An investigation of other-awareness and the collaborative process in low-functioning children with autism using shareable technology

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Declaration

I hereby declare that this thesis has not been, and will not be, submitted in whole or in part to another University for the award of any other degree. However, this thesis incorporates to the extent indicated below, material already submitted as part of required coursework and/or for the degree of:

Bachelor of Science with Honours

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which was awarded by the University of Sussex

The data reported in Study 2 of Paper 1 was collected for the undergraduate project of the degree above, however, was re-analysed before being incorporated in this thesis.

Signature:

February 2015

INCORPORATION OF PUBLISHED WORK

Paper 1 presented in this thesis has been published in a peer-reviewed journal. The paper reflects my own work with supervisory input from the second author. Full reference is detailed below:

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For Rebecca

Welcome To Holland

by

Emily Perl Kingsley

I am often asked to describe the experience of raising a child with a disability - to try to help people who have not shared that unique experience to understand it, to imagine how it would feel. It's like this......

When you're going to have a baby, it's like planning a fabulous vacation trip - to Italy. You buy a bunch of guide books and make your wonderful plans. The Coliseum. The Michelangelo David. The gondolas in Venice. You may learn some handy phrases in Italian. It's all very exciting.

After months of eager anticipation, the day finally arrives. You pack your bags and off you go. Several hours later, the plane lands. The flight attendant comes in and says, "Welcome to Holland."

"Holland?!?" you say. "What do you mean Holland?? I signed up for Italy! I'm supposed to be in Italy. All my life I've dreamed of going to Italy."

But there's been a change in the flight plan. They've landed in Holland and there you must stay.

The important thing is that they haven't taken you to a horrible, disgusting, filthy place, full of pestilence, famine and disease. It's just a different place.

So you must go out and buy new guide books. And you must learn a whole new language. And you will meet a whole new group of people you would never have met.

It's just a different place. It's slower-paced than Italy, less flashy than Italy. But after you've been there for a while and you catch your breath, you look around.... and you begin to notice that Holland has windmills....and Holland has tulips. Holland even has Rembrandts.

But everyone you know is busy coming and going from Italy... and they're all bragging about what a wonderful time they had there. And for the rest of your life, you will say "Yes, that's where I was supposed to go. That's what I had planned."

And the pain of that will never, ever, ever, ever go away... because the loss of that dream is a very very significant loss.

But... if you spend your life mourning the fact that you didn't get to Italy, you may never be free to enjoy the very special, the very lovely things ... about Holland.

* * *

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UNIVERSITY OF SUSSEX

Samantha Holt
For the degree of Doctor of Philosophy

An investigation of other-awareness and the collaborative process in low-functioning children with autism using shareable technology

Summary

Very little is known about the ability of low-functioning children with autism (LFA) to engage in collaborative activities. Children with autism have deficits in other-awareness, joint attention and imitation, skills considered fundamental in social cognition and associated with the ability to collaborate. Research has focused on identifying the impairments of LFA children's social interactional abilities in controlled experimental contexts with adult partners. However, there is a paucity of research investigating if LFA children can participate in collaborative activity with peers, and if so what form the collaborative behaviour takes.

Children with autism are highly motivated to interact with technology and technology is evolving fast offering opportunities to apply it to research. Therefore, we used innovative technology and a novel software architecture called Separate Control of Shared Space (SCoSS) on three types of shareable computer technology to aid our investigation of other-awareness and collaboration in LFA children.

Paper 1, describes two studies using a dual-control laptop to present picture-sorting tasks to children paired with an adult and peer. SCoSS was more effective at facilitating other-awareness in TD and LFA children than a standard interface. Crucially, LFA children showed no active other-awareness without the supportive interface. Paper 2 presented two different picture-sorting problems for

pairs of LFA children to solve. This yielded a model of collaborative problem-solving based on a sequence of three prerequisite capacities. Paper 3 successfully applied the SCoSS framework to picture-sequencing tasks delivered via tablet technology. As in paper 1, pairs of LFA children were only actively aware of a peer using linked dual-tablets, analogous to SCoSS.

In summary, the thesis presents evidence that the other-awareness of LFA children can be facilitated by technology to support collaborative problem-solving, providing a more complete profile of their abilities and offers evidence that LFA are sensitive to the type of collaborative partner.

Thesis Introduction

Thesis rationale

Paper 1 (Holt & Yuill, 2014) assessed other-awareness in four LFA boys aged 5 – 7 years and 32 (16 boys, 16 girls) TD preschoolers aged 2 – 4 years. This study found that the SCoSS interface compared to a standard interface generated more other-awareness in both the LFA and TD group. However, in LFA children the SCoSS interface supported active other-awareness that was entirely absent from the unsupported condition, while TD pre-schoolers were found to generate active other-awareness in both the SCoSS and non-SCoSS interfaces. The picture-sorting task used for this study in the SCoSS condition only required players to match each other's picture placement and the correct sorting component of the activity was not necessary. This led to Paper 2 that investigated the effect manipulating the demands of the task would have on LFA children's other-awareness of a peer.

In Study 1, only three of the four LFA boys who participated could use a mouse and difficulties with using a mouse were an obvious barrier for LFA children. This prompted us to use touch screen technology in our next study in an effort to include any LFA child who was motivated to participate.

Paper 2 investigated other-awareness and collaborative behaviour in eight LFA boys aged 4 – 10 years, using the SCoSS interface on a DT table. The table successfully removed the need for children to use a mouse. In this study our aim was to explore how pairs of LFA children collaborated to solve two different picture-sorting problems. Since Holt and Yuill (2014) demonstrated that active other-awareness was absent in the non-SCoSS condition it was decided to only employ the SCoSS interface to facilitate the collaborative activity in this study.

In Holt and Yuill (2014) a simple picture-sorting task was used, but participants in the SCoSS condition had only to match each other's picture placement to complete it. Paper 2 examined the effect of increasing the demand of the collaborative problem by asking LFA children to both match and correctly categorise (sort) pictures. We used a Low-constraint task (L-C) in which both players were required only to match each other's placement, as in Holt and Yuill (2014), and a High-constraint task (H-C), in which both players were required to match each other's placement and correctly categorise the pictures.

Analysis of the varying levels of success LFA children had in solving the two problems revealed three prerequisite capacities and yielded a model of collaborative problem solving.

Experimenter observations of the DT table technology were that when it was functioning smoothly it was an excellent platform for LFA children to use. However, the sensitivity of the device meant that if children placed a second hand on the table, as they did frequently, the second touch input would be recognised and the touch from their working hand would no longer operate effectively, causing frustration for the participants. The frustration would then affect their engagement and they would withdraw from the activity. This was particularly noticeable in the more learning-disabled LFA children, who were unable to adapt to the DT's requirements. Furthermore, the technology is not widely available in schools, the setup of the DT table was time-consuming and the area needed to accommodate it was relatively large for a school environment.

Taking into account these findings it was decided for the final study to adapt tablet technology, which is widely available in schools, is very portable and has an intuitive and robust touch input system.

A major difference of tablets from the shareable technology used in papers 1 and 2 is the fact that different users cannot be identified. Crucially, the SCoSS interface is reliant on being able to identify the user in order to implement constraints, such as users only being able to move pictures on their own side of the screen. This is key, as without this constraint one user can choose to play both games and therefore it may no longer support collaboration.

To resolve this problem, two linked tablets were used and software designed to put in place some of the features employed by SCoSS. By using linked dual-tablets the intention was that each user would clearly recognise one screen as belonging to them, but that the software would interconnect each user's inputs with the activity and accomplish similar constraints to the SCoSS framework.

Paper 3 investigated other-awareness and the collaborative process in eight LFA boys aged 5 – 12 years using dual-tablet technology. Owing to the modification of the software the final study compared the collaborative behaviour of LFA children sharing a single-tablet, regarded as representing a typical setup, to a dual-tablet, considered to offer collaborative support. The LFA children used both tablet conditions to participate in a collaborative activity with both an adult and peer partner. In paper 2 we had noted the significance of imitative behaviour in LFA children in facilitating collaborative activity. This was replicated in this final study, but we also found that an adult partner compared to a peer partner was more able to promote communicative behaviour during the collaborative activity.

Overview of Autism Spectrum Disorder

In the recent edition of the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM–5; American Psychiatric Association, 2013) the criteria for identifying individuals with autism has been revised to incorporate classic autism, Asperger syndrome (AS) and pervasive developmental disorder not otherwise specified (PDD-NOS) into one condition of autism spectrum disorder.

Autism spectrum disorder (ASD) is recognised by 'persistent deficits in social communication, social interaction and restricted, repetitive patterns of behaviour' (American Psychiatric Association, 2013). The DSM-5 highlights three main areas of social difficulty; 'deficits in *social-emotional reciprocity* e.g., failure to initiate or respond to social interaction, deficits in *communicative behaviours used for social interaction,* e.g., including the use of verbal or nonverbal communication and gesture, and deficits in *developing, understanding and maintaining relationships*, e.g., absence of interest in peers' (American Psychiatric Association, 2013). Symptoms appear early in development or when social demands are beyond a person's coping strategies, causing 'significant impairment' to the expected everyday functioning of someone of a similar intellectual level without ASD (American Psychiatric Association, 2013).

Prevalence

From the 1940's ASD was considered a rare condition, with only the more severely affected receiving a diagnosis and a prevalence estimate of 1 in 2000 (Rice et al., 2012). However, from the 1990's the prevalence has risen dramatically to approximately 1 in 100 (American Psychiatric Association, 2013; Baird et al., 2006; Rice et al., 2012) and ASD is now considered the most common neurodevelopmental disorder in children (Fombonne, 2009). It has been suggested that the upward trend of ASD prevalence could be accounted for by changes to the diagnostic criteria, including the broadening of the scope of diagnosis, substitutions from an alternative diagnosis to include ASD and also a decrease in the age of diagnosis (Fombonne, 2009; Williams, Higgins, & Brayne, 2006). However, Fombonne (2009) pointed out that because of the difficulties in comparing prevalence studies over time, an actual increase in prevalence could not be ruled out. A recent study of the average age of diagnosis for a USA state reported for autistic disorder 3.1 years, PDD – NOS, 3.1 years and 7.2 years for AS (Mandell, Novak, & Zubritsky, 2005). There is an absence of research on average age of diagnosis for the UK other than a study by Howlin and Asgharian (1999) that reported 5.5 years for children diagnosed with autism and 11 years of age for AS.

Gender bias

ASD is predominantly a male disorder with a higher incidence of ASD in males compared to females with a ratio estimate of 4:1 (Fombonne, 1999; Werling & Geschwind, 2013). The females who are diagnosed tend to be more severely affected, but for males and females diagnosed with autism and a moderate or severe intellectual disability the ratio shows less disparity, with a median score of 1.7:1 (Fombonne, 1999). It has been proposed that the naturally higher sociability of females compared to males may prevent the less impaired from being identified in screening tests and therefore some of the gender bias may indicate a failure to discern ASD in higher-functioning girls i.e., those without an intellectual disability. Nonetheless, there is clear evidence of a higher prevalence in males (Werling & Geschwind, 2013).

Autism and intellectual disability

Autism is a spectrum disorder and therefore the level of impairment experienced by people affected by the condition can vary greatly. In recognition of this an ASD diagnosis according to DSM-5 will now specify if there is, or is not an intellectual and/or language impairment and will also include an assessment of an individual's functioning according to three severity levels, with Level 3 'requiring very substantial support", level 2 'requiring substantial support and level 1 'requiring support' (American Psychiatric Association, 2013). The levels are accompanied with descriptors for both social communication and restricted, repetitive behaviours separately, so that the level of severity of the two domains attributed to an individual can be more clearly defined. This change reflects the fact that intellectual disability (ID) is very commonly associated with ASD. An individual is considered to have an ID with an IQ < 70 and ID can be separated into three groups: mild ID, IQ 55 to 69, moderate ID, IQ 40 to 54 and severe ID < 40 (Bittles et al., 2002). Approximately 70% of individuals diagnosed with autism will have ID, with about one third having a mild to moderate ID and another third severe to profound (Fombonne, 2007; La Malfa, Lassi, Bertelli, Salvini, & Placidi, 2004; Matson & Shoemaker, 2009).

It has been suggested that ID might be a causal factor in the autistic traits found in these individuals, but research has shown that 70% of people with ASD have ID compared to only 40% of people with ID having ASD (La Malfa et al., 2004; Matson & Shoemaker, 2009). Therefore, evidence demonstrates a clearer connection between ASD as a causal factor in ID rather than ID being responsible for autistic-like traits. The long-term outcome of individuals diagnosed with autism and ID is poor, with only a small minority of individuals with IQ < 50 achieving a good level of functioning by adulthood (Howlin, Goode, Hutton, & Rutter, 2004). Howlin et al. (2004) assessed the outcomes of 68 adults diagnosed as children with autistic disorder and found that IQ was strongly associated with adult outcome: children with mild to moderate ID, (IQ's between 50 and 69) remained very dependent, either living at home or in residential care, whereas children without an ID (IQ > 70) fared much better, with some very good outcomes e.g., living independently, with a job and friends. The poor long-term outcome for adults with ASD is estimated to cost the UK economy approximately £25 billion annually (Knapp, Romeo, & Beecham, 2009).

High-functioning and low-functioning autism

Due to the wide spectrum of impairment and level of function of individuals with autism, researchers have tended to divide autism into two groups, people without an ID, i.e., IQ > 70, classified as high-functioning autism (HFA), and people with an ID, IQ < 70, classified as low-functioning autism (LFA).

Participants with low-functioning autism

This thesis has focused on investigating the collaborative ability of low-functioning children with autism (LFA) aged between 4 and 12 years. To be considered low functioning for the purpose of this thesis, children required a statement of special educational need and to obtain this had been assessed by a multi-disciplinary team as having autism and ID.

Self-awareness and Other-awareness

Other-awareness and theory of mind

Other-awareness is the capacity to understand that another person has a separate identity from the 'self', physically and psychologically. It is only when the 'self' understands that the 'other' has their own thoughts, beliefs and desires is someone thought to be completely aware of the other: this capacity is termed a theory of mind (ToM) (Premack & Woodruff, 1978). ToM is commonly assessed using false belief tasks (Wimmer & Perner, 1983).

A widely used false-belief task is the Sally-Anne task (Baron-Cohen, Leslie, & Frith, 1985): Two puppets are introduced to the child, Sally and Anne. A scenario is then acted out with the puppets for the child to watch: Sally puts her marble in her basket and leaves the scene. Anne enters the scene and takes the marble from Anne's basket and puts the marble into her box. When Sally returns, the experimenter asks the belief question "Where will Sally look for her marble?" From around 3.5 years of age children are able to appreciate that Sally has a false belief, i.e., that her belief (the marble is in the basket) does not match reality (the marble is in the box)(Wellman, Cross, & Watson, 2001).

Understanding this distinction is believed to demonstrate the capacity of meta-representation, the capacity to have one's own representation of a situation. In the case of the Sally-Anne task, that Sally does not know Anne moved the marble, and also hold in mind at the same time Sally's belief that the marble is where she left it. Younger TD children who have not developed this capacity can only state the reality of the situation that the marble is in the box, and will therefore attribute Sally with knowledge that she cannot possess, that Sally will know to look in the box.

Children with autism are found to be impaired in ToM (Baron-Cohen et al., 1985) and it is proposed that for autistic individuals who are able to pass ToM tests it is effortful, with deficits in ToM considered a contributing factor to the social impairments found in ASD (Ozonoff, Rogers, & Pennington, 1991). However, ToM is a relatively late-appearing capacity in the typical development of other-awareness and the objective of this thesis is to focus on investigating other-awareness in LFA children who in all probability would be unable to pass ToM tests, and therefore deemed as developmentally pre-ToM. For this reason, assessment of ToM is considered outside the scope of this thesis.

The development of self and other-awareness

The relationship between self-awareness and the development of other-awareness has been explored by considering imitation of another person as the bodily manifestation of other-awareness. Self-awareness has been proposed to be represented by the capacity to pass a surprise-mark test (Amsterdam, 1972). In this test a child has rouge surreptitiously smudged onto its cheek and is then encouraged to look into a mirror. Children are considered self-aware if they notice the smudge. Asendorpf and Baudonnière (1993) examined how the ability of TD children to imitate the actions of unfamiliar peers related to the development of self-awareness. The self-recognition status of TD children was assessed at 19 months and they were placed accordingly into peer dyads of recognisers, non-recognisers and mixed recognisers and given identical toys to play with. Asendorpf and Baudonnière (1993) assessed continuous and simultaneous imitation, which they termed 'synchronic', as a valid example of other-awareness and found that TD children were only reliably able to imitate 'synchronically' the actions of an unfamiliar peer after they were able to pass a self-recognition test.

From this they argued that self-awareness and other-awareness as represented by 'synchronic' imitation of actions on objects develop simultaneously at 19 months of age. Nielsen and Dissanayake (2004) investigated 'synchronic' object imitation in TD children with adult partners and found that children engaged in sustained synchronic object imitation from 18 months, with the amount of time they spent imitating a partner during a play session increasing significantly in duration by 24 months. Therefore, other-awareness as represented by synchronic imitation of a peer is related to self-awareness and is proposed to emerge simultaneously from around 18 months in typical development. The notion that self and other awareness are interrelated was presented in the writings of Mead (1972) who forwarded the idea that psychologically one can only become truly aware of the self through the experience of social participation with others.

Suddendorf and Whiten (2001) proposed that mirror self-recognition and synchronic imitation are part of a group of capacities that represent the development of secondary representation, the ability to hold in mind more than one representation of the world, for example using a real object and pretending it is something else in children's play.

Self-awareness and other-awareness in autism

Self-awareness using the surprise-mark test has been explored in ASD children and self-recognition was found to be associated with general developmental level, such that ASD children functioning with a mental age of at least 1.5 – 2 years were able to pass the surprise-mark test (Dawson & McKissick, 1984; Ferrari & Matthews, 1983; Spiker & Ricks, 1984). Therefore, a specific deficit in self-recognition has not been found in ASD children that cannot be explained by a general developmental delay.

However, research on the emergence of self-recognition and synchronic imitation in ASD children is lacking. Although the capacities of self-awareness and other-awareness using the surprise-mark test and synchronic imitation are related in TD children, this association has yet to be explored in ASD children (Nielsen, Suddendorf, & Dissanayake, 2006).

It is proposed that the social-cognitive deficits found in ASD stem from impairments in self- and other-awareness (Baron‐Cohen, 2009; Frith & Happé, 1999; Hobson et al., 2006; Williams & Happé, 2010). This is supported by evidence from a functional magnetic resonance imaging study by Iacoboni (2006) that found the close relationship between mental representations of the self and the other were underpinned by an associated neural network and that self and other referential neural processing was found lacking in autism (Iacoboni, 2006).

Self and other referential behaviour in children with autism was tested by Hobson and Meyer (2005) using a sticker test. Children with and without autism were asked to show the experimenter where on her body to place a sticker. All of the non-autistic children gestured to themselves at least once compared to only half of the autistic children. Hobson and Meyer (2005) argue these findings demonstrate that the difficulty of children with autism in referring to themselves, to communicate something to the other, represents an impairment in the ability 'to adopt the bodily-anchored psychological and communicative stance of another person'. Williams and Happé (2009) used a computer task and a picture card game to investigate self-awareness in children with autism and their ability to monitor their own actions both on-line (during the activity) and from memory. The children were shown a computer screen with coloured squares that all moved when the participant moved the cursor, but of which only one of the squares the child was able to move. At the end of the activity the child was asked using the cursor to select the square they thought they were moving. The picture task was a lotto game that was played with an adult partner and two toys. So that the child played for themselves and a toy and the adult partner played for themselves and a toy. Each 'player' had eight cards to place on the lotto grid, at the end of the game the participant was asked to distribute the cards to each of the 'four' players. Williams and Happé (2009) compared the participants' performance to IQ-matched non-autistic children and found that children with autism were not impaired in their ability to monitor their own actions or attribute actions to themselves from memory. Therefore, children with autism may find it difficult to use self-referential action as a strategy to communicate to another person, but their self-awareness and ability to monitor and attribute their own actions to themselves are preserved skills.

Joint attention and Imitation

Developmental pattern of Joint attention and imitation in TD and autism

Joint attention involves the capacity of children to coordinate their attention to include another person and an object. These are complex behaviours that include *responses* to gaze and gestures from another person seeking to share attention to an object or event, and using gaze and gesture to *initiate* the sharing of attention to an object or event with another person: this is also termed triadic interaction (Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998). Tomasello (1995) propose that joint attention is the manifestation of the understanding that another person is an intentional agent with their own goals and ability to pursue them. Carpenter et al. (1998) assert that joint attention behaviours are all those that include a child's attempts to share, follow or direct an adult's attention and that the intentionality to incorporate the adult partner to form triadic interaction is demonstrated by the child alternating their gaze between the person and the object.

Carpenter et al. (1998) investigated the emergence of joint attention and imitation abilities of 12 male and 12 female children between the ages of 9 and 15 months interacting with an adult partner. They included tests to assess their ability to share attention, follow attention and behaviour and direct attention and behaviour. The ability to *share attention* was assessed by looking for episodes when children were in 'joint engagement' i.e., socially interacting face to face with an adult, incorporating a look to an object and back to the adult's face within 3 seconds.

Following attention was assessed by an adult calling for a child's attention and then alternating gaze between the child and a toy placed on either side of the room. The aim was for the child to follow the adult's gaze and look at the toy. A second test used the same procedure, but the adult added a point gesture towards the toy. *Following behaviour* was assessed by observing if children could imitate the actions performed by an adult on two different types of box. The first box had various attachments including a spring and spinner, and the adult performed instrumental actions e.g., pressing the spring. The second box had lights that would light up when the box was touched. The adult performed arbitrary actions such as touching the box with her head.

To assess children's ability to *direct attention* a soft toy appeared to dance out of sight of the adult and out of reach of the child with the aim of generating a 'declarative' gesture from the child, i.e., a gesture to bring another's attention to an object or event in order to comment or share interest. *Directing behaviour* was tested using a wind-up toy to encourage a request to have it wound up again or a toy was placed in a transparent locked box with the aim of eliciting an 'imperative' gesture in the child, i.e., a gesture used to request an object or assistance.

Carpenter et al. (1998) proposed a developmental pattern of emergence in which TD children develop the capacity to share, follow and direct another's attention before their behaviour (Table 1).

Table 1. The pattern of and mean ages of emergence of sharing, following and directing attention and behaviour in TD children, taken from Carpenter et al. (1998).

	Share /check 9 – 10 months		Follow 11 months	Direct 12 months
Attention	Joint engagement (9.0 months)	Proximal declarative gestures (10.5 months)	Gaze following and/ or point following (11.5 months)	Distal declarative gestures (12.6 months)
Behaviour			Imitation of instrumental and or arbitrary actions (11.9 months)	Imperative gestures (12.7 months)

Carpenter, Pennington, and Rogers (2002) used the same tests as Carpenter et al. (1998) in a similar investigation involving 12 LFA children aged 3 – 5 years. Carpenter et al. (2002) reported clear deficits in the joint attention and imitation abilities of LFA children, but also a different pattern of development from TD children (Fig 1). By ordering the main social cognitive skills by function and separating the domains of attention and behaviour Carpenter et al. (2002) discerned that the pattern of development with respect to sharing, following and directing was similar for LFA and TD children. However, the crucial difference was that TD children developed abilities related to sharing, following and directing another's *attention* before following and directing another's *behaviour*, whereas LFA children appeared to develop skills related to following and directing another's *behaviour* before sharing, following and directing another's *attention* (Table 2).

Table 2. The developmental pattern of functional abilities related to sharing, following and directing another's attention and behaviour in TD and LFA children (Carpenter et al. 1998; Carpenter et al. 2002).

Individually 83% of typically developing infants followed this pattern (Carpenter et al. 1998, 2002)				
Share attention	Follow attention	Follow behaviour	Direct attention	Direct behaviour
Individually 67% of LFA children followed the pattern below (Carpenter at al. 2002)				
Follow behaviour	Share attention	Direct behaviour	Follow attention	Direct attention
Imitative learning – child copies instrumental or arbitrary actions modelled by an adult on a box.	Joint engagement – child's spontaneous gaze switching from object to adult back to same object. Child's proximal declarative gestures, shows or verbalisations	Child's imperative point, gesture reach or verbalisations to obtain a toy locked in a transparent box or to rewind a wind-up toy.	Child follows the gaze and/or point of an adult to toys placed either side of the child.	Child's distal declarative gesture to direct adult attention to the sudden appearance of a toy.

We should be mindful that the ASD children in Carpenter et al. (2002) were significantly older than the TD sample in Carpenter et al. (1998) and although deficits were still apparent, half of the ASD sample were involved in intervention programs that included imitation. Therefore, the findings need to be taken with caution. Furthermore, joint attention behaviour relies on the display of gaze alternation between an object and another person and consequently, any manifest behaviour that did not fulfill that requirement would not have been considered. However, identifying and justifying behaviour as representing the sharing of another's attention is problematic and consequently, employing gaze alternation as a requisite condition is well-founded to corroborate other-awareness. Nevertheless, alternative measures of other-awareness (i.e, without incorporating gaze to another) that might stimulate the emergence of joint attention have not been identified.

Joint attention in TD children

Joint attention and imitation in typical infants and children has been rigorously studied in an attempt to understand their role in development and how they relate to language acquisition. From approximately six months of age a typical child will develop the capacity of joint attention (Bakeman & Adamson, 1984). Mundy et al. (2007) investigated the different aspects of joint attention by dividing it into four subcategories; responding to joint attention bids from an adult (RJA), initiating joint attention with an adult (IJA), initiating behaviour requests/regulation (IBR) e.g., using gaze or gesture to request attention or help from a partner, and responding to behaviour requests (RBR). Mundy et al. (2007) tracked the development of joint attention in 95 TD infants at 9, 12, 15 and 18 months of age and compared these to language tests at 24 months. Other measures of general cognitive function were taken and children were also grouped into typical cognitive development and those at risk of developmental delay (ARDD).

Mundy et al. (2007) found that RJA increased significantly with age for both the TD and ARDD groups, however, TD children responded to joint attention bids significantly more than ARDD children at all time points. However, this linear increase was not found for IJA, which showed a slight increase between 9 and 12 months, followed by a marginally significant decline at 15 months, only recovering to 15 month levels at 18 months. This pattern was the same for both groups with TD consistently initiating joint attention more frequently than ARDD children. IBR increased significantly with age and TD performed marginally to significantly better than ARDD at 9, 12 and 18 months. Children's RBR also increased significantly with age, however this was the only joint attention behaviour that was not affected by cognitive function. IBR and RBR were correlated, but there was no correlation between RJA and IJA. Mundy et al. (2007) interpreted the different developmental pattern of IJA from RJA to mean that they may be underpinned by related, but distinct processes.

In general RJA (9 and 12 months) and IJA (9, 12 and 15 months) predicted receptive language and RJA (9 months) and IJA (18 months) predicted expressive language performance at 24 months for both groups. However, when cognitive function at 18 months was taken into account, only RJA at 9 months and IJA at 18 months predicted receptive language at 24 months. When the effect of cognitive function at 18 months was taken into account only IJA at 18 months was a significant predictor of overall language ability (receptive and expressive) at 2 years.

In summary the general developmental pattern between TD and ARDD was the same. RJA, IBR and RBR increased with age, whereas there was a cubic pattern of development for IJA. In general cognitive function was found to affect the development of joint attention skills except RBR. Furthermore, the ability to initiate joint attention was the only aspect of joint attention that could reliably predict language ability beyond cognitive function. Therefore, it appears that IJA has a unique role to play in language acquisition.

Imitation in TD children

Maratos (1973) tested the development of imitation in 12 infants, visiting them every two weeks from 1 – 6 months of age. She noted the infants seemed able to imitate mouth, tongue and head movements more than at baseline measures until 2 months, when imitation waned and then from 4.5 months imitation skills such as arm and finger movements developed consistently and continued to increase with age. Killen and Uzgiris (1981) found that from 7½ months of age, TD infants were able to imitate an adult's simple actions with an object (banging or shaking a doll/block), from 10 – 16 months of age they were seen to imitate socially appropriate actions with objects, such as pushing a car along, whereas they were less likely to imitate inappropriate actions, such as drinking from a car. However, by 22 months of age, children imitated both types of actions.

Evidence demonstrates that imitation is an early-emerging skill used to initiate or maintain social interaction with adult partners. It is also the case that imitation remains a useful skill in establishing early play skills by supporting coordinated action in peers. Eckerman, Davis, and Didow (1989) longitudinally assessed the emergence of play skills in 14 TD peer dyads by observing their natural play every four months from 16 to 32 months of age. They reported a noticeable increase in coordinated acts with age and an increasing tendency for children to imitate their peer's non-verbal actions over time. Eckerman et al. (1989) noted that children did use words to direct a peer, but that it was very rare.

In another study, Eckerman and Didow (1996) considered the relationship of coordinated action, non-verbal imitation and children's verbal activity. They found that children were more likely to engage in verbal activity, such as describing their coordinated action or directing their partner's attention to their own activity, when they were engaged in episodes of coordinated action dominated by non-verbal imitative behaviour. Charman et al. (2000) also reported a longitudinal association between 15 TD children's imitation skills at 20 months and their expressive language ability at 44 months.

In summary, in typical early child development, awareness of a social partner and joint attention skills develop, advancing children's social and linguistic development with joint attention and communicative ability mediated by cognitive functioning. Other-awareness is facilitated by imitative skills that can further promote and sustain coordinated activity with both adult and peer partners, nurturing language development further.

Impairment of joint attention and imitation in autism

In contrast to TD children, less is known about the early development of infants with autism. This stems from the difficulty of identifying and diagnosing children early enough to study their development. However, this problem is being tackled by the use of prospective studies: the investigation of 'at-risk' children, i.e., younger siblings of children diagnosed with autism. One such study by Rozga et al. (2011) found that the frequency and duration of gazes, smiles and vocalisations infants made to their mothers at 6 months of age was not recognisably different between TD infants and the children who later received an autism diagnosis at 36 months. However, by 12 months, deficits in joint attention and requesting behaviour were identified. Significantly, there were no differences found between

TD and children later diagnosed with autism in responding to joint attention bids from adults to proximal objects (i.e., pointing to pictures in a book).

In a study of older LFA children Mundy, Sigman, and Kasari (1990) assessed joint attention abilities at two time points 13 months apart (mean of LFA age 3 years 9 months at first time point) and compared these to two-year-old children matched for mental age (MA) with ID and language matched (LM) with ID. They found that LFA children had joint attention deficits compared to MA and LM children and that, although joint attention behaviour increased in all groups with age, the disparity in performance remained and could not be accounted for by differences in IQ. Joint attention predicted language ability in LFA children 13 months later, with no association found between initial language ability and IQ. However, Mundy et al. (1990) did not find any differences between the groups in social behaviour that included tests such as initiating turn-taking by rolling a toy car to the experimenter, using a comb on the experimenter or throwing toys while smiling at the experimenter.

In a review of research on imitation in children with ASD, Williams, Whiten, and Singh (2004) reported a substantial impairment, in imitation and in particular imitation of motor actions. However, in line with Carpenter et al. (2002), Williams, Whiten, and Singh also evaluated the imitation of actions on objects as being a relatively preserved skill in ASD.

Importantly, joint attention and imitation are prospectively associated with language development (Charman, 2003; Kasari, Gulsrud, Freeman, Paparella, & Hellemann, 2012; Poon, Watson, Baranek, & Poe, 2012; Toth, Munson, Meltzoff, & Dawson, 2006; Williams et al., 2004). One such study by Toth et al. (2006) assessed the association of joint attention, imitation and toy play with ASD language development. Sixty preschoolers aged 3 – 4 years were assessed and their language development tracked every six months until 4 – 6.5 years. Toth et al. (2006) found that initiating a bid for joint attention (declarative gesture) and imitating the actions of an adult on objects immediately after seeing them was related to language ability at 3 – 4 years. The overall rate of language acquisition in the ASD children was in general delayed in comparison to rates related to typical development. However, individual differences showed that ASD children with more toy play and the ability to imitate the actions of an adult on objects, after a ten minute delay had faster rates of language acquisition.

A review of joint attention in children with autism by Bruinsma, Koegel, and Koegel (2004) discussed the consistent impairments demonstrated by research and the link between joint attention, intentional communication and expressive language. Bruinsma et al. (2004) emphasised the evident importance of joint attention as a prerequisite for intentional communication and functional speech. They also highlighted the need to consider how the environmental setting and the skill set of the social partner could affect ASD children's joint attention ability.

Although there is clear evidence of deficits in joint attention, the review by Williams et al. (2004), similarly to Rozga et al. (2011), found no discernible impairment in the ability of children with autism to respond to joint attention bids related to actions on proximal objects. Additionally, Mundy et al. (1990) found no specific LFA impairment in social behaviour, including actions with objects. Taking into account the early emergence of imitative actions on objects (Carpenter et al., 2002) and the finding that responding to attention bids to actions on objects and actions with proximal objects are unimpaired, it can be suggested that attention to actions on objects is a relatively preserved skill in children with autism and highlights its potential for supporting the social cognitive development of LFA children.

The majority of research investigating other-awareness, joint attention and imitation has used controlled assessments rather than the on-line assessment of children's naturally occurring spontaneous behaviour. This approach does not allow for a broader range of behaviour to emerge that less controlled settings may reveal. The aim of many interventions for ASD children is to improve their social and communicative skills during everyday interactions. Therefore, research that assesses the interactions of children with ASD while they participate in activities with a partner may elucidate methods that can support social-cognitive development in this group and ultimately contribute towards designing effective interventions (Jones, Carr & Feeley, 2006; Kaale, Smith & Sponheim, 2012;Kasari, Freemen & Paparella, 2006). Research on language development in TD children shows that exposure to different types of social partner is important, peer interaction aids language acquisition and offers vital experience for language socialisation, however, peer interaction is not sufficient as children also need considerable input from expert speakers to develop language competence (Hoff, 2006). Despite these findings in TD children there have been no systematic comparisons of the effects of different types of social partner e.g., adult, peer, parent or sibling on other-awareness or communicative behaviour in children with ASD.

Implications of research on joint attention and imitation in autism

It should be noted that Carpenter et al. (2002) found that in LFA children the capacity to imitate an adult's actions on objects was manifested earlier than their capacity to share attention, as evaluated by gaze alternation between an adult and object, a constituent of joint attention (Table 2). This finding may be fundamental in LFA development as it indicates that another's action on an object is more salient for LFA children than another's attention towards it. Accordingly, it could be argued that for LFA children, observing others' actions on objects might support the development of the capacity to share attention with another person.

However, what remains unknown in the study of joint attention and imitation is the other-awareness ability of children when gaze alternation between an object and partner is not evident. This is particularly pertinent for children with autism, who are defined by having unusual eye contact and patterns of visual perception (Behrmann, Thomas, & Humphreys, 2006). Consequently, elucidating other-awareness from behaviour that does not entirely rely on gaze alternation between a partner and an object is one of the aims of this thesis. Nevertheless, what is apparent, is the importance of attention to proximal objects, and the imitation of action on objects, in the development of LFA children's social interactional skills.

Collaboration

Joint attention, as discussed, is the ability to coordinate one's attention to include another person and an object. When an activity requires two people to coordinate their actions on an object in an effort to solve a problem, this can be termed collaborative or cooperative problem solving. The terms collaboration and cooperation are often used interchangeably when referring to group problem-solving activities in developmental research. However, it should be noted that in other disciplines, such as human computer interaction, (Roschelle &

Teasley, 1995), organizational (Hord, 1986) and higher educational research (Paulus, 2005) this is not the case.

Roschelle and Teasley, in 1995, defined collaboration as *"a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem."* (Roschelle & Teasley, 1995, p.70). In contrast, they describe cooperation as a *"division of labour among participants, as an activity where each person is responsible for a portion of the problem solving."* (Roschelle & Teasley, 1995, p.70). Therefore, collaboration is differentiated from cooperation in problem solving, by Roschelle and Teasley, as activities that bring about the 'mutual engagement' of participants to solve a problem together, compared to those that give participants individual problems to solve. This distinction of working on the same problem together compared to having different roles with the ultimate aim of achieving the same goal is consistent with that described by Hord (1986) and Paulus (2005).

In their studies investigating cooperation in children with autism, Liebal, Colombi, Rogers, Warneken, and Tomasello (2008) and Colombi et al. (2009) adopted Bratman's (1992) definition of a shared cooperative activity, detailing three 'slightly modified' main features; "(1) the cooperating partners are mutually responsive to each other, (2) they have a shared goal, (3) and they mutually support each other in their roles in order to achieve that shared goal" (Liebal et al., 2008, p. 225; Colombi et al., p. 143).

