs the child who is 'driving' around the maze with the object of avoiding the obstacles and collecting as many rewards as possible (see fig. 1). Both children can watch as the 'car' moves around the maze and succeeds or fails to secure the hidden treasure rewards. Different mazes were provided such that when a pair of children successfully completed one iteration of the task, a new and more difficult maze appeared on screen until a series of several mazes was completed. The computer programme gives the children alternate turns at being the driver or navigator with each successive maze. In order to prevent domination or exclusion of one of the partners, the computer programme locked each child's keyboard and mouse so that they were unable to move the 'car' during their turn as navigator. The children were therefore obliged to communicate. Collecting the rewards (the object of the task) was not possible without collaboration. In order to encourage cooperation rather than competition, it was explained to the children that the task was collaborative and all rewards collected were shared; regardless of who was driving the car. Therefore, when the driving child collected a reward this then appeared on both children's laptop screens, demonstrating they had both 'won' the prize as a result of joint effort. Performance on the task was measured in terms of the number of rewards collected by the pair. At pre-test, the children in general performed well on the task, so that they were successful in collecting most of the rewards. Consequently, there was a danger of a ceiling effect whereby no improvement would be registered at Time 1. Therefore, we constructed a more difficult version of the Maze Task for use at Time1 and Time 2 which included 'traps' (penalties) which the car could fall into, this made obtaining the rewards more difficult, and meant that reliance on good communication was even more crucial.

2.8. Procedure for Computer Task

The 32 dyads were invited one dyad at a time to play the 'Maze Task' collaborative computer game. The children played the game at their own schools in a quiet area where they were used to working but where interruptions by other children were eliminated. The third author instructed and supervised the children. The dyads were given a series of six mazes to practice. They were instructed in how to move the car around the maze; it was pointed out to them that each child had a different view of the maze and that only the navigator could see the 'hidden treasure' rewards and the obstacles. After the practice mazes, the children then played a series of 10 mazes unsupervised and their conversation was audiotaped as they did so. Generally this took around 10 minutes, taking the driver's turn first was alternated to control for order effects. The 32 dyads played the game at pre-test, Time 1 and Time 2.

2.9. Procedure for Communication Intervention Training Sessions

Of the 32 LP children taking part in the study, 16 were randomly assigned to the IG and 16 to the DIG. The intervention consisted of three, 30-minute tutoring sessions with the third author. The three sessions were each designed around one communicative skill each; the first session focused on asking for information that may be missing from the partners' descriptions, the second on giving good information (directions) to the partner and the third on requesting clarification. The content of the intervention was based on our observations of the significant differences between low- and high-pragmatic-skilled children during a dyadic task in our earlier study (Authors' blinded reference 1 here). The differences we found were in the use of different kinds of high-quality questions (including requests for clarification) and high-quality directions (the latter was a non-significant trend). Training methods were based on modelling approach as developed by Palincsar and Brown (1984). In the present study, in all three sessions the child played the game with the third author but at a much slower pace than with a peer, with the chance to ask questions and think about their responses. The adult began by modelling the particular skill that was the focus of the session (i.e., asking for information, giving good directions or asking for clarification). She modelled ideal versions of the skill first, followed by exaggeratedly poor exemplars. Children were asked which versions they 'liked best'. They were then invited to consider why this was, and discuss this with the adult. Discussions were framed within the context of the game and the usefulness (or otherwise) of communications were related back by the adult to the different visual perspectives in the game whereby the navigator had visual access to information that the driver did not. The purpose of this was to highlight the *consequences* of effective and ineffective communications within the specialised interaction of the game, the consequences in this context having been made more salient than in typical conversations by the addition of conspicuous rewards and obstacles. The children were then supported to put into practice these teaching points within the game and given feedback and verbal encouragement. Frequent reminders as to when a skill could be used (e.g., a question for information or clarification) were given, again within in the context of the game and with the aim of winning prizes. In sessions 2 and 3, a recap of the previous sessions' aims was given.

A training manual was written and followed to ensure consistency of tutoring. Sessions were strictly timed to 30 minutes only and all sessions used the same teaching mazes with paths, obstacles and rewards specifically designed to illustrate different types of communication relating to questions, directions and clarifications. The development of the computer game and training manual has been described in full elsewhere (Authors' blinded reference 2). The total time from pre-test measures (TPS, pre-test game) to post–test measures (TPS, post-test game) was not more than 5 weeks for each child. Time from post-test game to TPS administration was not more than 2 weeks for each child.

2.10. Post-test Measures

Performance measures.

The number of rewards ('hidden treasures') that the children accumulated as described above were used as measures of performance on the Maze Task.

Pragmatic skill measure.

All 32 LP children were re-tested using the TPS at Time 1 and Time 2. The third author administered the TPS at baseline, Time1 and Time 2. Blinding was not possible at Time 1 and Time 2 as the third author had also administered the intervention. As a precaution against bias, 100% of TPS tests were audio-recorded and coded by a second, blinded observer, agreement weighted Kappa = .79. According to guidelines proposed by Landis and Koch (1977), kappa values ranging from 0.41 to 0.60 are rated 'moderate', 0.61–0.80 as 'substantial', and 0.81–1 as 'almost perfect agreement'.

Verbal observation measures.

The children's interaction whilst playing the game was audio-recorded, transcribed in full and analysed using a verbal coding system designed specifically to capture the features of interaction generated by the Maze Task. The total interaction for each dyad was used for verbal analysis. All speech was reproduced verbatim, with start and end of speakers' utterances marked in seconds. Transcripts were checked for accuracy against the audio-recordings by the coders and the audio-recordings and transcripts were used simultaneously for coding.

2.11. Micro-Analytic Verbal Communication Coding

Design of coding system.

The coding system was created specifically for this study and incorporates elements from research into collaborative learning and into language impairment (Anderson, Clark & Mullin, 1994; Gottman & Parker, 1986; Kruger, 1993; Lloyd, Boada & Forns, 1992; Markell & Asher, 1984; Murphy & Faulkner, 2006, 2011 and Radzsiewska & Rogoff, 1988). The aim of the coding system was to capture aspects of the communication that are known to be associated with successful collaborative learning (e.g., effective questioning) as well as the social and affective dimensions of the interaction (e.g., positive comments about the game and/or partner). Three researchers (including the first and third authors) worked together to produce the coding system. Codes were initially drawn from the existing coding systems and included or excluded on the basis of discussion between the researchers and on examination of transcripts of pilot data. A small number of additional study-specific codes were also devised by consensus. All three researchers then coded 10 transcripts each of audio-recordings from the Maze Task with children who had piloted the task but were not participants in the main study. Inter-rater reliability between the coders was then calculated, and the codes more clearly described, refined, removed or added to where this was necessary to capture features of the interaction or to achieve satisfactory inter-rater reliability. This process continued until a coding system was devised and considered suitable by all three researchers. The final coding system contains 62 codes and is mutually exclusive and exhaustive; an abbreviated version is given in Table 1. The full system is available on request from the first author.

