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Piloting a digitally-mediated social story intervention for autistic children led by teachers within naturalistic school settings

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Abstract

Background: Social stories (SS) are widely used within the autism community. However, research into their effectiveness is mixed at best and mainly relies on single case study designs. Additional support from the researcher is also often provided, raising questions as to the use and effectiveness of SS within usual school settings.

Method: Seventeen school teachers developed and delivered personalised digitally-mediated SS with 22 autistic children (aged 5-11yrs) over a 4-week intervention period. Data was collected during a baseline period (1 week), throughout the 4-week intervention phase and at 6-week follow-up to consider changes in child behaviour, understanding and anxiety. A new assessment framework to evaluation treatment fidelity according to Gray's 10 Criteria was also developed.

Results: With the support of a new SS app teachers were able to carry out SS interventions with a high degree of fidelity within their usual school settings. Behavioural data showed significant improvements from baseline to week 4 for all measures relating to the goals of the intervention (including a reduction in anxiety and an increase in understanding), some of which were still present at follow-up.

Conclusion: This study has demonstrated that technology can be used to support teachers to develop and deliver SS interventions to autistic children within school settings. Such technology can now be used to facilitate much needed future, larger, controlled studies within this area. Implications for practice is discussed.

Introduction

Autism Spectrum Disorder (ASD; hereafter autism) is a lifelong neurodevelopmental condition, characterised by impairments in social communication and interaction, combined with restrictive and repetitive behaviours, activities and interests (American Psychiatric Association, 2013). The number

of children and young people with a diagnosis of autism has increased dramatically over the past two decades (CDC, 2014; Manning-Courtney et al., 2013) with a recent study reporting a prevalence rate of 1 in 59 children (Baio et al., 2018). Autistic children have also been found to be at increased risk of experiencing mental health conditions, such as anxiety as well as challenging behaviours (Hartley, Sikora, & McCoy, 2008) which can have a negative impact on daily activities and create life-long barriers to inclusion (Brereton, 2006). A wide range of interventions have been developed to support the needs of autistic children (see National Standards Report, 2015). However, many of these are complex, costly and require specialised training, meaning that in school settings, where such resources are limited, they can be difficult to implement and maintain (Lang et al., 2010; Machalicek, O'Reilly, Beretvas, Sigafoos, & Lancioni, 2007).

Social Stories™ (SS) is an intervention for autistic children that offers the potential for being relatively simple, flexible and low-cost (Chan et al., 2011). SS are highly structured and personalised social narratives, designed to address the behavioural, communicative and social difficulties associated with autism (Hutchins & Prelock, 2013). They provide visual support, detailing what to expect and what constitutes appropriate behaviour, with a primary goal of increasing the child's understanding of the situation. A set of specific criteria regarding their development and delivery is outlined by Carol Gray, and includes rules on sentence types and the ratio between them, to ensure the content has an emphasis on being descriptive, rather than directive (Gray, 2019; Gray & Garand, 1993). First introduced in the early 1990s, SS quickly became a popular intervention for use with autistic children (Green et al., 2006; Hess, Morrier, Heflin, & Ivey, 2008). In practice, they are considered by teachers to be both an effective (Moore, Wright, Williams, Moore, & Dempster, 2014; Reynhout & Carter, 2009), and acceptable (Rhodes, 2014) intervention. They are listed as one of the 'established' procedures for use with autistic children within the National Standards Report (2015), and are among the top five interventions parents have used with their autistic children (Green et al., 2006; Hess et al., 2008).

However, despite their popularity, there has been ongoing difficulties with establishing a strong evidence base regarding their effectiveness. Over the past 25 years there has been an increase in the number of published research studies investigating the effectiveness of SS and numerous reviews have been conducted (e.g. Ali & Frederickson, 2006; Garwood & Van Loan, 2019; Kokina & Kern, 2010; Leaf et al., 2015; Mayton, Menendez, Wheeler, Carter, & Chitiyo, 2013; McGill, Baker, & Busse,