Bratman's (B) definition of a shared cooperative activity used by Liebal et al. (2008) and Colombi et al. (2009) appears close to that of Roschelle and Teasley's (R & T) definition of collaboration. Both definitions require partners to show through their actions their intention to coordinate (R & T)/be responsive to their partner's actions (B) to solve a shared problem (R & T)/shared goal (B). However, Roschelle and Teasley describe a 'synchronous activity that results from the continuous attempt to construct and maintain a shared conception of a problem'. I believe this makes it clear that each collaborator shares and contributes to an evolving and 'corresponding' representation of the problem as they try to solve it; it is the striving to share a matching representation that is the fulcrum of collaboration. This is in contrast to the definition of cooperation described by Roschelle and Teasley, (1995), Hord, (1986) and Paulus, (2006) where each cooperator contributes evolving, but 'different' representations as they attempt to solve a shared problem, as in the case of division of labour.

For the purposes of this thesis I prefer to use the Roschelle and Teasley (1995) definition of collaboration, as opposed to cooperation, as the activities have been designed so that, two players have identical tasks to solve. With tasks interlinked in a way that necessitates the generation of corresponding representations during the problem solving process in order to reach a shared solution. This means there is no differentiation in role i.e., no division of labour in the activities designed for this thesis.

If the Roschelle and Teasley (1995) definitions of cooperation and collaboration are applied to the 'shared cooperative activities' described by Liebal et al. (2008) and Colombi et al. (2009) then I would suggest that they include both cooperative and collaborative activities. For example, in the Double-tubes task, there are two tubes that one person can drop a wooden block down for their partner to try to catch at the bottom using a container. To participate successfully in the shared activity both players need to agree on taking individual roles, by choosing which tube they will use and then coordinate their actions. Therefore according to Roschelle and Teasley's (1995) definition it is a cooperative task. The Elevator task also fits the criteria for a cooperative activity according the Roschelle and Teasley's definition, as it requires one person to push up a cylinder in order to allow another person to access an object. In these two examples each role is interdependent, but different. In comparison, the tube-with-handles task requires a pair of children to pull simultaneously at each end of a tube to open it in the middle to release a toy and the Trampoline task needs two people to hold both halves of a hand held collapsible trampoline to be able to bounce a block on it. In these activities, to successfully solve the problem both participants need to participate simultaneously taking matching roles, so therefore meet Roschelle and Teasley's criteria for a collaborative activity. Evidently the tasks used by Liebal et al. (2008) and Colombi et al. (2009) all meet Bratman's definition of shared cooperative activities; nonetheless it is important to highlight differences between collaboration and cooperation in order to identify and understand potential differences in outcomes that may occur from the two subtly different processes.

Imitation and coordinated activity

In preschool TD children imitation appears to have an important role in facilitating coordinated activity between adults and peers and is associated with communicative behaviour during the activity (Didow & Eckerman, 2001; Eckerman & Didow, 1996). As TD children get older, encouraging them to collaborate with peers has become an integral aspect of school education with the objective of enhancing their learning and development (Blatchford, Kutnick, Baines, & Galton, 2003). Children require many skills to enable collaboration with a peer, including other-awareness, (Holt & Yuill, 2014), the ability to coordinate joint action (Brownell, Ramani, & Zerwas, 2006) and observing and imitating a more knowledgeable peer (Johnson-Pynn & Nisbet, 2002; Ramani & Brownell, 2014).

Cooperation, intentionality and the Vygotskian intelligence hypothesis

Tomasello, Carpenter, Call, Behne, and Moll (2005) propose that the capacity to cooperate, using Bratman's (1992) definition of a shared cooperative activity, develops from the ability to both *understand another's intentions* and *share intentions with others*. They suggest that impairments in the ability of children with autism to cooperate with a partner stem from an inability to share intentions, even though they are found to have some understanding of others' intentions towards objects.

Colombi et al. (2009) investigated the imitation, joint attention and understanding of others' intentions to objects, in 14 children with autism aged 2.5 to 5 years, and compared their performance to 15 children matched for nonverbal and verbal mental ability with developmental disability (DD) of the same age. The study included tests of imitation, joint attention, understanding intentionality and cooperation. Imitation tests were manual actions without objects, actions on objects and spontaneous imitation e.g., copying an experimenter swaying to music. Joint attention was only responding to a request for joint attention.

The 'understanding intentionality' test used a failed intention paradigm: children were presented with eight objects one at a time, the experimenter either produced an action novel to the child or tried, but failed, to produce an 'intended' action. Children passed the understanding intentionality' task if they performed the experimenter's intended action. The cooperative tasks consisted of the four 'shared cooperative activities', discussed previously, with children partnered by an adult. Examining the results of the four shared cooperative tasks and considering and the Double-tubes and Elevator tasks as cooperative tasks, DD children scored significantly higher than LFA children on the Double-tubes task, but there was no difference in scores for the Elevator task, with both LFA and DD groups scoring at ceiling level. Considering the Tube-with-handles and trampoline task as collaborative, LFA children found both task significantly more difficult to do than DD children. Colombi et al. (2009) excluded the Elevator task scores from the final analysis, making a composite score of the one 'cooperative' task and the two collaborative tasks creating a single score of cooperation. Colombi et al. (2009) reported that LFA children were more impaired in imitation and joint attention than DD children and that both skills were factors affecting their ability to cooperate. Although, as the Elevator task was excluded in this instance the results primarily reflect differences in collaboration. LFA children were not found to perform differently to the DD children on tests of understanding another's intentionality towards objects.

Therefore, the deficits of joint attention and imitation in LFA children persist when cooperating and collaborating with an adult partner. However, LFA children were able to attend to the actions generated by an adult on an object and understood what the adult intended to do by producing the adult's failed action. This ability to understand intentionality could be associated with the preserved skills of attention to proximal objects and the imitation of another's action on objects, discussed previously.

Moll and Tomasello (2007) propose that by their definition, cooperative interaction is the driving force of social cognition, in a theory they term the Vygotskian intelligence hypothesis. They assert that cooperative activity can develop other-awareness by aiding the recognition through joint action that they are sharing a joint focus of attention with another person and from that awareness the child can then develop an understanding that the other person can have a different perspective of the shared experience from their own. This hypothesis positions joint activity as fundamental in the developmental process of TD children.

Therefore, the skills of joint attention and imitation demonstrated by Colombi et al. (2009) are considered prerequisites for the ability to participate in 'cooperative' activities and hence a possible reason for deficits in the capacity of children with autism to cooperate (Liebal et al., 2008). Furthermore, impairments in other-awareness, joint attention and imitation in children with autism may have a cumulative effect on their development, as they are less able to participate in joint activity, and impairments will be compounded by their tendency to engage in solitary activities (Hauck, Fein, Waterhouse & Feinstein, 1995) and so encounter even less exposure to other people.

Colombi et al. (2009) provide further evidence that joint attention and imitation are impaired in LFA children and that crucially they are skills that contribute to their ability to cooperate with an adult partner. However, the evidence was gathered by a battery of tests for each capacity and therefore cannot inform us about naturally-occurring spontaneous cooperative and collaborative activity in this group. The findings are valuable, but cannot entirely illuminate our understanding of these abilities in LFA children.

Autism, collaboration and cooperation using shareable technology

Children with autism are highly motivated to interact with technology (Golan & Baron-Cohen, 2006; Moore & Calvert, 2000; Ploog, Scharf, Nelson, & Brooks, 2012; C. Williams, Wright, Callaghan, & Coughlan, 2002) and from as early as 1973, Colby reported the positive effect of using computer technology to assist word learning in children with ASD, finding that thirteen out of seventeen non-verbal children with ASD repeated words generated by pressing a key on a computer keyboard during free play. Bernard-Opitz, Sriram, and Nakhoda-Sapuan (2001) designed a computer game to teach HFA children about solving social problems. Eight HFA children and eight TD children were shown animations of problem scenarios followed by a choice of possible solutions and then asked to offer alternative solutions. Ten training sessions that involved an adult trainer explaining the solutions were interspersed with six sessions without an adult giving explanations. The aim of the intervention was to increase the number of novel problem solutions children gave. HFA children produced significantly fewer novel ideas in the training sessions than TD children and although they did not perform as well as TD children, they did show improvement with increased exposure to the intervention. All children produced fewer novel ideas in sessions not explained by a trainer, but still did show improvement over time. This study demonstrates that a computer program can be designed with the aim of teaching a specific skill to children with ASD, in this case think of more novel solutions to a given problem.

However, concerns were raised that computers designed for ‘personal’ use could potentially isolate children with ASD further and possibly exacerbate impairments in social interaction and communication (Powell, 1996). With the advent of innovative multi-user (shareable computer) technology, researchers have tried to address these concerns by designing software that enables more than one user to interact with an interface at one time. This has opened up new avenues of research to find effective methods to support interaction between partners and individuals with ASD.

Bauminger-Zviely, Eden, Zancanaro, Weiss, and Gal (2013) used shareable technology to implement two interventions aimed to improve i.) social conversation and, ii.) collaboration in 22 HFA children, attending mainstream school (mean age 9 years). Pairs of children with the support of a trained adult were taught about the concepts of social conversation (No-Problem intervention using a laptop with multiple mice) and collaboration (Join-In intervention using Mitsubishi Diamond Touch interactive tabletop computer (DT)). Vignettes were presented to children to stimulate discussion about the concepts of social conversation and collaboration and they were given activities on the shareable technology to practice skills. Unfortunately, Bauminger-Zviely et al. (2013) fail to define what they mean by collaboration. They describe the Join-In intervention as aiming to teach children about the concept of collaboration through social problem solving vignettes, but do not describe in detail what that entails. The Join-In intervention also gives children 'cooperative dyadic activities' which were proposed to improve three unspecified dimensions of collaboration. However, Bauminger-Zviely et al. (2013) do not describe why they consider the activities as cooperative, or describe the activities in enough detail to judge whether they could be defined as cooperative or collaborative or give evidence as to why the cooperative activities function to target 'three dimensions of collaboration'. Bauminger-Zviely et al. (2013) reported an improvement in children's understanding of the concepts of collaboration and social conversation following the No-Problem and Join-In interventions. The behavioural measure of social engagement was a shared drawing task which was reported to have had a significant effect on children's "cooperative behaviours (i.e., child shows a behaviour or makes a statement that reflects an ability to collaborate with other children's suggestions or to give up his or her own idea in favour of another child's" (Bauminger-Zviely et al., 2013, p.339). The study by Bauminger-Zviely et al. (2013) reported an improvement in HFA children's understanding of the concepts they termed social conversation and social collaboration and is further evidence to support the efficacy of computerised interventions for HFA children. However, this study did not measure the ability of children with autism to collaborate or cooperate with a partner on a shared task using shareable technology.

Technology has also been employed to create virtual reality environments in order to provide scenarios and activities to help individuals with ASD experience social situations to develop social skills without the pressure of face-to-face interaction. Stichter, Laffey, Galyen, and Herzog (2014) designed iSocial a 3D virtual environment to teach HFA adolescents (aged 11-14, IQ <75) social skills that were then put into practice by collaborating as part of a group to create or play games in virtual worlds. Participants were 'physically distanced' from each other using individual computers and the intervention included 31 45-minute lessons over a period of four months. Therefore, in this study the participants only met in the virtual environment and do not practice skills in face-to-face situations. Measures of social responsiveness and executive function reported by teachers showed no significant change and a battery of ToM, executive function, attention and inhibition tests also demonstrated no change pre to post test. Although a significant improvement in social responsiveness was reported by the parents. The lack of positive change reported by Stichter et al. (2014) may be because the measures used to look for change were not tapping into the domain the intervention was addressing or it could suggest that for children to improve social skills they need face-to-face interaction.

Researchers have also restricted how users can interact with the activity delivered by the shareable technology with the intention of forcing users to interact with a partner. Ben-Sasson, Lamash, and Gal (2013) manipulated the level of enforcement administered by a DT computer and compared a free play (FP) computer environment to an enforced collaboration (EC) condition. Six pairs of HFA boys (8 – 11 years, IQ < 85) were given three puzzles in a FP mode and three in a EC mode i.e., both children had to touch the same puzzle piece at the same time to move it. The puzzles consisted of 16 pieces spread around a solution area and at the top of the screen a completed puzzle was visible for children to refer to. Ben-Sasson et al. (2013) reported more positive social interaction and collaborative play in pairs of children doing the puzzle task in the EC condition, there was no significant difference in negative social interaction between the FP and Piper, O'Brien, Morris and Winograd (2006) considered how 'cooperative' activities on a DT could be used to facilitate social skills in a therapy session given to two groups of children aged 12 years (five children with Asperger Syndrome, one with HFA, one with Apraxia, and one with Klinefelter's Syndrome). Piper et al. (2006) designed SIDES: Shared Interfaces to Develop Effective Social Skills to run on a DT as a tool to offer cooperative games. The study compared children's conversation and behaviour during a task in three conditions: no rules, human-enforced rules and computer-enforced rules. Group 1's conversation was described as 'better' and as encouraging cooperative group work when the computer-enforced rules were in place. Group 2 were reported as having more positive conversational interactions and less aggressive behaviour in the 'no rules' condition. Therefore, enforcing turn-taking or simultaneous action is found to be effective in HFA children.

A common theme of the studies previously mentioned using shareable technology is the fact that all the participants included were HFA children and therefore tells us little about the ability of LFA children. However, Battocchi et al. (2010) and Silva, Raposo, and Suplino (2014) have included LFA children in their studies of collaboration using shareable technology. Battocchi et al. (2010) presented a puzzle activity on a DT to 16 ASD boys aged 8 – 18 years that included 10 LFA and 6 HFA children. Pairs of children were given the puzzle to solve in two modes; free play (FP) that meant children could move pieces individually or enforced collaboration (EC) where children both had to touch puzzle pieces at the same time to move them. As the DT can identify individual users touch, children's 'touch' interactions with the DT during the tasks were used as measures of their interactions with each other. From the log files generated by the computer Battocchi et al. (2010) found that the EC condition increased their coordinated moves and simultaneous play and it took longer for the children with ASD to complete the puzzle compared to the FP condition. This is a key finding as it suggests that both HFA and LFA children can be supported to collaborate with a partner if constraints are put in place to facilitate it. Battocchi et al. (2010) used log files as the measure of children's interactions with each other and the activity and this is an accurate and unbiased method of gathering data. However, it does not give a complete picture of the children's interactions as it does not give information about where the children are looking, if they are gesturing or verbalising, essential information necessary to extend our understanding of collaboration in children with ASD.

Silva et al. (2014) describe a 'collaborative' game presented on a multiuser tabletop. The study included 5 LFA young people aged 10 – 17 years. The game gives users different roles to play: one player selects clothes from a shelf and puts them in a box while a second player catches them in a cart and then moves the cart to a 'parking lot', players are then free to dress a soccer player with the clothes. It should be noted, that as players of Silva et al.'s game have different roles to perform to complete the shared problem, using Roschelle and Teasley's (1995) definition adopted by this thesis, this would be a cooperative task. Silva et al. (2014) compared the interactions of players in three phases with an increasing number of constraints on how users could interact with the game making it necessary for users to coordinate their actions in order to progress through the activity. Silva et al. describe how the interaction patterns between users varied in different pairs of children, with constraints in general having a positive effect on LFA children's interactions with their partner. This suggests that constraints can be an effective way to increase interactive behaviour in LFA children.

In general researchers have identified the skills they 'judge' necessary to collaborate with another on a task and have used computer activities aimed to improve those skills in ASD. This is valuable, but it is also important to determine the range of skills that children with ASD 'employ' in their efforts to collaborate with a partner on a shared computer task. With this method it may be possible to establish what factors in the child may support, or impair collaboration.

Furthermore, with this understanding it may be possible to target 'particular' skills in 'individual' LFA children with the purpose of developing their collaborative skills more effectively.

The aim of the studies presented in this thesis is to investigate in fine detail the skills LFA children demonstrate during a collaborative computer activity and thus start to address the lack of evidence in the area of LFA and collaboration research. It is important to address this limitation in our understanding of this group due to the potentially crucial role collaboration may play their social cognitive and language development.

Overview of the technological aspects of this thesis

The aim of this thesis was to examine other-awareness and the collaborative process in LFA children. This was achieved by firstly appraising the optimal way of facilitating collaborative activity and secondly, by developing an *other-awareness* coding scheme to try to identify the range of other-awareness behaviour in LFA children's opened interactions with different partners. Three aspects of the collaborative activity were considered:

1. Facilitating collaboration through shareable technology.
2. Facilitating collaboration through the design of the computer software.
3. Facilitating collaboration by taking into account the interests of the user group.

Separate Control of Shared Space (SCoSS)

Shareable technology is well-placed to provide a unique contribution to the understanding of the social-cognitive development of ASD individuals. It offers interdisciplinary research opportunities to design environments that can manipulate contingencies and so support selectively specific types of behaviour, e.g., joint attention or imitation. Yuill and Rogers (2012) presented a framework for designing multi-user computer technology to support collaboration. They proposed three mechanisms that underpin collaborative behaviour and suggest these can be manipulated through providing contraints to enhance it. Firstly, "*Awareness of others,* the degree to which awareness of users' ongoing actions and intentions is present or made visible moment-to-moment, secondly, *Control of action* - the extent of each user's control over actions and decisions, thirdly Av*ailability of information* - the ways in which background information relevant to users' behaviour and to the task is made available, or externalized" (Holt & Yuill, 2014, p. 238).

Yuill and Rogers (2012) discuss how Separate Control of Shared Space (SCoSS: Kerawalla, Pearce, Yuill, Luckin & Harris, 2008) uses these mechanisms to support collaboration. Kerawalla et al. (2008) proposed that users with multiple mice sharing a single interface were more likely to produce cooperative than collaborative behaviour, as tasks are often designed for single use. Even with multiple mice users cannot easily interact with an individual task element simultaneously. Therefore, it is probable that users will divide up problems and take on individual roles i.e., cooperate to solve a shared problem. It is also possible, when sharing a single user interface with multiple mice, for one user to complete a task on their own.

Kerawalla et al. (2008) designed Separate Control of Shared Space (Fig 1) with 'core properties' they suggest overcome these potential barriers to collaboration by "*the provision of separate control over an identical version of the task for each child, within their own private screen space, that is visible to both participants*." (Kerawalla et al., 2008, p.195). Thus, users can only interact with their own task elements, but are able to coordinate their actions with their partner's to interact simultaneously on identical task elements within their own task space. Both users can also see their partner's ongoing task state and this, Kerawalla et al. (2008) argue is a resource to stimulate discussion toward solving the shared 'identical' problem. Users can also be required to agree with each other during the problem solving process by clicking their own 'We agree' button: only if their individual game states are showing agreement will users be able to proceed (Kerawalla et al., 2008).

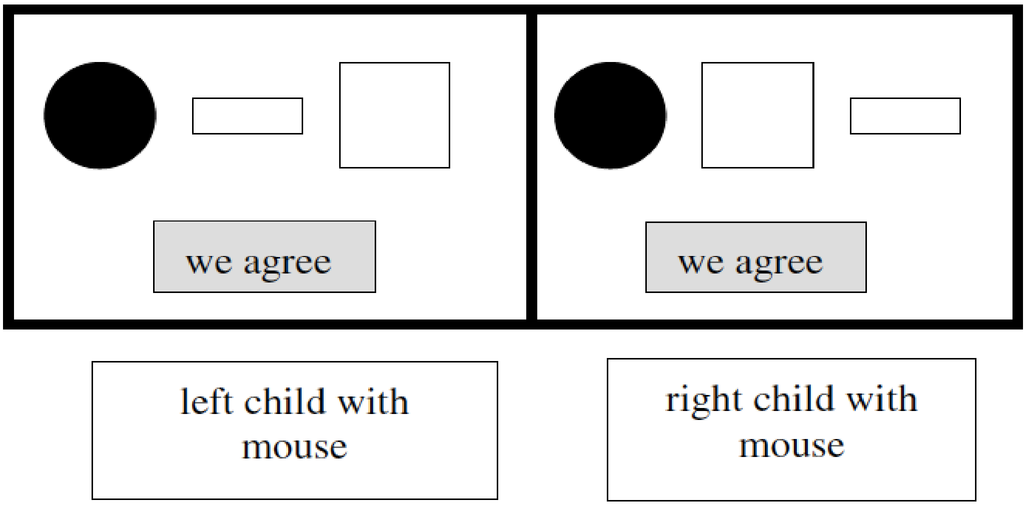


Figure 1. SCoSS interface showing two identical task configurations with two mice for dual control taken from Kerawalla et al. (2008).

Kerawalla et al. (2008) offered a word categorisation task to 64 TD children (aged 7 – 9 years) working in pairs with either dual control of a single user interface (Fig 2) or dual control of the SCoSS interface (Fig 3). The word categorisation task was adapted from Cartwright (2002) as part of the Riddles project[1] investigating language awareness skills in TD children with the aim of improving language comprehension through discussion. Kerawalla et al. (2008) gave children 12 words that varied on two dimension; 1) semantically and 2) at a surface level e.g., 1 = animals or weather, 2 = word length 4 or 7, (goat, buffalo, rain, thunder, shown in Figure 1 and Figure 2) to sort into a coloured 2 x 2 grid. Children were presented with words one at a time and had to click on the 'we agree' button to get a new word. Words that were placed in corresponding positions and therefore showing agreement became highlighted green. When three words were correctly placed completing one of the four coloured boxes of the 2 x 2 grid the words changed colour to match the box colour of the grid and the words could no longer be moved. Children were given textual information in the 'Hint' box telling them if they were correct or giving clues and prompts.

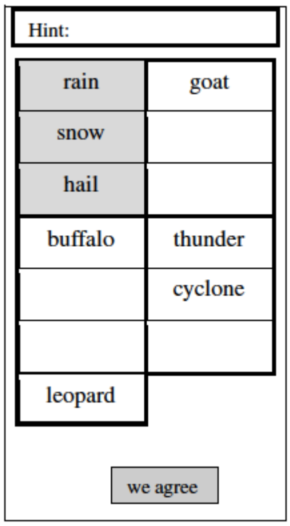


Figure 2. Word categorisation task displayed as a single interface for use on a shared screen with two mice for dual control, taken from Kerawalla et al. (2008).

[1] The Riddles project was funded by EPSRC grant code GR/R96538.

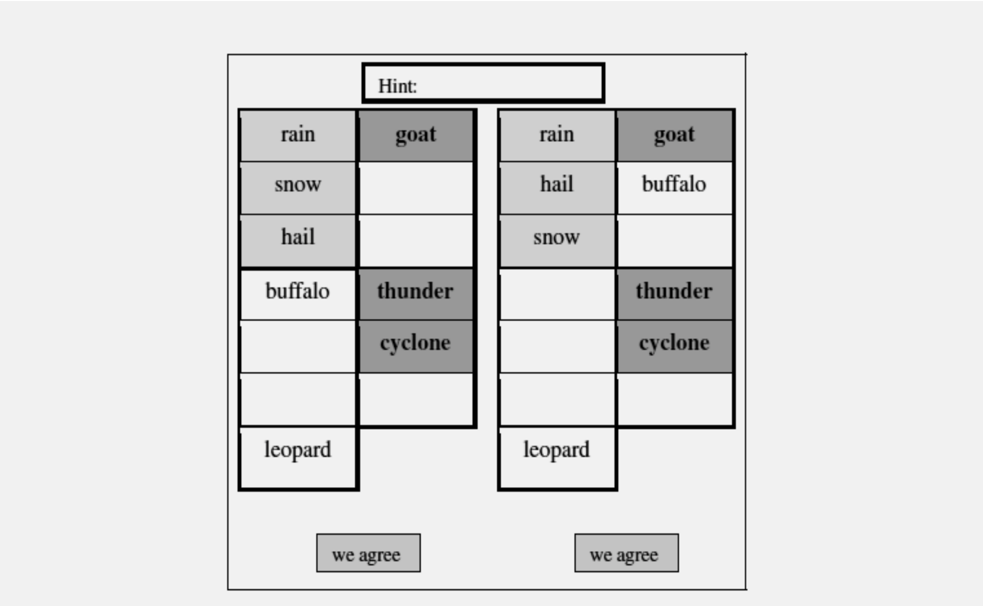


Figure 3. Word categorisation task displayed on the SCoSS interface, showing two identical tasks for children to work on simultaneously using dual mice for dual control, taken from Kerawalla et al. (2008).

To support children's understanding of collaboration, Kerawalla et al. (2008) delivered three lessons, two to teach about collaboration, following lessons plan devised by Wegerif, that were downloaded from the internet, and the third to discuss about reaching agreement and resolving disagreements. In pairs children practiced the word categorisation task firstly, as a paper and pen activity, secondly, a practice round with dual control of either a single or SCoSS interface and then three experimental rounds of word categorisation tasks with dual control of either the single or SCoSS interface.

Kerawalla et al. (2008) presented a qualitative analysis of children's interactions during the word task using the single or SCoSS interface. For the single interface, they described less equitable, 'e.g., a child not using their mouse, one child doing the task independently, interrupting or undoing their partner's work, not paying attention to what their partner is doing, clicking 'we agree' to dominate or rush partner, working on different words at the same time or taking turns' (Kerawalla et al., 2008, p. 200). They proposed that in contrast the separate working spaces of the SCoSS interface meant children demonstrated disagreement and agreement explicitly and that the requirement to show agreement by pressing 'we agree' 'fosters discussion' thus promoting 'useful educational dialogue' (Kerawalla et al., 2008).

Kerawalla et al. (2008) noted that SCoSS demonstrates agreement between partners when corresponding words on both players' game representations turn green. However, this feature cannot be offered by a single interface. Kerawalla et al. (2008) argue that it is the separate spaces that enable players to explicitly see disagreements and the greenness highlighting agreements, which they propose mediates discussion. In comparison using a single interface, disagreement was often resolved by players replacing words with other words, actions that "essentially override and delete previous ones, making a similar representation of disagreement impossible" Kerawalla et al., 2008, p. 201).

Shareable technology and SCoSS used for this thesis

The collaborative activity used for this thesis was presented on three types of shareable technology: a laptop with dual mouse control shown in Figure 4 and Figure 5 (Holt and Yuill, 2014), a Mitsubishi Diamond Touch interactive tabletop computer shown in Figure 6 (DT, Paper 2) and interlinked dual tablets shown in Figure 7 (Paper 3). The shareable technology employed for Paper 1 and Paper 2 of this thesis adapted the SCoSS software used by Kerawalla et al. (2008) from the word catergorisation task created for TD children to become a picture-sorting task.

The activity was selected after talking with the class teachers and teaching assistants of the autistic unit of the special needs school used for Paper 1. The teachers confirmed a picture-sorting task was a familiar paper-based activity for the children. The images selected to create the picture-sorting categories were chosen after discussion with the teaching staff to make certain the images were preferred by and familiar to the LFA children. The picture-sorting activity was a simple 2 x 1 categorisation task intended to make the task manageable for LFA children.

The change of task necessitated alterations to the appearance of the SCoSS interface from that used by Kerawalla et al. (2008). Instead of a 2 x 2 grid generating four features by which materials could be categorised, as in the Kerawalla et al. (2008) study, the grid was simplified to a 2 x 1 grid. A 2 x 1 grid meant LFA children would only have to sort materials into two categories, illustrated in Figure 4 (SCoSS interface) and Figure 5 (single interface).

Other adaptations included making the grid boxes more brightly coloured than those used by Kerawalla et al. (2008) with the intention of making the two grids appear more distinct. Also the hint box was not used to give extra feedback, prompts or clues as because of the limited reading ability of the LFA children this role could be played by the experimenter. As in the Kerawalla et al. (2008) study, images were delivered to children one at a time, but extra feedback was added, when the 'we agree' button was pressed. If players were in agreement, as shown by images in corresponding positions on their individual grids, the 'we agree' button flashed green before delivering another new image to sort. However, if all the images were not in corresponding positions the 'we agree' button would flash red and another picture was not delivered. In light of the LFA children's comprehension difficulties it was thought helpful to give them visual feedback on their game state. Although, adaptations were made to the SCoSS interface, the affordances that the interface offered remain the same, as described by Yuill and Rogers (2102) and therefore it is believed to provide support for a collaborative activity according to the Roschelle and Teasley (1995) definition, adopted by this thesis.

Paper 3 of this thesis used tablet technology to create a novel interlinked dual-tablet configuration[2] (Fig 7) to replicate the affordances provided by the SCoSS interface originally presented on a shared screen. Tablet technology was chosen, as after discussion with special schools it became apparent that it was technology they were investing in and that they reported LFA children were frequently interacting with. Therefore, it offers the benefits of LFA children being familiar with it, being an available resource in special schools and has potential as a tool to develop and deliver a computer based intervention using an adapted form of SCoSS to support collaboration.

The dual-tablet configuration still provides "separate control over identical versions of the task for each child, within their own private screen space, that is visible to both participants" (Kerawalla et al., 2008, p.195) affordances considered essential to facilitate a collaborative activity. Kerawalla et al. (2008) also describe the importance of separate spaces in order to display agreement and disagreement using computer feedback. This is achieved with dual tablets by interlinking interactions with each tablet via wifi technology. Agreement is still represented by a green border and users' interactions with both tablets are interlinked so that new images will not appear unless both screens are in agreement, and computer

[2] Many thanks to Stefan Kreitmayer for the software development

feedback from pressing the 'we agree' button is still provided. Therefore, this adapted version of the SCoSS interface for use on dual tablets originally presented by Kerawalla et al. (2008) is judged to provide the same criteria of support for a collaborative activity according to Roschelle and Teasley's (1995) definition.

When using the SCoSS interface in the studies for this thesis, as previously mentioned, to receive another image, children had to show agreement i.e., images had to be in corresponding positions on both game representations. Children's 'agreement' was demonstrated by a green border surrounding images shown in Figures 4, 6 and 7 on the three shareable technologies. As in the Kerawalla et al. (2008) study images were delivered to children one at a time. In Paper 1 children only had to show agreement by placing images in corresponding positions on their individual grids: they did not have to correctly sort their images. This represented a 'matching only' constraint. This was similar to the Kerawalla et al. (2008) study as 'matching' also generated a green border around corresponding words regardless of objective correctness. However, in the Kerawalla et al. (2008) study once three words were correctly placed in a box on the grid, their correct agreement was fixed by the computer and the children could no longer move them. However, in the design of the picture-sorting task for Paper 1, all the images could be freely moved around the grid throughout the activity. In Paper 2 the level of agreement required to receive another image was manipulated. This meant that in order to show agreement to get a 'green border' in one condition, images only had to be placed in corresponding positions. In the other condition, images had to be correctly sorted and also show agreement with their partner. Therefore in the second condition a green border would only appear if both children had correctly categorised and put their images in corresponding positions on both game representations.

In Paper 1 and Paper 2 of this thesis LFA children were given a picture-sorting task, whereas in Paper 3 LFA children were presented with a picture-sequencing task. Picture sequencing was selected as an appropriate LFA collaborative computer activity as it is again familiar to LFA children at special school. Picture sequencing is a skill that is targeted by teachers and is also used to help LFA children understand their daily routines.

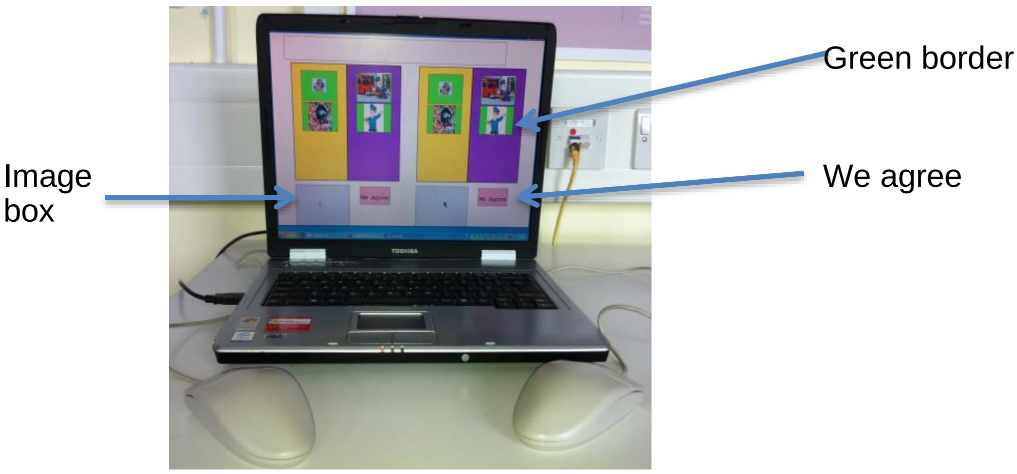


Figure 4. The SCoSS interface on dual-control laptop showing two identical game representations on a shared screen with two mice for dual control. The green borders around the images can be seen as the images on both game representations are showing agreement, i.e., are in corresponding positions on the grid.

Figure 5. The single interface, one shared game representation with two mice for dual control. The task is complete, but it should be noted that there are no green borders around the images.

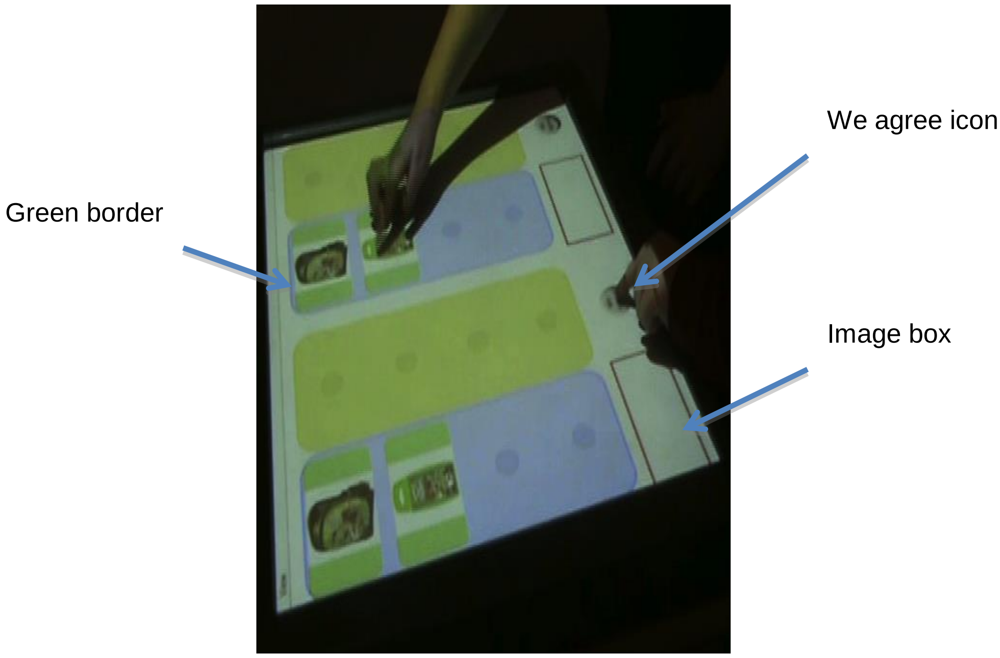


Figure 6. The SCoSS interface on the DT. LFA children are showing 'agreement' as demonstrated by the green border surrounding the images.

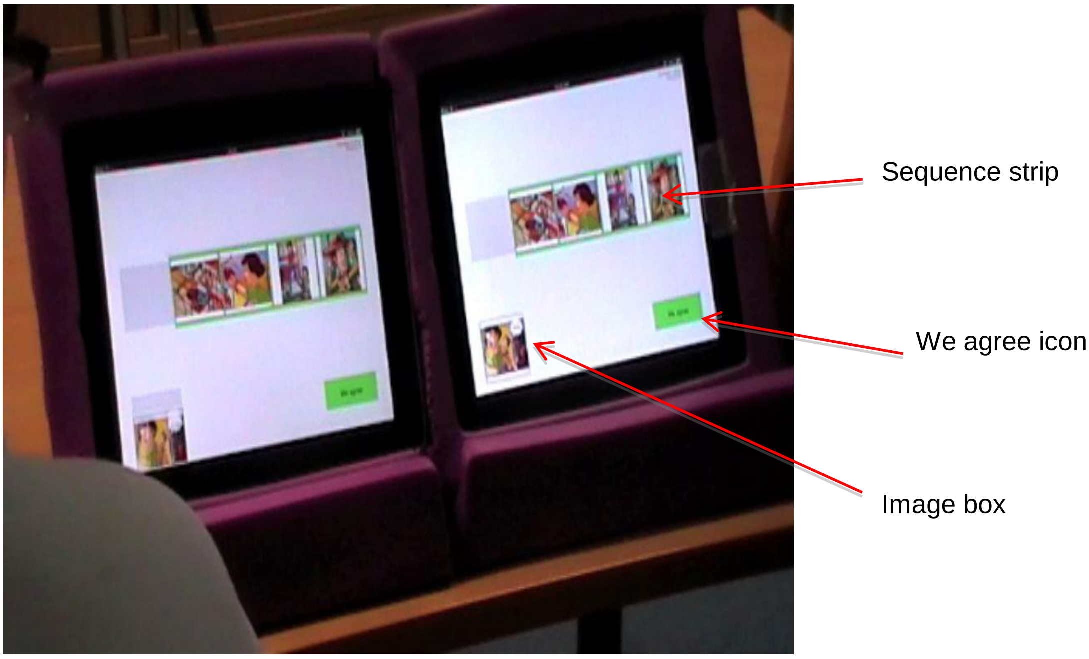


Figure 7. Dual tablets with two identical game representations. The collaborative-software controlling the picture-sequencing activity on the dual tablets was developed to link the actions of both users so that SCoSS features 2, 3 and 4 pertain to this dual configuration.