Segmentation.

Talk was segmented into utterances defined as speech bounded by pauses of at least 1 second or by the other child’s speech. Utterances were then further segmented into thought units. A thought unit is one expressed idea or fragment as defined by Gottman and Parker (1986) a thought unit can be one utterance or several. However, we wished in this study to preserve utterances as separate items for coding as giving instructions for example, can extend over several utterances but would be coded as one thought unit only. Conversely, segmenting speech into utterances only would lose some of the subtlety occurring when children express more than one idea per utterance; therefore, we retained both of these methods of segmentation. As an example 'It's my go now. I'm really good at this' with the response from the other child as 'Have you finished now?' would be segmented as one utterance, but two thought units for the first child, and one utterance and one thought unit for the replying child.

Coding procedure.

Segments (as defined above) were then coded according to whether they were task-related or non-task-related (i.e., off task talk, chatting about unrelated events). Task-related talk was then divided into main categories as follows: Directives, questions, responses, statements and 'other'. Directives were then divided into (a) 'navigational instruction', relating to directing the partner around the maze, and (b) other directives. Sub-codes were then applied for both navigational instruction and other directives as per Murphy and Faulkner (2011). Questions were categorised as questions for clarification, questions checking understanding and questions for information. The quality of questions for clarification was then coded as per Lloyd et al., (1992) into high, medium or low. For example, 'What?' was rated as of lower quality than 'Which one of the houses do you mean?'. Responses to directives and questions were coded as: relevant/irrelevant, ignoring or non-responses. If a relevant response was given, it was coded as 'adequate' or 'inadequate'. Responses that were agreements and disagreements were coded as agreements to act (compliance), disagreements to act (non-compliance) or agreements and disagreements on matters of fact (Murphy & Faulkner, 2011). Disagreements were then secondarily coded to indicate whether they were accompanied by an explanation or discussion (Kruger, 1993). 'Feeling' codes were also included to reflect positive and negative statements about oneself, the game or directed to the child's partner.

Coding inter-rater reliability.

Transcription was carried out by a professional transcription company (blind to children's status). All transcripts were coded by a researcher unconnected with the study who was blind to the intervention status of the dyads (IG or DIG), 10 % of the videotapes were then coded by the first author, also blind, to test inter-rater reliability. For the coding of segmentation, the value of weighted Kappa = .86. Kappa values for all verbal codes ranged from .60 to .97 with the exception of 'Question for Understanding Partner' where Kappa = .50 and 'Encourage' where Kappa = .50. The total number of segments coded as 'unclear' (where neither transcribers nor coders could decipher what was said) was less than 1 % for both HP and LP children, all unclear statements were retained within the analyses.

2.12. Attrition of Participants from Baseline to Time 2

None of the LP children assigned to either the IG or the DIG left the study before the end. However, two of the HP partners did leave and needed to be replaced. Accordingly, we replaced these with two other gender-matched partners who met the criteria for HP with their TPS and BPVS scores and who were familiar with the Maze task from one of our previous studies. These new partners were also classmates of their LP partners. Scores from Time 1 and Time 2 measures of these two dyads with replacement HP partners were checked; there were no substantial differences with the rest of the sample therefore this data was retained within the study.

3. Results

3.1. Data Analytic Strategy

Data collection for this study took place at three time points: baseline pre-tests before the intervention, Time 1 post-tests after the IG children (but not the DIG children) had received the intervention and Time 2 post-tests after the DIG children had received the delayed intervention. Our main comparison concerns the changes in the measures from baseline to Time 1. Baseline scores were subtracted from Time 1 scores to give a score of the difference. Two-way comparisons were then conducted between the IG and DIG children on this change data. Data for some of the outcome measures; performance on the computer task and the verbal codes were not normally distributed, hence non-parametric statistics were used. As this was an exploratory study looking at children's communication using micro-analytic methods and a detailed verbal coding system, this necessitated a high number of statistical comparisons. For this reason, the significance level for the verbal code results has been set at a more conservative 3% rather than the conventional 5% in order to reduce the probability of false significant results. An estimate of effect size, *r*, was calculated for our non-parametric tests as proposed by Rosenthal and Rubin (2003).

3.2. Participant Characteristics

Before proceeding with main analyses, differences of age, gender and baseline TPS, BPVS and CCC-2 scores were examined between the IG and DIG children and for IG and DIG HP partners, in order to detect any marked imbalances between the two groups. Parametric and non-parametric statistics were used as appropriate; scores are given in Table 2. There were no significant age differences between the groups and no significant differences in TPS, CCC-2 or BPVS scores between IG and DIG children or between the TPS and BPVS scores of the HP partners of the IG and DIG children. There was a non-significant gender difference in the composition of the groups. We also examined CCC-2 results for the LP children in order to provide a comparison to clinically-recruited samples. For our sample, the TPS and the CCC-2 were reasonably consistent with one another; 32 children scored one standard deviation below the mean on the TPS, 24 of these children (75 %) were at or very close to clinical levels as indicated by validation data for CCC-2 (Bishop, 2003). Bishop (2003) suggests that scores below 60 on the GCC scale are indicative of problems in the clinical range, and also that a SIDC score of −15 or less is an indicator of an autism spectrum disorder; 23 of the children in our sample had GCC scores below 60 and one child received a SIDC score of −14, just one point away from the cut-off score of −15 suggesting the presence of an autism spectrum disorder.

3.3. Computer Task Performance

Number of rewards.

This score was calculated by taking the proportion of all possible available rewards that the children won at Time 1 and subtracting the proportion of all possible available rewards that they had won at baseline (proportions were used as the number of possible available rewards could vary according to the way in which children completed subsequent mazes). As shown on Table 3, the difference between Time 1 and baseline scores for the IG group was M = - 0.14, SD = 0.24, whereas the difference for the DIG children was M = - 0.31, SD = 0.26, this was a significant difference U = 80.5, p = .03, r = -.32, thereby supporting our first prediction. Figure 2a illustrates mean scores obtained by the groups at baseline, Time 1 and Time 2 and shows that at baseline, both the IG and DIG children were winning just over 10 rewards, at Time 1 however, performance for both groups appears to deteriorate, but improves again by Time 2. The reason for the apparent deterioration is that the computer task was made much more difficult at Time 1 due to the risk of a ceiling effect after better than expected performances by the children at baseline. At time 2, no valid comparison can be made between the IG and DIG group, as both have received the intervention by his time. However, a within-participants comparison from Time 1 to Time 2 illustrates possible changes in the DIG group as a result of having received the intervention.