2015; Qi, Barton, Collier, Lin, & Montoya, 2018; Reynhout & Carter, 2006, 2011; Rust & Smith, 2006; Styles, 2011; Test, Richter, Knight, & Spooner, 2011; Wright et al., 2016). While several individual case studies report positive findings, for example indicating a reduction in problem behaviours (e.g. Crozier & Tincani, 2005; Scattone, Wilczynski, Edwards, & Rabian, 2002) or an increase in appropriate behaviours (e.g. play skills - Barry & Burlew, 2004; lunchtime - Bledsoe, Myles, & Simpson, 2003) associated with SS, conclusions from literature reviews and meta-analyses have been less favourable. Such reviews highlight a wide variation in terms of both effectiveness and effect sizes across studies and participants, and a series of methodological weaknesses. Kokina and Kern, for example, classified 51% of their included SS as 'highly effective', while almost all the remaining stories (44%) were classified as 'ineffective'. Similarly, McGill et al (2015) found effect sizes to vary from small to large. Such variation may be linked to differences in the way SS are implemented (e.g. intervention setting, duration of intervention, adherence to Gray's guidelines), the skills/experience of the person who develops/delivers the story, and/or child characteristics (e.g. age, cognitive ability, autism diagnosis, comprehension). Given the personalised nature of SS this variation is perhaps not entirely unexpected. However, while the flexibility and high level of personalisation are notable strengths of SS interventions, in order to maximise therapeutic benefits there needs to be a clear understanding of how and when they should be implemented, and for which children they are likely to work best for.

The accessibility of SS to parents and practitioners also raises potential issues regarding fidelity which have been highlighted by reviews of the available literature that have raised issues relating to ecological validity (Mayton et al., 2013; Styles, 2011). Styles, for example, raises specific concerns regarding the development and delivery of SS, suggesting that researchers have been too involved in the implementation of interventions which form part of research studies, meaning that findings may not represent the practice within usual school settings. Also, McGill et al. (2015) found that effect sizes were considerably larger when SS were delivered by researchers, compared to teachers, stressing the need for teachers to be able to implement them independently, and with fidelity. Thus, the apparent simplicity, flexibility and low cost of SS may enable a level of access to the development and delivery of the intervention that could undermine its effectiveness, compared to when the intervention is developed and delivered in line with the intervention guidelines set out by Carol Gray. Within the context of research it has been well documented that the SS described often fail to comply

with the recommended construction, and it has even been suggested that the stories that deviate from the guidelines are more effective than SS that conform to the guidelines (Reynhout & Carter, 2006, 2009; Tarnai, 2012). The relationship between adherence to Gray's guidelines and SS effectiveness is therefore unclear. Very little research has considered how SS are used by teachers outside the context of a controlled research study, and the application of Gray's current guidelines (Gray, 2010, 2019). Information from a survey of teachers in 2006, for example, indicated that around 40% of SS deviated from Gray's recommended sentence ratios (Reynhout & Carter, 2006) but no studies to date have considered the implementation of SS in relation to the current 10 criteria (Gray, 2010), and how this impacts on effectiveness.

One possibility for providing support to teachers delivering SS interventions within naturalistic settings may be through the use of digital technology, which could enhance fidelity. Digital interfaces, such as iPads and tablets, are relatively inexpensive and often readily available within classrooms. They have the potential to reduce variability in story delivery and support the development of SS consistent with Carol Gray's guidelines through providing appropriate tutorial information (for a systematic review of the benefits of iPads for autism interventions see - Kagohara et al., 2013). Computers, video modelling and smart boards have been used for SS intervention within classrooms with varying success (Chen, 2018; Hagiwara & Myles, 1999; Sansosti, 2006; Xin & Sutman). Teachers and autistic children report they prefer computer-based SS compared to the traditional paper format (Mancil, Haydon, & Whitby, 2009), and the evidence for computer-based interventions for autistic children, whilst mixed, is promising (Alzrayer, Banda, & Koul, 2014; Kagohara et al., 2013; Ramdoss et al., 2012). In Karal and Wolfe's (2018) review, for example, the addition of a number of visual components specific to digital technology (e.g. including photographs of participants in the SS), were associated with the most effective SS.

In a recent Randomized Control Trial, 'Anonymised' demonstrated positive changes in behavioural outcomes associated with a digital SS intervention using a prototype for a new SS app (SOFA: Stories Online For Autism), that was co-developed with the autistic community (SOFA-app.org). The authors found significant improvements between baseline and follow-up (6 weeks after the intervention) for the intervention group (n = 9 autistic children), compared to an attentional control group (n = 6 autistic children). Whilst these early findings are encouraging, the SS in this study were developed and delivered by a Researcher, as opposed to the teacher, and they were delivered

adhering to a highly controlled research protocol (i.e. twice a day for a two-week period). The literature above, however, suggests that whilst this may be effective within the context of a research study, this may not accurately reflect how teachers use SS within their usual practice, without the additional support of a Researcher.