Separate Control of Shared Space and shareable technology

SCoSS has four features proposed by Kerawalla et al. (2008) to support joint action and collaboration and these features are provided by the shareable technology used in this thesis as follows:

1. Users in Paper 1 and Paper 2 have identical tasks to solve on a shared screen,

with representations of both their own and their partner's games side by side on the same screen. In Paper 3 the screen is not shared, but each user has a tablet with an identical game representation on, setup side by side on a stand and both tablets are interlinked via wifi.

2. Users' inputs are constrained so that they only have control of their own task space, and therefore cannot control any of their partner's task elements. In paper 1 this is achieved by each of the dual mice only controlling one half of the task space. In paper 2 the DT can identify individual users and so the table is programmed to only respond to touch inputs from each user on their own half of the task space. In paper 3 each user had their own tablet.
3. If both users have placed identical task elements in corresponding positions on the task grid and the elements are correctly placed according to the constraints set by the activity, then this correct agreement will be explicitly indicated by the surrounding area of each correctly placed item being highlighted in green. This offers users information to support negotiation and understanding during the problem-solving activity.
4. All the activities present the task elements one by one, so that at each stage users have to come to a joint agreement on where to position items correctly. This is demonstrated explicitly by users clicking a 'We agree' icon. Users cannot continue without this agreement, as the next item in the task will not appear until they click 'We agree'. If users are in agreement, (and correct according to any additional constraints) they will receive another picture in the image box. If the users are in agreement, (but incorrect

according to any additional constraints) the 'We agree' icon will flash red and another picture will not be delivered.

Designing engaging digital environments for autism

For each study the LFA children and teaching staff were interviewed to ascertain what the children would find engaging. It was judged essential to harness the LFA children's inherent interests as an additional strategy to promote engagement with the activity and hence facilitate collaboration. This strategy has been shown to be effective at improving ASD children's learning outcomes. Koegel, O'Dell, and Koegel (1987) involved children with autism in selecting learning materials and demonstrated that allowing non-verbal children with autism to choose their own word-learning materials increased their learning. Likewise, Dunst, Trivette, and Masiello (2011) found that following the interests of preschoolers with autism led to an increase in the children's language, cognitive, social, and motor development.

There is a drive to recognise and include the views of ASD children regarding issues that affect them. This has led to a strong tradition of involving ASD children in the participatory design process giving them a central role in designing digital learning environments (Parsons & Cobb, 2013). Frauenberger, Good, Alcorn, and Pain (2013) describe a participatory design process that took into account children's feedback. By creating annotator tools for a touch screen computer interface, that included smiley and sad faces, children with autism could indicate the aspects of the digital environment they liked or disliked and the researcher used these external representations of the children's thoughts to initiate discussions.

Frauenberger et al. (2013) noted how aspects of the design process were found to have positive and unexpected effects on the children with autism's social interactional abilities, including joint attention, spontaneous speech to peers and adults not directly involved in the activity to draw their attention to it, as well as emotional self-regulation. This approach was also used to create a virtual environment to help develop the social skills of adolescents with AS by Parsons et al. (2000) who included a group of (AS) adults in the design process of a virtual environment to help AS adolescents practice social skills. Therefore, to make progress in designing effective digital environments for individuals with ASD it is important to take into account their views and interests.

Other-awareness coding scheme

As discussed, the method for identifying other-awareness typically relies on gaze alternation between an object and a partner to confirm awareness of the other person incorporating the object. However, children with autism are known to have unusual patterns of eye gaze (Behrmann et al., 2006) and so gaze alternation may not be a useful measure of other-awareness in children with autism and relying on gaze alteration may restrict our understanding of other-awareness in this group. To overcome this problem an other-awareness coding scheme was developed to incorporate any other-awareness behaviour that emerges between two individuals participating in a joint activity. It should be noted that the coding scheme assumes that both participants are involved in the same activity simultaneously.

Other-awareness was divided into two sub-types: *attentional* other-awareness and *active* other-awareness. *Attentional* other-awareness is defined as behaviour that is *related to* the action of an interactional partner and is akin to joint attention, but crucially does not necessarily require eye gaze alternation, e.g., watching a collaborative partner interact with the activity. *Active* other-awareness is defined as behaviour that is *related to* and *contingent on* the action of an interactional partner, e.g., watching your partner's action and contingently reacting to it, such as imitating a partner's action or pointing to inform a partner to press the 'We agree'.

Engagement measures were also coded, as they are a prerequisite for other-awareness. If a child is not engaged with the activity then it is hard to draw conclusions about whether or not other-awareness is in their repertoire. LFA children's level of engagement with the activity was assessed using measures of approach to task and withdrawal from task.

Coding scheme development

Investigations of the collaborative process in LFA children are rare and even rarer involving LFA children participating with a peer partner on a joint computerised activity. Furthermore, as the previous research by Kerawalla et al. (2008) used TD children, the experiment on LFA children reported in Holt and Yuill (2014) was the first time that SCoSS on a dual-control laptop had been given to children with autism. Therefore, it was unknown if LFA children with their cognitive and fine motor impairments would be willing or able to use the technology even before any additional concerns as to whether they would be able to work with a partner on the task.

My aim was to explore all the behaviour LFA children demonstrated when working on a joint computerised activity with a partner. As the task differed from that used by Kerawalla et al. (2008) and the interface had not been used with LFA children it was considered appropriate to develop a coding scheme from the observations of the LFA children's actual behaviour after the initial set of data was gathered, rather than to apply an already existing coding scheme. With this in mind I used an inductive method to develop the coding scheme aiming to closely reflect what was observed during LFA children's interactions with the technology and crucially how computer and partner interactions were connected.

To achieve this goal, firstly, the experiments were videotaped from two angles. The face view to captured children's interactions with the interface, their gestures, eye movements, head turns and affective responses toward their partner as well as toward their own and partner's side of the computer screen. A second view from behind the children was used to capture in more detail the children's interactions with the interface. Before analysis the two views were spliced together, appearing side-by-side so as to run simultaneously with each other with the same time stamp. Presenting the data this way meant observations from both angles were used to produce a more accurate representation of children's interaction with a partner and the technology for analysis.

The design of the task on both the SCoSS and single user interface requires that players press the 'we agree' button/icon before they can receive another image in the image box. As such, each successful 'we agree' press was used to mark the start of an episode for analysis up until players pressed the 'we agree' again, at the point when a new image would appear another episode would commence. This enabled the entire duration of each activity to be divided into manageable sized episodes for analysis.

The LFA data for the first study using SCoSS (Paper 1) was collected and analysed before the TD data. This means that the coding scheme was initially developed to represent the behaviours observed in a very small sample of LFA children. After the data for the TD sample was gathered the existing coding scheme was applied. However, during the analysis any behaviour that was observed in the TD sample that did not appear in the existing coding scheme e.g., turntaking was added. Following this it was thought necessary to reanalyse the LFA children's behavioural data to verify that these new behaviours had not been missed in the original analysis.

The coding scheme initially noted all the behaviours that the LFA children displayed and it was only after analysis that they were judged to fall into two distinct categories, each with two subcategories i.e., *other-awareness* (active other-awareness, attentional other-awareness, Appendix 4) and *engagement* (approach to task and withdrawal from task, Appendix 5). Further analysis of TD and LFA children in the studies presented in this thesis did not change either the other-awareness or engagement categories. However, the affordances offered by the different shareable technologies and the constraints put in place by SCoSS used throughout the research presented in this thesis was found to alter users behaviour. This led to iterative adjustments and refinements of the coding scheme resulting in clear definitions of active other-awareness and attentional other-awareness that could be considered appropriate for use with each shared activity. The three coding schemes used for each paper presented in this thesis are attached in the appendices; Paper 1 (Appendix 1), Paper 2 (Appendix 3) and Paper 3, (Appendix 4 and 5).

The LFA participants in the studies presented in this thesis, and in particular those with more communication difficulties, often found the unreliability of the technology a source of frustration and upset and in extreme cases the participants would withdraw from the activity. It was necessary and fair to take this into account and so the coding schemes made a distinction between withdrawal from the task due to technological breakdown and withdrawal from the task due to a lack of engagement.

Data analysis

During analysis for all the studies presented in this thesis the data was always initially analysed at a micro behavioural level coded according to the descriptors of the types of behaviour that fall under the other-awareness and engagement categories. The inter-rater reliability test for both the TD and LFA sample reported in Paper 1 and inter-rater reliability for Paper 2 used the data from the micro level of analysis producing Kappa scores that according to (2000) Watkins and Pacheco (2000) represent excellent (LFA) to good (TD) inter-rater reliability. This also suggested that the other-awareness and engagement coding schemes were a replicable method of representing the data. Having generated good to excellent inter-rater reliability at the micro level, it was thought reasonable that the inter-rater reliability test for Paper 3 was performed using the higher-level categories. Quantitative analysis of the data was then grouped into the higher-level categories and qualitative data was described using both the micro and higher-level data.

Each child's behaviour was analysed using the coding scheme individually taking account of their interactions with their partner, but not reliant on their partner's responses to their interactive behaviour. Because the peer-peer LFA data could not be considered independent and the sample sizes were too small to do parametric tests by pairing data, non-parametric test were used when appropriate. The data was not divided by the duration of the activity to give a standardised score of frequency, as I believe that the length of time that LFA children spend in a joint activity is an important aspect of the collaborative process. Therefore, standardising the frequency of behaviour over time loses that information, in that LFA children may not produce behaviour at a more frequent rate, but they may spend longer periods of time experiencing the joint activity when supported by SCoSS technology.

A timeline of behaviour for each participant was coded numerically according to the coding schemes used for each study (Appendices 1, 3, 4, and 5). This raw data was then classified into one of the four higher-level categories: active other-awareness, attentional other-awareness, withdrawal from task and approach to task. Active and attentional other-awareness scores at times were also combined to give an overall other-awareness score during analysis, whereas, withdrawal from task and approach to task scores were always dealt with separately.

Research and data collection

The data for this research was collected first hand from the specialist autism departments of two special schools in Sussex, UK. Three of the participants in study 2 of Paper 1 also took part in the experiment of Paper 3, but there was approximately four years between data collection for each paper.

The literature review was researched using Google scholar, University of Sussex Library search, Psychinfo, and PsychArticles.

Summary of thesis contribution

The novel contribution of this thesis is that it presents the first model of collaborative problem-solving for LFA children working with peers. Additionally, it presents evidence that LFA children have collaborative capacities that are not apparent without appropriately-designed support. This highlights the need to find appropriate support to facilitate social interaction in this group and potentially reduce the effects of their social and cognitive impairments. Finally, it provides an insight into the quantitative and qualitative differences of other-awareness that an adult or peer partner can promote during collaborative activity.

Paper 1

Facilitating other-awareness in low-functioning children with autism and typically-developing preschoolers using dual-control technology

Abstract

Children with autism are said to lack other-awareness, which restricts their opportunities for peer collaboration. We assessed other-awareness in non-verbal children with autism and typically-developing (TD) preschoolers collaborating on a shared computerised picture-sorting task. The studies compared a novel interface, designed to support other-awareness, with a standard interface, with adult and peer partners. The autism group showed no active other-awareness using the standard interface, but revealed clear active other-awareness using the supportive interface. Both groups displayed more other-awareness with the technology than without and also when collaborating with a peer than with an adult partner. We argue that children with autism possess latent abilities to coordinate social interaction that only become evident with appropriate support.

Keywords

Childhood autism, Other-awareness, Collaboration, Social cognitive development, Computer technology, Separate Control of Shared Space

Children diagnosed with autism have well-documented impairments in social interaction and communication, including marked deficits in reciprocal social interaction, such as a lack of sharing enjoyment and interests with others. A central feature of children with autism is the lack of awareness of the other as a partner in interactions and this deficit of other-awareness is considered a diagnostic characteristic by the Diagnostic and Statistical Manual of Mental Disorders 4th Edition (American Psychiatric Association, p 70, 1994). This lack of awareness can be manifested in behaviours such as not acting contingently on others' actions and disrupted patterns of attention towards others. According to Smith (1999), almost half of preschool children with autism have no speech, while those with speech tend to use it to satisfy their primary needs rather than as a social communicative tool. Children with autism can become absorbed in repetitive types of self-stimulatory behaviour such as flicking their fingers in front of their eyes or spinning objects (Smith, 1999) and tend to engage in solitary activities (Hauck, Fein, Waterhouse & Feinstein, 1995) . When demands are placed upon them to interact, or stop what interests them, they may become anxious or aggressive (Smith, 1999). Of children diagnosed with autism, about a third will have a mild-to-moderate learning disability and over a third severe to profound (Fombonne, 2007).

Much of the literature demonstrating deficits of other-awareness has relied upon experimental methods assessing the reflective, conceptual understanding of the other as an intentional agent, as exemplified by Theory of Mind (ToM) tests. Unfortunately low-functioning children with autism (LFA), those with severe learning and communications disabilities, are typically unable or unwilling to participate in assessments and this is reflected in the preponderance of studies involving children who are verbal and relatively high in communicative function. This means that any potential for other-awareness in LFA children is unknown. Some researchers are using more naturalistic methods to tease out capacities without requiring articulated verbal responses. Begeer, Rieffe, Terwogt, and Stockmann (2003) used two scenarios to test if task interest would facilitate ToM in high-functioning children with autism (HFA) and children with pervasive developmental disorder not otherwise specified (PDD-NOS) by observing their behaviour. Children were either promised or not promised a reward if they successfully completed a task. The experimenter then made an excuse to leave the room briefly, allowing a confederate to remove an essential piece of the task, supposedly without the experimenter's knowledge. Other-awareness was demonstrated if the children spontaneously informed the experimenter of the missing piece upon his return. Hobson and Meyer (2005) assessed other-awareness simply by asking lower-functioning children with autism where to place an engaging sticker on another person.

Both studies demonstrate ways of overcoming difficulties in assessing other-awareness in children with autism and in particular LFA children: studying reactions to situations rather than responses to stories, and using methods to engage children's interest. The importance of task engagement for this group was demonstrated by Koegel et al. (1987), who found that allowing non-verbal children with autism to select their own word-learning materials increased their learning. Likewise, Dunst et al. (2011) found that following the interests of preschoolers with autism led to an increase in the children's language, cognitive, social, and motor development. The present paper reports two studies using materials specifically tailored to the interests of the children for providing behavioural assessment of other-awareness in children with limited language abilities.

Recently, theorists have proposed that other-awareness is intimately related to self-awareness and crucially that the social-cognitive impairments found in children with autism may stem from these deficits (Baron-Cohen, 2009; Frith & Happé, 1999; Hobson et al., 2006; Williams & Happé, 2010). Hobson and Meyer (2005), with their novel sticker-test study, found that unlike TD children, children with autism failed to refer to the self, by pointing to their own bodies when showing the other where to place a sticker. Hobson and Meyer suggest this lack of social connectedness arises from a failure to relate to another's mental state using the capacity to assimilate "the other's orientation towards the world, including towards the self" (2005, p. 482). If deficits of self-awareness and other-awareness are a fundamental aspect of the social-cognitive impairments of children with autism then it is important to understand theoretically the nature of any limitations and find practical ways to support awareness. Williams and Happé (2010) investigated limitations using knee-jerk (Shultz, Wells, & Sarda, 1980) and Transparent Intentions task (Russell & Hill, 2001). They found that autistic children compared to age- and ability-matched children with developmental delay were significantly less able to identify their own knee-jerk reflex as unintentional and also their own actions and another's mistaken actions as unintentional. Williams and Happé considered that this indicates that the impairments in self-awareness are as acute as those found in other-awareness.

Most work investigating other-awareness in LFA children has used controlled and narrative-based methods rather than the on-line assessment of other-awareness abilities in spontaneous behaviour, for example while participating with another person on a collaborative activity. This is surprising as many interventions for young children with autism target other-awareness in the form of joint attention skills, with the aim of improving on-line social interaction (Jones, Carr & Feeley, 2006; Kaale, Smith, & sponheim, 2012; Kasari, Freeman, & Paparella, 2006). Furthermore, there has been no systematic comparison of whether other-awareness in children with autism differs according to the nature of the partner, for example, a peer vs. an adult. We know that in typical development, interactions with peers and adults tap different developmental processes with different sorts of benefits (Tudge & Winterhoff, 1993). It is therefore important in assessing joint action to compare interactions with different categories of partner.

Sharing joint attention by definition requires the ability to take account of the other: other-awareness. Joint attention is positively related to social communication abilities in both children with autism (Charman et al., 2003) and TD children (Mundy & Gomes, 1998) and is a requirement of joint action (Colombi, Liebal, Tomasello, Young, Warneken & Rogers, 2009). Such joint action requires contingency of one actor's response on the initiating action of the other, e.g. child A points to an object and child B in response moves it. This active form of other-awareness as shown by *contingency* of coordinated *related* actions is thus a core feature of collaborative activity. By examining the actions of LFA children during episodes of joint action, brought about within a collaborative game, we can assess the relatedness and contingency of actions, to inform us of children's understanding of the relation between own and other's actions, and hence their other-awareness.

We propose that other-awareness can be expressed in two forms: *active* other-awareness and *attentional* other-awareness. Active other-awareness is shown in a joint activity when one partner waits for the other to perform a prerequisite action before following up, which without waiting for the other to act would not result in the desired outcome. This is the structure of the tasks used by Warneken, Chen and Tomasello (2006) to explore the development of cooperation in 18-24 month old TD children: for example, Child A has to lift and hold a tube up and wait while Child B retrieves an object from the tube which has become accessible through A's action. Attentional other-awareness can be illustrated by a behaviour that is related to, but not contingent on the partner's actions, for example watching one's partner perform an aspect of the collaborative task before continuing with your own related, but non-contingent action. The crucial difference here is that continuing one's own action is not contingently reliant on the other's action; the child may monitor the actions of their partner for a while and then continue with their own part of the collaborative activity.

An integral part of collaborative activity is the partnership between the individuals involved. The lack of this is particularly salient in LFA children, who tend to resist interactions with others, preferring solitary activities or tolerating only limited interactions with adult partners (Hauck, et al, 1995). There is a growing body of research showing that children with autism respond positively to computer-assisted instruction and that they often have a particular preference for the computerised environment (Golan & Baron-Cohen, 2006; Moore & Calvert, 2000; Ploog et al., 2012; Williams et al., 2002). Multi-user computer technology has been shown to encourage turn-taking in adolescents with Asperger's Syndrome (Piper, O'Brien, Morris & Winograd, 2006) and we propose that multi-user computer technology provides a level of engagement that may support children with autism to participate in collaborative activities.

Shareable technology has a particularly important role to play in supporting collaboration, and has the crucial benefit of enabling designers to manipulate the environmental contingencies so as to support one form of behaviour over another. Yuill and Rogers (2012) presented a framework for designing multi-user computer technology to support collaboration, through manipulating three mechanisms which they claim underpin collaborative behaviour; (i) *Awareness of others* - the degree to which awareness of users' ongoing actions and intentions is present or made visible moment-to-moment (ii) *Control of action* - the extent of each user's control over actions and decisions (iii) *Availability of information* - the ways in which background information relevant to users' behaviour and to the task is made available, or externalized. These authors explain how an existing multi-user interface, Separate Control of Shared Space (SCoSS: Kerawalla, Pearce, Yuill, Luckin & Harris, 2008), supports collaboration by facilitating these mechanisms.

SCoSS provides separate control of identical versions of a task for each child to work on in their own private screen space while also being aware of their own and their partner's workings (Fig. 1a). The aim of the design is to encourage shared understanding through being aware of own and other's task state while still allowing individual control. The performance of TD children on a word categorisation task using a SCoSS interface (Fig. 1a) was compared to a single user (non-SCoSS) interface (Fig. 1b) by Yuill et al. (2009), who found that pairs of children using the SCoSS interface generated a greater number of complex justifications in the decision-making process, and improved accuracy on the task compared to individual practice with feedback.

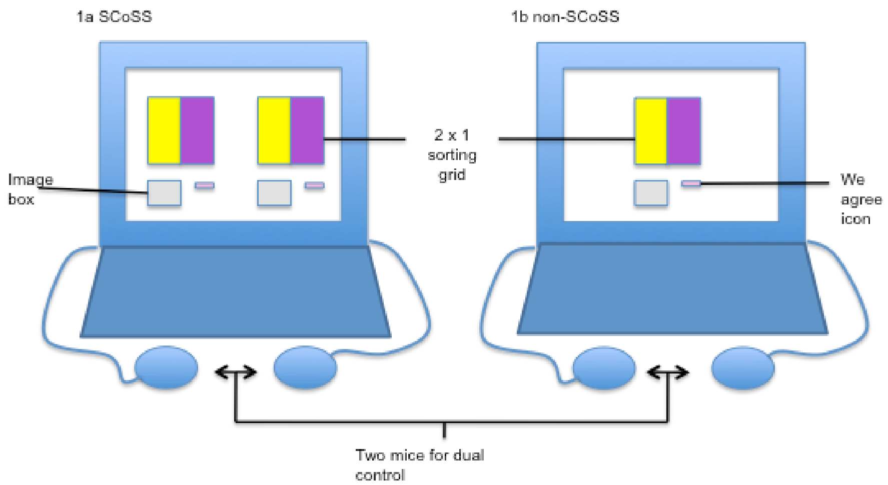


Figure 1. SCoSS and non-SCoSS computer interfaces. 1a: SCoSS interface with two mice for control of one's own screen space and two representations of the sorting game. 1b: non-SCoSS interface with two mice each controlling the whole space and a single representation of the picture sorting game.

The design of the SCoSS interface means that it is not essential for users to be able to communicate verbally or even make eye contact with each other in order to progress through the task, since they can see the effects of their partner's actions on their own on-screen task representation. Further, they cannot solve the task successfully without awareness of their partner's actions on the task, as described in more detail in the Method section. We hypothesise that this results in conditions that support other-awareness. The SCoSS game actions are controlled by the movements performed by each child using their mouse, as represented by differently-coloured cursor movements on the screen. Williams and Happé (2009) found that children with autism were as able as age- and ability-matched TD children to monitor and identify their own cursor movements from those made by another person.

The current paper has four aims: 1) to assess baseline other-awareness behaviours in collaborative tasks, 2) to assess the role of the type of partner on other-awareness, 3) to evaluate if the SCoSS computer interface elicits higher levels of other-awareness than the task on a more standard (non-SCoSS) interface and 4) to compare the behaviour of LFA children to that of TD children. Previous work with SCoSS suggested improved collaboration in TD children, but did not assess instances of behaviour that showed other-awareness as defined above. In Study 1 we establish a baseline of other-awareness behavior in TD 2 – 4 year old children while they played a picture-sorting game with an adult or peer partner using the SCoSS or non-SCoSS computer interface. From this we can identify what typical other-awareness behaviours the different partners engender and any variation in behaviour generated by the different interface designs. In Study 2 we examine the other-awareness behaviour of four boys aged 5 – 7 years, diagnosed with autism, severe learning disability and limited or no speech, while they played the same computer game in pairs and with an adult partner using the SCoSS and the non-SCoSS interface. We then discuss the findings of other-awareness between TD and LFA children.

Study 1: Influence of software support and partner type on other-awareness in typically-developing preschoolers

Method

Participants

Thirty-two children (16 boys, 16 girls) aged 2–4 years (*M* = 46.0 months, *SD* = 8.7 months) from two preschools in West Sussex, UK, participated in this study. Parental consent was given for the children to participate and to be videotaped. Children were free to withdraw from the experiment at any time.

Procedure

Picture-sorting task design. Seven, 2 x 1 picture-sorting games were created using children's television cartoon characters. Each game consisted of six pictures with three different, but similar images of two characters (Fig. 2) Participants from each preschool in small groups (4 – 8 children) were shown the picture-sorting task using a paper mock-up. The paper mock-up consisted of the single interface and the six images used for the computer practice round, materials were laminated and velcro attached to fix the pictures to the screen mock-up, this was used by the experimenter to explain the picture-sorting task and the requirement to press the 'we agree' button to get more images to the participants.

The aim was to give as little verbal instruction as possible to take into account the difficulties that the children with autism would have with understanding verbal instructions in Study 2. Therefore, once participants were seated to take part in the experiment they were simply told that they were to work with their partner (peer or adult) to complete the picture-sorting game. If it was the SCoSS condition participants were also told about the need to agree on picture placement in order to get another picture.

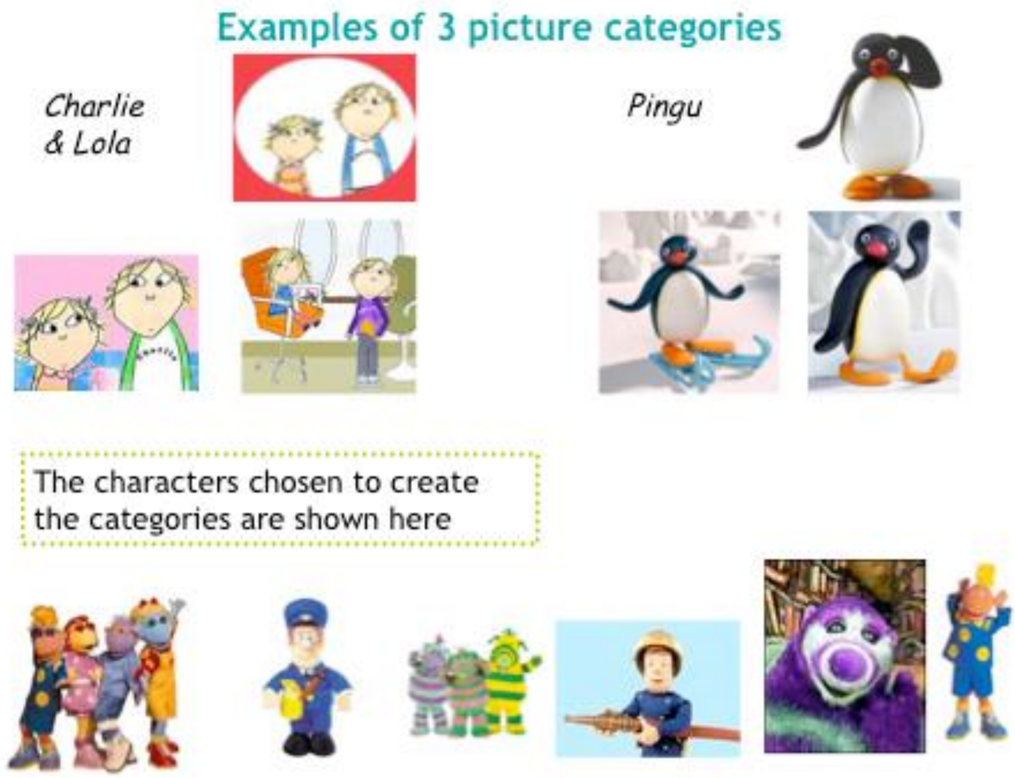


Figure 2. Images used to create the picture-sorting activities. Charlie & Lola and Pingu are examples of two complete sets of three images used to generate a category. The five characters depicted below were used to create the five remaining categories used for the tasks.

The children were randomly put in same-gender pairs and then randomly assigned to one of four conditions produced by crossing software type (SCoSS, non-SCoSS) and partner type (adult, peer) one procedural round is shown in Table 1. The adult partner was always an experimenter who was instructed to interact naturally while playing the task. Testing took place in a corner of the preschool playrooms during the morning session and was completed over a two-week period. Children sat side by side at a small table with a laptop PC and were shown their mice. A camera in front of the children captured their faces and a second camera behind them captured the computer screen. Each task took between 1–7 minutes to complete.

Table 1. One round of the experimental procedure for the four conditions.

Participant	Group instruction with paper mock-up	Practice round with computer	Experimental round
A	A	non-SCoSS with adult partner	non-SCoSS with adult partner
B	B	SCoSS with adult partner	SCoSS with adult partner
C + D	C + D	non-SCoSS Peer partners C + D	non-SCoSS Peer partners C + D
E + F	E + F	SCoSS Peer partners E + F	SCoSS Peer partners E + F

Separate Control of Shared Space (SCoSS)

The SCoSS interface (Fig. 3) has four special features to support collaboration and shared understanding. First, the users have the same task to solve, with representations of both their own task state and their partner's on the same screen. Second, each user has a mouse that controls their own task space, but cannot control any of their partner's task elements. Third, the achievement of agreement, both users placing identical task pieces in corresponding task spaces, is explicitly represented as items that are agreed become highlighted in green. With these features it would still be possible for users to work on the task independently, but the fourth feature constrains this by having points in the task where both users have to come to an explicit joint agreement about where the task pieces are placed, demonstrated by clicking the 'We agree' icon. Children cannot continue without this, as the next item in the task will not appear until they click 'We agree'. When players agree and both sides match, each player receives another identical game piece to sort.

The game starts with a picture appearing simultaneously in each player's image box. The players can each use their cursor to drag and drop their picture onto a cell of their own game representation according to where they think it should go. Attempting to drop the picture onto the other player's grid will return the picture to the image box. A single player clicking their 'agree' icon will not deliver a new picture, even if the two representations are identical: both 'agree' icons need to be clicked. To complete the game, six pictures need to be placed on to the grid in matching positions. Each player, to progress, needs to act in concert with the partner: even if each partner simply sorts the pictures 'correctly', they still need to show agreement at the appropriate moments, contingent on their partner's actions in placing pictures on the grid[3].

[3] Because Study 2 included children who might find the sorting conceptually difficult, we used a version of the task where the sorting did not need to be correct: the two sets just needed to be in agreement.

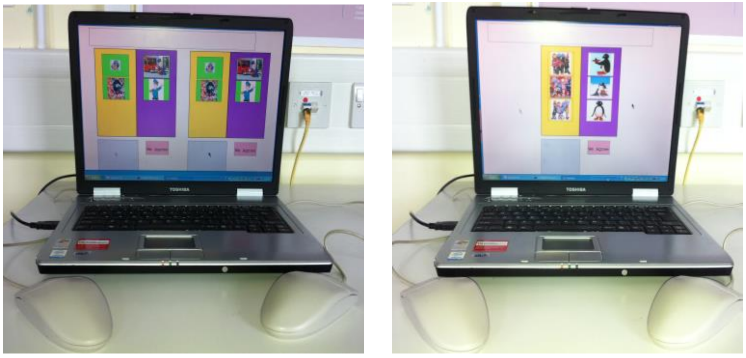


Figure 3. Computer interfaces, on left (Fig *2*a) SCoSS interface, on right (Fig 2b) non-SCoSS interface.

Non-SCoSS interface

This provides a single representation of the joint task (Fig. 3). When the first picture appears in the image box, either player can use their cursor to drag and drop it onto the single grid. Either player can then click the shared 'We agree' icon with their cursor and a new picture appears in the image box. This is typical of joint tasks on shared computers, and allows one person to dominate and the other to be passive.

Coding

Videotapes were analysed for two classes of behaviour: other-awareness (active and attentional) and task engagement (approach and withdrawal).

Other-awareness was divided into two sub-types. Active other-awareness and attentional other-awareness share the attribute of relevance; that the action of one child can be deemed to be relevant to the action of another, e.g. one child watching another while taking part in a joint activity. The fundamental difference between the two categories is the assumption of intentional contingency: an individual is displaying active other-awareness behaviour if their action is related to and intentionally contingent on the action of their partner. To be able to assume this, the action needs to show an intentional relationship to the action of their partner and to follow in sequence their partner's action. By analogy, in a football (soccer) game, when player A moves towards the goal with the ball and player B observes the progress of A, then B is displaying relevant behaviour. If B attempts to intercept the ball once A has kicked it, then B has shown intentional contingency, and hence has displayed active other-awareness. Equally if player A noticed player B and then called out, gestured, or clearly passed the ball to him, player A's behaviour would also be coded as active other-awareness. However, if player B did not attempt to intercept the ball, but continued to observe player A, B's behaviour would be coded as attentional other-awareness. If player A did not notice or show any intention to pass the ball to player B, player B's observing and intercepting the kicked ball would still be coded as active other-awareness but Player A would be showing no other-awareness.

In Figure 4, Child B shows active other-awareness, because, having placed his image on to the grid, he actively waits for his partner A to move A's piece on to the grid before clicking to get the next picture. Child A shows attentional other-awareness, because he clicked his 'We agree' icon after Child B, but does not show any indication of behaviour that is intentionally contingent e.g. waiting while his partner acts on the game or indicating his intention to agree. In another example, A places his picture on the grid and B places his identical picture on to the grid, but in a non-matching position: A then moves his already-placed picture, so that both games are now matching. A had already placed his picture on the grid, so the act of adjusting the placement to match his partner's placement is a related and contingent response that shows intentionality to match his partner. Engaging in turn-taking is a third example, e.g. where one child either verbally announces an intention to take turns or moves their cursor aside to indicate to their partner that it was their turn.

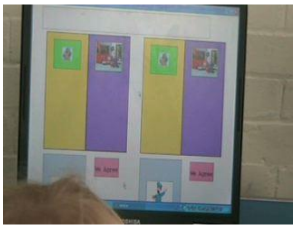


Figure 4a. Pictures appear in both player's image boxes simultaneously

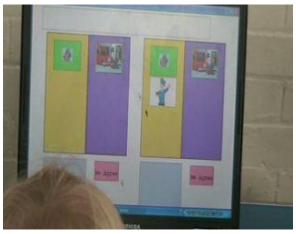


Figure 4b. Right-hand-side picture placed on grid by Child B (black cursor)

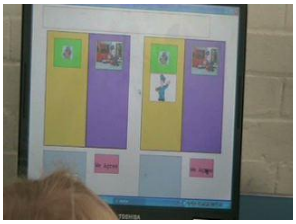


Figure 4c. Child B (on right) waits for Child A (left side) to place his picture: B hovers his black cursor over the We agree icon, but does not yet click it

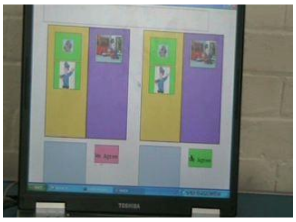


Figure 4d. Child A (left side) places his picture so that it matches Child B's. B quickly clicks 'We agree', now green, showing it was pressed before Child A's,

which is still pink. B's behaviour is contingent on and relevant to A's action, hence active other-awareness

Figure 4. Illustration of active other-awareness.

Further examples of attentional other-awareness are shown in Figure 5 below.

Figure 5a. Child on left watches partner move his picture on to the grid, showing attentional other-awareness

Figure 5b. LFA Child on right has placed his 3rd Postman Pat picture (left-side game) then removed his hand from his mouse and turned to watch and wait for his partner to catch up (teacher is in centre)

Figure 5. Attentional other-awareness.

Engagement level was coded as approach to task or withdrawal from task for individual children. Approach included behaviour such as repeated, apparently random clicking the 'We agree' icon, moving towards the screen to look closely at the pictures and smiling or laughing in response to the game. Withdrawal included displays of frustration, wandering away from the activity and giving up trying to use the mouse.

Inter-rater reliability, on a random selection of 37.5% of the data, produced a Kappa statistic of k = 0.68, considered to represent good agreement (Cohen, 1960; Watkins & Pacheco, 2000). As withdrawal from task represented less than 0.02% of the total behaviour coded, we just analysed approach to task behaviours.

Results

Given that the children are typically-developing and the task is well suited to their capabilities, we expected to see other-awareness regardless of interface type. We made no predictions about the effects on other-awareness of partner type. The dependent variables were frequency of other-awareness (active and attentional) and engagement. Probabilities are reported using two-tailed analyses using an alpha level of .05.

An independent samples t-test of other-awareness comparing SCoSS and non-SCoSS showed that children using the SCoSS interface produced significantly more other-awareness behaviours (M = 7.75, SE = 1.40) than children using the non-SCoSS interface (M = 3.25, SE = .94) $t(30)$ = 2.66, p = .01, a medium to large effect size r = .44, displayed in Figure 6.