From Time 1 to Time 2, the DIG group, having now received the intervention, increased the proportion of rewards that they won by a significant amount $M = .20$, $S.D. = .24$, Wilcoxon $Z = -3.01$, $p < .001$. By comparison the IG group, having improved significantly more than the DIG group between baseline and Time 1, did not improve to a significant extent between Time 1 and Time 2 $M = .05$, $S.D. = .23$, Wilcoxon $Z = -0.74$, $p = .24$.

3.4. Measure of Pragmatic Skill

At Time 1, the IG children's scores on the TPS had increased by $M = 8.38$, $SD = 3.91$, which was significantly more than the DIG children whose scores had increased by only $M = 5.50$, $SD = 3.75$, Mann-Whitney $U = 66.5$, $p = .01$, $r = .42$, providing support for our second prediction. Figure 2b (consistently with the results for rewards scores shown by figure 2a) shows that at baseline, the DIG children's mean TPS score was higher (although not to a significant level) than the IG children's. By Time 1, the IG children's scores are significantly higher, but by Time 2, after which the DIG had also received the intervention, the DIG children's scores had caught up again with those of the IG children.

As with results for the rewards, a within-participants comparison serves to illustrate possible changes in the DIG group after receiving the intervention. From Time 1 to Time 2, the DIG group, increased their TPS scores significantly $M = 3.28$, $S.D. = 1.24$, Wilcoxon $Z = -2.45$, $p < .001$. By comparison the IG group, having improved significantly more than the DIG group between baseline and Time 1, did not significantly improve between Time 1 and Time 2 $M = 1.20$, $S.D. = 1.04$, Wilcoxon $Z = -1.60$, $p = .12$.

3.5. Verbal Communication Measures

For verbal communication measures, technical issues prevented audio-recording for one pair of children, therefore for the IG group n = 16 but for the DIG group n = 15 only. In total there were 62 codes in the verbal coding system, however, 32 of these codes occurred less than 1 % of the time and differences were non-significant, these are therefore not reported in Table 4.

Verbal communication measures low-pragmatic scoring children Time 1.

Total use of speech segments by the two groups was IG M = 107.84, SD = 39.77, DIG M = 105.07, SD = 35.05, these differences were non-significant Mann-Whitney U = 82.0, p = .34, r = .08. In order to control for slight differences in the time for different dyads to complete the task, for each child, verbal interaction codes were expressed as a percentage of the total number of the child's segments. Table 4 shows the mean percentage difference of the verbal communication measures, these data represent the difference between scores at baseline and at Time 1; hence, some of the numbers are negative, as the scores were higher at baseline than Time 1. Guidelines for values of effect sizes of r shown on the table have been suggested by Cohen (1988) such that 0.1 is 'small', 0.3 is 'medium' and 0.5 or over is 'large'. Differences between the IG and DIG children are evident in two main elements of communication; the use of questions and the expression of positive statements. The IG children who had received the intervention used significantly more questions than the DIG children. Furthermore, these were of high-quality, seeking specific pieces of information. There was no increase in low-quality non-specific clarification requests (labelled 'Clarification requests non-specific' on Table 4) such as 'What?' 'Huh?' or medium-quality specific clarification requests e.g., 'The bridge, did you say?' (labelled 'Clarification requests – specific' on Table 4). Increases were seen in 'Elaborating' clarification questions, which ask the partner for greater detail to elaborate on a previous instruction, in 'Maze Features' questions, which ask detailed questions referring to features in the mazes such as trees, houses etc. and in 'Information' questions, which question aspects such as rules and practical procedures of the task. These three types of question were combined together (labelled 'questions for information-seeking – total' on Table 4) and differences between the IG and

DIG children were striking, with means of 6.33 (IG) and -1.85 (DIG) and an effect size of .60. The rationale for using these questions had been modelled by the researcher in the intervention and the children were encouraged to practice them during the training sessions. It appears that this training generalised to the post-intervention computer game interaction with a peer. However, there were no significant differences between the IG and the DIG children in the use of high-quality navigation directives, despite the fact that these had also been included in the intervention training sessions with the researcher. Therefore, these results provide some support for our third prediction, but not all communication types improved.

The IG children also made significantly more positive statements whilst playing the computer game with a peer than did the DIG children, a result we had not predicted. When 'self' positive statements such as 'I'm good at this', 'This is fun', 'I've won another one!', and 'other' positive statements directed to their game partner such as 'Well done, you did it!', 'I like playing with you' were combined (labelled 'positive total' on Table 4), the IG mean was .25 showing a very slight increase over baseline, whereas the DIG mean was -1.27. The DIG decrease in positive statements was probably engendered by the increase in difficulty of the game from baseline to Time 1, whereas the IG children, having had the benefit of the intervention, may have been expressing greater ease with the game and with the social interaction.

Verbal communication measures at Time 2.

Scores for IG and DIG children were calculated at Time 2 by subtracting Time 1 counts for the verbal codes from Time 2 counts. Comparisons of the IG and DIG groups at Time 2 showed no significant differences, as would be expected as both by this time have received the intervention. However, within-participants tests from Time 1 to Time 2 for the DIG group showed that the use of 'questions for information-seeking – total' increased significantly from *M* = 5.17, *S.D.* = 3.06 at Time 1 to *M* = 8.32, *S.D.* = 6.22 at Time 2, Wilcoxon *Z* = 1.99, *p* = .02, *r* = -.35, an indication that they may, in the same way as the IG group, have benefitted from the training sessions with the researcher. There was also a near significant increase from Time 1 to Time 2 in the use of positive feeling statements from *M* = .79, *S.D.* = 1.24 to *M* = 2.01, *S.D.* = 2.14 Wilcoxon *Z* = 1.81, *p* = .04, *r* = -.30. Finally, there was also a significant increase in the use of high-quality navigational directives, Time 1 *M* = 10.00, *S.D.* = 6.29, and Time 2 *M* = 14.81, *S.D.* = 11.17 Wilcoxon *Z* = 1.88, *p* = .03, *r* = -.35. These results, although indicative only as they are within-participant tests without a control group, do parallel the findings at Time 1 and in addition suggest that some improvement may also have occurred in the use of high-quality navigational directives.

Verbal communication measures HP partners at Time 1 and Time 2.

We examined possible changes in communication in the children partnering the LP children, to explore the possibility that the intervention may, as a result of modifying the LP children's communication, have also influenced the way in which the HP children responded to them. The HP partners of the IG and DIG children showed almost no significant changes in the verbal behaviours, either at Time 1 or at Time 2. The exception was an increase in questions checking partner's understanding ('Understand Partner') at Time 1 by the HP children who had partnered IG children (an increase of *M* = .10, *SD* = 1.97 for IG partners versus a mean decrease of *M* = -1.48, *SD* = 2.65 for DIG partners, Mann-Whitney *U* = 67.5, *p* = .01, *r* = -.38). By Time 2 however, levels of the Understand Partner code were similar for the HP children partnering the IG and DIG children (IG partners *M* = .50, *SD* = 1.19, DIG partners *M* = .66, *SD* = .94, Mann-Whitney *U* = 92.0, *p* = .15, *r* = .21).