The current study aimed to address concerns about the ecological validity of the SS research base by considering how teachers use SS within the context of their usual school practice over a prolonged period (4-weeks). A primary focus was to assess treatment fidelity, specifically to investigate the extent to which the teachers followed Carol Gray's latest guidelines (10 criteria, Gray, 2010) with the support of technology provided by the SOFA app. Measures of behavioural frequency and intensity, closeness to the SS goal (see Marshall et al. (2016), the child's perceived understanding of the situation and anxiety levels were all monitored in order to consider effectiveness over the 4 week period and at a 6-week follow-up. A secondary aim was to consider a range of intervention and child characteristics in order to attempt to better understand how SS should be implemented and for which children they are likely to be most successful for.

Method

Participants

Twenty-three autistic children were recruited to take part in the study. Children were selected to participate if they were confirmed by their teacher to meet the following inclusion criteria: a clinical diagnosis of autism; aged between five and eleven years with receptive and expressive language skills above a single word level. Teachers also provided an overview of the children's capabilities (see Table 1), based upon the criteria from Reynhout and Carter (2009) and Kokina and Kern (2010). One child declined to engage with the intervention, leaving 22 children (18 males; 4 females) with a mean age of 8.25 years (range = 6 – 11, *SD* = 1.74). Four children had an additional diagnosis of intellectual disability, one had an additional diagnosis of ADHD and one had an additional diagnosis of dyspraxia.

The three levels of severity that teachers used to rate the children related to the levels of support identified by DSM-5 APA, 2013), namely 'requiring support', 'requiring substantial support', and 'requiring very substantial support'. However, the methods by which teachers, clinicians and researchers operationalize severity largely depend on individual preference, background, and training (Weitlauf et al., 2014). Class teachers rating have been found to correlate well with both formal assessments of the diagnostic criteria for autism (Azad et al., 2016) as well as parental ratings – although parents can rate slightly higher (Constantino et al., 2003; Nordahl-Hansen et al., 2013; see also Kanne et al., 2009; Jepsen et al., 2012).

TABLE 1

Seventeen teachers (which includes teaching-related staff) volunteered to take part in the study, developing (i.e. writing) and delivering (i.e. presenting to the child) the SS intervention over a 4-week period. The teachers' characteristics and experience with SS were identified and are presented in Table 2.

TABLE 2

Procedure

Participants were identified following a recruitment phase that employed an opportunity sampling technique. This was conducted via email to recruit autism specialist and mainstream schools in the South West of England. Teachers of participating schools were invited to take part in a study to investigate the effectiveness of a new SS app (SOFA-app, see below) during a three-month period between Easter and Summer vacations. Prior to the intervention, a set-up meeting was scheduled with each of the participating schools and the Researcher (first and/or second author) to identify children meeting the inclusion criteria. A brief training session was also provided on how to use the SOFA-app, and teachers were provided with information on Gray's criteria (within a tutorial section in the SOFA-app and a printed handout). The teacher working with the child identified one target behaviour per child (e.g. hitting other children) that they felt would be appropriate for addressing with a SS and the goal of the intervention (e.g. not hitting other children). Thus, the goal of the intervention

directly related to the target behaviour and is a reliable way of teachers reporting SS intervention data (Marshall et al., 2016). A personalised SS was developed for each child by their teacher using the SOFA-app prototype. Stories were then delivered individually to each child by their teacher via an iPad over a 4-week period. Teachers monitored the children's behaviour using the 'weekly behaviour diary' (see below) during the week prior to the study (baseline), over the 4-week period, and at the 6-week follow-up (10 weeks after the start of the 4-week intervention). After the study, the category of the SS was identified by the first two authors, to identify if they were targeted at reducing inappropriate behaviour, increasing positive behaviour or preparation for change/event – including whether anxiety reduction was mentioned in this latter category (Kokina & Kern, 2010; Qi et al., 2018). A framework was also developed and applied enabling assessments to be made as to whether Carol Gray's 10 Criteria were followed. This involved both analysis of the SS texts and responses to an online questionnaire, completed by the teachers (see Appendix A).