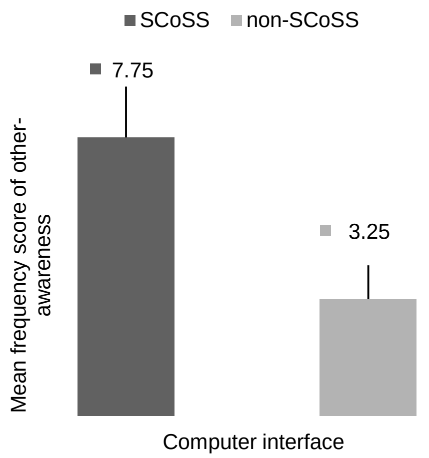


Figure 6. Mean frequency of other-awareness behaviours of TD children for each interface.

A Multivariate Analysis of Variance (MANOVA) on the frequency of active and attentional other-awareness required square-root transformation of frequencies to meet the assumptions for MANOVA. The assumption of independence of observations was met by the random assignment of children to experimental conditions. Bartlett's test for sphericity was non-significant, p = .27 and Levene's test for the dependent variable attentional other-awareness was non-significant p = .15, but was significant for active other-awareness p < .05. A significant Box's M test of homogeneity of variance-covariance matrices Box's M (p = .001) is not of concern as the sample sizes were equal and Pillai's Trace is robust to violations of homogeneity of variance-covariance matrices in this situation (Field, 2005; Hair, Black, Babin, Anderson, & Tatham, 2006). There were considered to be no potential problems from the undue influence of outliers.

The MANOVA revealed a main effect of partner F (2,27) = 5.34, p = 0.01, η^2 = .28 with the follow-up univariate ANOVA showing that children displayed significantly more active other-awareness behaviours when partnered by a peer

(M = 4.88, SE = 1.14) than by an adult (M = 1.25, SE = 0.39), F (1,28) = 9.28, p < .01 (Fig. 7).

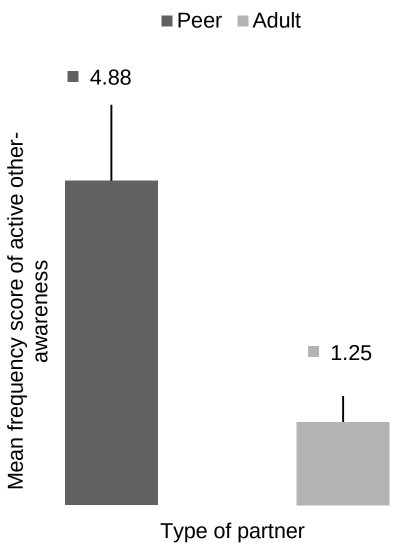


Figure 7. Mean frequency of active other-awareness behaviours of TD children for each partner type.

There was also a main effect of computer interface F (2,27) = 15.28, p < 0.01, η^2 = .53 with the follow-up univariate ANOVA showing that the SCoSS interface supported significantly more attentional other-awareness (M = 4.13, SE = .70) than the non-SCoSS (M = 0.75, SE = .31), F (1,28) = 28.92, p < .001 (Fig. 8).

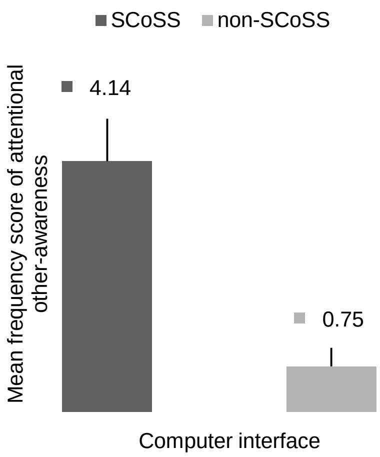


Figure 8. Mean frequency of attentional other-awareness of TD children for each interface.

A univariate ANOVA on the frequency of approach by category of interface and partner showed that children produced significantly more approach behaviours when using the SCoSS interface (M = 16.63, SE = 3.10) than the non-SCoSS interface (M = 7.51, SE = 1.88), F (1,28) = 47.84, p < .05. There were no differences found in approach scores according to identity of partner.

Discussion

These typically-developing children unsurprisingly displayed both active and attentional other-awareness when using either interface. Other-awareness is a natural part of solving the joint picture-sorting task, supporting understanding and coordination of behaviour with a partner. However, the SCoSS interface produced significantly higher levels of other-awareness than the non-SCoSS interface, particularly for attentional other-awareness, and also produced higher frequencies of approach behaviours. These findings suggest mechanisms which help to explain why the SCoSS interface has been found to support collaboration in TD children.

The results also show that type of partner had significant effects on other-awareness, particularly notable since no data has been reported on the effect of such support for adult-peer collaboration. There was significantly more active other-awareness when children worked with a peer than with an adult, regardless of interface type. Children treated their peer partner as an equal agent involved in the activity, as shown for example by turn-taking, initiated either verbally or just by moving their cursor to the side of the screen, thereby intimating their partner could take control. This behaviour reflects an understanding that their peer partner would want to take part in the activity. In contrast children tended to show less other-awareness with an adult partner. The children did not seem to regard the adult partner as an equal contributor, but as a facilitator, only engaging when help was needed Eckerman, Whatley, and Kutz (1996) found that over time a peer becomes the preferred social partner and our finding that children aged 2–4 years no longer saw adults as play partners when performing the same role as peers is in line with these findings.

The findings show that TD children naturally show other-awareness behaviours, both active and attentional, with or without the support of the SCoSS interface, when they are doing a simple collaborative activity, and that more such awareness is shown when working with peers than with adults. It may be that SCoSS is primarily helpful for TD children when the task is intentionally at the limit of their abilities and requires frequent re-thinking, as with the tasks designed by Yuill et al. (2009). We might then expect that children with autism and learning disability, who will be challenged by any collaborative working, may benefit from a SCoSS interface as a support to their awareness of others. Our coding method enables assessment of such awareness in non-verbal children. In Study 2, we investigate whether other-awareness might be apparent in such children using the two types of interface, with peers or adults as partners.

Study 2: Influence of software support and partner type on other-awareness in low-functioning children with autism

Given that SCoSS software seems to support other-awareness in TD children, we anticipated that it might facilitate this in children who are supposed not to demonstrate such capabilities. In the following study, we investigated whether LFA children would be able to play the collaborative game with another person in a way that could reveal other-awareness behaviour. We predicted that SCoSS would encourage other-awareness if the children did participate, although it is not clear which type of other-awareness they will display. The prevailing literature discussed earlier suggests impairments or absence of other-awareness. We might expect to see attentional awareness because the software works in such a way as to stall the task when classifications do not match between players. However, it was not clear whether children with autism would show active other-awareness by anticipating their partner's actions, as shown by the TD children in

Study 1. As regards the role of partner, there is little literature directly comparing children with autism interacting with adults vs. peers. Such children tend to have considerably more experience alongside supportive adults than alongside peers who might share their social difficulties, but it is not clear that this will translate into higher levels of awareness of an adult.

Participants

Four boys aged 5–7 years (M = 79.5 months, SD = 9.5 months) with a diagnosis of Autistic Spectrum Conditions and severe learning disability attending a unit for children with autism within a special school in East Sussex, UK. The school provides education for children with a wide range of disabilities from 4-16 years of age. A statement of Special Educational Need (SEN) prepared by the Local Education Authority is required to attend the school. The four children also had communication difficulties with limited or no speech, and had speaking, listening and Information and Communication Technology (ICT) skills ranging from level 4 to 6 of the P Scales, a set of descriptors produced by the Qualifications and Curriculum Authority (2009) to record the abilities of pupils with a special educational need in the UK working below Level One of the UK's National Curriculum for school children. All participants were assessed at level P5 or above for ICT that describes the ability to "move a device to manipulate something on screen" and to be able to "make connections between control devices and information on screen" (Qualifications and Curriculum Authority, 2009). All children used the Picture Exchange Communications System (PECS) either to enhance their communication or as their main method of communication.

Procedure

Picture-sorting task

The teachers were consulted to identify the children's favourite cartoon characters, used to create the games.

As in Study 1, the experiment consisted of four conditions, necessitating a within-subjects design. The four children were placed in two pairs (A + B, C + D) using the teachers' advice. The children were helped one at a time to do a practice round with a paper mock-up and then with the computer (non-SCoSS condition). All children then did the non-SCoSS - adult condition first, followed by the other 3 conditions in a different order for the two pairs (Table 2).

Table 2. Experimental procedure.

Participant	Instruction with paper mock-up	Session 1 Practice round	1st Round	Session 2 2nd Round	Session 3 3rd Round
A	A	A non-SCoSS with adult	A + B SCoSS	A SCoSS + Adult	A + B Non-SCoSS
B	B	B non-SCoSS with adult		B SCoSS + Adult	
C	C	C non-SCoSS with adult	C + D Non-SCoSS	C + D SCoSS	C SCoSS + Adult

D	D	D non-SCoSS with adult		D SCoSS + Adult

An available class teacher was the partner in the non-SCoSS with adult condition and the experimenter was the adult partner in the SCoSS with adult partner condition. The children sat in front of the laptop at a table in their classroom. Some assistance was given to help them progress through the game, for example a verbal prompt to remind them they needed to click the 'We agree' icon to get another picture. Each condition took between 1-4 minutes to complete. A camera was placed in front of the children to capture the front view, and the cursor movements the children made with the computer task were digitally inlaid onto the video in the top left corner, as shown in Figure 5b. A teacher or teaching assistant was present throughout testing to help with behaviour and communication. Testing took place over three morning sessions. However, due to student sickness, the non-SCoSS experimental condition for children A + B had to be run four weeks later preceded by a brief practice round.

One child, C, had difficulties in using the mouse, although he demonstrated an understanding of its use by often clicking it and looking at the screen, but without being able to control the cursor's position. He instead pointed at the screen to indicate where he wanted items to go and was helped with mouse use. Child D had difficulty with 'drag and drop' so was helped in the practice and then was able to use it independently in the experimental conditions.

The coding scheme was as in Study 1. Inter-rater reliability on 25% of randomly-selected data produced a Kappa of 0.95, considered to represent excellent agreement (Cohen, 1960; Watkins & Pacheco, 2000).

Results

Analysis of the mean frequencies of each behaviour type is presented descriptively because of the small sample. As with the TD children, other-awareness was markedly more frequent in the SCoSS (*M* = 5.88, *SE* = 1.87) than the non-SCoSS condition (*M* = 1.63, *SE* = 1.21) as shown in Figure 9.

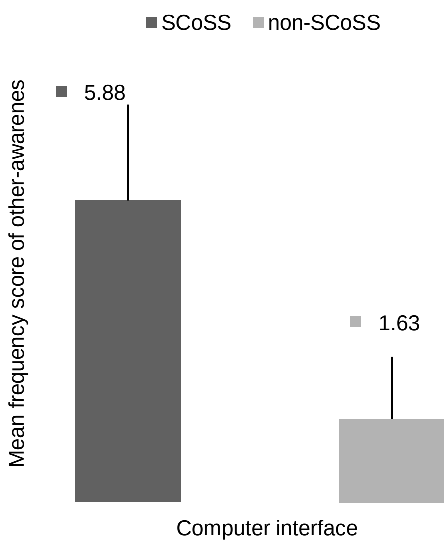


Figure 9. Mean frequency of other-awareness behaviour for LFA children for each interface.

The different subtypes of other-awareness are of particular interest. LFA children showed more other-awareness of both types in SCoSS than non-SCoSS, but only ever exhibited active other-awareness with the SCoSS interface interface (Fig. 10). Additionally active other-awareness within the SCoSS condition was twice as common when paired with a peer than with an adult (Fig. 11). The ICT P5 level assessment of three of the LFA children (B, C and D) describes a lack of awareness of others when using computers in their everyday functioning at school and this was borne out by our findings as no active other-awareness was displayed by the LFA children when using the non-SCoSS setup. Child B however, was assessed at P6 for listening, his highest score of his three P levels reported, outlining his ability to respond to others. These teacher assessments would predict impaired active other-awareness but intact attentional awareness, and indeed this was supported by B's performance. In the non-SCoSS condition B produced no active other-awareness, but a high frequency of attentional other-awareness compared to the other LFA children. In contrast, when using the SCoSS interface, Child B displayed both active and attentional other-awareness.

Child C was the least able of the LFA participants, reflected by the lowest total P Level scores. This child did not display active other-awareness with either interface, but was found to exhibit attentional other-awareness when partnered by a peer using both interface types, with attentional other-awareness being twice as frequent in the SCoSS-peer condition. Child D had a P5 assessment for speaking, listening and ICT illustrating a general deficit in awareness of others in his everyday functioning. This is confirmed by our findings using the non-SCoSS interface where he showed no active or attentional other-awareness. However, using the SCoSS interface partnered by a peer he displayed both types of other-awareness.

Child A was assessed by his teacher in the three areas as being able to 'hold a short conversation', respond to others, and use ICT to interact with both pupils and adults. This would predict a display of both active and attentional other-awareness in the non-SCoSS condition. In fact, he only showed attentional other-awareness using the non-SCoSS interface when partnered by an adult, perhaps because of the high level of impairment of his partner in the peer condition. However, when using the SCoSS interface Child A's partner showed active awareness, which may have facilitated A's own awareness behaviours.

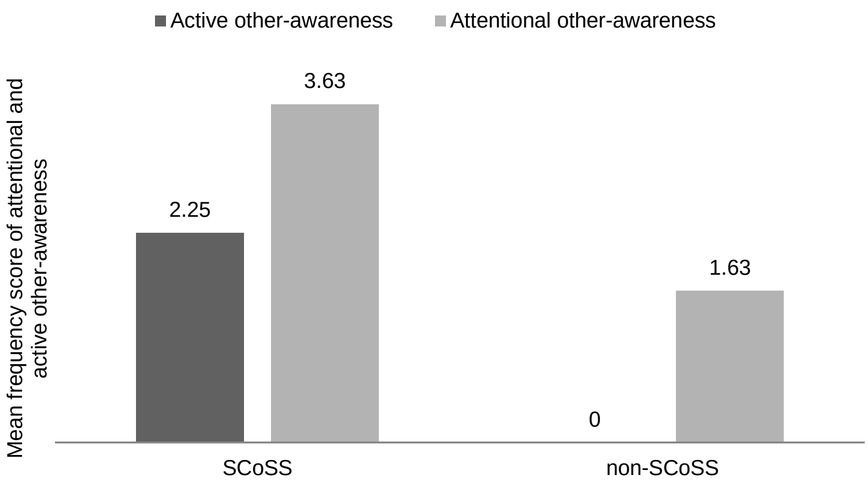


Figure 10. Mean frequency of active and attentional other-awareness behaviour for LFA children by interface type.

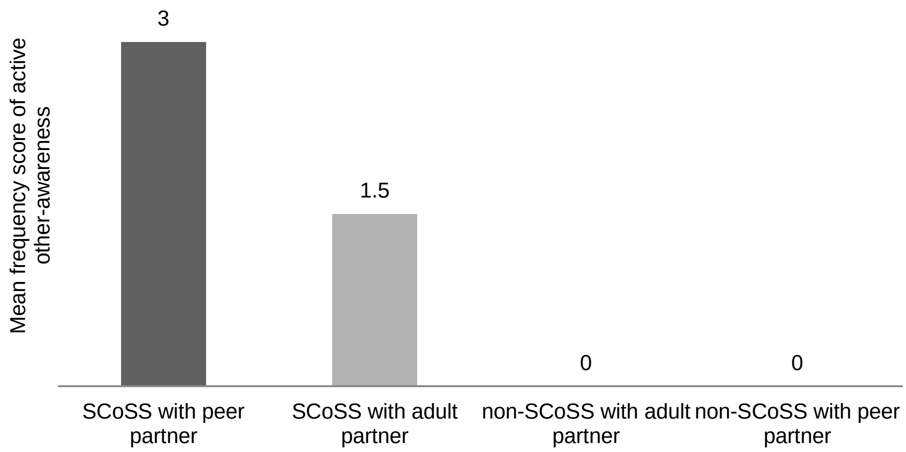


Figure 11. Mean frequency of active other-awareness behaviour for LFA children for each partner- interface condition.

Attentional other-awareness occurred with both interfaces but was more frequent in the SCoSS (M = 3.63, SE = 1.06) than the non-SCoSS condition (M = 1.63, SE = 1.06). There were also different patterns according to identity of partner. LFA children displayed higher levels of attentional other-awareness with a peer than with an adult (Fig. 12). The highest levels of attentional other-awareness were demonstrated when with peers and using the SCoSS interface (Fig. 12). The difference in behaviour by interface and partner was illustrated by the case of Child D. He failed to look at his partner at all, peer or adult, in non-SCoSS, even when the peer was very noisy, but in the SCoSS-peer condition he turned to look at his partner (Fig. 5b) twice within two minutes, and also at the computer screen while waiting for the partner to catch up.

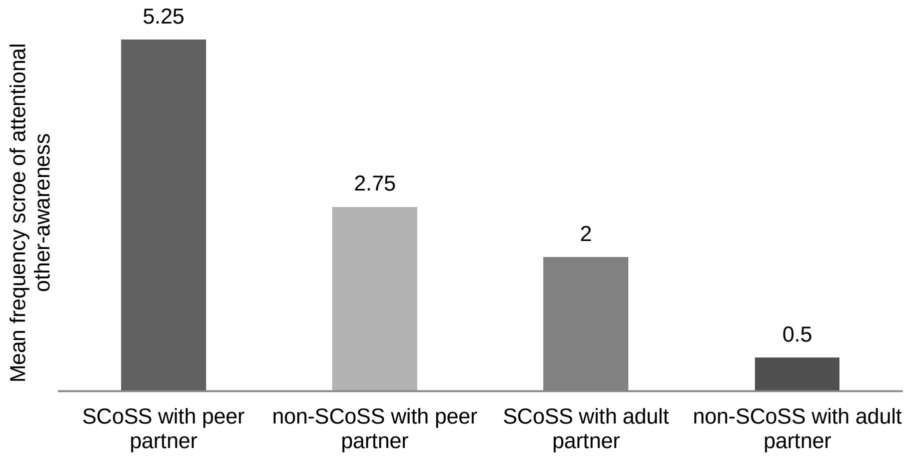


Figure 12. Mean frequency of attentional other-awareness for LFA children in each condition.

Engagement

LFA children displayed high levels of approach behaviour when using the SCoSS interface both with adult and peer partners (peer M = 8.50, SE = 2.31, adult M = 8.0, SE = 2.31) with a lower level of engagement in the non-SCoSS condition, both with a peer (M = 3.25, SE = 2.31) and with an adult (M = 1.25, SE = 2.31). This pattern was exemplified by the behaviour of Child B. He showed a similar low number of approach behaviours in all conditions except when using SCoSS with a peer partner; this condition elicited 8 of his total of 13 approach behaviours.

Child D showed no positive affect using the non-SCoSS interface. However, when he used the SCoSS interface he smiled, and even laughed and began to sing in response to his adult partner singing. Child C was the least able LFA child and demonstrated 19/20 of the total number of withdrawal behaviours across all conditions. However, he also exhibited the highest number of positive engagement behaviours; almost half of the total number displayed by all children (40/84), with 31 of these 40 instances occurring while he used the SCoSS interface. He was also seen to smile, exclusively in the SCoSS-adult condition. Child C also stood and watched intently as child A and child B played the game together, a very unusual level of engagement, as noted by his teacher and key-worker.

Discussion

The LFA children in this study only displayed active other-awareness behaviour when supported by the novel SCoSS interface. Critically, this finding indicates that LFA children may possess latent active other-awareness abilities that only emerge with carefully-tailored support, and further, that absence of other-awareness skills in one situation cannot be taken as evidence for a general impairment. This is exemplified by the behaviour of child B, who in the SCoSS condition, partnered by a peer, demonstrated frequent episodes of active other-awareness; waiting contingently to press the 'We agree' icon and trying to match his pictures onto those of his partner. However, with the same partner in the non-SCoSS condition, child B sat back, relinquished his hold on his mouse, and withdrew into self-stimulatory behaviour whilst continuing to watch the computer screen intently. The striking difference in his behaviour highlights how differently his abilities would be assessed if he were observed in only a standard computer condition. The differences in other-awareness behaviour were apparent for all four children when supported by the SCoSS interface compared to the non-SCoSS interface. We propose that the SCoSS interface afforded support to constrain and mediate the social demands of the task for the LFA children, so that all the children irrespective of their level of functioning showed other-awareness.

This small sample of children also showed more other-awareness, of both types, when partnered by a peer than by an adult. The use of different adults in the two interface conditions could have influenced children's performance differentially. However, one would expect this to result in lower other-awareness and engagement in the SCoSS condition, with an unfamiliar adult, whereas the results show lower other-awareness and engagement in the non-SCoSS condition with a familiar adult. The findings of this study are clearly limited by the very small sample size, so replication is important. However, the results are striking, particularly since the children had the additional challenge of using the mouse technology. The use of touch interfaces might support interaction beyond what we found in the current study.

Although LFA children often find social interaction difficult, our findings suggest that, as with TD children, play with peers can support social interaction and that appropriately-supported interaction with a peer may provide more likely opportunities than with an adult partner to bring about the development of other-awareness skills in social interactions. Liber, Frea, and Symon (2008) reported that the social play skills of children with autism could be improved through peer-mediated strategies with peers who have developmental disabilities, including autism, even though the play partners needed some support. Zercher, Hunt, Schuler, and Webster (2001) trained TD children to support children with autism in an integrated play group setting and reported increases in joint attention, symbolic play and verbal ability. These findings add to evidence that supporting interacting with a peer partner can bring about the development of new skills in social interaction.

General Discussion

The two studies show a revealing pattern of similarities and differences between TD and LFA children, using significance testing with the larger TD group and descriptive analysis with the smaller and more heterogeneous clinical sample. First, both groups of children showed more other-awareness with the SCoSS interface than the more traditional non-SCoSS interface. This finding supports the proposal of Yuill and Rogers (2012) that if the mechanisms of awareness of others' actions, control of the interface and availability of background information are in place by appropriately-constrained multi-user technology, collaborative processes can be supported. Although it was clear that TD children benefitted from the SCoSS interface, with a higher frequency of other-awareness behaviours, SCoSS did not yield other-awareness behaviour that was entirely absent in the non-SCoSS condition, unlike the findings of the LFA children. TD children showed both subtypes of other-awareness that we identified, active and attentional, in all conditions, and the SCoSS condition in particular facilitated their attentional other-awareness.

Second, and crucially, active other-awareness was only apparent for the LFA children when they were enabled by the SCoSS interface to participate in a collaborative activity, suggesting that technology can be used to support children with autism to take part in shared collaborative tasks. Without the SCoSS support, active other-awareness behaviour was absent and there was also a lower frequency of attentional other-awareness. This small study clearly has limitations given the sample size, and the known heterogeneity of children in the LFA group. However, the behavioural differences found show existence proof that interfaces designed to support specific functions can elicit behaviours not otherwise reported, suggesting caution in drawing blanket assumptions about other-awareness in children with autism.

There is evidence to suggest that children with autism have both sensory processing and motor impairments (Dawson & Watling, 2000) influencing their ability to take part in a computer activity. The side-by-side arrangement of the work space in the SCoSS interface makes it clearer to distinguish one's own from another's workings compared to the shared single representation of the non-SCoSS potentially alleviating the sensory processing workload. The SCoSS interface also reduces the work space that the LFA children need to move objects within compared to the non-SCoSS which may in turn reduce the motor control needed to complete the task. Further research is warranted to consider the possible sensory and motor advantages offered by the SCoSS interface.

The studies also demonstrate the utility of the new fine-grained behavioural measures of other-awareness developed to code contingency and relevance in children's collaborative interactions. It would be useful to know whether there are other settings in which children with LFA might demonstrate such awareness. Anecdotally, the teachers of the LFA children found their students' behaviours with SCoSS remarkable, but it may be that such behaviour is apparent in other contexts, if an appropriate method of coding is used to help detect behavioural contingency. It is important to note that the materials for the picture sorting tasks were carefully selected to be attractive to the LFA children and that although the SCoSS interface was shown to be crucial in supporting the LFA children to collaborate, they were highly engaged in all conditions. Without a high level of engagement we judge it is unlikely that the SCoSS interface alone would be enough to bring about other-awareness interactions in LFA children.

Both studies revealed differences in other-awareness behaviours according to identity of the partner. Both groups showed more active other-awareness of a peer partner than of an adult, though the LFA children apparently could only do this with the support of the constrained, SCoSS, interface. Unlike TD children, who spend ever-increasing time over development with their peers, LFA children tend to have very limited peer interactions in both quality and quantity throughout their development. Further research is warranted to investigate the potential effect this lack of peer interaction has on the development of children with autism and whether interventions focusing on collaborative activities with peers could lead to qualitative changes in the nature of peer social interaction.

Participating in shared collaborative activities, Moll and Tomasello (2007) propose, drives social cognitive development. They term this the Vygotskian Intelligence hypothesis. The hypothesis places the emphasis on the activity of sharing a joint goal to which both partners are equally committed as a fundamental aspect of a child's development. Therefore deficits of self-awareness and other-awareness in children with autism may have a cumulative effect on their development, if it means they are less able to participate in collaborative activities. The impairments of self-awareness and other-awareness will be compounded further by the tendency of children with autism to engage in solitary activities and so have even less exposure to the 'other'. This could create a vicious circle where difficulties with self-awareness and other-awareness in turn limit collaborative activities resulting in further social cognitive impairment and continued delay in the development of other-awareness. We would predict following on from Moll and Tomasello's hypothesis that children who do not participate in shared collaborative activities, such as those with autism, would not encounter the experiences necessary to develop social skills at the same rate or possibly with the same trajectory as those children who do. Further investigation of the nature of collaborative difficulties in autism is important in both understanding, and intervening to support their social development.

Paper 2

Collaborative problem-solving supports other-awareness and imitation in low-functioning children with autism.

Abstract

Collaborative activities promote social-cognitive development in typically-developing children. Children with autism are impaired in other-awareness, joint attention and imitation, limiting collaborative opportunities. We assessed other-awareness and collaborative behaviour in eight low-functioning boys with autism (LFA) working in pairs to solve problems with two different types of software support for collaboration. This yielded a model of collaborative problem-solving based on a sequence of three prerequisite capacities: 1. An understanding of how

to interact with the activity. 2. The capacity to coordinate one's own action with another's, exemplified by two forms of imitation: *follower imitation*, adopted to navigate novel experiences without an understanding of the other's intention and *strategic imitation*, used to overcome a partner's lack of coordinated action, by imitating his uninformed actions. 3. The capacity to encourage coordination of another's actions with one's own. The framework of collaboration provides new research questions and highlights the role of imitation in collaboration in LFA children.

Keywords

Autism, Collaboration, Imitation, Multi-user technology, collaborative problem-solving.

Encouraging children to collaborate with peers in order to enhance their learning and development has become an integral aspect of school education for typically developing (TD) children (Blatchford et al., 2003). However, there is very little research investigating whether and how children with autism can collaborate, and what there is mostly involves high-functioning children with autism (HFA), those with an IQ within the average range, i.e., without a learning disability. Given that as many as 70% of children diagnosed with autism will also have an intellectual disability, i.e., low-functioning autism (LFA), (Matson & Shoemaker, 2009; Fombonne, 2007) and such children have a far poorer prognosis (Howlin et al., 2004) it is essential that research also considers the LFA group, in order to gain a theoretical understanding of the prerequisites of collaboration and to inform practical approaches to bring benefits of collaboration to this group.

Children require many skills to enable collaboration with a peer including attending to a partner's actions, coordinating joint action (Brownell et al., 2006) and observing and imitating a more knowledgeable peer (Johnson-Pynn & Nisbet, 2002; Ramani & Brownell, 2014). It is unsurprising if children with autism find collaboration difficult given that in early development they demonstrate impairments in joint attention (Charman et al., 2003; Charman et al., 1997) and imitation (Williams, Whiten & Singh, 2004). Colombi et al. (2009) investigated the relationship between joint attention, imitation and the ability to cooperate with an adult partner in children with autism. They found that compared to children with developmental delay (DD) children with autism were more impaired in imitation and joint attention and that both skills were related to their ability to cooperate. However, they did find that children understood another's intentions towards an object as well as DD children.

Carpenter et al. (1998) examined the emergence of social cognitive skills that included the emergence of joint attention and imitation, in a longitudinal study of TD children aged 9 to 15 months, interacting with adults. In a similar investigation involving children with autism, Carpenter, Pennington and Rogers (2002) used the same tests as Carpenter et al. (1998) with LFA children aged 3 – 5 years. Carpenter et al. (2002) found clear deficits, and a different pattern of development from TD children (Table 1). By ordering the main social cognitive skills by function and separating the domains of attention and behaviour. Carpenter et al. (2002) point out that the pattern of development with respect to sharing, following and directing, was similar for LFA and TD children (Fig 1). However, the critical difference was that TD children developed abilities related to sharing, following and directing another's *attention* before following and directing another's *behaviour*, whereas LFA children appear to develop skills related to another's *behaviour* before *attention*.

Table 1. The developmental pattern of functional abilities related to sharing, following and directing another's attention and behaviour in TD and LFA children (Carpenter et al. 1998, 2002).

Individually 83% of typically developing infants followed this pattern (Carpenter et al. 1998, 2002)				
Share attention	Follow attention	Follow behaviour	Direct attention	Direct behaviour
Individually 67% of LFA children followed this pattern (Carpenter at al. 2002)				
Follow behaviour	Share attention	Direct behaviour	Follow attention	Direct attention
Imitative learning – child copies instrumental or arbitrary actions modelled by an adult on a box.	Joint engagement – child's spontaneous gaze switching from object to adult back to same object. Child's proximal declarative	Child's imperative point, gesture reach or verbalisations to obtain a toy locked in a transparent box or to rewind a wind-up toy.	Child follows the gaze and/or point of an adult to toys placed either side of the child.	Child's distal declarative gesture to direct adult attention to the sudden appearance of a toy.

	gestures, shows or verbalisations			

Observational studies of the earliest forms of social interactions between mothers and infants have described the emergence of imitative acts such as copying each other's mouth, hand and finger movements and gaze following from around two months of age, with pointing, waving and clapping by 12 months (Uzgiris, Vasek, & Benson, 1984). Masur (1989) found the imitation of actions on objects more frequent than copying gestures or actions without objects in infants aged 10 – 12 months. However, there is some controversy as to whether the behaviour seen during the newborn period is imitation (Anisfeld, 1996; Jones, 2009). Jones (2009) argues that imitation does not occur in TD infants before 18 months and that what is reported as imitation is in fact emulation, imitation-like behaviour that is goal-driven, insomuch as the behaviours are approximations of modelled behaviour and not exact imitation. The focus of the child during emulation is said to be achieving the same outcome as the demonstrator and not mimicry. Nevertheless, findings on copying related to actions on objects appear to be more established, even though there is still some debate as to what constitutes imitation and emulation (Whiten, McGuigan, Marshall-Pescini, & Hopper, 2009). We mention this distinction, but note that we use imitation to refer to an event when a child contingently imitates a partner's action, be it verbal, gestural or with an object. For us contingency is the key feature and by that we mean that the imitative behaviour occurs before another action, using this criteria we can allow the LFA children more time to copy their partner's action and still identify it as imitative.

Imitation is an early emerging ability in typical development, enabling infants to initiate and maintain social interaction with adults. As children begin to interact with peers, imitation is still a noticeable strategy. Eckerman et al. (1989) found that between 16 – 32 months, pairs of TD infants showed an increase in coordinated acts with age and, in particular, their peer's non-verbal actions. In another study, C. O. Eckerman and Didow (1996) noted that children were more likely to participate in verbal activity when they are engaging in non-verbal imitative behaviour. Thus in early peer interaction the ability to coordinate action via imitation between one's self and a social partner appears to be important in facilitating social play and aiding a typical pattern of development.

Less is known about the development of joint attention and imitation in children with autism. This is due to the difficulty of identifying younger children with the condition. In the US the average age of diagnosis is thought to be around 4yrs 5 months (Developmental & Investigators, 2014) and an international review reported a mean age range of 3 years 2 months to 10 years (Daniels & Mandell, 2014). This problem is being overcome by prospective studies of the 'at-risk' younger siblings of children with autism. One such study by Rozga et al. (2011) investigated the social-communicative behaviour of children aged between 6 and 36 months who later received an autism diagnosis. There were no differences found in the frequency or duration of gaze, smiles or vocalisations made toward mothers at 6 months between children later diagnosed with autism and TD children or siblings that did not receive an autism diagnosis (non-ASC siblings). However, by 12 months of age impairments in joint attention and requesting behaviour were apparent in children later diagnosed with autism. Notably, Rozga et al. (2011) did not find differences between TD, non-ASC siblings and children with autism in responding to joint attention bids from an adult to a proximal object (e.g. pointing to pictures in a book). A review of the imitation skills of children with autism by Williams et al. (2004) also found there to be no discernible impairment in the capacity to respond to joint attention on a proximal object.

Therefore, responding to bids for joint attention on proximal objects is a relatively preserved ability in children with autism. This finding, combined with the developmental pattern of social-cognitive skills in LFA children presented by Carpenter et al. (2002), suggests that activities encouraging interaction with a partner via actions on a proximal object are worthy of further research in this group.

Activities occurring between at least two people incorporating coordinated actions on an object are referred to as collaborative activities. Collaboration as defined by Roschelle and Teasley, (1995), is "a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem." (Roschelle & Teasley, 1995, p.70). We use this definition of collaboration because it reflects the requirement to understand the intentions and take into account the perspective of the collaborative partner through synchronous activity and is more suited to tasks that do not have different roles assigned to participants (Warneken & Tomasello, 2006).

Collaboration in LFA children was considered in a study by Holt and Yuill (2014) investigating whether Separate Control of Shared Space (SCoSS: (Kerawalla, Pearce, Yuill, Luckin, & Harris, 2008), a computer interface designed to encourage collaboration in TD children, (Yuill, Pearce, Kerawalla, Harris, & Luckin, 2009) could be used to facilitate LFA children's other-awareness. The SCoSS interface, shown in Figure 2, displays both players' game representations simultaneously, enabling them to compare their own game state to their partner's, and also requires players to place pictures in corresponding positions, i.e., show agreement of the task solution.

Holt and Yuill (2014) assessed the extent to which pairs of TD and LFA children showed awareness of the other when collaborating on a shared picture-sorting task, using a laptop with dual mice control. They compared a typical, unconstrained, user interface with a SCoSS interface and found that LFA children with the support of SCoSS showed more overall other-awareness; in particular, they showed active other-awareness, behaviour that was related to and contingent on their partner's, such as contingently copying their partner's placement, behaviour that was never apparent when they used the typical computer interface. Holt and Yuill (2014) noted that LFA children unskilled at using a mouse were unable to take part in the study and the present study has tried to overcome this by using a Mitsubishi Diamond Touch interactive tabletop computer (DT) that uses more accessible touch screen technology (Fig. 2).

It is well-accepted that children with autism find computer technology motivating and beneficial to their learning (Fletcher-Watson, 2014; Golan & Baron-Cohen, 2006; Moore & Calvert, 2000; Ploog, Scharf, Nelson & Brooks, 2013; Williams, Wright, Callaghan & Coughlan, 2002). Computer-mediated collaborative activities have been used as interventions to look for measures of change in social cognition. Bauminger-Zviely et al. (2013) used a Diamond Touch surface (DT) to enable pairs of HFA children aged about 9 years to learn about collaboration and to participate in collaborative activities. They found increased measures of social engagement and understanding of the concept of collaboration. Stichter et al.

(2014) used remote interaction via computers to enable 11 HFA students aged 11-14 years to take part in 3D virtual collaborative games. Assessments of the children did not show any improvement, but parental ratings of social responsiveness did show a significant improvement.

Other research has focused on manipulating the design of the computer environment to look for effects on how children interact with a partner during collaborative activities. Some shareable technology gives designers the capacity to add constraints to how users can interact within the computer environment and these constraints can be manipulated to encourage collaboration (Yuill & Rogers, 2012). Early indications suggest that constraining how the user interacts with shareable technology is effective. Piper et al. (2006) found enforcing turn-taking helped adolescents with Asperger syndrome solve a collaborative puzzle game. Ben-Sasson, Lamash and Gal, (2012) used constraints with a DT surface to compare a free play computer environment to an Enforced Collaboration (EC) condition. Pairs of HFA children showed more positive social interaction and collaborative play doing the puzzle task in the EC condition, when the computer environment was constrained so that both children were required to touch the same puzzle piece at the same time to move it. Piper et al. (2006) and Ben-Sasson et al. (2013) both use constraints to enforce collaboration and demonstrate that this approach is effective at facilitating turn-taking and synchronous action in HFA children. However, our approach is to use constraints to encourage rather than enforce joint action and so provide collaborative scaffolding to LFA children.

Given that the constraints provided by the SCoSS interface support other-awareness; behaviour related to and/or contingent on a partner's in collaborative activities, constraints have been manipulated to investigate other-awareness in

LFA children further. Collaborative activities were implemented in two conditions: in Low-Constraint condition (L-C) players needed just to sort the material in the same way as their partner, whereas in High-Constraint (H-C) players had to agree with their partner and also had to be correct according to an external standard. Video recordings were analysed to look for effects on the children's awareness of their partner and collaborative or non-collaborative behaviour.