4. Discussion

4.1 Summary of results

The present study aimed to trial an intervention designed to aid children with social communication difficulties specifically in the context of peer collaboration. An important goal for interventions, particularly those concerned with social communication training, is generalisation beyond the context in which skills are taught.

The intervention showed promise; the children appeared to be able to learn the use of complex, information-seeking questions in the training sessions with the researcher. This learning then generalised to behaviour with a peer when playing the computer game, accompanied by a superior performance on the game compared to those who had not received the intervention. Finally, learning from the intervention subsequently generalised to the Test of Pragmatic Skills (TPS).

More specifically, when playing the computer task with a peer after receiving the intervention the children showed a high increase in the use of information-seeking questions (effect size r = -.60) by comparison to those who had not received it. As learning to use these types of question was the object of two of the training sessions with the researcher, it appears that the teaching was successful. A more indirect measure of achievement was that the dyads with the children who had received the intervention, during the post-intervention game, won a larger proportion of the ‘treasures’, 70% as opposed to 55% by those who had not.

4.2 Consideration and implications of findings

A more detailed consideration of the results raises a number of interesting questions. Firstly, the children who received the intervention successfully increased their use of information-seeking questions and their scores on the Test of Pragmatic Skills. An examination of the reasons behind this success suggests that a number of different elements may have contributed. Although research using computer technology for interventions with language-impaired children is still relatively new, indications are that it provides huge potential for making tasks motivating and enjoyable (Ploog, Scharf, Nelson & Brooks, 2013;

Wainer & Ingersoll, 2011). For example, Moore & Calvert (2000) designed a task for children with autism incorporating attractive colours, animations, music and interesting sounds. The computer task was markedly more effective and motivating than social reinforcement such as smiles and positive comments from teachers. Similarly, we found that children reported very high levels of enjoyment with the game in our study, and almost always asked to continue when they had reached the end. A feature of the Maze Task that we used was that it seemed to reproduce a natural, familiar situation; children reported that they often played computer games with their friends, in fact several claimed to have previously played the Maze Task specifically, even though it is not available commercially. Therefore, we propose that enjoyment and motivation were high, and that ecological validity may be reasonably good, as this is a common scenario for children.

Use of computer technology enabled us to include a number of features into the intervention that we anticipated may contribute to the children's ability to learn to use skills for collaboration. Harris (1996) proposed that language aids the development of the ability to visualise another person's perspective because conversation constantly reveals the existence of alternative points of view, hence encouraging the individual to adopt another person's perspective imaginatively. Consistently with Harris's (1996) theory, research has indicated that visual perspective-taking is adversely impacted by specific language impairment (Farrant et al., 2006). It was our intention therefore that the computer game, with dissimilar views on different laptops and programmed switching from 'driver' to navigator', would provide a novel and more striking visualisation of two individuals' differing perspectives, and of the need to switch between these perspectives than is usually available in everyday conversation. In this way, we aimed to highlight emphatically the existence of differing individual perspectives to children who, ordinarily, may struggle to be aware of these in their usual social interactions.

Another possible element contributing to the effectiveness of the intervention concerns the process of providing instructions to a partner. This, rather than moving the car oneself, may have facilitated cognitive ‘distancing’ as proposed by Hala, Pexman, Climie, Rostad & Glenwright (2010). These authors describe a series of studies concerning strategic deception tasks; these tasks require perspective-taking and executive control, specifically inhibition. The performance of children who had failed the tasks improved significantly when they were provided with an ‘ally’ or ‘team-mate’ who carried out actions on their behalf when the children instructed them to do so. Hala et al., (2010), hypothesise that the ‘ally’ condition acts as a kind of psychological distancing and nudges the child into adopting a third-person perspective. We speculate that the Maze task, where directions are provided by the navigator to a driver, may produce a similar effect.

In combination then, high motivation and enjoyment, striking illustration of differing perspectives and providing directions to an ‘ally’ appear to have contributed to significant gains by the children in pragmatic language skills.

A second point to be considered is that the children who had received the intervention improved with regard to asking information-seeking questions, but not with giving high-quality directions which was also one of the aims of the training sessions. Although the reasons cannot be determined definitively, we propose that this difference relates to the characteristics of the computer task which was designed to challenge the perspective-taking abilities of the children. Asking questions in order to obtain information to move to a target reward requires remembering and understanding that the other child has privileged information not available to oneself. Giving directions would require one additional perspective switch i.e., holding the partner child’s perspective in mind whilst simultaneously searching the display in front of oneself for the requisite information. It is possible that this potentially more difficult task was just too challenging to be achieved within the three sessions provided by the intervention. Field notes taken during the training sessions of the intervention indicate that some of the children managed to improve their directions at least some of the time, but this was inconsistent and frequently forgotten by the time of the next session. Possibly a greater number of sessions would consolidate this emerging learning.

A third point for reflection is that not only did the intervention cause a change in the communication of the children with social communication disorders, but also in that of the peers who partnered them in the computer game. Partners of the children who had received the intervention used more questions to monitor their partners, or check their understanding (e.g., ‘Did you understand that?’, ‘Have you got it?’ ‘What are you doing now?’). It is possible that playing the game with a child who had received the intervention made the game easier and less demanding for both partners, such that the HP partners had a little more capacity to be supportive by asking questions to check their partner’s understanding. Some support for this notion comes from the finding that children have been shown to resort to more egocentric social behaviour when faced with cognitively-demanding (i.e., requiring more abstraction, memory or inhibitory skills) communication tasks (Nilsen & Graham, 2009). The implications are therefore that children who receive some training in how to collaborate with their peers may enjoy a double benefit; not only are they able to deploy more effective communication skills themselves, they additionally receive more support from their collaborative partners. Another important, related point was that the number of positive statements made by the children who had received the intervention increased significantly compared to those who had not received it. This was not a result we had predicted. We surmise that the significantly higher number of positive comments by the trained children reflected greater confidence and enjoyment of the game. (It may also be worth noting here that the means for the partners of the children who had received the intervention also showed the same pattern i.e., an increase in positive statements and a reduction in negative ones, although these differences did not reach statistical significance). The social dimension of the intervention is an important one. Collaborative work can frequently be disrupted when children are unable to manage to social demands of the task, for example, by aggressive or withdrawn behaviour (Brinton et al., 2000, Chiu & Khoo, 2003), damaging conflicts (Azmitia, 1998) or domination and exclusion of some individuals (Arjava, Hakkinen, Rasku-Puttonen & Etelapelto, 2002, Dembo & McAuliffe, 1987). Whilst constructive and enjoyable interaction is generally associated with improved collaborative learning (Howe, 2010), the repercussions of positive affect during interaction could be even wider-ranging for children with social communication difficulties who are known to suffer poor peer relations (Conti-Ramsden & Botting, 2004, Laws et al., 2012). The intervention targeted communication skills for peer collaborative work specifically; however, as other authors have argued (e.g., Johnson-Pynn & Nisbet, 2002; Kimhi & Bauminger-Zviely, 2012, Tolmie et al., 2010) the benefits of collaborative work can be more than just cognitive and can extend to a child's social status among his/her peers, providing opportunities for friendships and acquaintanceships. Future work could usefully explore the wider social impacts of this intervention.