SOFA-app development

Kim et al. (2018) reviewed nearly 700 mobile device apps listed under "Autism Apps" and found the 0.6% has direct evidence to support their usage. All this evidence was pilot study data and did not include clinical trials. Fletcher-Watson et al. (2015) conducted the first clinical trial for an autism app and did not find any direct evidence to support its use (see also Parsons et al., 2019a; Zervogianni et al., 2020a;b). Based on previous research literature (Constantin, 2015; Yuan and Zhong, 2013; Zaffke et al., 2015: Zhu et al., 2014), an initial set of app features desirable for SS was created to be included in an online survey. 84 practitioners and 34 parents with at least 2 years' experience developing and delivering SS for autistic children completed the online survey identifying the features they would like to see in a SS app (see Appendix B). A survey of app stores identified 19 social stories apps. Of these, only one had more than half of these desired features (StoryMaker had 12/22: Constantin et al., 2016). SOFA-app was co-developed with the autism community (see Parsons et al., 2019b) and addresses all 22 features, and a prototype was used for the present study (see online supplementary material for screenshots). The SOFA-app will run on mobile devices (smartphones and tablets) with Android and IOS operating systems (SOFA-app.org, released on April 2nd, 2020). It was not possible to use the app after the pilot (until this release date).

Measures

Teacher Weekly Behaviour Diary: A specifically designed questionnaire containing six questions to be answered at the end of each week ==by the class teacher==. These questions measure a range of behavioural factors associated with the target behaviour of the SS and included the goal-based measure recommended by Marshall et al. (2016) as the first question. The diary required the teacher to track and rate the child's progress from baseline to post-intervention. The questions use an 11-point scale from 0 through to 10 (after Marshall et al, 2016). The wording of the labels on the extremes of this scale varied dependent on the construct being assessed. For example, the first question (the goal-based measure) asks teachers 'How close is the child to reaching their goal (related to the SS) today?' A response of 0 is 'Goal Not Met' and 10 is 'Goal Reached'. The other five questions assessed behavioural frequency, severity, intensity, perceived child's understanding of the behaviour, and perceived anxiety. There was also a free text box for teachers to write any additional comments they felt may be appropriate. The goal-based measure was considered our primary outcome measure. The measure of understanding was included to consider Gray's premise that the goal of a SS is to improve social understanding, for example of expectations and events, which may (or may not) lead to more effective responses (see - Ali & Frederickson, 2006; Gray & Garand, 1993).

Online Questionnaire: An online questionnaire was developed to assess general aspects of story development and implementation ==by the class teacher== (i.e. When did the child read the story, total number of times the story was read), and also specific features relating to Gray's criteria that could not be gained from reading the SS text alone (i.e. was a comprehension check included, how was the story monitored, reviewed, edited etc. – see supplementary materia for details). There was also a free text box for teachers to write comments relating to their perceived effectiveness of the SS intervention.

Intervention: During the intervention phase, class teachers were advised to deliver the SS once or twice a day (Monday through Friday) for up to four weeks. Teachers could support the delivery to the child of the SS on the iPad as much or as little as needed. Participating teachers were required to complete the Teacher Weekly Behaviour Diary for the week prior to the intervention phase (baseline) and at the end of each intervention week to track each child's progress. Six weeks after the

intervention, teachers were sent a link to an online version of the Teacher Weekly Behaviour Diary to identify any longer-term benefits of the intervention. This request was followed-up with emails and phone calls (with limited success, see analysis below).

All appropriate approvals for the procedures used were granted by the University of [ANONYMISED] Psychology Ethics Committee.

Carol Gray Assessment Framework (CGAF): An assessment framework was developed as part of the study to enable a procedure for evaluating each SS according Gray's 10 criteria (Gray, 2010 – see supplementary material). As the guidance provides instruction for the *process* of story writing and delivery it is not possible to simply assess whether a story meets the full criteria based on reading the text alone. Five (1, 3, 5, 6, 8) of the 10 criterion can be assessed this way. Of the remaining five, two (2 & 7) can be assessed by a mixture of self-report questions (answered by the teacher) and reading the SS text. The final three criterion (4, 9, 10) cannot be assessed by reading the SS. We developed a series of self-report questions for teacher to complete in order to ascertain whether they were following the guidelines to or not (see supplementary material). Criteria 10 covers ten separate points associated with implementation, four of which related to the teachers' long-term use of SS (Organize the Stories; Mix & Match to Build Concepts; Story Re-runs and Sequels to Tie Past, Present, and Future; Recycle Instruction into Applause). These long-term use items were not relevant to the current intervention, so questions were devised to assess the first 6 points (edit; plan for comprehension; plan story support; plan story review; plan a positive introduction; monitor).