We consider engagement with the activity as a prerequisite for other-awareness: if a child is not engaged with the activity then it is hard to make a judgement about whether or not they are capable of being aware of another person. We approach this problem by analysing the LFA children's engagement with the activity using measures of approach to or withdrawal from the task.

A previous study by Holt and Yuill (2014) found LFA children were able to complete a simple picture-sorting activity and so we expected participants to show some success in the low-constraint activity, but had no predictions about how they would perform with the additional challenge in the high-constraint activity. Holt and Yuill (2014) noted that LFA children benefitted more from the SCoSS software when working with a peer partner rather than an adult. The present study considered these findings and used the SCoSS interface to further investigate collaborative problem-solving between LFA children partnered by peers.

Method

Participants

Eight boys diagnosed with autism (as assessed by a multi-disciplinary team including a paediatrician) aged 4 – 10 years (*M* = 91.6 months, *SD* = 26 months) attending the specialist Autistic Spectrum Department of a special school in West

Sussex, UK. Four children from class 1 consisted of younger and/or more learning disabled children with autism, aged 4 – 7 years and four children from class 2 consisted of older and/or less learning disabled children, aged 7 – 10 years. The children also all had a diagnosis of moderate to severe learning and communication difficulties. A statement of Special Educational Need is required to attend the school. Parental consent was given for the children to take part in the study and to be videotaped. Ethical approval was granted for the study and children were free to withdraw from the experiment at any time.

Shareable technology

A Mitsubishi Diamond Touch interactive tabletop computer (DT), shown in Figure 1, was the shareable technology used for this study as the platform to run the Separate Control of Shared Space (SCoSS) design architecture (Holt & Yuill, 2014; Kerawalla et al., 2008). SCoSS (Fig. 1) has four features to support collaboration and shared understanding. First, the users have the same task to solve, with representations of both their own task state and their partner's on the same screen. Second, each user controls their own task space, but cannot control any of their partner's task elements. Third, if both users' representations have correctly-placed game pieces, according to the task requirement, correct agreement is explicitly represented by those pieces becoming highlighted in green (Fig. 1): incorrectly placed pieces or pieces not in agreement are not highlighted. With these features it would still be possible for users to work on the task independently, but the fourth feature constrains this by having points in the task where both users have to come to an explicit joint agreement about where the task pieces are placed, validated by each child independently clicking their 'We agree' icon. Children cannot continue without this, as the next game piece in the task for sorting will not appear until they do so. When players have correctly placed game pieces according to the task requirements and both sides match, each player receives another identical game piece to sort. This is a touch-based version of the architecture described by Holt and Yuill (2014).

Procedure

The DT surface was set up in a room across the hall from the children's classrooms. Children played in peer partnerships selected by their class teacher. Throughout testing children were accompanied by a key-worker or teacher who remained in the room. As part of another study children had already experienced three different picture-sorting games with a key-worker or class teacher using the DT before being partnered by a peer. Therefore, all had an adult-supported experience with the technology before testing. Each child stood on one of two conductive pads setup on one side of the DT screen, so that children stood shoulder to shoulder. A camera was set up on a tripod in front of the children to capture their faces and a second beside them to capture their interactions with the activity on the DT surface. The task content was projected onto the tabletop surface so that the children could interact with it using touch. Children could only interact with the DT surface if they remained standing on their pad, enabling the DT to recognise individual users inputs with the surface content.

As the level of language understanding varied between the children no verbal instructions were given before the children started the picture-sorting tasks. Verbal direction was given to the children when needed to help them to interact with the technology and to give encouragement when required to keep them on task. If children could not progress through the task some assistance was given that was reflected in the coding scheme. The aim was to try, giving as little help as possible, to support the peer partnerships attempt the tasks in the two experimental conditions.

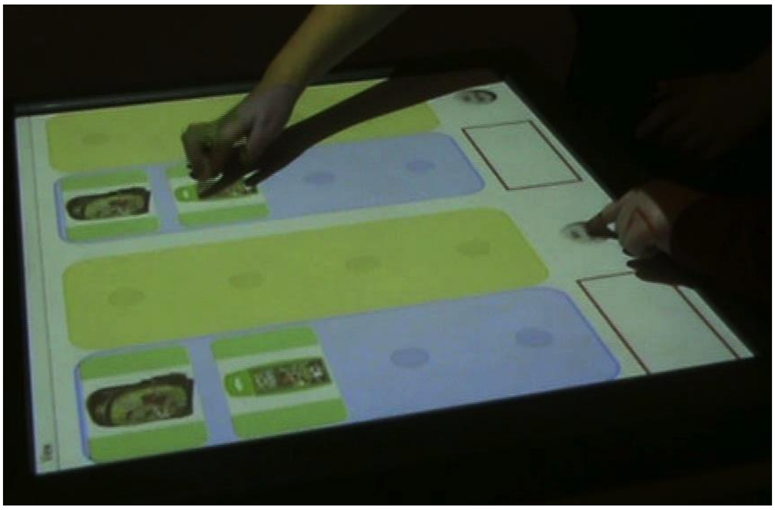


Figure 1. SCoSS interface showing two separate, but identical games, one for each of child. Touch constraints prevent the children from being able to interact with their partner's side of the surface, but the games are linked so that each side must show agreement in order to progress through the activity.

Picture-sorting task design

The teachers and children of both classes were interviewed to identify the children's favourite characters from television, books or movies. This information was used to create two separate groups of images appropriate for class 1 and 2 from which picture-sorting tasks were created. Each class had a novel set of images to sort for each round of their game.

Class 1 picture-sorting task

A 3 x 2 picture-sorting task was used, as this was considered challenging for the children in this class. The tasks were made up of three different images from two different children's characters, for example three images of 'Mr Men' book characters in one category versus three images of different characters from 'Thomas the Tank Engine' stories (Fig. 2).

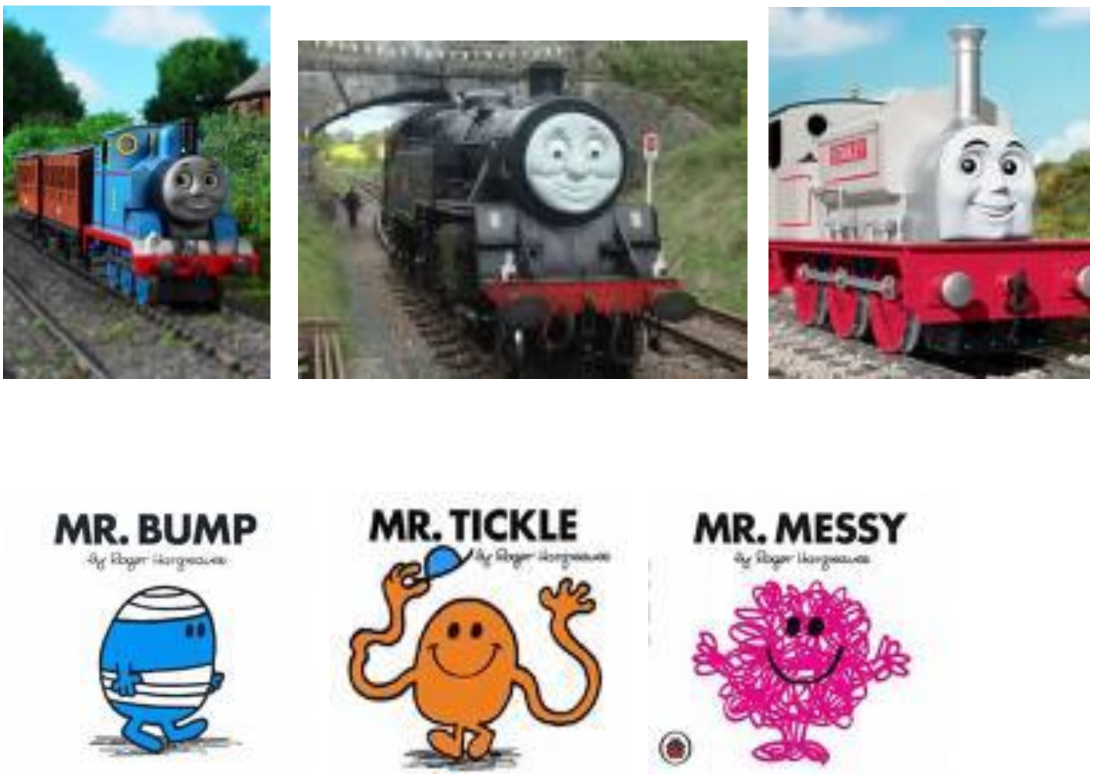


Figure 2. Shows three images for each character making up a two category picture-sorting activity.

Class 2 picture-sorting task

The children in class 2 were older and/or less learning disabled and to make the task more demanding a 4 x 2 picture-sorting task was used. The same character or set of characters appeared in both categories, but differed in some respect, for example, four different images of a children's character versus four images of merchandise displaying the same character e.g. duvet set, back-pack, playing cards. Another example is character figurines versus scenes from an animated cartoon (Fig 3).

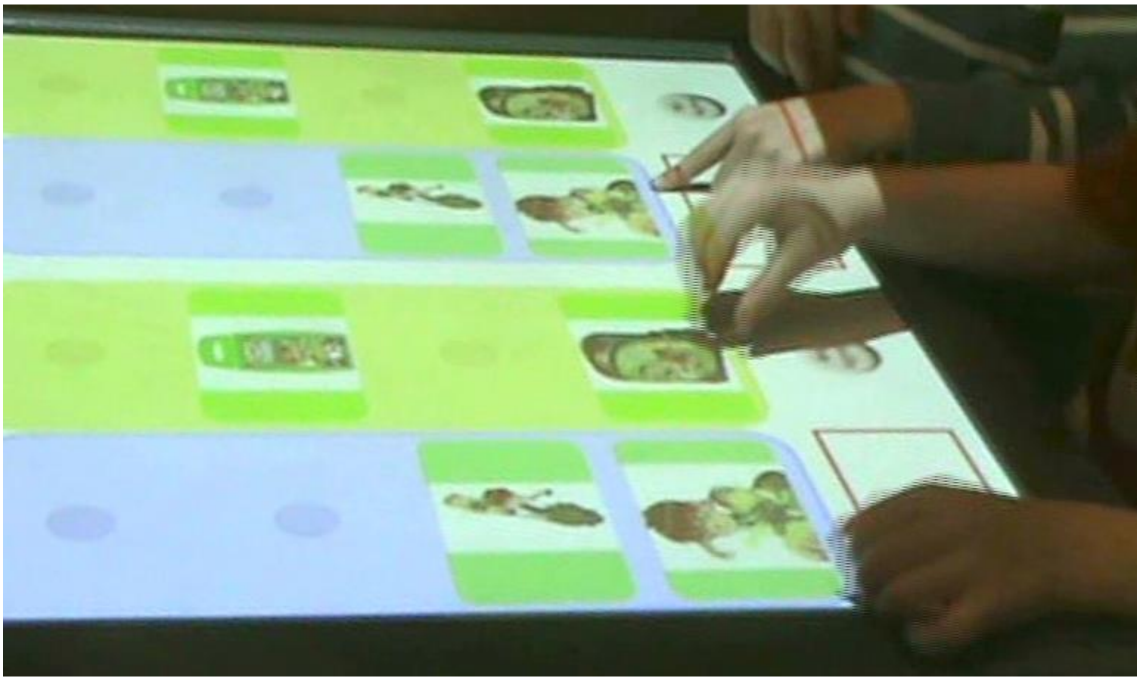


Figure 3. Illustrating a picture-sorting task generated by using one character to create two categories that differ in some other respect, in this example it is a cartoon character versus merchandise of the same character.

Low-constraint task (L-C) – Matching only

In this activity both players are required to put the same pictures as their partner in corresponding positions on their own half of the interface, producing a visual indication of agreement. Agreement is indicated by a green border appearing around the 'matching' images, so that pressing the 'We agree' icon will generate a new picture. The pictures do not have to be correctly sorted into categories, as long as they are matching the partner's arrangement (Fig. 4). Images that are not 'matching' will not have a green border surrounding them, and if this is the case, when pressed the 'We agree' will flash red and another picture will not appear.

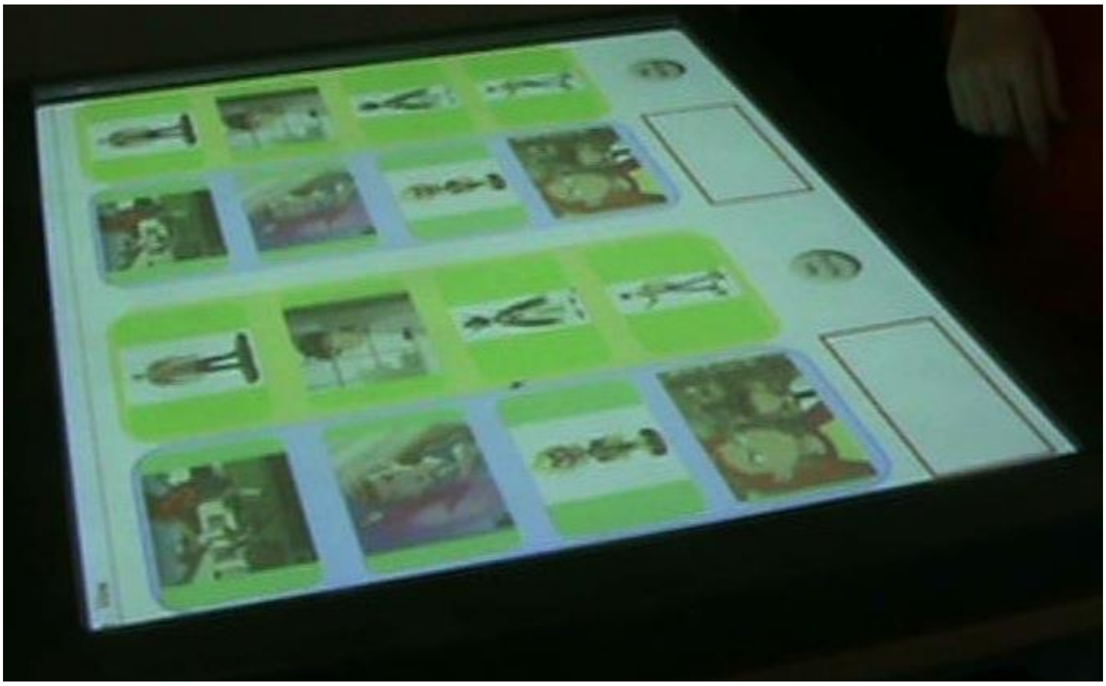


Figure 4. Low-constraint (L-C) condition. The image shows one of the 4 x 2 picture-sorting tasks used for class 2. The pictures shown are four images of Category 1, toy figurines of the character, and four in Category 2, cartoon scenes. In Figure 2

pieces are not sorted according to category, but are showing agreement on the matching criterion, indicated by the green highlight around each game piece

High-constraint task (H-C) - Matching and categorising

As in the L-C condition, players need to match their game pieces so that they are placed on the grid in corresponding positions, but also are required to categorise them. A game that is 'matching and correctly categorised' is shown in Figure 3, where images of the character are categorised in the blue column, and merchandise of the character are sorted into the yellow column. When pictures show agreement, by being both 'matching and categorised' on both sides of the screen, then a green border will appear around the images, and pressing the 'We agree' will release a new picture to sort. Whereas, images that only show agreement on one criterion e.g., 'matching only' or 'categorised only', will not be showing agreement, according to the H-C criteria. Therefore, a green border will not surround those images and the 'We agree' icon when pressed will flash red and another image will not appear. A correctly completed game is shown in Figure 5.

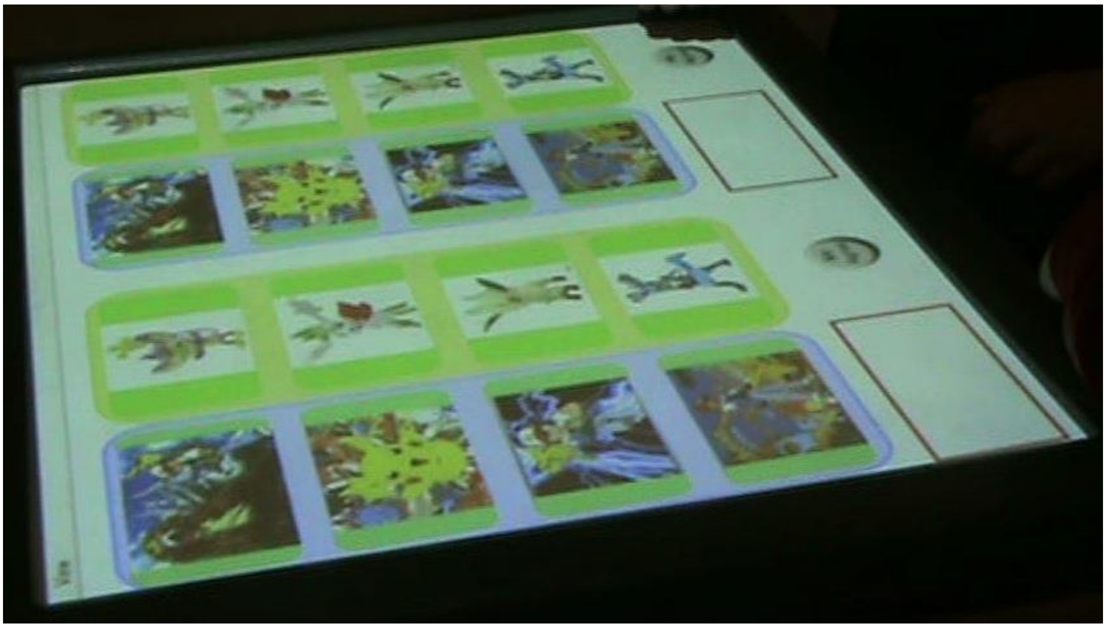


Figure 5. High-constraint (H-C) condition. Images of four toy figurines and four scenes from a cartoon series about the same characters are shown. The task is complete, with the two participants showing matched and correctly categorised images.

The experiment was a within-subjects design with one independent variable; the level of constraint: L-C; images are required to be placed in matching positions on the grid and H-C; matching and images must be correctly categorised. The order of condition was randomly allocated to pairs (Table 2). The game order for the experimental procedure is shown in Appendix 2. There were two dependent variables: 1) other-awareness (attentional and active) and 2) task engagement (approach to task and withdrawal from task) shown in Appendix 3. Strategy types were also coded. The data from class one and class two were combined for further analysis.

As some of the LFA children found the tasks challenging, in either the L-C and/or the H-C conditions, a judgment call on when to finish the tasks was made by taking into account the children's behaviour toward the activity (.e.g, persistant withdrawal from the activity) and advice from the participants' key-workers/teachers. If children were frustrated with the task, but still engaged they were prompted by the experimenter and/or key-worker/teacher to facilitate their progression through the task, however, adult prompting was reflected in the coding scheme.

Table 2. Experimental procedure.

Practice Rounds	Round 1	Round 2
Participants played 3 games with a teacher/keyworker as a partner.	L-C peer - peer	H-C peer - peer
	H-C peer - peer	L-C peer - peer
	L-C peer - peer	H-C peer - peer
	H-C peer - peer	L-C peer - peer

Analysis

Other-awareness

Video recordings were analysed for other-awareness as defined in Holt and Yuill (2014): other-awareness includes *attentional other-awareness*; and *active other-awareness*. Attentional other-awareness means behaviour that is attentionally relevant to the partner's, such as watching the partner's actions while both take part in a joint activity. Watching the partner as the child withdraws from the activity would not fulfil the criterion as their partner's behaviour is no longer in the context of a joint activity. Active other-awareness behaviour also requires attentional relevance, but must also be intentionally contingent on the actions of their partner, e.g., watching the actions of a partner and then imitating them. Inter-rater reliability of other-awareness coding on a random selection of 25% of the data produced a Kappa statistic of k = 0.71, considered to represent good agreement (Cohen, 1960; Watkins and Pacheco, 2000).

Engagement

Task engagement was coded as the frequency of approach to task or withdrawal from task behaviour produced by the child. Approach included behaviour such as repeated clicking of the 'We agree' icon, moving towards the DT to look closely at the pictures and smiling or laughing in response to the game. Withdrawal included displays of frustration or wandering away from the task. Inter-rater reliability of task engagement on a random selection of data from 5 of the16 sessions produced a Kappa statistic of k = 0.83, considered to represent excellent agreement (Cohen, 1960; Watkins and Pacheco, 2000).

Strategy types

The videos were also coded to investigate the strategies LFA children used to progress through the computerised task that required joint action. The strategy coding differed from the other-awareness coding in the respect that the main focus was to identify behaviour that brought about task success rather than awareness of the task partner. It should be noted that this will naturally consist of behaviour that has already been coded in the other-awareness coding scheme, but that by changing the focus from interaction to collaboration, it may be perceived how one supports. By changing the focus to task-related strategies two categories were identified behaviour that demonstrated 'no collaborative orientation' as opposed to task-related behaviour that was judged to show a collaborative orientation. (Table 3).

No collaborative orientation describes behaviour that demonstrates a focus on one's own activity, without referring to or taking account of the actions of their partner, such as placing a picture on the grid and moving it around until the green border appeared, meaning that pressing 'We agree' would result in the arrival of a new picture, without showing awareness of their partner's action. This means the strategy coding scheme is different from the other-awareness coding scheme as children can demonstrate awareness of a partner and still show no intent to collaborate to solve the picture-sorting activity. We included adult (experimenter) interaction in this category as this was a strategy that LFA children used to progress through the task, such as asking the adult a task-related question or following adult direction offered to support task progress. However, the adult related behaviour was not coded as collaborative because the adult was standing away from the table giving the child prompts to support understanding of the task and collaboration with the peer partner to bring about task success rather than interacting with the LFA child on the joint task.

Collaborative orientation was coded when a child's behaviour was in some way contingent on and/or interdependent on their partner's behaviour and the task i.e., directing the partner's task related attention or behaviour, such as helping their partner by gesturing or explaining where to put the picture e.g. "Move that there" or "Put the toys in there and movies in there", or bringing their partner's attention to the 'We agree icon'. The peer-partner did not have to respond for the attempt to be coded as having a collaborative orientation, but if the partner did follow the peer's behaviour contingently by either imitating his action or responding in some way appropriately, then both actions of directing and following either attention or behaviour was coded as collaborative. Inter-rater reliability, on a random selection of data from 6 of the16 sessions for each strategy code produced a Kappa statistic of k = 0.78, considered to represent excellent agreement (Cohen, 1960; Watkins and Pacheco, 2000).

Imitation

We observed that imitation of a peer could stem from two quite different sources of apparent motivation:

Follower imitation: imitation of a partner's action by a participant naïve to the objective of the activity showing no understanding of their partner's intentions or discernible collaborative intent, e.g., when a child copied the picture placement of his partner, but did not contingently press the 'We agree' icon, showing a lack of knowledge about the demands of the task or slavishly imitating many of their partner's behaviours including task-unnecessary or excessive interactions with the DT.

Strategic imitation: intentional copying of a naïve partner by a more knowledgeable participant as a means to progress through the activity, shown in Table 3. Both types of imitation show active other-awareness and the ability to follow another's behaviour, but strategic imitation might be preceded by a failed attempt to direct another's behaviour (Fig. 6), or to direct another's attention, in order to encourage their partner to coordinate their behaviour with their own. The endeavor to bring about coordinated action via strategic imitation is judged to show a collaborative intent by the imitator.

Strategic and follower imitation inter-rater reliability, on a random selection of data from 6 of the16 sessions produced a Kappa statistic of k = 0.82, considered to represent excellent agreement (Cohen, 1960; Watkins and Pacheco, 2000).

Table 3. Strategy codes for picture-sorting task.

No collaborative orientation	Collaborative orientation
Adult directed task-related behaviour e.g., adult	Direct peer behaviour – using gesture or verbal

reminds child to press 'we agree'.	instruction.
Ask adult a task-related question.	Follow peer direction – respond appropriately to peer direction.
Trial and error: placing a picture and pressing 'we agree' to receive feedback.	Ask peer a task-related question e.g.' Is this right?' - Direct attention.
Random placement of picture (placing picture in various slots, but not pressing 'we agree' to get feedback about correctness).	Prompted to direct peer behaviour - Follow instruction from adult to give instruction to peer e.g., tell/show ___ to press his 'we agree'.
Sorting/matching: placing the picture in the correct place to get another picture without reference to partner's game/positioning.	Strategic imitation: intentional copying of partner's placement with an observable grasp of the need to work with the partner to solve the activity. E.g., imitation preceded by a failed attempt to get his partner to move their game piece to match his and as a consequence the strategic imitator matches his partner's positioning, or imitation of a placement that generates a matching game state, succeeded contingently by pressing the We agree.
Follower imitation: blind copying of partner's placement with no observable grasp of the need to work with the partner or understanding of the task requirements or understanding of the partner's intentions e.g., by matching or pressing We agree. Often accompanied by a reluctance to interact with the activity until their partner has acted and imitating even when this is not shown to be a successful strategy to progress through the activity.	

1. 2. 3.

Figure 6. LFA children in the L-C condition demonstrate strategic imitation; 1) Both children have placed their 5th picture on their grids in non-matching positions, 2) M points to non-matching picture and asks C to move it so it matches his, but C does not respond, 3) M strategically imitates C so they can progress through the activity.

As some of the LFA children found the activity challenging in either the L-C and/or the H-C conditions, a judgment call was made as to when to finish the task taking into account the children's behaviour toward the activity (.e.g, persistant withdrawal from the activity) and advice from the children's key-worker/teacher. If children were frustrated with the task, but still engaged with the activity they were prompted by the experimenter and/or their keyworker/teacher in order to facilitate their progress through the task, however, adult prompting was reflected in the coding scheme.

In two of the four conditions LFA children participate in peer-peer partnerships, as a result the data is not independent. Therefore, non-parametric related samples Wilcoxon's signed-rank tests were the appropriate analysis for the data. However, the results must be considered with caution due to the increased chance of a type I error when running repeated tests. Effect sizes are also reported; an *r* value of .3 is considered a medium effect and .5 a large effect size according to Cohen's criteria (Cohen, 1992).

Results

Engagement

Related-samples Wilcoxon signed-rank tests were performed on the frequency of withdrawal from task and approach to task behaviour. The LFA children were found to be engaged with the task, showing significantly more approach to task than withdrawal behaviour in both the L-C condition (approach M = 10.50, SE = 2.26, withdrawal M = 1.75, SE = .80) T = 0, z = -2.52, p < .05, r = -.63 and the H-C condition (approach M = 20.88, SE = 4.91, withdrawal M = 1.50, SE = .68), T = 0, z = -2.37, p < .05, r = -.59. There were no significant differences found between the frequency of approach to task between the two conditions (T = 6, z = -1.68, p >.05). We can therefore be confident that the children were engaged with the activity in both the L-C and H-C conditions.

Other-awareness

A related-samples Wilcoxon signed-rank tests demonstrated that LFA children were more actively aware of their peer partner when they were solving the H-C activity (M = 14.13, SE = 3.84) compared to the L-C (M = 6.50, SE = 2.58) T = 0, z = -2.20, p < .05, r = -.55 (Fig. 7). As children were engaged in both conditions we can assume that the significant difference found was due to the additional challenge of the H-C activity facilitating more active other-awareness. Attentional other-awareness was almost twice as frequent in the H-C tasks, but this was not significant (Fig. 7). In the L-C condition, where simple agreement was sufficient to solve the activity, three out of the four pairs completed the task successfully. In the H-C condition, game pieces had to be both matching and correctly categorised, and although three of the four pairs of LFA children interacted with the task, only one pair successfully completed it.

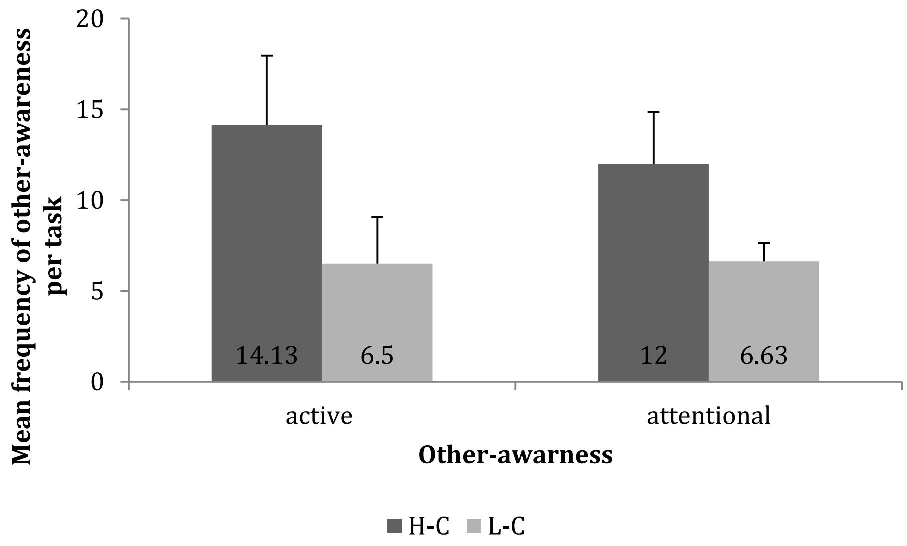


Figure 7. Total mean frequency (and standard error) for active and attentional other-awareness for low and high constraint conditions per task.

Collaboration

The videotaped data was explored further using the strategy coding scheme and individual data including active and attentional other-awareness is reported in Table 4 and Table 5. The data from pairs of LFA children's active and attentional other-awareness and their task-related collaborative and non-collaborative oriented strategies were analysed further to investigate how they related to increasing task success.

Table 4. Frequencies of active other-awareness (o-a) and collaboratively oriented behaviour displayed by LFA children doing the picture-sorting activity in the H-C (correctly categorised and matching) and L-C (matching) conditions.

			Collaborative orientation									
	Active o-a		Direct peer Behaviour		Follow peer direction		Ask peer a question		Prompted to direct peer behaviour		Strategic Imitation	
Pair	H-C	L-C	H-C	L-C	H-C	L-C	H-C	L-C	H-C	L-C	H-C	L-C
1 - B	7	1	0	0	0	0	0	0	0	0	1	0
1 - E	27	18	0	0	0	0	0	0	0	0	2	1
2 - P	0	0	0	0	0	0	0	0	0	0	0	0
2 - S	0	0	0	0	0	0	0	0	0	0	0	0
3 - W	21	17	15	10	0	0	0	0	6	1	4	9
3 - A	12	4	0	1	5	3	0	0	0	0	0	0
4 - M	24	8	10	3	0	1	0	0	0	0	4	1
4 - C	22	4	0	1	5	0	4	0	0	0	0	0

Table 5. Frequencies of attentional other-awareness (o-a) and task-related behaviour judged not to display a collaborative orientation by LFA children doing the picture-sorting activity in the H-C (correctly categorised and matching) and L-C (matching) conditions.

			No collaborative orientation											
	Attentional o-a		Adult directed task-related behaviour		Ask adult task-related question		Trial and Error placement		Random placement		Sort/match picture		Follower imitation	
Pair	H-C	L-C	H-C	L-C	H-C	L-C	H-C	L-C	H-C	L-C	H-C	L-C	H-C	L-C
1 - B	7	8	4	3	20	4	15	9	8	8	2	0	0	0
1 - E	20	8	2	0	0	0	2	0	1	2	0	0	14	10
2 - P	2	8	1	2	0	0	1	0	5	2	0	0	0	0
2 - S	5	8	3	3	0	0	0	0	2	0	0	0	0	0
3 - W	26	6	1	2	0	0	5	0	0	0	4	8	0	0
3 - A	14	10	1	2	0	0	7	6	9	1	0	1	7	1
4 - M	8	1	2	0	7	0	14	11	0	0	5	2	0	5
4 - C	14	4	1	0	0	0	8	2	2	0	3	4	6	1

The analysis of active and attentional other-awareness and task-related collaborative and non-collaborative oriented strategies revealed three *Prerequisite capacities* necessary for increasing success on the computerised picture-sorting joint task using the supportive SCoSS interface:

1. A basic understanding of how to interact with the activity.

To participate in any activity a child needs to understand simply how to interact physically within the context he is experiencing. This is the foundation for collaboration from which all else emanates. Without this knowledge the child can only be a bystander. In this task the children need to understand that they can move the pictures on the DT surface using touch and that pressing 'We agree' may generate a new picture. All children initially had adult supervision for three games using the DT surface. To learn how to use the DT from the adult partner during the practice rounds children would need to be at least attentionally aware of her. It is possible that a child who does not learn by attending to the adult partner could use a trial and error strategy, exploring the features of the DT surface. However, this sort of exploratory behaviour was not observed in child S (pair 2) who was found unable to independently interact with the DT surface did not display any 'trial and error' behaviour in either the L-C or H-C condition (Table 5), but required adult prompting. Child S did demonstrate some attentional other-awareness of his partner, but this was fleeting. It could be argued that this was perhaps due to a lack of motivation, but S was excited and looked intently at the pictures, verbalising approximations of the characters' names repetitively while clapping his hands when they appeared. Neither was it a motor issue, as with prompting or hand-over-hand support from his key-worker he was seen to interact with the DT surface successfully, but without this encouragement and physical support he returned to the role of observer.

All the other children in this study demonstrated the basic ability of *understanding how to interact with the activity,* by interacting independently with at least one game piece. Six of the eight participants were found to have a clear grasp of how to interact with the DT by spontaneously moving each game piece as it appeared and by moving them around the interface and pressing the 'We agree' icon, whether or not they successfully progressed through the task.

2. The capacity to coordinate one's own action with another's.

Coordinating one's own action with another's can simply be achieved by imitating a partner's action (e.g., 'You did that, so I do that'). This is facilitated by the SCoSS interface and the design of the task that requires the children to place their game pieces on matching spots on the grid, thereby encouraging simple coordinated action. Completing the L-C condition's 'matching only' requirement without any understanding of the matching criterion is *only* possible if one child in a pair uses follower or strategic imitation throughout. This situation requires that *both* children in the dyad must display *a basic understanding of the activity from an individual perspective*, and *one* child additionally displays *the capacity to coordinate one's own action with another's* to successfully complete the task.

This was the case for Pair 1 in the L-C condition: B demonstrated *a basic understanding of the activity from an individual perspective* as he rapidly moved his pictures around the grid asking the experimenter "Do we agree?" He clearly understood that putting his picture on the grid and pressing 'We agree' generated a new picture, but was only once observed to coordinate his actions with his partner's (Table 4 and 5). However, child B was found only once to be actively aware of his peer partner and although he frequently asked "Do we agree?" he showed little understanding of what was meant by the term. He would repeat the phrase continually to the experimenter as a means to receive feedback about his own game state, rather than his own compared to his partner's (Table 5, 'ask adult task-related question'). Child B's partner E demonstrated both of the first two prerequisites he independently interacted with the activity and also showed the capacity to coordinate his actions with his partner's. This was confirmed by the H-C = 27 and L-C 18 active other-awareness behaviours his high level of follower and strategic imitation he produced relative to his partner's low level of imitative behaviour. As a result of them both having prerequisite 1 and one of them (E) having prerequisite 2 the pair was able to successfully complete the L-C task.

The need for *both* children in the dyad to display prerequisite 1, *a basic understanding of the activity from an individual perspective*, and at least *one* child to additionally display prerequisite 2, *the capacity to coordinate one's own action with another's* to successfully complete the task is demonstrated by the failure of Pair 2. As discussed previously child S did not show an *understanding of the activity from an individual perspective* and as predicted was unable to *coordinate his own action with another's* as demonstrated by his lack of active awareness of his peer partner and any collaborative orientation (Table 4). His partner P did demonstrate the first prerequisite, but was unable to coordinate his actions with his partner's, as evidenced by his lack of active awareness of his partner, imitative behaviour (follower or strategic imitation)or collaborative orientation. This deficiency in prerequisties 1 and 2 resulted in the pair failing to complete the task or progress through it independently. What is unknown is whether child P partnered by a child possessing the first and second prerequisite could have as predicted progressed through the task.

3. The capacity to encourage coordination of another's action with one's own.

When faced with an activity that requires joint working to solve a problem, it is unlikely that both participants will share equal knowledge or insight into how to proceed. Therefore, throughout the collaborative experience a participant will need, at times, to coordinate the partner's actions with their own in order to precipitate a shared understanding. This capacity to encourage coordination of another's action with one's own is comparable to what Carpenter at al. (2002) termed directing anothers behaviour.