4.3 Strengths of the study

The study aimed to deal with the limitations of previous studies on children with social communication difficulties (Cappadocia & Weiss, 2011; Gerber et al., 2012; Rao et al., 2008) and included a randomised controlled design with blinded post-test assessment. In addition, the following points were addressed:

(a) A carefully sampled group of children using both the TPS to identify the children most at risk from a pool of over 200 and the CCC-2 to describe the profiles of these children;

(b) Targeting of specific discrete communication skills;

(c) An intervention focusing on one training technique in isolation, with a manual entirely specifying the intervention as opposed to the evaluation of a package of training;
(d) Pre- and post-test assessment with formal tests as well as micro-analytic coding examining details of the children's conversations.

(a) Previous studies have used a variety of methods for sample selection, from clinical diagnoses to universal interventions including all children in a particular class or school. We used an elicitation test (the TPS) administered face-to-face by a researcher, backed up by the CCC-2 completed by teacher, thus providing us with two different sources of information for each child selected. Typically, studies in this area use one source only (Gerber et al., 2012).

A concern expressed by other authors (Law et al., 2013) is that a high proportion of children with language and communication disorders do not seek help from health or educational services. In response to this concern, we aimed to recruit a broad group of children with social communication difficulties within mainstream schools (i.e., not limited to those with clinical diagnoses). It was notable therefore that results from the CCC-2 showed that three-quarters (24 out of 32) children, showed symptoms indicative of difficulties severe enough to warrant referral to specialist services. The total sample pool comprised 201 children, therefore, this equates to around 12% of all children scoring at around clinical levels. The CCC-2 is not designed to provide a clinical diagnosis, simply to give an indication of which children may benefit from further investigation by a specialised professional (Bishop, 2003). Nevertheless, this high proportion is consistent with previous studies highlighting under-diagnosis in the general population (Bishop & McDonald, 2009; Law et al., 2013). This high prevalence underscores the importance of interventions that can be rolled out to the population of children in general, as opposed to those available from clinical or educational specialists only (Law et al., 2013).

(b) The intervention described here focused on training a specific, discrete set of communication skills. The strength of the approach used in the present study is firstly, that the success of an intervention targeted on particular specific skills can more easily be assessed than a wider, more inclusive one, and secondly, the particular skills targeted here had been established by a previous study (authors' blinded reference 1) to be those that differed from children scoring highly on the TPS.

(c) Also, the intervention concentrated on one training technique (modelling using the computer task) only, as opposed to the evaluation of a package of training. The latter is more typically undertaken for children with social communication disorders (e.g., Adams et al. 2012, see Cappadocia & Weiss, 2011; Gerber et al., 2012; Rao et al., 2008 for reviews). The evaluation of entire packages has considerable advantages from a clinical point of view, providing complete interventions ready for use. However, a strength of the approach used here is that for research purposes it enables individual evaluation of particular elements, therefore determining which may ones may or may not be useful (which are the 'active ingredients') for future inclusion into broader-ranging interventions. Furthermore, the training manual in our study specified the intervention precisely, with no allowance made for variation from child to child.

(d) Our assessment of children's response to the intervention relied on two different sources of information, namely, a formal test, the TPS, as well as micro-analytic coding. The advantage of using micro-analytic coding is that it provides a process measure in addition to the outcome measure given by the TPS scores. That is, as well as a measure of the final effects of the intervention from the TPS, a process measure provides some indication of how these effects may have been achieved. In this case, the micro-analytic coding suggests that the children's communications were modified directly, but that the intervention was not successful with all the targeted communications.

4.4 Study limitations

One limitation of the present study is that it is difficult to isolate the effects of the modelling training intervention from the effects of the novel presentation of different visual perspectives in the computer game. It is possible that the children improved solely or partially through additional practice or familiarity with the game rather than through the modelling training techniques used. Future work would be needed to disentangle the relative effects of (1) practice alone, (2) the modelling and feedback sessions and (3) the presentational features exclusive to the computer game. Two particular observations however, argue for the possibility that the improvements obtained were brought about by a *combination* of the modelling training and the computer task presentation rather than *solely* by practice. Firstly, at Time 1, the children significantly increased their TPS scores as well as their performance scores on the game. The effect of the intervention generalised to the TPS and was thus more likely to be due to real learning gains as opposed to mere familiarity with the computer game. Secondly, the changes that occurred in verbal communication with peers after the intervention related *specifically* to the communications in which the children had been trained not to other communications. For example, the rate at which children ignored partners' questions, which had been shown to be highly characteristic in our previous study (author's blinded reference 1), did not differ in this study post-test between children receiving and not receiving the intervention, whereas the rate of information-seeking questions did.

A further limitation of our study is that, although carefully selected and randomised, our sample was small, with only 16 children in each arm. Individual training sessions plus micro-analytic observation are time-consuming methods and for practical purposes inevitably limit the sample size. It is possible therefore, that some statistical analyses are subject to Type II errors.

4.5 Conclusion

Taking the results from this trial together, the use of computer technology to support children with social communication disorders looks encouraging. Interventions need to raise children's awareness of how to use language in social situations and technology may be able to do this in a more salient fashion than currently available methods.

This article describes findings of a randomised controlled trial for an intervention consisting of three half-hour sessions only. The fact that we obtained some positive results with this relatively modest input suggests that, at the very least, this may be a direction worthy of further development and investigation. Future studies could profitably include functional outcome measures such as children's changes in friendships and sociometric status and engaged participation during collaborative school activities.