The H-C task requires that players place their pictures in matching positions on the grid and also correctly categorise them, so matching alone is not sufficient to progress through the activity. Therefore, to make progress at least one child in a pair needs to be able to develop an understanding of both rules to be able where necessary support the learning of a naïve partner, yet to gain understanding of the objective of the task. This would necessitate the ability to *encourage the partner to coordinate his actions with theirs* in order to receive feedback from the DT to develop an understanding of the task. If the naïve partner does not respond to this guidance by following another's behaviour then the pair will only make progress with outside intervention. This was observed, with differing outcomes, in Pair 3 and Pair 4.

Successful completion of the task in the L-C condition for pair 3 was the result of child W strategically imitating his partner, as demonstrated by the nine strategic imitative behaviours he produced, compared to the one follower imitation behaviour generated by child A (Table 4 and 5). Both children in Pair 4 in the L-C condition were observed to direct their peer's behaviour as well as to follow the other's behaviour in the form of follower imitation (Table 4 and 5), but child M was also observed to imitate his partner strategically to enable progress through the activity (Table 4).

However, this strategy of strategically imitating a partner was not successful strategy for the H-C task, as the pictures also need to be correctly categorised. The additional constraint of categorising the pictures in the H-C condition is believed to push a peer partner, where able, to take the lead by correctly categorising a picture and then needing to encourage his partner to imitate his placement, therefore use the third prerequisite skill, *The capacity to encourage coordination of another's action with one's own.*

Pair 3 were unable to complete the H-C condition as although third prerequisite, *the capacity to encourage coordination of their partner actions* was seen to be emerging in child W (direct peer behaviour, Table 4) his partner, A, was only seen to display follower imitation and lacked strategic imitation and so was unable to coordinate his actions with his partner's effectively. Because of this lack of effective coordination in the form of strategic imitation (Table 4) in child A, W looked unsure of how to proceed and so was prompted by the experimenter to "help" his partner. W then tried to *encourage coordination of his partner's actions with his own* and attempted to direct his partner's behaviour by pointing to his partner's side of the interface, showing him where he should place his picture. As the task progressed, W correctly categorised his pictures and started to spontaneously direct his partner's behaviour by saying "Now put them in the same place as me". However, when his partner A did not respond W would use the proposed earlier emerging and therefore potentially more established second prerequisite and *coordinate his actions with his partner's* resulting in the pair's task only 'matching' again and so task progress was found to be unattainable for pair 3 in the H-C condition despite success in the LC.

The three prerequisites for collaborative problem-solving a computerised joint task appeared more established in Pair 4. The pair smoothly completed the L-C condition and initially approached the H-C task with the same strategy of continuing to coordinate their actions with child M using strategic imitation four times (Table 4) and child C using follower imitation five out of a total of six times (Table 5) while moving their pictures around the grid using a relatively high level trial and error behaviour (Table 5). However, the pictures were never correctly categorised and therefore the frequent pressing of 'We agree' did not generate a new picture. Eventually, frustrated, M said to the experimenter, "Oh help!" and as the peer partner's were making little progress after sometime the experimenter encouraged the pair to "think about the pictures you've got". M described the pictures in detail and when asked by the experimenter, "Are they similar?" responded, "They are not".

From this point M demonstrated he understood the goal of the task and moved his two pictures onto separate strips and told his partner, "You have to look for things that are similar" and pointing to his partner's pictures "That's one from the movies and that one's toys" while directing his partner's attention, articulating a perfect description of how to sort the pictures into their two categories. This is a key moment, as from this juncture both children became *'mutually engaged in a coordinated effort to solve the problem together'* (Roschelle & Teasley, 1995, p.70). M encouraged his partner to coordinate his actions with his own (3rd prerequisite) and C responded by coordinating his actions with his partner's (2nd prerequisite) until he also came to understand the aim of the task. The pair then demonstrated a shared understanding of the task by discussing the positioning of the character's on the grid and working 'simultaneously in a coordinated effort to complete the task together'. Pair 4, were therefore judged to have collaboratively problem-solved the computerised picture-sorting task. The findings from the analysis of the pairs of LFA children's other-awareness abilities, the relationship between the three collaborative prerequisite capacities and children's increasing ability to solve a computerised joint task are illustrated in Table 6.

Table 6. Model of Collaborative Problem-Solving: illustrating the interplay between the manifestation of other-awareness, collaborative abilities and level of success of pairs of LFA children supported to work together on a computerised activity.

Other-awareness (o-a) →	Prerequisite →	Enables varying level of task success
Attentional o-a is required to support observational learning in order to gain prerequisite 1.	1. A basic understanding of how to interact with the computer activity.	Prerequisite 1 enables interaction with the computer activity without reaching a solution
LFA children require attentional o-a and at least one requires active o-a to facilitate task success using prerequisite 2.	2. The capacity to coordinate one's own action with another's.	Prerequisite 2 enables success in the L-C (matching only) task. As one player using strategic imitation is enough to achieve task success.
LFA children require active o-a and attentional o-a to facilitate prerequisite 3.	3. The capacity to encourage coordination of another's action with one's own.	Both LFA children require prerequisite 2 and at least one requires prerequisite 3 to enable success in the H-C (correct & matching) task. As strategic imitation is not enough to enable task success.

Discussion

LFA children demonstrated active other-awareness using the SCoSS interface replicating the findings of Holt and Yuill (2014), and importantly the H-C activity presented a greater challenge than the L-C exposing the three prerequisite capacities necessary for collaboration and their relation with other-awareness. We found that a higher level of constraint in the activity increased LFA children's other-awareness, with children in the H-C condition demonstrating more active other-awareness behaviour than in the L-C condition. We can be confident that the H-C effect on active other-awareness was not due to a lack of engagement in the L-C condition as there were no significant differences found in children's approach to task between the two conditions. Manipulating the level of constraint revealed the different skills and capacities LFA children needed to be able to interact with a peer and ultimately collaborate to solve a task. This paper proposes a model of collaborative problem-solving (Table 3) that illustrates the interplay between attentional other-awareness, active other-awareness and capacities related to coordinating and encouraging coordination of joint action, that give rise to collaboration in pairs of LFA children.

The only collaborative partnership in our study, according to the Roschelle and Teasley (1995) definition, was observed in the dyad in which *both* children demonstrated attentional other-awareness and active other-awareness and the three collaborative prerequisites:

1. A basic understanding of how to interact with the activity.
2. The capacity to coordinate one's own action with another's.
3. The capacity to encourage coordination of another's action with one's own.

The capacity to coordinate one's own action with another's can be seen in terms of secondary intersubjectivity (Trevarthen., 2005); the capacity to include their own and their partner's intentions towards the task in order to achieve coordinated action. We believe this is the case for strategic imitation; the imitator demonstrates an appreciation of his partner's lack of task understanding and compensates for this by coordinating his actions with his partner's, demonstrated after failed attempts to encourage his partner to copy him. The second prerequisite can also be demonstrated by *follower* imitation, blind copying that does not explicitly demonstrate task understanding or recognition of the other's intentions, but a strategy that is useful in novel situations to compensate for a lack of intention understanding. Such a position of acknowledging the existence of simple cooperative actions without intention understanding is proposed by Fantasia, De Jaegher, and Fasulo (2014). Further work could investigate whether follower imitation is an adaptive style of imitation that LFA children employ in other contexts to compensate for a lack of understanding about the world and if HFA children use it in novel situations that require understanding of another's intentions.

Secondary intersubjectivity also seems essential to enable *the capacity to encourage coordination of another's action with one's own*: the act of asking or gesturing for coordinated action is an explicit manifestation of intention understanding. The third prerequisite is akin to scaffolding, where a more knowledgeable other can facilitate performance beyond what could be achieved by his partner on his own. However, in this situation of LFA peer collaborative problem-solving, *either* collaborative partner may encourage coordination of his partner's action with his own, as initially neither participant has more knowledge than their partner, and therefore understanding is developing as much through the feedback given by the software following incorrect action, as much as agreements on correct responses and support from the experimenter that enable the pair to progress through the task. This indicates that in this context the collaborative process can facilitate a bottom-up generation of knowledge as well as top-down transfer to the partner.

The fact that *both* children needed to possess all three capacities to problem-solve the H-C task collaboratively highlights how collaboration occurs in the interactions between two (or more) mutually engaged individuals with their behaviour tied together by the activity. We suggest that looking at pairs of LFA children working together, rather than extrapolating from the behaviour of an individual LFA child interacting with a TD partner, makes it possible to reveal more clearly the collaborative interaction (Yuill, 2014). This approach excludes the possibility of a 'helpful' partner supporting the child unintentionally in ways that may not only be entirely beneficial, as an overly helpful adult partner might reduce spontaneous collaborative behaviours that may only emerge during the natural setbacks that occur when children problem-solve together, as proposed by Holt & Yuill, (2014).

LFA children were observed to need, at a minimum, attentional other-awareness to be able to interact with the activity independently. We suggest that in order to learn how to use the technology, LFA children need to be attentionally aware either of the adult partner during the practice rounds or a more knowledgeable peer partner. Attentional other-awareness does not require the child to share eye gaze, but rather display awareness of another by attending to their action during a joint activity. Whereas, in general joint attention is confirmed using eye gaze alternation between another person and an object (Carpenter et al., 1998). Therefore, by using a joint activity we were able to identify awareness of another person incorporating actions on an object by assessing LFA children's interrelated actions with a partner. For example, a child participating in a joint activity could pause to watch their partner's interactions with the task before continuing their own related activity. Therefore, showing attentional other-awareness without needing to include eye gaze alternation between the object and the partner. Attentional other-awareness was found to be a necessary ability to enable simple actions, as evidenced by the LFA child who was unable to interact independently with the activity. LFA children showing a lack of attentional other-awareness would therefore need support to learn how to interact with an activity before being able to benefit from working with a peer.

Six out of eight children demonstrated active other-awareness and the capacity to coordinate their actions with a partner, and all used follower or strategic imitation, but only two out of the six were able to encourage coordination of another's actions with their own. This suggests that imitation is a necessary skill to facilitate the collaborative process, but not sufficient, as imitation alone could not generate collaboration. Imitation is a known impairment in children with autism (Williams et al., 2004) and this study proposes a potentially useful distinction between two types of imitation: follower and strategic, used by the LFA children to facilitate joint action. This study investigated collaboration in pairs of LFA children and we were able to observe imitation in naturalistic complex interactions in LFA children.

However, intentions can only realistically be inferred behaviourally and so was done conservatively. Follower imitation is consistent with recent work suggesting the imitation in TD children is behaviour that imitates faithfully the actions of a demonstrator that cannot be interpreted as goal-driven (Whiten et al., 2009). Therefore, findings in this study related to follower imitation in LFA children may be an example of an adaptive behaviour adopted to navigate unfamiliar experiences and excessive imitation of behaviour (over imitation) and verbal copying (echolalia), as seen in children with autism, might be an over-expression of that coping mechanism.

In contrast, strategic imitation enabled children to overcome a partner's lack of coordinated action or placement imitation and illustrated secondary intersubjectivity, the ability to understand and take into account one's own and another's intentions towards an object. The H-C activity put pressure on the LFA children not only to coordinate their actions, but also to go beyond joint action to joint problem-solving. Therefore, collaborative tasks that facilitate strategic imitation could be an important means of supporting LFA children to develop higher metacognitive skills.

Our model of collaborative problem solving is consistent with the findings of Carpenter et al., (2002), that LFA children are able to follow behaviour (coordinate one's own action with another's) before being able to direct behaviour (encourage coordination of another's action with one's own). The present results extend their findings and highlight the potential for skill acquisition through interactions with an LFA peer. The earliest social-interactional skill in the Carpenter et al. (2002) model for LFA children is the ability to follow another's behaviour, i.e. being able to imitate the actions that an adult partner made on an object (box). This finding has two important aspects: firstly, the LFA child's attention was constrained during the social interaction by the presence of a proximal object and secondly, the earliest interactional behaviours were imitations of another's actions on an object. This suggests that constraining LFA children's awareness to include another person and a proximal object while also encouraging imitative behaviour might support the emergence of social interactional skills, such as other-awareness, joint attention, imitation and collaboration. The SCoSS interface provides such an environment by regulating children's attention to increase other-awareness and facilitates imitation to promote collaboration.

One implication of the finding that LFA children develop the ability to follow behaviour before being able to share attention is that they might struggle to benefit in the same way as TD children from episodes of primary intersubjectivity, i.e., mother-child, face to face social interaction (Trevarthen & Aitken, 2001). These early interactions typically do not include actions on objects and one proposition is that actions on a proximal object give a clear indication of where to focus their attention and thus facilitate social interactional exchanges. In TD children sharing attention with another about an object (secondary intersubjectivity) is said to emerge after primary intersubjectivity, from around nine months of age, and is theorised to represent the beginnings of understanding the other person as a separate intentional agent acting towards the object (Trevarthen & Aitken, 2001). If LFA children do not benefit from episodes of primary intersubjectivity and only begin to develop an understanding about the other through secondary intersubjectivity, then although the interactions may possibly look similar, it is unlikely that the LFA children will have developed the same understanding as TD children about the other as an intentional agent. It is possible LFA children learn about the social world initially via their interactions with others facilitated by objects. This could have implications for increasing the efficacy of early interventions for children with autism and warrants further research to investigate the relation between people and objects and early social interaction in children with autism.

Moll and Tomasello (2007) propose, in the Vygotskian intelligence hypothesis, that participating in shared collaborative activities drives social-cognitive development. They place emphasis on sharing a joint goal, to which both partners are equally committed, as a fundamental aspect of typical child development. Therefore, from this viewpoint, it is actions on objects that promote social-cognitive development and furthermore joint activities that focus on actions on objects may be of particular benefit to LFA children. Our findings suggest that LFA children need to be attentionally aware of a partner before being able to participate fully in joint activities, but that joint activity does facilitate other-awareness. If it is the case that LFA children need actions on objects to bring about other-awareness and initiate social cognition then the person in the interaction would always be competing for the child's attention with the object or action. This may have consequences for the typical developmental pattern, but can at least function as a stepping-off point for the crucial advent of social cognition.

The present study using the SCoSS interface extends previous findings by demonstrating that careful manipulation of the task design as well as the software interface can facilitate the development of collaborative problem-solving between pairs of LFA children. The results highlight the varying abilities of LFA children, even in this small sample, and suggest a sequence in which children may acquire the skills to collaborate. For example, a child needs support to learn how to interact with the activity independently before being expected to work with a peer. When this first skill is acquired, pairs of children could practice simple matching tasks in order to develop their ability to coordinate their actions with another's and subsequently improve their other-awareness capacity. When children have these skills in place they should be ready to move on to a task that requires them both to coordinate their actions while also working together to solve a problem i.e., collaborate. This study found that the use of simple collaborative tasks delivered via a computer interface designed to encourage joint action supported other-awareness of a partner, imitation and facilitated collaboration in LFA children. This was a small sample and so further research is needed to test our findings and to see if continued exposure to collaborative activities in LFA children can bring about qualitative changes in social cognition.

Paper 3

Collaborating using a novel dual-tablet setup facilitates other-awareness and communicative behaviour in low-functioning children with autism

Abstract

Low-functioning children with autism (LFA) are impaired in other-awareness, joint attention and imitation, with a poor prognosis for developing language competence. However, better joint attention and imitation skills are predictors of increased language ability. Our study demonstrates that a collaborative activity delivered on a novel dual-tablet setup facilitates active other-awareness, incorporating imitation and communicative behaviour, in 8 LFA boys with limited or no language, aged 5 – 12 years. LFA children did a picture-sequencing activity using single and linked dual tablets, partnered by an adult or by an LFA peer. Overall, the dual-tablet configuration generated significantly more active other-awareness than LFA sharing a single tablet. Active other-awareness was observed in LFA peer partnerships using dual-tablets behaviour absent when peer partnerships shared a single tablet. Dual tablets facilitated more communicative behaviour in adult-child partnerships than a single tablet. We propose that supporting collaborative activities in LFA children facilitates other-awareness and communicative behaviour and that adult and peer partnerships make different, but essential contributions aiding social-cognitive development through the collaborative process.

Keywords

Low-functioning Autism, Other-awareness, Collaboration, Imitation, Communication, Shareable technology, Social-cognitive development.

Other-awareness emerges early in development and can be observed in the fact-to-face interactions of mothers and infants from around one month of age (Trevarthen, 1979). Self and other awareness are thought to be intimately linked with the emergence of early social abilities in children, such as joint attention and imitation. From around six months of age a typical child will develop the capacity to include objects in self and other referential cognitions, in social interactions based on joint attention (Bakeman & Adamson, 1984). Joint attention involves the capacity of children to coordinate their attention to include another person and an object. These are complex behaviours that include *responses* to gaze and gestures from another person seeking to share attention to an object or event, and using gaze and gesture to *initiate* the sharing of attention to an object or event with another person (Carpenter et al., 1998). Joint attention is also believed to serve two functions: firstly imperative requests, for another to retrieve an object for them and secondly, declarative requests for another to share attention to an object or event (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Bates, Camaioni, & Volterra, 1975).

Imitating the actions of another person is a common behaviour that suggests an awareness of the other. Evidence from Killen and Uzgiris (1981) suggests that in typically-developing (TD) children this may emerge from around 7½ months of age, when infants were found to be able to imitate an adult's simple actions with an object (e.g. banging or shaking a block). Slightly older infants aged from 10 – 16 months were seen to imitate object appropriate actions, such as pushing a car along, more than inappropriate actions, such as drinking from a car, whereas, by around 22 months of age, children were able to imitate both types of acts with equal ease.

Asendorpf and Baudonnière (1993) consider 'synchronic' imitation, defined as the continuous and simultaneous imitation of another's actions, to be an indicator of other-awareness. To investigate any relationship between the development of self and other awareness, they assessed the self-recognition status of 19 month-old infants using the surprise-mark test (Amsterdam, 1972), argued to represent the development of self awareness, and their ability to imitate synchronically. In the surprise-mark test a child has rouge surreptitiously smudged on to its cheek and is then encouraged to look into a mirror: if a child notices the smudge it is considered self-aware. Asendorpf and Baudonnière (1993) placed TD children into peer dyads of recognisers, non-recognisers and mixed recognisers following assessment of their self-recognition status, and then gave them identical objects to play with. Asendorpf and Baudonnière (1993) found that TD children were only reliably able to imitate 'synchronically' an unfamiliar peer's actions after they were able to pass the surprise-mark test at about 19 months. Asendorpf and Baudonnière (1993) suggest these findings show that self-awareness and other-awareness develop simultaneously in TD children.

Similarly, Nielsen and Dissanayake (2004) found that TD infants partnered by an adult experimenter began to engage in sustained synchronic object imitation from 18 months, with time spent imitating a partner during a play session increasing significantly in duration by 24 months. The developmental courses of self and other awareness as represented by synchronic imitation of a partner appear related, but emerge later in comparison to contingent imitation of a partner's actions on objects. Therefore, in typical development, watching an adult and then contingently imitating their behaviour emerges before TD children can pass a surprise-mark test, suggesting that this form of imitation may facilitate the development of self- and other-awareness.

Children with autism are shown to have impairments in imitation (Rogers, Hepburn, Stackhouse, & Wehner, 2003; Williams et al., 2004) and in joint attention (Bruinsma et al., 2004; Charman et al., 1997). These impairments are considered fundamental in affecting their long-term outcome, since, in children with autism, better joint attention and imitation skills are robustly associated prospectively with superior language development (Charman, 2003; Kasari et al., 2012; Poon et al., 2012; Toth et al., 2006; Williams et al., 2004). Therefore, activities that facilitate other-awareness, joint attention and imitation may be important in aiding the development of such children's social-cognitive and communicative abilities.

The fundamental skills of joint attention and imitation are seen as prerequisites for participation in collaborative activities (Colombi et al., 2009a) and hence a possible reason for deficits in the capacity of children with autism to cooperate (Liebal et al., 2008). Moll and Tomasello (2007) propose in the Vygotskian intelligence hypothesis (VIH) that cooperative interaction is the driving force of social cognition. Through cooperative interactions they suggest that a child develops an awareness of the other person. Moll and Tomasello propose that children do this by first, recognising the sharing of a joint focus of attention, and that from this triadic awareness, they can develop an understanding that the other person can have a different perspective of this shared experience. This understanding that others have individual thoughts, beliefs, emotions and intentions is believed to be a critical aspect of social cognition and a primary impairment in autism (Baron-Cohen et al., 1985; Frith & Happé, 1999; Williams & Happe, 2010). In their VIH, Moll and Tomasello (2007) assert that TD children must experience frequent episodes of cooperative interaction to fully benefit. Therefore, given that children with autism are impaired in skills considered as prerequisites of cooperation and also have a tendency to play in isolation (Hauck et al., 1995) such a hypothesis would predict deficits in social-cognitive development in this group.

It is generally accepted that children with autism find computer technology motivating and beneficial to their learning (Fletcher-Watson, 2014; Golan & Baron-Cohen, 2006; Moore & Calvert, 2000; Ploog, Scharf, Nelson & Brooks, 2013; Williams, Wright, Callaghan & Coughlan, 2002). Taking this into account researchers have turned their attention to investigating how shareable computer technology can help support collaboration and the social interactional skills of children with autism.

Bauminger-Zviely et al. (2013) used laptops with dual mice and a Mitsubishi Diamond Touch interactive tabletop computer (DT) surface with pairs of high-functioning children with autism (HFA). Following the intervention they found increased social engagement and understanding of the concept of collaboration. Ben-Sasson, Lamash and Gal, (2012) found more positive social interaction in pairs of HFA children doing a collaborative puzzle task using a DT surface. Holt and Yuill (2014) developed a specially-constrained version of dual-mouse shared technology based on the Separate Control of Shared Space (SCoSS) model (Kerawalla et al., 2008) to facilitate collaboration in low-functioning children with autism (LFA) through supporting other-awareness. The LFA children were partnered by an adult or by a peer and presented with a picture-sorting activity using SCoSS versus an unconstrained dual-mouse condition. Holt and Yuill (2014) found active other-awareness behaviours in LFA children using SCoSS, whereas this interactional behaviour was absent without the collaborative support. Holt (Paper 2, this thesis) found concordant results using a SCoSS set-up on a DT table. Pairs of LFA children were given two different picture-sorting problems: a picture matching task and a picture matching and categorising task to solve together. The SCoSS environment constrained how players could interact with the task: LFA children were found to display more other-awareness and in particular active other-awareness doing a task with more constraints in place.

SCoSS exploits three mechanisms proposed by Yuill and Rogers (2012) to facilitate collaboration: firstly, boosting the awareness of a partner, secondly, controlling users' responses to be contingent on their partner's, and thirdly, increasing the availability of background information by providing cues about previous agreement. Capitalising on these mechanisms, SCoSS was found to be effective in supporting other-awareness and collaborative activity in LFA children.

This study used the SCoSS framework to develop an interface supporting the three mechanisms of collaboration using tablet technology. Tablet technology has a robust touch input system, easily accessible for many lower-functioning children, and is widely available in schools.

In extending the SCoSS architecture to tablet devices a dual tablet setup was created to allow for individual touch identification. The dual tablets were linked using wireless technology so that the SCoSS framework could be applied to support collaboration. Tablets were arranged side-by-side in two cases on stands to create a shareable computer environment to afford the collaborative features of the SCoSS model. The collaborative software designed for a dual-tablet setup affords the four features offered by SCoSS; 1. Identical tasks to solve. 2. Own task control provided by an individual tablet. 3. Achievement of agreement i.e., positioning of task pieces that correspond with partner's is explicitly represented by agreed items highlighted in green. 4. Control of task progress, by having points in the task where both users have to come to an explicit joint agreement about where the task pieces are placed, demonstrated by clicking the 'We agree' icon.

Previous work shows that the identity of the partner participating in a joint activity, e.g., peer or adult, makes a difference to interaction. In observations of LFA children during free-play and a lunch-time meal setting, Hauck et al. (1995) and Jackson et al. (2003) found differences in the quality and quantity of spontaneous social interaction between peers and adult teachers. Our previous work (Papers 1 and 2) also show differences in how technology supports peer-peer and adult-child interactions. The aim of this study was to investigate whether and how collaborative software using shareable dual tablet technology could support other-awareness and collaboration in LFA children in ways consistent with other implementations on the laptop and large DT surface, and whether this operated in different ways depending on the type of partner (adult or peer). This study compared the behaviour of LFA children presented with a picture-sequencing task in two tablet configurations: a single tablet and a dual tablets (Fig. 1) and with two types of partner: a peer or an adult.

Other-awareness, joint attention, imitation and communicative behaviour are all fundamental aspects of social interaction, and are impaired in autism. We developed a coding scheme (Holt & Yuill, 2014) to identify other-awareness behaviour displayed during a collaborative activity using two subcategories; *attentional* other-awareness and *active* other-awareness. Attentional other-awareness is defined as behaviour that is *related* to a partner' action and active other-awareness is defined as behaviour that is *related* to and *contingent* on a partner's action.

Paper 2 highlighted how important imitation was to enable collaboration in LFA children. Qualitative analysis of active other-awareness in Paper 2 revealed two forms employed by LFA peer partnerships to enable task success: follower imitation and strategic imitation. The collaborative features of the SCoSS model require that for children to jointly solve the task they are required to 'agree' and therefore are encouraged to coordinate their actions. These forms of imitation were found to facilitate coordinated action in peer partnerships in Paper 2. For this reason we will also qualitatively examine any imitative behaviour produced by LFA children in this study.

Engagement is a prerequisite of other-awareness: if a child is not engaged then it is impossible to make assumptions as to whether or not other-awareness is in their repertoire. For this reason, LFA children's engagement with the task is also assessed. Engagement includes: measures of the children's approach to, or withdrawal from, the task. This avoids the assumption of an incapacity for other-awareness when in fact a child has failed to be engaged by an activity.

Method

Participants

Eight boys aged 5 – 12 years (*M* = 9.2 years, *SD* = 3.3 years) took part who were diagnosed with autism and severe learning difficulties, attending one of three classes within the Autistic Spectrum Conditions Department of a special school in East Sussex, UK. Ethical approval was granted for the study and parental consent was given for the children to take part and to be videotaped. A key-worker was with children at all times to make sure they were happy to participate and the children were free to withdraw from the experiment at any time.

Design

The experimental design was within-subjects with two independent variables: tablet configuration (single or dual, shown in Figure 1) and partner (adult or LFA peer). The dependent variables were: other-awareness (active other-awareness and attentional other-awareness) and engagement (approach to task and withdrawal from task).

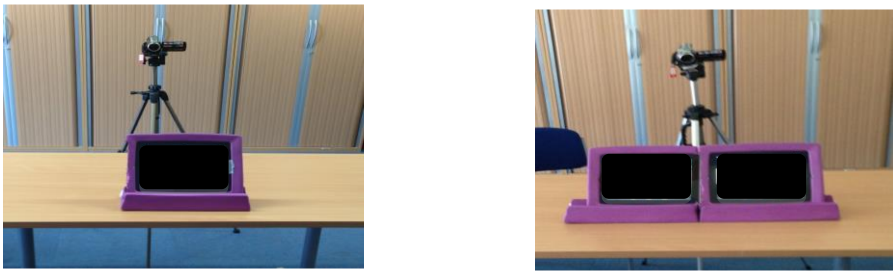


Figure 1. Set up of the single-tablet condition (left) and the dual-tablet condition (right).

Procedure

The study was carried out in a separate room close to the children's classrooms with equipment set up as shown in Figure 1. The class teachers' advice was used to place children into pairs. All participants had a practice round with an adult before testing began with each of the single and dual tablet conditions. The adult throughout the practice and testing rounds was the experimenter. Children completed the adult-child condition before the peer partner condition. This was to give the LFA children as much experience of the activity with adult support before they worked in peer partnerships. The order of the single and dual tablet conditions was counterbalanced, as shown in Table 1. A session for each pair took approximately 20 minutes and there was a week between the first and second sessions.

Table 1. Experimental procedure.

Session 1			
Tablet	Practice Round Adult-Child	First Round Adult-Child	Second Round Peer-Peer
Single	Child 1 Child 2	Child 1 Child 2	Child 1 + Child 2
Dual	Child 3 Child 4	Child 3 Child 4	Child 3 + Child 4
Single	Child 5 Child 6	Child 5 Child 6	Child 5 + Child 6
Dual	Child 7 Child 8	Child 7 Child 8	Child 7 + Child 8

Session 2			
Tablet	Practice Round Adult-Child	First Round Adult-Child	Second Round Peer-Peer
Dual	Child 1 Child 2	Child 1 Child 2	Child 1 + Child 2
Single	Child 3 Child 4	Child 3 Child 4	Child 3 + Child 4
Dual	Child 5 Child 6	Child 5 Child 6	Child 5 + Child 6

Single	Child 7 Child 8	Child 7 Child 8	Child 7 + Child 8

Picture-sequencing activity

Five different picture-sequencing tasks were created, depicting a simple sequence of events, using well-known children's characters (see Fig. 2 and Fig 3). Pictures were presented sequentially in a random order (the same, random sequence appeared in the same condition). Pressing the 'We agree' icon delivers the first of five pictures to be sequenced into the image box (Fig. 2). The same picture sequence was used for the two practice rounds in each screen condition. Different picture sequences were used for each experimental condition.

Single tablet

Pairs sharing the single tablet (Fig. 2) can both interact with the interface, although the tablet can only respond to one touch input at a time. Pressing the 'We agree' icon delivers the first picture into the image box. The picture can be placed anywhere onto the 5-space sequencing strip and then pressing the 'We agree' will deliver another picture into the image box. The pictures do not need to be correctly sequenced in order to progress through the task. Therefore, other than the requirement to place pictures on the sequencing strip there are no other constraints (Fig. 2). Players are free to move correctly-placed pictures throughout the activity.

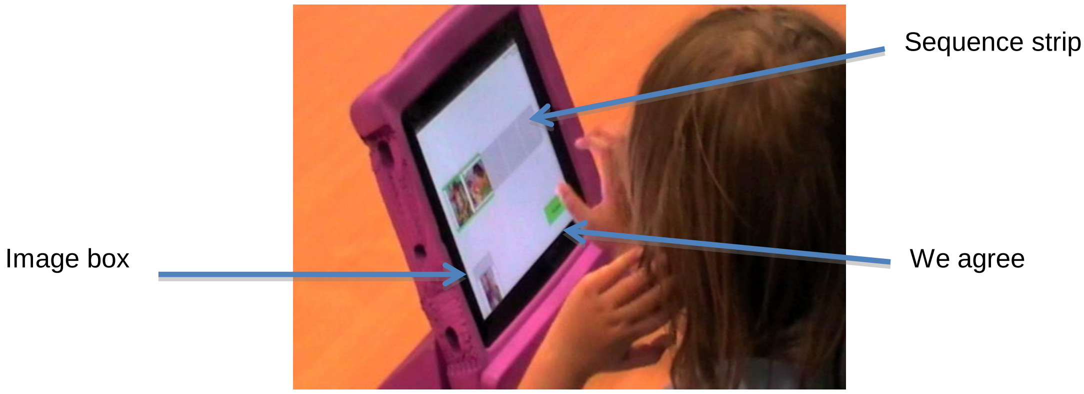


Figure 2. Single tablet showing one game representation to be shared between two players. Two pictures are placed on the sequence strip and the green border is visible. The 'We agree' has flashed green informing players that a new picture is arriving, shown in the image box.

Dual tablets

'We agree' icons on both tablets must be pressed to receive the first and subsequent pictures into both image boxes simultaneously (Fig. 3). Players are required to place their picture on to the sequencing strip. The pictures do not need to be correctly sequenced, but they must be placed in corresponding positions on each tablet. When pictures are in 'matching' positions on both game representations, the borders around both players' picture/s will turn green. 'Greenness' informs the players that the game state is correct (Fig 3). If pictures on both screens of the dual tablets are not in matching positions, pressing the 'We agree' will not generate another picture in the image box and the 'We agree' icon will flash red informing players that they are incorrect. The picture borders remain uncoloured around pictures that are not in matching positions. Players are free to move correctly-placed pictures throughout the activity.

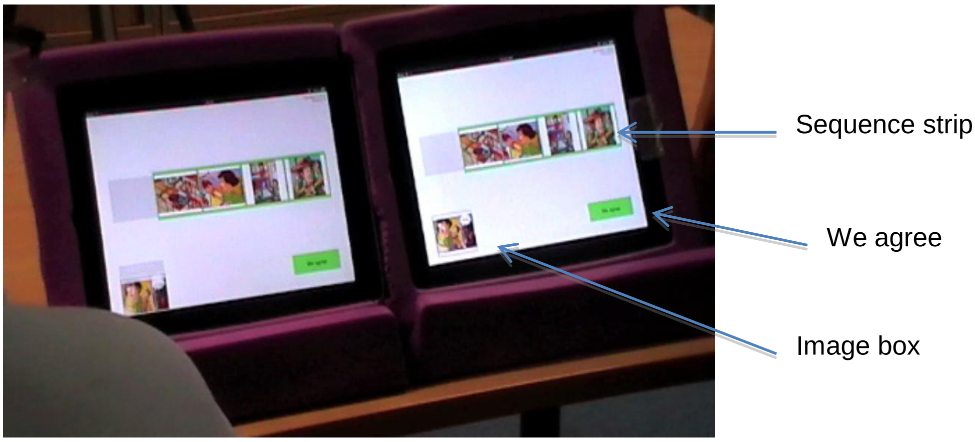


Figure 3. The picture-sequencing task on dual tablets.

Coding

Other-awareness

LFA children's behaviour was coded for attentional other-awareness and active other awareness. A*ttentional other-awareness* is behaviour that is judged to be related to a partner's e.g., pausing while interacting with an activity to watch a partner interact with the activity, as shown in Figure 4. A*ctive other-awareness* is behaviour that is related to and contingent on a partner's actions e.g. child A places a picture on the sequence strip then watches a partner place the same picture on the strip and when game representations are identical, child A contingently presses the 'We agree', shown in Figure 5.

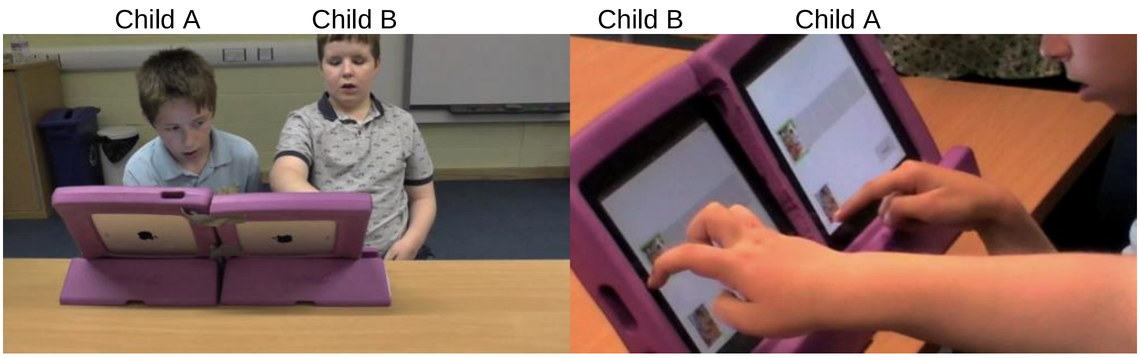
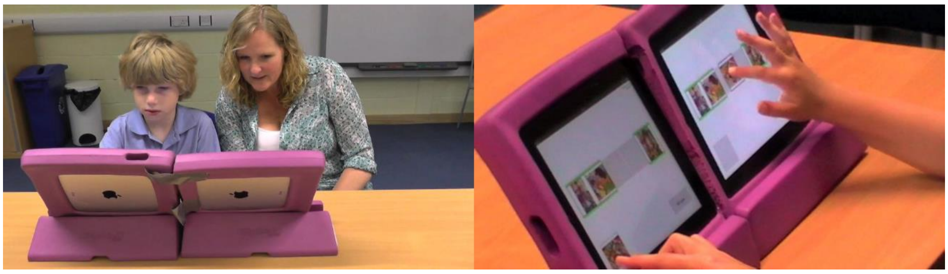
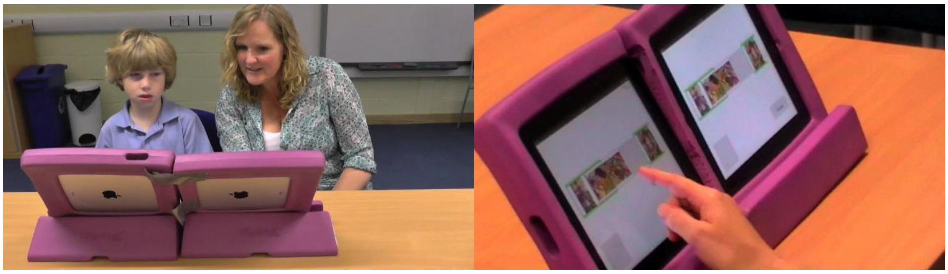


Figure 4. Attentional other-awareness on dual tablets. The face view (left) demonstrates that child A is observing his partner and the screen view (right) shows that child A has paused his activity and child B is interacting with the activity.