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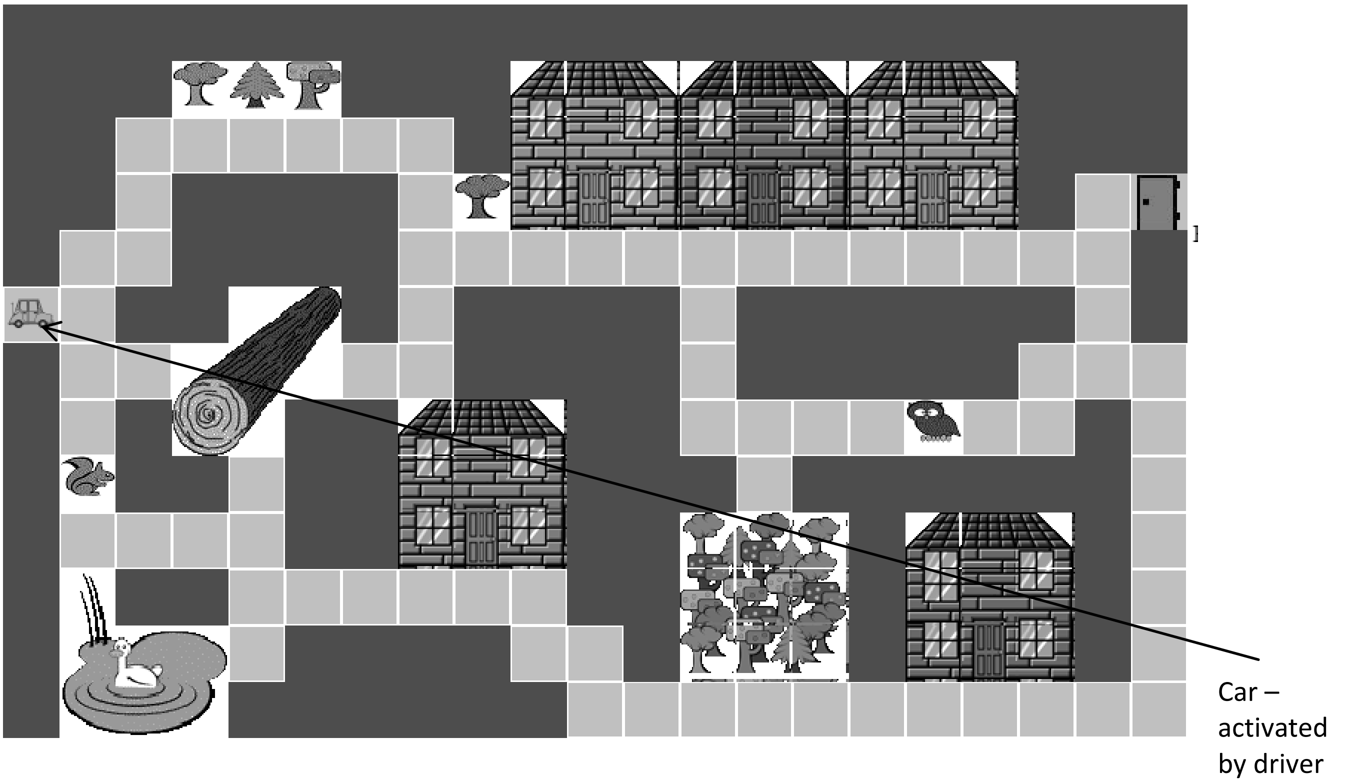
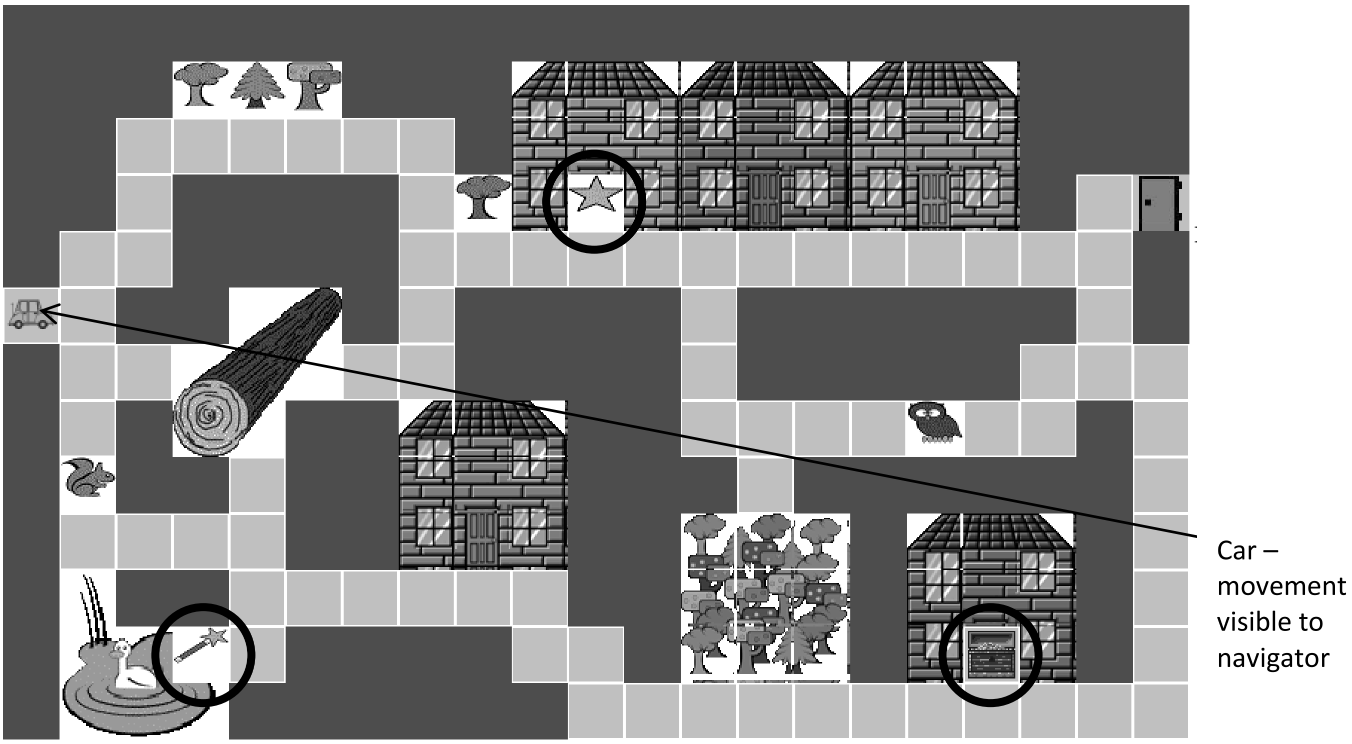
Figure