Child places his picture on his sequence strip.



Child watches as partner places their picture in the corresponding position.

Child contingently presses his We agree.

Figure 5. Active other-awareness on dual tablets.

Imitation

Following fine analysis of active other-awareness in Paper 2, two forms of imitative behaviour displayed by peer partnerships were revealed*: follower imitation,* the imitation of a partner's action by a participant naïve to the objective of the activity, showing no understanding of their partner's intentions related to the task or discernible collaborative intent and *strategic imitation,* defined as intentional copying of a naïve peer partner as a means to progress through the activity, displaying task understanding and collaborative intent.

Other-awareness, (incorporating follower and strategic imitation) was coded by two experimenters, one naïve to the hypothesis, with a Kappa inter-rater reliability statistic on a random selection of 25% of the data of k = 0.94, considered to represent excellent agreement (Cohen, 1960; Watkins and Pacheco, 2000).

Engagement

LFA children's level of engagement with the activity was assessed using measures of approach to task and withdrawal from task. Video recordings were coded by two experimenters, one naïve to the hypothesis, with a Kappa inter-rater reliability statistic on a random selection of 25% of the data of k = 0.80, considered to represent excellent agreement (Cohen, 1960; Watkins and Pacheco, 2000).

Analysis

The experimental design was repeated measures and as the peer-peer data is dependent in order to run parametric tests the data would need to be paired resulting in only four data sets that could not be analysed parametrically. Therefore, to overcome the dependent data, non-parametric related samples Wilcoxon's signed-rank tests were used. However, the results must be considered with caution due to the increased chance of a type I error when running repeated tests. Effect sizes are also reported; an r value of .3 is considered a medium effect and .5 a large effect size according to Cohen's criteria (Cohen, 1992).

Results

The results of engagement measures will be reported to ascertain that the LFA children participating in this study did not show a significant level of withdrawal from task behaviour to confirm that any differences found in other-awareness were not due to a lack of engagement. The findings regarding effects on active other-awareness and attentional other-awareness behaviour of LFA children interacting with a single or dual tablet setup partnered by an adult or peer will be reported. We will then explore qualitatively the effect of tablet setup and type of partner on active other-awareness.

Engagement

We look at withdrawal first as from this measure we can assess whether or not LFA children remained involved with the activity. Overall the mean frequency of withdrawal from task was low in all conditions (Fig. 6) and there were no differences in withdrawal behaviour in LFA children using single or dual tablets with a peer partner ($T = 6$, $z = -.95$, $p > .05$) or an adult partner, ($T = 1$, $z = -.45$, $p > .05$). Therefore, we can assume that children remained engaged with the activity in all conditions.

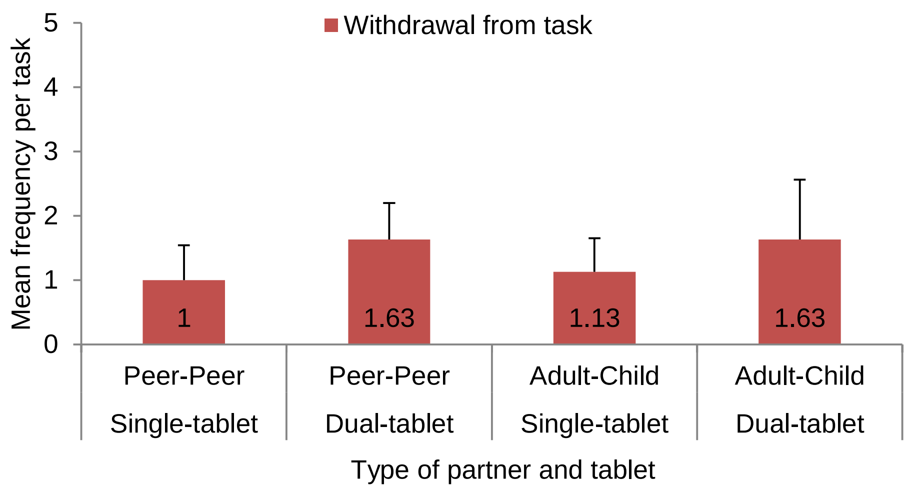


Figure 6. Mean frequency and standard error of withdrawal from task behaviour displayed by LFA children partnered by an adult and peer using a single or dual tablet.

The test results in Figure 7, show that a single tablet set up for LFA children had a significant effect on their frequency of approach to task behaviour, with the mean frequency of approach to task of peer partners using a single tablet, around half that of the other conditions. LFA children partnered by a peer displayed significantly more approach to task using a dual tablet compared to a single tablet ($T = 1$, $z = -2.38$, $p < .05$, $r = -.42$), and also significantly more approach behaviour using a single tablet partnered by an adult than partnered by a peer ($T = 1.50$, $z = -2.31$, $p < .05$, $r = .41$). In contrast, there were no significant differences found in approach to task for single and dual tablets when an LFA child was partnered by an adult ($T = 6$, $z = -1.36$, $p > .05$). Notably, peer partnerships using the dual tablets generated the highest mean frequency of approach to task behaviour and the lowest sharing a single tablet.

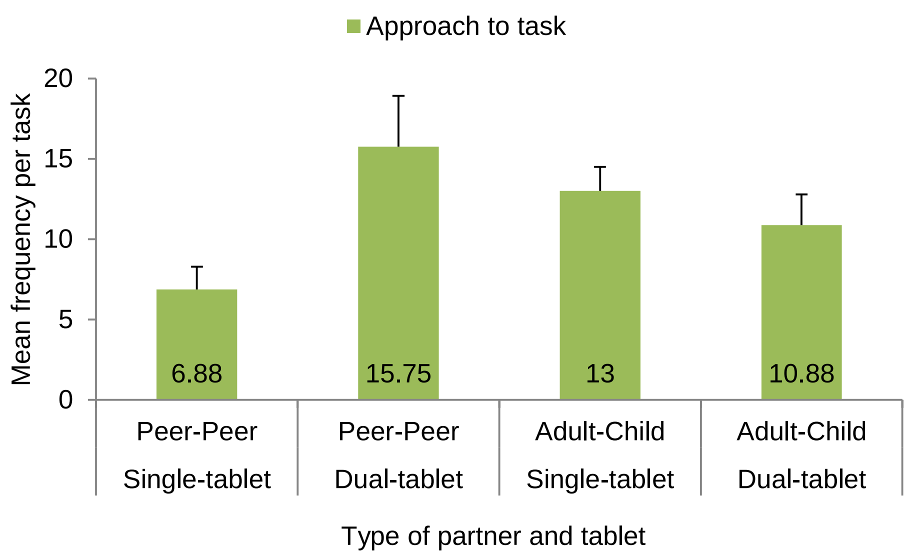


Figure 7. Mean frequency and standard error of approach to task behaviour displayed by LFA children partnered by an adult and peer using a single or dual tablet.

Active Other-awareness

The results in Figure 8 shoe that peer partnerships displayed no active other-awareness of partner in the single-tablet condition, but demonstrated significantly more active other-awareness in the dual tablet condition, (T = 0, z = -2.03, p < .05, r = -.36). Active other-awareness was absent in the single-tablet with peer partner, condition, but it was evident in this condition with an adult. With dual tablets and an adult partner, LFA children displayed significantly more active other-awareness compared to a single tablet (T = 1, z = -2.39, p < .05, r = -.42).

Overall there was no effect of partner on active other-awareness for dual tablets, (T = 6, z = -1.69, p = .09). However, LFA children were significantly more actively aware of an adult partner compared to a peer partner using a single tablet (T = 0, z = -2.03, p < .05, r = -0.37).

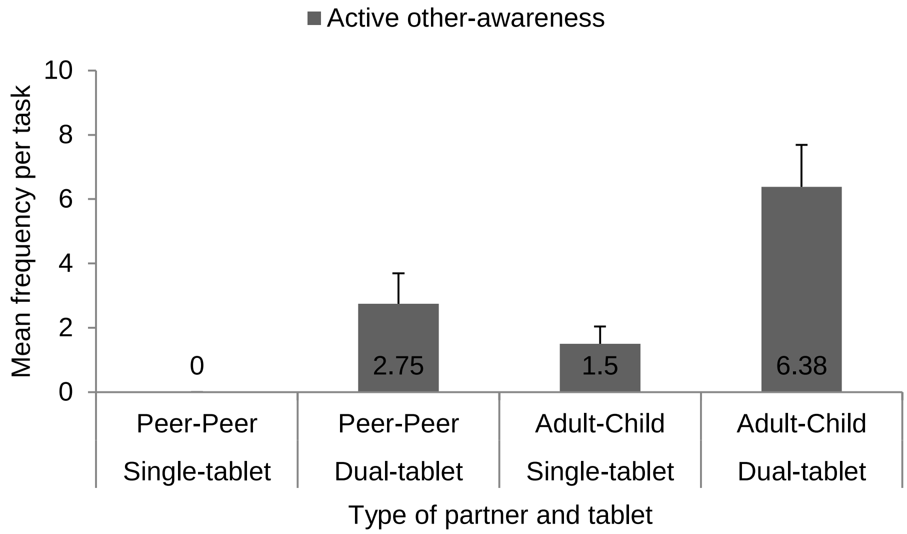


Figure 8. Mean frequency and standard error of active other-awareness behaviour produced by LFA children partnered by a peer or adult using a single or dual tablet.

Attentional other-awareness

Results for attentional other-awareness, in Figure 9 show that children in peer partnerships were also more attentionally aware of their partner using the dual tablets compared to a single tablet (T = 0, z = -2.03, p < .05, r = -0.36), as were children partnered by an adult (T = 2, z = -2.25, p < .05, r = -.41). Overall there was no effect of partner on attentional other-awareness for dual tablets (T = 17.50, z = -.07, p = .94) or for a single tablet (T = 6.50, z = -1.27, p = .20).

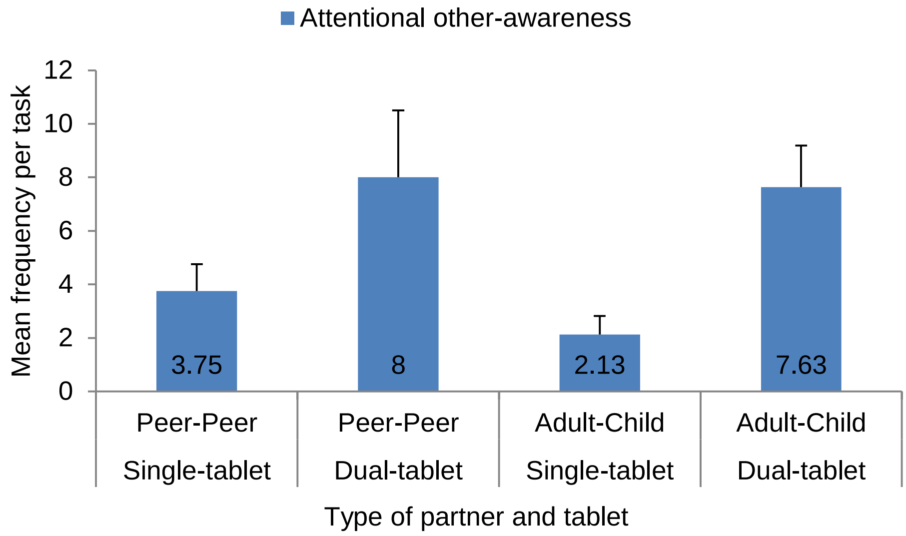


Figure 9. Mean frequency and standard error of attentional other-awareness behaviour produced by LFA children partnered by a peer or adult using a single or dual tablet.

Further analysis of other-awareness behaviour

The other-awareness behaviour generated by LFA children in the four conditions is described below in fine detail using the frequency of the subtypes of behaviour that make up the active and attentional other-awareness coding (Appendix 4 and 5).

Peer-peer using single tablet

LFA children were not able to coordinate their behaviour in order to perform the activity with a single tablet. In general one child would begin the activity and the experimenter would need to encourage the other child to participate. Peer partners sharing the single tablet only displayed attentional other-awareness, the vast majority of which was looking at the tablet *screen* while their partner did the activity (26/30). The remaining four attentional other-awareness behaviours was 'looking at the *partner* while he did task.

Adult-child using single tablet

LFA children displayed a greater variety of other-awareness behaviour with an adult partner using a single tablet compared to a peer partner. Active other-awareness was low in frequency, but apparent, and consisted of follower imitation (1/12) and verbal imitation (3/12) and some communicative behaviour. Communicative behaviour comprised responding appropriately to information given by the experimenter (3/12) and pointing to inform partner about the game (2/12). Interestingly, one child, twice, actively prevented the adult partner from interacting with the activity by pushing their hand away. This behaviour was only seen in the adult-child single tablet condition.

Peer – Peer using dual tablets

The dual tablet facilitated a greater number of active other-awareness in peer partnerships with over a quarter of the total other-awareness behaviour being active (22/86). Of the active behaviour 41% was imitation, strategic (7/22) or follower imitation (2/22) (Fig. 10). Peers using the dual tablet were observed to interact with their partner's screen (illustrated in Fig. 11). This was surprising as peers were reluctant to 'invade a peer's space' in order to interact with the shared screen using the single tablet. This type of active behaviour was quite frequent, making up 32% (7/22) of the active other-awareness behaviour in this condition. There was a very small, but important emergence of communicative behaviour (2/22), in this case, 'pointing to inform their partner about the game'. This was significant as the LFA children rarely communicated with each other during the tasks.

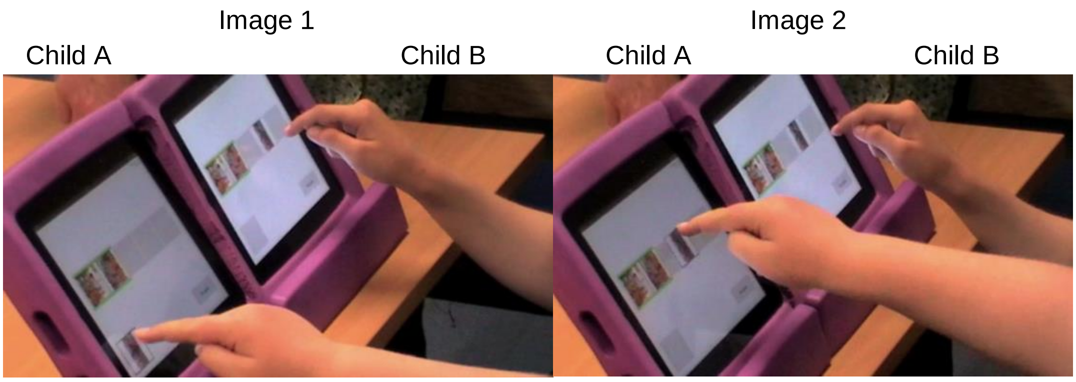


Figure 10. In image 1, child A watches child B place his third picture on the strip and contingently places his picture onto the same slot on his sequence strip, shown in image 2, displaying follower imitation. The imitation is judged as follower as child B does not press his 'We agree' following the imitative action and therefore does not display an understanding of the requirement to match, but is using imitation to overcome his lack of understanding.

Interacting with partner's screen

The child is actively aware of his partner demonstrated by his action on his partner's game.

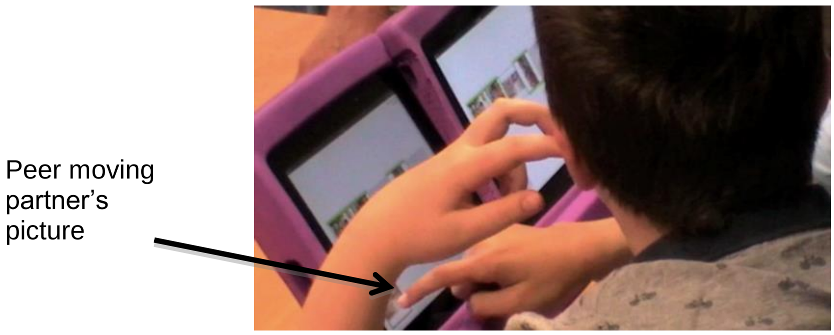


Figure 11. The image shows a pair of LFA peers using dual tablets. The child in the picture has just interacted with his screen, but his picture remains in the image box, so his partner leans across to place his partner's picture on the sequence strip. Therefore, placing both pictures in corresponding positions on their respective strips, so that pressing the 'We agree' icons will generate another picture.

Adult–child using dual tablets

Of the total other-awareness produced by children partnered by an adult using dual-tablets, 45% (51/112) of instances were active. Analysing the active other-awareness revealed that an adult partner promoted communicative behaviour, increasing from 2 instances using dual tablets with a peer partner to 16 instances with an adult partner. This accounted for 31% (16/51) of the active other-awareness behaviour produced by children with dual-tablets partnered by an adult. The communicative behaviour consisted of two forms, firstly, 'telling or pointing to inform partner about the game' (3/51) and was observed in two of the LFA children. The second form was 'responding appropriately to information or a behavioural request' from the adult partner and accounted for 15/51 of active other-awareness and was seen in four of the eight participants. Imitation represented 24% of active other-awareness, with strategic imitation accounting for 7/12 and follower the remaining 5/12. LFA children partnered by an adult using dual tablets also interacted with the adult partner's screen (7/51), although proportionally less frequently compared to peer partnerships using dual tablets.

Image 1 Image 2

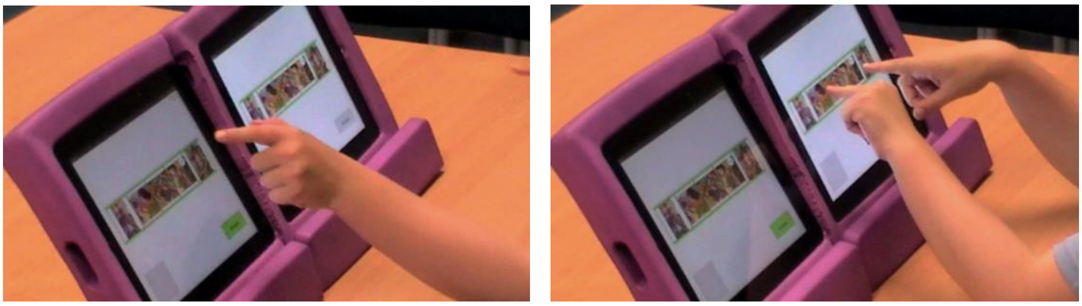


Figure 12. Child-adult partners using dual tablets. All the pictures were on the sequencing strip and the child spontaneously gestured to the adult's screen (image 1) and then to two pictures on his screen (image 2), using the game representations to indicate (correctly) to the adult partner that the pictures were not in the correct sequence.

Communicative behaviour

Communicative behaviour in the LFA children consisted of informing their partner about something related to the activity or responding to information given by the partner. In both instances the communicative behaviour could be either verbal or gestural. This often took the form of responses to questions about picture placement such as, "Where do you want to put it?" or "Where's mine?" with children pointing in response. A rare occurrence was a verbal response such as "yes" or imitating verbal comments about the picture sequence.

The LFA children in this study had limited verbal ability, but with dual-tablets a participant did use gesture to share information with his peer and with an adult partner. However, an adult partner with dual-tablets was able to scaffold communicative behavior by using the reference of the joint activity to initiate responses to information and this form of communicative scaffolding achieved a response from half the LFA children in this study. Most notable was the attempt by one child to use approximations of words accompanied with gestures to indicate the need to reorder the picture sequence, so that the pictures would be in the correct sequence (Fig 12). This was obviously effortful for him, and his speech was unclear, but by using his own and his adult partner's pictures as a shared reference point he was able to communicate his idea clearly. This was surprising, as the pictures did not have to be in the correct order to complete the task and the child instigated an opening for further dialogue between himself and his adult partner. The same child also made two gestural attempts to communicate with his peer partner in the dual-tablet condition by pointing to his partner's 'We agree' icon and image box to encourage his partner to interact with the activity. However, using the single-tablet he completed the task without taking much notice of his adult partner and making no such communicative attempts.

Discussion

The main finding of this study is that LFA children, with the support of a dual tablets incorporating collaborative software, were observed to successfully participate in a collaborative activity with a peer, generating significantly more active other-awareness behaviour than sharing a single tablet. In comparison, LFA peer partners sharing a single tablet were unable to coordinate their behaviour to work collaboratively and active other-awareness was absent. The order of the single and dual tablets was counter-balanced and so LFA children who experienced the dual tablet condition before the single tablet condition were found to display active other-awareness of a peer partner, but did not demonstrate active other-awareness in the subsequent single tablet condition. Therefore, in peer partnerships the dual tablet configuration was required to enable joint activity in

LFA children. Furthermore, the dual tablet configuration facilitated significantly more active other-awareness in adult-child partnerships.

This evidence suggests that a supportive environment can facilitate social interaction and collaboration in LFA children as found by Holt and Yuill (2014) for a constrained dual-mouse set-up. These findings also demonstrate further how exploiting the collaborative framework put forward by Yuill and Rogers (2012) can support design for collaboration.

The dual tablets were shown to be more effective at facilitating active other-awareness in LFA children particularly when partnered by an adult. The adult partner in this study facilitated many active other-awareness behaviours by directing the child's attention to the activity, asking task-related questions and commenting on the pictures, in an attempt to catch the LFA partner's interest. Responding to such calls for attention by adult partners is an early emerging skill in children with autism (Carpenter et al., 2002; Rozga et al., 2011). Nevertheless, LFA children in this study needed the support of the collaborative software and dual-tablet technology to exhibit this kind of response. However, the study by Carpenter et al. (2002) reported the findings of adult-child interaction and not peer-peer. Therefore, this study presents evidence that LFA children with collaborative support can use gesture to direct a peer partner's attention to a joint activity. Furthermore, this study shows that adult partners using a collaborative setup can also promote LFA children to use gesture to share information, as well as to facilitate the capacity to respond appropriately to information from the adult partner.

Our finding that using collaborative-software to support other-awareness in LFA children facilitates communicative behaviour is in line with research that demonstrates joint attention ability predicts language ability (Charman, 2003). This relationship also suggests that supporting joint attention online i.e., moment-to-moment during a joint activity, in children with autism may facilitate the emergence of communicative behaviour.

The levels of withdrawal from the task for each condition were low and similar for either type of partner, suggesting that the children were not disengaged from the activity. However, LFA children showed significantly less approach behaviour when working with a peer using a single-tablet than with a dual-tablet. This lower frequency of approach to task in the single-tablet condition for peer partnerships may illustrate the challenge LFA children have in working with another LFA peer without appropriate support. It may also reflect an inability to initiate interaction with an activity, when this involves sharing a single–tablet with a LFA peer. This proposal is supported by the fact that LFA children remained attentionally aware of their peer partners during the single–tablet condition and with dual-tablets they produced the highest mean frequency of approach to task behaviour.

In Paper 2 of this thesis a model of collaborative problem-solving for LFA children was introduced, proposing three prerequisite capacities needed to collaborate: 1. A basic understanding of how to interact with the activity. 2. The capacity to coordinate one's own action with another's. 3. The capacity to encourage coordination of another's action with one's own. This model was developed from observing the differing levels of success LFA children demonstrated in their efforts to solve a picture-sorting activity using SCoSS with a low collaborative constraint of 'matching' a partner's positioning and a high collaborative constraint of 'matching' and correctly categorising pictures. The task used for the current study was a picture-sequencing activity that did not require the pictures to be correctly sequenced. The single-tablet task simply required LFA children to place pictures in any order on the single sequencing strip. The dual-tablet had a collaborative constraint in place, just requiring children to put pictures in corresponding positions on their individual sequence strips. All of the LFA children in this study showed the first capacity of the ability to interact with the activity, as all were able to move a picture from the image box on to the sequence strip. However, this study did not present children with the high collaborative constraint of Study 2, correctly sequencing the pictures, hence players did not need to go beyond coordinating their action with their partner's (prerequisite 2) as this alone would lead to task success. However, as mentioned previously, one participant did gesture to the adult partner's sequence and his own sequence in an attempt to consider the sequencing aspect of the task, and this may have led to the emergence of the third prerequisite if he had continued, but at this point the task was complete and his efforts waned. This highlights the importance of setting the appropriate level of collaborative constraint in order to provide the right degree of encouragement to bring about collaboration for a particular child.

Our findings demonstrate that dual tablets were of benefit in situations involving both types of partner; dual tablets used by adult-child partnerships were found to promote more communicative (verbal and gestural) and imitative behaviour and peer partnerships were found to support peer imitation. Joint attention and imitation are associated with language development in children with autism (Charman, 2003; Kasari et al., 2012; Poon et al., 2012; Toth et al., 2006;

Williams et al., 2004). Therefore, it would be profitable to assess whether dual tablets used to promote imitation through joint activities have potential as an intervention to support language development in LFA children. Different forms of imitative behaviour such as contingent object imitation (Killen & Uzgiris, 1981) emerge before synchronic imitation (Asendorpf & Baudonnière, 1993; Nielsen & Dissanayake, 2004) in typically developing children and we have found that collaborative activities in LFA children require the use of a variety of imitative skills and also that the type of partner has an effect on the frequency of imitation. Therefore adult and peer partners may offer complementary roles to aid development of imitation and collaboration through the collaborative process. We propose that when using computer technology to support joint activities and collaboration in LFA children that such an intervention needs to take advantage of both adult and peer partnerships. The findings of this study are limited due to the small sample size and also the fact that the data generated by the sample is dependent and thus necessitated the use of a number of non-parametric tests increasing the likelihood of a type 1 error. Therefore, further research is important to validate and extend these findings.

Thesis Discussion

Overview of thesis contribution to the field of autism research

The most prominent and novel contribution of this thesis is the finding that LFA children *only* demonstrated active other-awareness of a peer partner during a collaborative activity when they were supported by software that was intentionally designed to facilitate joint action. This finding was initially observed in study 2 of Paper 1 using a dual-control laptop and replicated in Paper 3 using dual tablets. Furthermore, *without* collaborative software support active other-awareness of an adult partner was also absent using a dual-control laptop and significantly less frequent sharing a single tablet. Therefore, the outcome for active other-awareness remained true regardless of the type of shareable computer platform the collaborative software was presented on or genre of partner.

The findings of the thesis of the positive effect of collaborative software and shareable technology to facilitate joint action in LFA children are important, however research is essential to investigate the effects of extended collaborative experience on LFA children's development.

This thesis also submits an other-awareness behavioural coding scheme: used to evaluate the relatedness and contingency of actions between a LFA child and partner to identify attentional other-awareness and active other-awareness. The development and application of this novel other-awareness coding scheme is believed to have made the findings of this thesis feasible by establishing other-awareness definitions, that can be applied to naturally occurring interaction, that rely on contingency of action as opposed to eye gaze alternation.

Another important contribution of this thesis is the novel model of collaborative problem-solving, (Paper 2) which highlights three prerequisite capacities necessary to engender improving collaborative success in LFA children. The model offers insight into the type of collaborative support that would most benefit an individual LFA child depending on evaluation of their prerequisite status. This model can enable researchers and computer scientists to apply Yuill and Rogers' (2012) mechanisms of collaboration framework to design collaborative environments offering different degrees of collaborative constraints tailored to promote joint action specifically focused on a LFA child's individual level of need.

For example, an LFA child possessing the first and second prerequisite capacities, (the skill to interact with an activity plus the ability to coordinate his action with another's) would need support to establish the third prerequisite: the capacity to encourage coordination of a partner's action with his own. From identifying his collaborative status the aim would be to engage him in an activity with more constraints to promote a higher level of collaboration i.e., a joint activity that requires agreement on two or more features to make task progress when using collaborative software (e.g., matching and correctly categorising). The 'matching' necessitates coordinated action and the addition of a second task feature (categorising) means at least one participant has to 'encourage a partner to follow his lead' to be able to receive computer feedback from identical game states, in order to solve the picture categorising problem. Therefore, both LFA children would need to possess at the least, the first two prerequisite capacities for collaborative problem-solving to potentially occur, and one partner to have all three to increase the likelihood of its occurrence.

Taking into account the relationship between the development of collaborative prerequisites and the ability to collaborate in a joint activity an integral element is the collaborative partner. This thesis has found that peer partners, presented with an activity with two task features to jointly solve, can be pushed to collaborate according to Roschelle and Teasley's (1995) definition of collaboration. Furthermore, an adult partner has been found to promote communicative behaviour in a LFA child. However, the findings of this thesis concerning effects related to the type of partner on LFA children's collaborative skills are preliminary and more work is warranted to pursue this further.

Overview of thesis findings

Active other-awareness in autism

Study 2 of Paper 1 and Paper 3 investigated the effect on LFA children's other-awareness of the nature of collaborative partner (adult or peer) and type of software interface (supportive or unsupportive). In Paper 1, LFA children using a more standard setup of sharing one game representation with dual-control did not interact with the joint activity in a manner that demonstrated any action contingent on or related to their partner's: active other-awareness was absent in both peer and adult-child partnerships. Remarkably, the same partnerships did exhibit active other-awareness when using the SCoSS setup of two inter-linked game representations. Paper 3 using SCoSS derived collaborative software on dual-tablets replicated Paper 1's findings for LFA peer partnerships. However, in contrast to Paper 1, Paper 3 found that LFA children partnered by an adult did display active other-awareness sharing one game representation on a single-tablet.

It should be noted that the adult partners in the non-SCoSS condition of Paper 1 were the class teacher and teaching assistant, whereas in all other experimental conditions of Paper 1 and Paper 3 the adult partner was the author of this thesis. The decision by the author to be the adult partner was made to control for the potential confounding variable of interactive style of adult partner that could arise from using several teachers and teaching assistants, with possible varying methods of approach. The author endeavored to engage LFA children equally in all conditions and maintain a standardised interactive style. Therefore, the findings of paper 3 suggest that an adult partner, if made aware of collaborative requirements, may be able to behave in a way to support collaboration even without supportive software, but that collaborative software may facilitate LFA children to be actively aware of an adult partner who is not aware of how to support collaboration. Nevertheless, statistical analysis of Paper 3 still confirmed that LFA children were significantly more actively aware of an adult partner using the dual tablets with collaborative constraints compared to sharing a single tablet.

The manipulation of H-C and L-C activities presented using the SCoSS interface in Paper 2 revealed that pairs of LFA children were significantly more actively aware of a peer partner when collaborating to solve the H-C activity (match and categorise) compared to the L-C activity (match). The H-C activity not only required children to match each other's positioning, consequently supporting coordinated action, but also to come to an agreement about which category a picture belonged to, hence promoting joint problem-solving. Inspection of active other-awareness findings of this thesis indicate that the highest mean frequency of active other-awareness was found in peer partnerships working to solve the problem with a high level of collaborative constraint (H-C) using SCoSS in Paper 2 compared to any other condition from all three papers (Table 1).

Table 1. Mean frequencies of active other-awareness and attentional other-awareness displayed by LFA children in the collaborative and standard setups of all the studies of this thesis.

Collaborative setup

Technology	Mean frequency of Active other-awareness per task		Mean frequency of Attentional other-awareness per task	
	Peer	Adult	Peer	Adult
Laptop	3	1.5	5.25	2
Dual tablet	2.75	6.38	8.00	7.63
High collaborative constraint				
	SCoSS H-C		SCoSS H-C	
DT	14.13*		12	

* Highest mean frequency of active other-awareness

Standard setup

Technology	Mean frequency of Active other-awareness per task		Mean frequency of Attentional other-awareness per task	
	Peer	Adult	Peer	Adult
Laptop	0	0	2.75	0.5
Single tablet	0	1.5	3.75	2.13
Low collaborative constraint				
	SCoSS L-C		SCoSS L-C	
DT	6.5		6.63	

Notably, the overall highest frequency of active other-awareness occurred in Paper 2, where software constraints were manipulated in the H-C condition, in accordance with the three mechanisms of collaboration presented by Yuill and Rogers (2012) thus demonstrating further how the collaborative framework can be applied to promote collaborative behaviour. Unfortunately we did not have an adult-child comparison group in Paper 2, so we do not know the effect the L-C and H-C conditions would have had on LFA children's other-awareness with an adult partner.

In summary the research on active other-awareness in this thesis demonstrates that active other-awareness was not apparent in *peer* partnerships using non-supportive set-ups. However, this was not always the case for LFA children working with *adults*, who in Paper 3 were found actively aware of their adult partner using a single as well as a dual tablet set-up. This suggests that an adult partner can provide a degree of scaffolding to support LFA children's active other-awareness during natural interaction using a typical computer set-up.

Attentional other-awareness in autism

The overall findings of this thesis regarding LFA children's attentional other-awareness of a collaborative partner is that collaborative software delivered on shareable technology facilitated a significant increase in the mean frequency of attentional other-awareness compared to non-supportive setups (Table 1). Furthermore, there were no significant differences in attentional other awareness apparent depending on the type of collaborative partner, i.e., peer or adult. Therefore, attentional other-awareness in LFA children was found to be sensitive to the effect of the technological aspects of the collaborative support and did not show any effects attributable to the type of partner.

The arrangement of the shareable technology and supportive software of this thesis subdivide the interface of the activity so that a portion of the joint activity was designated for each individual player. For LFA children the difference in arrangement from a shared single game representation to dual interlinked games may promote the recognition that they have a part to play in the activity. If this is the case, the dual game arrangement could be predicted to raise attentional other-awareness in children independent of their ability to interact with the activity and therefore may explain the difference in attentional other-awareness found in this thesis.

Attentional other-awareness findings of Paper 2 related to the manipulation of constraints within the activity itself were comparable to the findings for active other-awareness in this study, in the respect that attentional other-awareness was almost twice as frequent in the H-C condition compared to the L-C condition. However this difference was not significant.

Summary of findings depending on type of partner

This thesis provides some evidence that the nature of the partner (adult or peer) during a collaborative activity can make a quantitative and qualitative difference to the interactive behaviour of LFA children. LFA children sharing a single-tablet, in Paper 3, were found to be significantly more actively aware of an adult partner compared to a peer. In contrast, the type of partner did not affect active other-awareness using a dual-tablet or attentional other-awareness using single or dual tablets. This finding indicates that an adult partner is able to scaffold a relatively low frequency of active other-awareness in LFA children in joint activities that are not delivered using collaborative technology (Table 1). However, when LFA children participated in activities supported by collaborative setups the effect of type of partner on active other-awareness was no longer significant.

Collaborative prerequisites and type of partner

In Paper 2, qualitative analysis of LFA children's ability to solve two problems with differing levels of collaborative constraints revealed three prerequisite capacities LFA children needed in order to collaboratively problem-solve with a peer partner. Paper 3 found that these collaborative prerequisites apply to interactions with adults as well as peers.

Qualitative analysis of the active other-awareness behaviour of LFA children, in Paper 3, indicate that an adult partner elicited more communicative behaviour than a peer with collaborative support, evident in two forms, 'responding appropriately to information or a behavioural request', and 'telling or pointing to direct another's attention and behaviour'. The former shows the second collaborative prerequisite: the capacity to coordinate one's own action with another's. The latter communicative behaviour demonstrates the ability of the LFA child to initiate a request to share another's attention with the aim of directing their behaviour, and is an example of the third collaborative prerequisite: the capacity to encourage coordination of another's action with one's own. The finding that collaborative software on dual-tablets with an adult partner facilitates communicative behaviour is important, as 'responding appropriately to information or a behavioural request', and 'telling or pointing to direct another's attention and behaviour' is akin to the joint attention behaviours assessed by Mundy et al. (2007) of initiating joint attention, responding to bids for joint attention and initiating behavioural requests. In that study Mundy et al. (2007) found that initiating and responding to joint attention and initiating behavioural requests were all affected by cognitive function and therefore it can be expected in

LFA children (with associated ID) that this would be an area of their development that would benefit from support.

Furthermore, Mundy et al. (2007) reported that initiating joint attention and responding to bids for joint attention were predictive of language ability. Accordingly, facilitating communicative behaviour (e.g., responding appropriately to information or a behavioural request and telling or pointing to direct another's attention and behaviour) by supporting collaborative activity may well promote the development of both receptive and expressive language ability in LFA children. However, it should be noted that the research of Mundy et al. (2007) was from assessments of TD children and children at risk of development delay, so possibly the relationships between specific aspects of joint attention and ID and joint attention and language may not hold true for children with ASD.

Separate Control of Shared Space

The three mechanisms proposed by Yuill and Rogers (2012) to facilitate collaboration are; 1. raising the awareness of a partner, 2. controlling users' responses to be contingent on their partner's, and 3. increasing the availability of background information by providing cues about previous agreement. The family of SCoSS software used throughout this thesis exploits all three mechanisms and an integral feature of SCoSS software is the 'matching' constraint. This constraint requires players to come to an agreement about where to place pictures, so that players' individual game representations are identical. Therefore, matching requires that players take account of their partner's game state, accordingly raising awareness of their partner. Not only has the matching requirement raised awareness of a partner, but additionally, it has been found to increase contingent responses to a partner and in particular the use of imitation by LFA children.