Figure 1. Driver and navigator views of Maze Task

Maze: Driver view



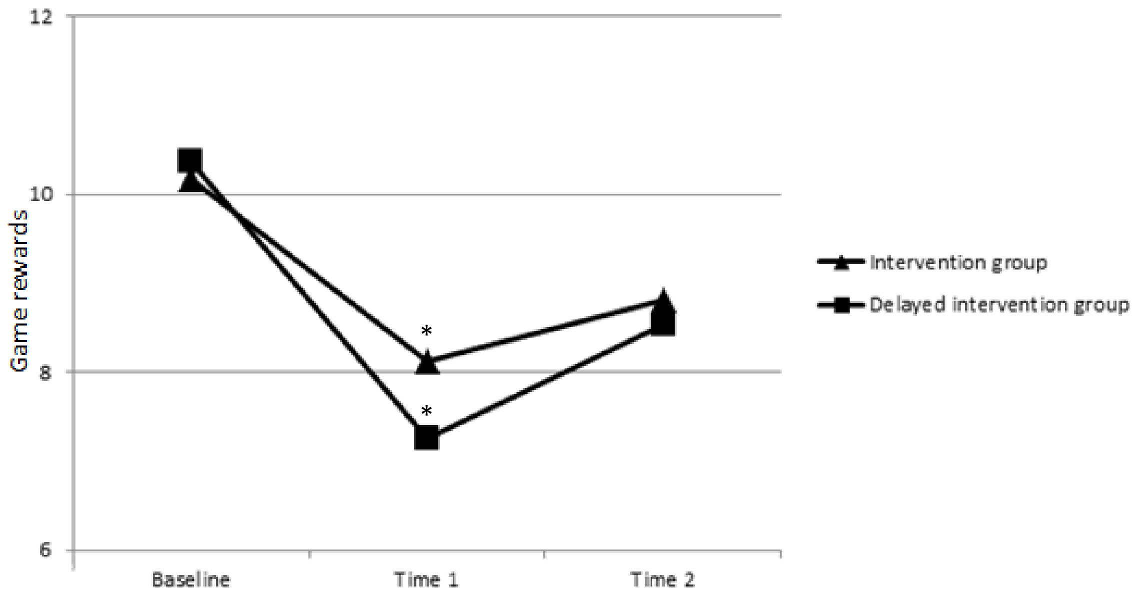
Maze: Navigator view



Note: 'Treasures' visible to navigator but invisible to driver are highlighted (circles not present on original computer task for the intervention)

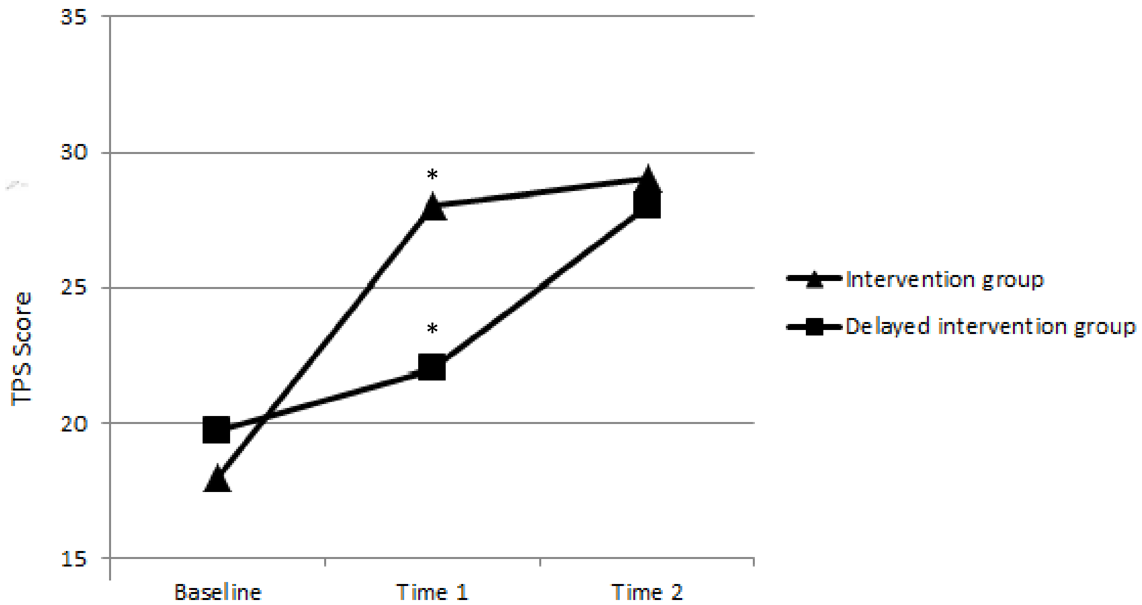
Figure

Fig. 2. Effect of the intervention on Intervention and Delayed intervention groups measured by (a) task performance (b) TPS scores



* significant difference p = .03

(a) Change in Task performance measured in game rewards



* significant difference p < .01

(b) Change in TPS scores

Table 1

Table 1. *Abbreviated verbal coding system designed for computerised Maze Task*

Segment code	**Examples**
'Hard' directives (non-navigational): Overtly commanding directives	'You take your turn now' 'Stop talking'
'Soft' directives (non-navigational): Directives requesting, suggesting or inferring	'It should be my turn now, please' 'That's not allowed'
Standard navigational directives: Relevant but no reference to maze features	'Go down, now up, up, stop there'
Irrelevant navigational directives:	'Go on the squares' (applies to all possible moves)
High-quality navigational directives: Includes reference to maze features e.g. houses or trees	'Go to the blue house' 'The prize is in the forest, go there'
Low-quality non-specific clarification question: Request merely asking for repetition	'Pardon?' 'Huh?' 'What?'
Medium –quality specific clarification question: request to repeat part of the directions or confirmation	'Go down to the bridge and then…' Q: 'Go to the bridge did you say?'
High-quality elaborating clarification question: Request for additional information than that provided	'Go to the church' Q: 'The big one or the little one?'
Understanding partner: Questions monitoring partner, checking understanding or partner's feelings	'Do you like this game?' 'Did you get that?'
Maze Features question: concerning partner's maze	'Have you got a red house on yours?'
Task Request question: request for directions	'Can you tell me where to go now?'
Information question: task-related information	'What's the arrow for?'
Ignoring response: ignores question and continues with navigation	Q: 'Have you got a house?' R: 'You go down, past the flowers'
Irrelevant response: off-task talk response to task-related question	Q: 'Have you got a house?' R: 'I like ice-cream'

Acknowledgement: brief, <3 words, driver role only	'Yeah' 'Uh-huh' 'Ok'
Non-response: No response when one expected	(silence, 2 seconds or more)
Inadequate response: fails to provide adequate requested information	Q: 'Where is it?' R: 'There' (when 'there' not visible to partner)
Adequate response: provides adequate information	Q: 'Have you got a church?' R: 'Yes'
Agree-Fact: Agreement with statement of fact	Q: 'It's the green one next, isn't it?' R. 'Yes, next to the yellow'
Agree-Act: agreement to act, comply to a directive	'Tell me where the treasure is' R: 'Ok'
Disagree-Fact: Disagreement with statement of fact	'That tree is big' R: 'No, it isn't'
Disagree-Act: non-compliance with a directive	'Do it now' R: 'No, I'm not doing it'
Discussed Disagreement: with explanation	'Let me drive now' R:'No, it's my turn'
Non-discussed Disagreement: without explanation	'You let me drive now' R:'No'
Task Intention: telling partner intentions	'I'm driving to the pond now'
Clarification: providing unsolicited clarification	'It's a bit further down, you'll see it'
Inform: All other information	'I don't know what you mean'
Encourage: support for partner	'Yeah, you're doing it right, that's it'
Feeling negative other: negative to/about partner	'You're stupid'
Feeling positive other: positive to/about partner	'We're friends' 'I like playing with you'
Feeling negative self: negative feelings about self/task	'I keep getting it wrong' 'I'm bored'
Feeling positive self: positive feelings about self/task	'Yay! I'm good at this' 'Another prize!'
Off-task talk: Chat unrelated to task	'I'm going swimming after school'

Table 2

Table2.

Participant Characteristics According to Intervention Group

	Age years *M* (*SD*)	BPVS *M* (*SD*)	TPS *M* (*SD*)	CCC-2 GCC *M* (*SD*)	CCC-2 SIDC *M* (*SD*)	Gender
Intervention Group	5.48 (.27)	95.31 (19.30)	18.68 (3.09)	62.81 (21.89)	10.56 (11.80)	M = 5 F = 11
Delayed Intervention Group	5.45 (.24)	96.00 (15.60)	19.66 (2.69)	55.26 (19.60)	10.53 (11.04)	M = 8 F = 8
Intervention Group partners	5.52 (.22)	100.25 (7.99)	29.87 (1.54)	Not applicable	Not applicable	M = 5 F = 11
Delayed Intervention Group partners	5.48 (.26)	105.31 (9.56)	29.50 (1.09)	Not applicable	Not applicable	M = 8 F = 8

Note: for all groups n = 16

Table 3

Table 3.

Performance and Outcome Measures by Dyad and Individual

		Trial group				
		Intervention Group[a] (IG)	Delayed Intervention (DIG) Group[b]			
		M (SD)	*M (SD)*	*U*	*P*	*R*
Proportion of Rewards Won[c]	Baseline	.84 (.11)	.86 (.13)	113.5	.30	-.09
	Time 1	.70 (.21)	.55 (.22)	80.5	.03*	-.32
	Time 2	.75 (.16)	.75 (.18)	117.0	.46	-.02
TPS scores[d]	Baseline	18.69 (3.09)	19.75 (2.43)	93.5	.09	-.23
	Time 1	27.06 (3.92)	25.25 (3.86)	66.5	.01**	-.42
	Time 2	28.26 (2.86)	28.53 (2.82)	101.5	.33	-.08

[a] n = 15, [b] n = 16, [c] These figures represent rewards won by the dyad [d] These figures represent individual scores of the IG or DIG children on the Test of Pragmatic Skills (TPS).

Table 4

Table 4. Verbal Communication Measures by Individual: Frequency of Observations Expressed as a Percentage of Total Number of Verbal Segments, Baseline Scores subtracted from Time 1 Scores, Communications Targeted by the Intervention are Highlighted in Italics

		Trial group				
		Intervention Group[a] (IG)	Delayed Intervention (DIG) Group[b]			
		M (SD)	*M (SD)*	*U*	*P*	*R*
General directives	Hard directives	-0.56 (2.65)	0.07 (2.29)	118.0	.47	-.02
	Soft directives	3.03 (2.99)	2.08 (1.38)	109.5	.35	-.07
Navigation directives	Standard	-12.86 (23.75)	-3.77 (12.46)	125.0	.46	-.02
	High-quality	*0.00 (10.20)*	*0.64 (10.29)*	*113.0*	*.40*	*-.05*
Clarification requests	Non-specific	-0.92 (1.94)	-0.47 (1.87)	103.5	.26	-.12
	Specific	0.32 (3.76)	1.09 (2.76)	118.5	.48	-.01
	Elaborating	*2.61 (3.71)*	*0.78 (3.36)*	*82.0*	*.06*	*-.26*
General questions	*Maze features*	*0.26 (1.36)*	*-0.72 (1.10)*	*73.0*	*.02*	*-.35*
	Information	*3.12 (4.62)*	*-0.09 (2.36)*	*71.0*	*.02*	*-.34*
	Information-seeking (total)[c]	*6.33 (7.55)*	*-1.85 (5.32)*	*36.0*	*<.001*	*-.60*
	Task request	0.44 (3.52)	-0.71 (4.00)	93.5	.15	-.19
	Understanding partner	-0.11(1.41)	-1.08 (2.58)	105.5	.27	-.10

Responses	Ignoring	-1.44 (3.20)	-1.85 (4.51)	118.0	.47	-.02
	Acknowledge	1.21 (8.37)	0.03 (6.42)	89.0	.10	-.22
	Inadequate	-0.69 (2.11)	-0.10 (1.62)	100.0	.21	-.14
	Adequate	-3.43 (7.45)	-3.40 (5.91)	118.0	.48	-.02
Agreements	Agree-Fact	1.56 (3.80)	1.69 (3.16)	74.0	.31	-.09
	Agree-Act	-0.86 (1.60)	-1.57 (1.85)	98.0	.19	-.16
Disagreements	Disagree-Fact	-1.29 (2.94)	0.43 (6.56)	82.0	.07	-.26
	Disagree-Act	-0.83 (2.60)	-0.31 (2.85)	112.0	.38	-.06
	Discussed	-1.31 (3.17)	-0.22 (4.27)	100.0	.22	-.14
	Non-discussed	-0.81 (2.42)	0.34 (4.33)	102.0	.25	-.13
Statements	Task intention	-0.66 (4.46)	-1.48 (3.22)	96.0	.18	-.17
	Clarification	0.51 (2.29)	1.08 (3.12)	118.5	.48	< -.01
	Inform	-1.36 (8.05)	-0.31 (5.49)	120.0	.51	< -.01
	Encourage	-0.31 (0.44)	-0.39 (1.37)	119.0	.49	< -.01
Feeling codes	Negative-other	-0.22 (1.48)	0.01 (2.04)	104.0	.26	-.11
	Positive-other	0.41 (0.96)	0.02 (1.96)	110.0	.34	-.07
	Negative-self	0.10 (0.26)	-0.08 (0.46)	99.5	.18	-.23
	Positive-self	-0.16 (1.76)	-1.29 (2.13)	78.0	.04	-.30
	Positive Total	.25 (2.22)	-1.27 (2.28)	72.0	.02	-.34
	Negative Total	-.11 (1.48)	-.21 (2.14)	115.0	.43	-.03
	Off-task talk	-0.46 (2.63)	-1.46 (2.73)	85.5	.07	-.25

[a] n = 15, [b] n = 16, [c] This figure comprises the combined total of Elaborating Clarification Requests, General Questions: Maze Features and General Questions: Information.