Imitation

This thesis has detected two forms of imitation made apparent through LFA children's efforts to coordinate their actions to jointly solve the activities presented using the collaborative software: follower imitation and strategic imitation. Both forms of imitation demonstrate active other-awareness: contingent action that is related to the actions of a partner, but with different apparent underlying motivations.

Follower imitation is defined as the imitation of a partner's action by a participant naïve to the objective of the task, showing no understanding of their partner's intentions related to the task or discernible collaborative intent. The LFA child appears to use this form of imitation as a strategy to compensate for a lack of task understanding.

Strategic imitation is defined as the intentional copying of a naïve peer partner as a means to progress through the activity, displaying task understanding and collaborative intent. Therefore, strategic imitation shows an understanding of a partner's lack of intention towards the task. Intention understanding is typically assessed by an imitator performing the failed action of another person (Colombi et al., 2009a), whereas, in this instance the LFA child is displaying knowledge that his partner is lacking intention towards the task by imitating his uninformed action, therefore compensating for his partner's deficit. We argue that strategic imitation represents a form of perspective taking and, as proposed by Moll and Tomasello (2007) in their VIH, speculate that it might be a useful driver of social cognition.

Reflections of collaboration in LFA children using a SCoSS interface

Collaborative problem solving using Roschelle and Teasley's (1995) definition, as previously stated, is *"a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem."* (Roschelle & Teasley, 1995, p.70). Kerawalla et al. (2008) argued that the SCoSS interface supported collaboration by offering four features; 1) A separate control of elements in 2) their own private screen space with identical tasks to solve simultaneously 3) with agreement and disagreement explicity displayed and 4) constraints in place so that partners have to come to agreement to progress through the task. They found this promoted collaboration in TD children. The adapted versions of SCoSS implemented by the studies presented in this thesis offer the same four features as Kerawalla et al. (2008). Therefore, the evidence presented in this thesis suggests that the SCoSS interface was also effective at supporting LFA children in their efforts to work collaboratively with a partner compared to a single interface. Furthermore, LFA children paired with a peer were found to be unable to work together to complete a task when using dual control of a single interface. However, this is in contrast to the TD peer sample from study 1 of Paper 1, who were found to divide up the task and take turns i.e., cooperate with their peer partner to complete it. Therefore, some contexts may lend themselves towards cooperation i.e., the division of labour to complete a shared task, and dual-control of a single interface may be one such context, which is manageable for TD children, but not for TD children.

However, in studies exploring cooperation in LFA children, (Colombi et al. 2009; Liebal et al., 2008) individual roles were clearly defined and completion was reliant on two children performing two separate roles. In contrast, with dual-control of a shared single interface completing the task in a cooperative manner was not necessary: one individual could complete it unaided. This feature of unconstrained cooperation was not explored in the research for this thesis, but the choice to, or inability or unwillingness of LFA children to cooperate or collaborate when not constrained to do so is an aspect that warrants investigation.

In this thesis I have discussed the difference between collaboration and cooperation, with the essential difference described as a division of labour that should arise in cooperation, but not in collaboration. Despite this apparent subtleness of distinction, the consequences may be substantial in terms of the representational ability required for either process. According to Roschelle and Teasley's (1995) definition of collaboration, 'generating and maintaining a shared' representation of a problem is proposed to be essential for people to collaborate. If this is so, do people who cooperate generate different representations as they solve their portion of the problem, which then converge to a shared representation of the solution and hence are the representational skills required to maintain a shared representation while striving to solve a problem compared to representations needed to generate individual representations that converge on a shared solution? In other words, is it cognitively more demanding to collaborate than to cooperate or are they equal, but different, and if so what skills are necessary to facilitate these capacities? Roschelle and Teasley (1995, p.76) describe a 'cooperative pattern' of speech turn-taking they propose helps to construct a 'joint problem solving activity' (Roschelle & Teasley, 1995, p.76). This could suggest that, is cooperation is a prerequisite skill of collaboration.

Roschelle and Teasley (1995) argue that the internal shared representational or 'conceptual space' necessary for collaboration is "constructed through the external mediational framework of shared language, situation, and activity" (Roschelle & Teasley 1995, p.70). Thus, if we consider that LFA children do not have the benefit of typical language or communicative development, that should then affect their ability to use a 'shared language'. Their deficits in joint attention are a possible reason for difficulties experiencing a 'shared situation' and their deficits in imitation, potentially affect their capacity to participate in a 'shared activity'. Given these two factors, it is unsurprising that LFA children have difficulty collaborating with a peer partner under 'normal' circumstances. Therefore, it can be predicted that creating a shared conceptual or representational space in typical unsupported conditions would be challenging for LFA children. Indeed Colombi et al. (2009) did find that joint attention and imitation were positively associated with LFA children's ability to cooperate.

This thesis presents evidence that the SCoSS interface supported the collaborative process in LFA children doing a shared computer task. Therefore, these findings may be attributed to the four features the SCoSS interface offers which facilitate the generation of internal representations of a shared problem by reducing the reliance on the "externally mediated framework of shared language, situation and activity" (Roschelle & Teasley, 1995, p.70).

As previously discussed, if the cooperative tasks used by Colombi et al. (2009a) are assessed according to Roschelle and Teasley's (1995) definitions, I suggest they are a mix of both collaborative and cooperative tasks. Taking this into account, Colombi et al.'s (2009) findings are reveal that the LFA children had less difficulty with one of the cooperative activities, which was removed from the analysis due to their ceiling level performance. This is perhaps some evidence that those LFA children found cooperating less challenging than collaborating.

It should be noted that the picture-sorting activity used in Paper 1 and the picture-sequencing task used in Paper 3 simply required LFA children to place images in corresponding positions on their individual grids. This simple activity was chosen as the LFA children were known to have significant learning disabilities and as the novel SCoSS interface had only been administered to TD children (Kerawalla et al., 2008; Yuill et al., 2009) I was unsure if the LFA children would manage a harder task. Consequently, even though a 'picture-sorting/sequencing' problem was given to the LFA children, in fact they only had to show agreement, demonstrated by placing images in corresponding positions on their individual grids and therefore did not have to sort/sequence the images. Of course, there were no constraints preventing the LFA children from 'sorting' the images if they so chose. Even so, the LFA children find it difficult to coordinate their actions to show agreement, even at such a low level. Some of the LFA children when they partnered a peer did work out that they only needed to copy each others' image placement to progress through the task to complete it, and in pairs where they both realised the 'matching only' requirement, I would argue that from this shared understanding, collaboration occurred. The LFA children in this situation coordinated their actions, worked simultaneously and are therefore assumed to have generated shared representations of the problem internally from the external matching representations demonstrated in their individual screen space. Further, as LFA children were unable to discuss their ideas the construction of internal/external shared representations during the problem solving process was evidenced by their related and contingent (active other-awareness) behaviour.

Observation of active other-awareness in LFA children was crucial to judge collaborative behaviour. For example, in situations where only one child (A) in a peer partnership was judged to have understood the ‘matching only’ requirement of the sorting/sequencing tasks, he could be found to coordinate his actions with his partner, working simultaneously, but progressing by ‘strategically imitating’ his partner’s actions. In this situation child A could be judged as having related and contingent actions, whereas his partner, child B may show only attentional other-awareness (related behaviour). It should be acknowledged that in such a case the children are probably not generating a shared conception of the problem. Even though, child A is showing collaborative skills it is problematic to say ‘he’ is collaborating a point also made by Yuill (2014). However, I would argue that during the development of skills essential for collaboration, children will not always be ‘collaborating’. To return to the example, can child B be said to be cooperating? He is freely participating alongside his partner even if his behaviour is not contingent on his partner’s, but as argued by Fantasia et al. (2014), such low level interaction in LFA children may well be an example of early emerging cooperative skills.

Being able to collaborate with a partner to solve a computer task without SCoSS support is the outcome of a shared understanding of an intention to solve a problem together, without distributing labour cooperatively. This unsupported ability was not seen in LFA children in the studies presented in this thesis. This finding suggests that very little can be learnt about the collaborative process in LFA children from giving them a standard computer interface with one representation of a task to share, other than confirm they are impaired in this capacity, a point also made by Fantasia et al. (2014). Further, it adds to the growing body of evidence that LFA children are impaired in the ability to collaborate (Colombi et al., 2009a; Liebal et al., 2008). It is important to confirm such impairments, but it is as important to establish what support can be put in place to alleviate deficits and explore, if effective, whether such support can bring about long-lasting improvements that can additionally generalise to other contexts. Furthermore, the evidence in this thesis demonstrates that under the right conditions LFA children have the potential to collaborate.

By administering the SCoSS interface as a method to facilitate collaboration in LFA children working together to solve a computer task, this thesis has presented evidence that LFA children are able to display collaboration with varying degrees of success. Nevertheless, much more work needs to be done to elucidate the developmental processes of cooperation and collaboration using clearly explicit definitions as discussed here. With this knowledge we may then be able to determine if one is a precursor of the other and therefore share fundamental skills or if they are in fact distinct processes. This is key, as shareable technology is being used increasingly often as an intervention aiming to support cooperation and collaboration in children with autism. In order to be effective it is necessary to have a better appreciation of the developmental course of these processes and whether or not they are connected.

Further implications for theory and research

Carpenter et al. (2002) highlight that LFA children develop the ability to share another's attention after the ability to follow another's behaviour and point out that this developmental pattern differs from that found in TD infants. These developmental patterns were produced by trying to elicit specific joint attention skills, which as previously discussed, rely on gaze alternation between an object and another person (Carpenter et al., 1998). The investigation of other-awareness in this thesis did not try to initiate specific aspects of interactional behaviour, such as joint attention or imitation, but rather identified behaviour that occurred naturally during a joint activity. Using this approach this thesis has found that attentional other-awareness develops before active other-awareness in LFA children, that is, children show awareness of a partner's actions on a proximal object before they are able to show action on a proximal object that is related to and contingent on their partner's action. In terms of types of behaviour, this means LFA children, for example, watch their partner interacting with the joint activity before they show any form of imitative behaviour. This thesis is not presenting conflicting evidence to Carpenter et al. (2002), but rather it has added to the existing findings by identifying a type of other-awareness from which the ability to follow another's behaviour could emerge.

Eye gaze and autism

Gernsbacher, Stevenson, Khandakar, and Goldsmith (2008) present evidence that the covert attention skills of ASD individuals are intact and in some cases superior to non-ASD people. Covert attention describes the ability to monitor events that are perceived using peripheral vision and does not require a person to use eye gaze or a head turn to attend to an event. The arrangement of the family of SCoSS setups used throughout this thesis meant that LFA children worked side-by-side, rather than face-to-face. The evidence of covert attention in ASD reviewed by Gernsbacher et al. (2008) suggests that side-by-side positioning for LFA children may be beneficial by lending itself to the use of peripheral vision. The use of covert attention by ASD individuals is in line with the findings of this thesis, that LFA children showed attentional awareness of another without necessarily employing eye gaze or a head turn. Nevertheless, the LFA children in this study did also use more direct eye gaze and head turns to observe a partner's actions.

It should be noted that the some of the other-awareness behaviour of LFA children observed during this thesis would not have been identified using standard measures of joint attention as children participated in the joint activities without always producing gaze alternation. Furthermore, this thesis proposes that to fully understand the developmental process in LFA children we must develop assessment tools that can fully evaluate social interactional behaviour and not rely on using typical development as a blueprint to inform our decision-making regarding the design of interventions to promote social-cognitive development in ASD.

Motivation

This thesis found that LFA children showed a relatively high frequency of attentional other-awareness of a peer partner when presented with the collaborative activity in non-supportive conditions, but LFA participants were unable to translate this interest into active other-awareness. Supportive setups using collaborative-software enabled LFA children to actively interact with a peer. Consideration of these findings suggest that LFA children's higher frequency of attentional other-awareness in unsupported conditions represents an interest in interacting with their peer partner that is evidenced by the emergence of active other-awareness in supported conditions. The social motivation theory of autism posited by Chevallier, Kohls, Troiani, Brodkin, and Schultz (2012) predicts that deficits in social motivation are a cause of the impairments found in social cognition in children with ASD. However, this thesis presents evidence that LFA children did not withdraw from joint activities, but rather without appropriate support tended to act as mere observers. However, the same participants with collaborative support were able to actively interact with a partner and take part in a joint activity. Therefore, social motivation deficits do not seem to be a complete explanation of the results of this thesis.

The evidence in this thesis supports the idea that specific impairments in social cognition hinder LFA children's social-cognitive development by affecting their ability to participate autonomously in cooperative and collaborative activities. This lack of frequent experience of autonomous social interaction further affects their continuing social-cognitive development resulting in a decrease in their drive for social interaction.

Collaborative software

The difference between the SCoSS (Papers 1 and 2) and collaborative software (Paper 3) used for this thesis and the standard set-up comparisons used is the fact that each user has their own individual game representation that is linked to a partner's as opposed to sharing one game representation. The family of SCoSS software ensures that the activity is collaborative by linking users' game moves as previously discussed. Consequently, with the collaborative software LFA children can compare their own game state to their partner's without holding their partner's action or intention toward the game in mind. Therefore, any representational capacity that may be required, in order to share one game representation is avoided by explicitly making a partner's interactions with the shared activity available. Evidence suggests that LFA children can identify their own actions from another's moment-by-moment and from memory (Williams & Happé, 2009). So it can be assumed that LFA children are cognisant of the difference between their own and their partner's actions. Thus, the collaborative software may support the development of other-awareness and representational ability in LFA children.

Model of collaborative problem-solving

Paper 2 contributes a unique model of three prerequisite capacities LFA children need in order to participate in a collaborative problem-solving computerised task.

1. A basic understanding of how to interact with the activity. This fundamental ability can be achieved through attentional other-awareness: *awareness that is related to a partner's action.* In all the studies for this thesis the collaborative software was novel to the LFA children and to give them as much experience of the activity with adult support before they worked in peer partnerships they were always given a practice round with an adult and adult-child tasks before any peer-peer experimental conditions. Nevertheless, some of the LFA children were still unable to participate independently in the joint activity with a peer or adult partner. Children unable to participate independently showed very limited spontaneous attentional other-awareness and what little they did display was with hand-over-hand support or prompted by an adult.

Therefore, LFA children lacking in the first prerequisite might benefit from activities with an adult to scaffold their attentional other-awareness to the adult's interactions and this may support coordinated activity and help them to be able to interact independently with the collaborative interface. When children are able to interact independently with the activity LFA children may benefit from peer-peer activity with low collaborative constraint. However, the findings of this thesis do not advocate that LFA children need to be able to independently complete a picture-sorting activity before participating in a joint activity with a peer, but be merely capable of attempting it.

2. The capacity to coordinate one's own action with another's. This capacity equips LFA children with the ability to learn through coordinated action and is exemplified by follower imitation. This pragmatic imitative skill enables a child to learn through copying a partner's actions without possessing an understanding of a partner's intentions. If two children possessed this capacity they were able to successfully complete a matching-only task. Strategic imitation was another strategy used by LFA children to navigate the matching-only task. This skill enabled a more proficient player to make task progress by intentionally copying the actions of a naïve peer partner. This meant that in peer partnerships where one of the peers did not have the second prerequisite, a partner could implement this form of imitation to coordinate his actions with his partner's and facilitate task success.

3. The capacity to encourage coordination of another's action with one's own. Manipulation of the collaborative constraints administered by the SCoSS software in Paper 2 highlighted that to solve a problem with more than a matching-only constraint, follower and strategic imitation were not sufficient to make task progress. For a problem with a higher level of collaborative constraint (e.g., a problem with two attributes to consider) at least one of the LFA children of a peer partnership needed to be able to realise that the problem contained more than a matching element, and to solve the problem, had to encourage their partner to follow their actions. This was a challenge for LFA children with limited communicative ability. However, it was observed that some of the LFA children given the H-C task, did manage to encourage their partner to coordinate their actions with their own, in order to solve the more challenging problem (Paper 2). LFA children in adult-child partnerships in Paper 3 were also observed to produce the third prerequisite, but in view of the fact that Paper 3 only presented an L-C activity, this thesis can only suggest that the third capacity may have emerged in peer partnerships using collaborative software if they had been given the additional challenge of an H-C activity.

Collaboration in TD preschoolers

Study 1 of Paper 1 investigated collaboration in 32 TD children aged 2 – 4 years. This was considered an appropriate comparison group: the youngest TD children who would be able to use a computer mouse and attempt a collaborative computer activity with both an adult and peer. In line with our findings for LFA children, TD children also benefitted from collaborative-software, showing significantly more other-awareness using SCoSS than non-SCoSS. Interestingly, like LFA children, TD children also showed an effect of partner; they were significantly more actively aware of a peer than an adult. However, unlike LFA children, TD children did not need the SCoSS interface to facilitate active other-awareness and there were no significant differences found between SCoSS and the non-SCoSS interfaces. TD children were very comfortable using a standard interface and managed sharing one game representation by taking turns or dividing the two categories of pictures between them so that they sorted one group of pictures each. The ability to organise turn-taking to facilitate joint action in the unsupported computer set-up demonstrated that TD preschoolers had the capacity to both coordinate their actions with their partner's and also encourage coordination of a partner's actions with their own. Therefore, TD preschoolers could collaboratively problem-solve without support.

Overview of engagement findings

Overall LFA children rarely withdrew from any of the activities presented in all the papers for this thesis, irrespective of the type of shareable technology or if they were using supportive software or not. On average approximately only one withdrawal behaviour was observed per task throughout the research. The fact that LFA children showed very little withdrawal behaviour independent of the type of computer technology or software they used during research for this thesis replicates the frequently-reported finding that children with autism are motivated by computers (Ploog et al., 2013).

However, the profile for approach to task behaviour in LFA children is somewhat more complex, showing effects of type of computer set-up on engagement:

Paper 1 compared the effect of SCoSS to a non-SCoSS software interface and Paper 3 similarly compared a single tablet to a dual tablets and both papers also examined the effect of partner type i.e., peer or adult. Approach to task behaviour reported in both papers was more than twice as frequent when children used the set-up designed to support collaboration compared to a more typical set-up. The type of partner was not found to affect approach to task behaviour.

In Paper 2 LFA children worked in peer partnerships to solve two collaborative problems using SCoSS on a DT surface H-C (matching) and L-C (correctly categorised and matching). LFA peers doing the H-C activity demonstrated approximately twice as many approach to task behaviours than when doing the L-C activity, although this difference was not significant. Additionally, the H-C condition produced the highest mean frequency of approach to task behaviour per activity demonstrated throughout this research.

The engagement findings of this thesis indicate that LFA children were motivated to engage with technology, but that the type of partner did not have a significant effect on engagement. However, the design of the collaborative software including more constraints could potentially have an influence on increasing LFA children's engagement more than shareable technology alone. Furthermore, by evaluating children's engagement with the activities presented during research for this thesis, the findings can be more confidently attributed to differences in LFA children's other-awareness and not due to task withdrawal.

Development of other-awareness coding scheme

Other-awareness: the capacity to be aware of sharing an activity or event with another person. Divided into two subtypes: attentional other-awareness, awareness that is related to a partner's action and active other-awareness, action that is related to and contingent on a partner's action.

The other-awareness coding scheme is a novel contribution to the field of autism research, enabling the analysis of interactive behaviour between collaborative partners. Its development during the research presented in this thesis has honed its function to effectively identify other-awareness. As discussed the identification of other-awareness often relies on gaze alternation. However, children participating in the collaborative computer activity were able to watch their partner's interactions with the activity, showing other-awareness without needing to gaze at their partner and back to the object. For example active other-awareness was coded when a child, A, placed a picture on the grid without pressing 'We agree' and waited for his partner, B, to make a move. Once B had moved his picture on to the grid, A acted contingently by pressing his 'We agree'. Therefore, A did not need to alternate eye gaze to confirm his awareness: his contingent action was verification. Taking a similar example to illustrate attentional other-awareness: child A placed his picture on the grid without pressing 'We agree' and waited for his partner B to make a move, watching his partner's side of the screen. In this example when partner B made his move A remained watching and did not act contingently. These are just two examples, but clearly show how gaze alternation is not necessary to establish the existence of other-awareness behaviour. This method of using related and contingent action to identify other-awareness has only been applied to LFA children and such a coding scheme may be useful to evaluate the other-awareness of ASD individuals of all levels of functioning and advance our understanding of the development of this fundamental capacity in ASD.

Challenges and limitations

The studies presented in this thesis have investigated the performance of LFA children working together on computerised tasks using a supportive interface, therefore these findings cannot be generalised to the collaborative process in other contexts, such as their ability to categorise tangible objects with a partner. Thus, further research investigating a wider range of tasks is necessary to consider other contexts, in addition to tracking the developmental pattern of collaboration in LFA children as discussed earlier.

Thesis gender bias

As discussed in the thesis introduction, ASD is predominantly a male disorder, with ratios of about 4:1. Nevertheless, research suggests that in LFA children the ratio of males to females is closer to 2:1 (Fombonne, 1999). However, this was not the experience of the author when recruiting LFA participants for this thesis. Girls were not available in the ASD units of the special schools that took part. Whether this is an effect of problems with diagnosis or a true reflection of the situation, further research is warranted to explore the issue of ASD diagnosis and the lack of research including females with ASD.

Sample size

A weakness of this thesis is the small sample sizes of each paper, although this is not unusual in autism research. A review of social skills interventions for individuals with autism by Reichow and Volkmar (2010) reported 66 studies and of them only nine studies had more than five participants. The occurrence of small sample sizes in autism behavioural research may be due to the challenges of working with individuals with autism and in particular LFA children. This may be made more problematic by the small class sizes in special schools compared to mainstream schools making it harder to gather larger sample sizes efficiently.

Assessment measures

In retrospect it may have been advantageous to have more measures of LFA children's functioning. It is important to explore potential relationships between IQ, verbal mental age and non-verbal mental age and other-awareness ability as there is a limited and mixed picture regarding the association between IQ, joint attention, imitation and also language ability in LFA children.

Reflections on running technology-based experiments in schools with LFA children

The teaching staff were always very enthusiastic and pleased to support the research presented in this thesis. The LFA children in the studies were motivated to use the technology, which was also a benefit. However, the LFA children's keen interest was accompanied by many challenges, as they would often try to explore the technology, rather than follow the experimental procedure. For example, in study 2 of Paper 1 some of the LFA participants would press the computer keys managing to freeze the computer, and they also managed to find a way to use the cursor to erase the interface. The keyboard was covered with a thick piece of paper to prevent them pressing the keys, but it would have been better to disable the keyboard, if it were possible. In Paper 3, there was a similar issue with LFA children pressing the 'home' button, returning them to the start screen. This was successfully resolved by covering the home button by taping some thick paper over it. Generally, this type of behaviour only occurred at the start of the sessions and once children were involved in the activity they remained on task.

In study 2 of Paper 1 and in Paper 3 the set-up in the special school was quite straightforward. I was assigned a classroom and given plenty of time to set-up the technology and videotaping equipment, with the assistance of another research student. The technology for Paper 1 was a laptop with two mice and for Paper 3 two tablets, and was therefore relatively easy to transport and set-up. The LFA children were brought to participate by their teacher or key-worker, who remained in the room throughout testing.

The SCoSS software in Paper 1was an application that was preloaded onto the laptop computer, whereas in Paper 3 the SCoSS software was controlled and ran on the tablets from a server accessed via wifi. In theory this should have made little practical difference for running my study. However, it was almost impossible to access the special school's internet, due to a very secure firewall. It took over an hour to find a member of staff who had some knowledge of how to enable access to the internet on our devices. Fortunately, during data collection for this study, I was assisted by the software developer, and his help was essential to solve the IT problems.

The experiment for Paper 2 used a DT table that consists of a large horizontal screen, a projector with a stand, two conductive mats, a laptop and many cables and connector leads. The DT, compared to the other technology used for this research was more arduous, as the large heavy equipment that was more difficult to transport. It was also more complex to set-up, requiring care sequencing and calibration to work.

When it is set-up the DT table is quite a large piece of equipment, and required a sizable proportion of the room offered by the special school to run the experiment. In all the experiments carried out for this thesis the equipment was taken away after each daily session, and because of the amount and size of the DT.

The difficulty of running the study for Paper 2 was also made all the more difficult, by the lack of availability of a second researcher. This was problematic as carrying and setting up the equipment, making sure the camcorders were turned on, following the experimental procedure and adjusting the equipment when things went wrong, would have been overcome with help.

Of all the shareable technology used during the research for this thesis, the DT was the least robust for use with LFA children. The specific table was an experimental model, kindly on loan from Mitsubishi, and did not come with technical support and had been given fairly frequent usage for other studies with only limited maintenance.

Users were required to remain on the mat to be able to interact with the DT, and I had to frequently ask the LFA children's key-workers to adjust the positioning of the children. Further, there were a variety of issues related to the 'touch' recognition of the DT surface. It can only recognise one 'touch' from an individual standing on each mat, and so if children placed their 'nonworking' hand on the edge of the table and this hand made contact with the surface, which they frequently did, the interactions of their 'working' hand would not be recognised or only recognised intermittently. Unfortunately, it was often difficult to spot this quickly, as the contact could be barely noticeable and this caused some frustration for the children it affected. The wires that connected the mats to the DT, could also become loose or lose for undiagnosable reasons, so sessions often had to be suspended to regain the connection.

The interface for the DT was projected onto the surface, and if the LFA children noticed this, they become distracted at times. For example children lay across the table and looked at the coloured lights projected onto their hands and arms. They were also distracted by the controlling laptop, which had a replication of the screen projection. Some of the LFA children would compare the two screens. Nevertheless, when it was set-up and working well, the DT was an excellent piece of technology to run the SCoSS application on, in order to support joint activities between LFA peers in school. With its ability to identify individual users being a particularly valuable feature not available with some other touch table systems.

All the technology and software used for this thesis was innovative, and so at times unreliable. With the TD children in study 1 of Paper 1, it was possible to explain what was happening when problems arose. The TD children that took part in the study were compliant and content to wait, while the software or hardware was restarted. However, with the LFA participants, and in particular with those with more communication difficulties, found the unreliability of the technology difficult to cope with, and could be understandably be a source of frustration and upset, and in extreme cases the participants would withdraw from the activity.

Children with autism can become absorbed in repetitive types of behaviour, such as flicking their fingers in front of their eyes. When demands are placed upon them to interact with others or stop what interests them, they can become anxious or aggressive (Smith, 1999). The LFA children who participated in the research for this thesis, although sharing the same core difficulties including a learning disability, had very varied levels of functioning in terms of expressive language, repetitive and anxious types of behaviour. This was expected and so I took a flexible approach to how much support children needed. It was important that the activity of interacting with a partner was not a negative experience, and I made a judgment call regarding the level of experimenter intervention during the experimental process on an individual basis, with the proviso that experimenter intervention was as minimal as possible. Experimenter support was frequently related to helping children use the technology. However, in some of the peer partnerships, hand-over-hand help was deemed appropriate. The experimenter facilitation was only necessary in peer-peer partnerships, as naturally in peer-adult partnerships this was available from the adult partner.

This experimenter facilitation generates a limitation in regards to experimental control, although this dynamic approach to experiments with LFA children in everyday environments may be an inevitable and more useful approach with this participant group.

Future directions

The SCoSS framework and collaborative software have been found more effective at supporting other-awareness in LFA children compared to a non-SCoSS standard setup. The Vygotskian intelligence hypothesis forwarded by Moll and Tomasello (2007) propose that collaborative activity is the driving force of social-cognitive development in TD children. However, the effect of long-term exposure to collaborative activity in LFA children is as yet unexplored. Therefore, the findings in this thesis suggest a promising direction of research would be to investigate the long-term effect of repeated exposure to supported collaborative activities in LFA children.

Manipulating the level of constraint within the collaborative activity was shown to further support active other-awareness. However, this thesis only presents evidence from one study (Paper 2) using LFA peer partnerships, and more research investigating the influence of constraining the activity using collaborative software and exploring the role played by the type of partner is warranted. This thesis has focused on peer and adult partnerships, but proposes that research should also consider how other partnerships, such as parents and siblings could affect other-awareness in LFA children.

Autism research comparison groups

The term LFA has been used to distinguish the children in this thesis as having an intellectual disability, but even within the LFA group there is a very wide range of ability. This was particularly noticeable in the participants of Paper 2: in this study the participants attended a special school that had altered its enrolment policy from only accepting children with moderate learning disability (MLD) to also admitting children with severe learning disability (SLD). Hence, the ASD unit of Paper 2 tended to have a wider spectrum of ID than the participants in Papers 1 and 3, as those participants attended a long-established special school, serving children with SLD to profound ID. From the qualitative analysis of a purely LFA sample in Paper 2, it has been possible to construct a model of collaborative problem-solving. It was made possible by being able to compare and analyse the varying abilities of LFA children with other LFA children. Considering these findings it may be more informative and effective at reducing the adaptive impairments of LFA children to compare and analyse their behaviour to other LFA and also possibly HFA children. To date interventions have been designed using research based on comparisons of ASD to typical development to discern deficits in the abilities of ASD with the aim of improving specific skills to reproduce typical development in the ASD population. However, trying to replicate typical development in ASD individuals has had limited success in reducing poor long-term outcomes in this group (Kasari & Smith, 2013). Therefore, using knowledge gathered from comparisons of LFA to LFA and LFA to HFA might help to create interventions that close the gap in adaptive functioning between these related groups and have more potential to improve long-term outcomes for LFA children.

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Appendix 1
Dual-control laptop – Coding scheme

Approach	Withdrawal	Active Awareness	Attentional Awareness
Smiling - 1	Crying - 8	Looking at *screen* while waiting contingent with continuing own task - 13	Watching screen as partner does task - not preceding continuing own task – 24
Pointing at screen - 2 (for reward/or imitating adult)	Hitting /pushing self/other – 9	Looking at *partner* while waiting contingent with continuing own task - 14	Watching partner as he does task - not preceding continuing own task – 25
Moving closer to screen - 3	Angry standing up - 10	Trying to use partner's mouse -15	Giving up mouse use when able to use it – 26
Clicking 'We agree' icon when games don't match - 4	Moving/looking away -11 (not distracted by another activity)	Looking at mouse contingent on continuing own task - 16	Clicking on We agree icon when games match, but not after waiting – 27
Clicking 'We Agree' icon when told to - 5	Giving up mouse use due to an inability to use it - 12	Moving piece to match partner's arrangement without correction being given - 17	Moving piece to match partner's arrangement after correction is given – 28
Trying to use mouse although unable - 6		Moving correctly placed piece so it doesn't match partner's arrangement - 18	Looking at mouse while partner does task – 29
Looking at own mouse while trying to use it - 7		Pointing at screen to inform partner where to put their piece - 19	Looking from partner to screen - 30
		Attempting to put own piece on top of partner's piece – 20	
		Engaging in turn-taking - 21	
		Place a piece and look at partner for response – 22	
		Asking/indicating for help to use mouse to move piece – 23	

Appendix 2

Game order for experimental procedure

Game Code	Game Name	Content	Condition
AP	Mr Men + Tweenies (4x2)	Mr Men (Books) V Tweenies (group pictures)	Practice round with Adult
A1	Teletubbies + Toystory (4x2)	Teletubbies (characters with no background V Toy story (Woody, Buzz, Jessie and various characters from film)	Game 1 Adult partner
A2	NumberJacks + Postman Pat (4x2)	Numberjacks (scenes) V Postman Pat (scenes all with PP)	Game 2 Adult partner
A3	Mr Men + Thomas the Tank (4x2) CM NS3	Mr Men (characters from cartoon series V different tank engines from cartoon series)	Correct Matching Non-SCoSS Game 3
A4	Night Garden + Postman Pat (4x2) CM S4	Night Garden V Postman Pat	Correct Matching SCoSS Game 4
A5	Tweenies + Teletubbies (4x2) AM S5	Tweenies (Milo, Fizz, Bella) V Teletubbies (Tinky winky, Lala, Dipsy, Po)	Matching SCoSS Game 5
A6	Toy Story + Thomas the Tank (4x2) AM NS6	Toy Story (Jessie & Woodie, Woodie & Buzz, Mr & Mrs Potato-head, Buzz) V Thomas	Matching Non-SCoSS Game 6

Class B			
Game Code	**Game Name**	**Content**	**Condition**
BP	Pokemon 1 (4x2)	Pikachu V Ash	Practice round with Adult
B1	Transformers 1 (4x2)	Cars V Robots	Game 1 Adult partner
B2	Ben 10 (4x2) M NS6	Ben 10cartoon scenes V toy figures	Matching Non-SCoSS Game 6
B3	Pokemon 2 (4x2) CM S3	Pokemon catoon V Pokemon toy figures	Correct Matching SCoSS Game 3
B4	Ben 10 (4x2) CM NS4	Ben 10 merchandise V Ben 10 cartoon character	Correct Matching Non-SCoSS Game 4
B5	Transformers (4x2) M S5	Transformer scenes V Transformer toy robots	Matching SCoSS Game 5
B6	Cards (4x2)	Ben 10 V Pokemon trading cards	Game 2 Adult partner

Appendix 3

MULTI-USER DIAMOND TOUCH INTERACTIVE TABLE TOP CODING SCHEME

	Active Other-awareness		Attentional Other-awareness
12	*Waiting* while looking at their partner's ***screen*** as partner is doing the task, then *pressing 'We agree'* ***before*** *partner*	26	Looking at their ***partner's screen*** as their partner does the task
13	*Waiting* while looking at ***partner*** as they do the task, then *pressing 'We agree'* ***before*** *partner*	27	Looking at *partner* as they do the task
14	Looking from partner to screen ***contingent on*** continuing own task	28	Looking from ***partner*** to ***own screen*** – visual checking
15	Moving already placed piece to match/copy their partner's arrangement without correction being given, but after looking at partner's side	29	Clicking 'we agree' when games match, but ***not*** after waiting or ***not*** before partner presses 'we agree'
16	Moving already placed piece to match/copy their partner's arrangement after correction is given	30	Looking from partner's side of screen and to own side of screen
17	Looking from partner's side of screen and own side of screen and then moving piece to match/copy partner's arrangement		
18	Attempting to put own piece on partner's matching piece		
19	Telling & or pointing to inform partner about the game		
20	Responding appropriately to information given by partner		
21	Asking/indicating for partner's help		
22	Responding appropriately to request for help by partner		
23	Watching partner make a move and clearly copying action		
24	Moving already placed piece so it doesn't match partner's arrangement following their partner placing their piece correctly		
25	Engaging in turn-taking –indicated verbally or behaviourally		

	Approach to task		Withdrawal from task
1	Smiling	6	Crying
2	Clicking we agree to start game, and when game's state is such that clicking we agree will not give another picture – do not count randomly repeated presses	7	Moving/looking away (not distracted by another activity / person /noise unrelated to game)
3	Randomly moving piece around	8	Giving up due to an inability to move pieces
4	Trying to move or press partner's pieces without looking or indicating to partner	9	Playing with lights or laying on table
5	Moving piece when told to by experimenter	10	Angry, frustrated behaviour to table

***If table stops working properly or the experimenter thinks it isn't working, stop coding until it is running properly again and mark time lapse**

**** Do not code if one of the children leaves the table i.e., only code if both children present and mark time lapse**

Appendix 4

Tablet other-awareness coding scheme

Active Other-awareness	Attentional Other-awareness
Waiting while looking at their partner's ***screen*** as partner is doing the task, then *pressing 'We agree'* ***before*** *partner*	Looking at their partner's ***screen*** as their partner does the task
Waiting while looking at ***partner*** as they do the task, then *pressing 'We agree'* ***before*** *partner*	Looking at ***partne****r* as their partner does the task
Looking from partner to screen ***contingent on*** continuing own task	Looking from ***partner***/**screen** to ***own screen*** **–** visual checking
Moving already placed piece to match/copy their partner's arrangement without correction being given, but after looking at partner's side	Clicking 'we agree' or moving piece after looking at **partner/partner's screen** but not contingent on partner's action
Actively preventing partner from interacting with the game	
Imitating verbally game related comments	
Trying to move partner's game pieces	
Telling & or pointing to inform partner about the game	
Responding appropriately to information given by partner	
Asking/indicating for partner's help	
Responding appropriately to request for help by partner	
Watching partner make a move and clearly copying action	
Engaging in turn-taking –indicated verbally or behaviourally	

Appendix 5

Tablet engagement coding scheme

Approach to task	Withdrawal from task
Smiling / laughing related to task	Moving/looking away from task (not distracted by another activity / person /noise unrelated to game)
Clicking we agree to start game	Giving up due to an inability to move pieces
Randomly clicking We agree moving piece around	Playing about with technology instead of with task
Randomly moving game pieces around interface without reference to partner' game	Angry, frustrated or distressed behaviour
Moving piece when told to by experimenter	