Scoring: Two scores were calculated for each SS. The first related to the story writing process. This was based on criteria 1-9 and resulted in a possible score of between 0 and 9. Three of the first 9 criteria (2, 5, 7) required more than 1 question to asses. The point was given if all elements were fulfilled. The second score related to story implementation, criteria 10. A score of between 0-6 was given according to the 6 distinct elements.

Data Analysis

Firstly, the Carol Gray Assessment Framework (CGAF) was applied, independently to each SS by two of the authors. Any discrepancies in ratings were resolved via discussion. For the behaviour diaries, the overall mean and individual child means were calculated for the six variables: goal; frequency; severity; intensity; understanding; anxiety. The frequency, severity and intensity variables all related to the child's negative behaviours (even when the focus of the SS was targeted at improving positive behaviour). The baseline and week four scores from each question were compared using a paired samples t-test to explore intervention differences. Due to multiple comparisons, a Bonferroni correction was applied resulting in a significance threshold of $p < 0.008$ (0.05/6). Effect sizes were calculated using Cohen's d for all comparisons. For two children, teachers did not provide data for the Teacher Weekly Behaviour Diary, therefore data for 20 participants was analysed. There were occasional missing elements from these data sets (0.02% of the Teacher Weekly Behaviour Diary), which are reflected in slightly different totals in the tables and degrees of freedom in the t-tests. As noted above, the attempt to identify longer-term effectiveness data at 6-week follow up was not completely successful. Eleven teachers replied, but it should be noted that this was after many communication attempts and consequently not consistently six weeks after the end of the intervention.

A number of intervention factors (CGAF scores, SS category) and child characteristics (level of autism, cognitive ability, language skills, reading skills, level of challenging behaviours) were considered in relation to SS effectiveness. SS effectiveness was calculated based on the change in scores on the goal-based measure (primary outcome) from baseline to the end of the intervention (week 4). In addition, in order to consider whether there were any changes in the child's perceived understanding that may not have translated to a behaviour change, we also calculated the change in scores on the understanding measure from baseline to week 4. Correlations between the continuous measures (CGAF scores) and effectiveness scores were calculated. Independent t-tests or one-way ANOVAs were used to explore differences in mean effectiveness scores based on the child characteristics listed above. Finally, the teacher comments were analysed in order to consider any other factors that may have influenced the effectiveness of the intervention.

Results

Intervention Characteristics and Fidelity

During the intervention, the SS were delivered between 3 and 30 times (*M* = 14.55, *SD* = 7.09), mostly within the school setting only. Often, they were read either once or twice a day, with a number of teachers commenting that they started by reading the story every day and then reduced to as-and-when the child required. ==If the goal of the SS had been reached, for example, the SS was no longer read.== Just over one third of the stories (36.4%) were aimed at reducing a negative behaviour (e.g. to stop dribbling and chewing inappropriate items). Just under one third (27.2%) were targeted at increasing a positive behaviour (e.g. appropriate behaviour in the playground). The remaining 36.4% focussed around reducing anxiety and/or preparing for a novel change/ event (e.g. school tests - SATS). Almost all teachers (88.9%) reported that they had followed Gray's guidelines. However, of those who reported adhering to the guidelines, 3/16 (23.1%) did not meet the criteria for the sentence ratio when this was independently assessed. Full details of the intervention characteristics and adherence to each of Gray's 10 criteria are presented in Table 3 below.

TABLE 3

Effectiveness: Weekly Behaviour Diary

A paired samples t-test was conducted using data from twenty children. There was a significant difference in the rating of reaching the goal behaviour, such that the children were closer to reaching the goal behaviour by week four (M = 5.65, SD = 2.62) compared to baseline (M = 3.15, SD = 2.18), t(19) = -5.11, p < .001, d = 1.04; see Figure 1A). In addition, there were significant pre and post intervention decreases in perceived frequency (week four (M = 4.58, SD = 2.80); baseline (M = 6.53, SD = 2.80); t(18) = 3.25, p = .004, d = .70; see Figure 1B), severity (week four (M = 4.60, SD = 2.40); baseline (M = 7.15, SD = 2.16); t(19) = 6.27, p < .001, d = 1.12; see Figure 1C) and intensity (week four (M = 4.95, SD = 2.72); baseline (M = 6.53, SD = 2.57); t(18) = 3.03, p = .007, d = .60; see Figure 1D) of the target behaviour. There was also a significant increase in the perceived understanding the child had of the issue (week four (M = 6.65, SD = 2.13); baseline (M = 4.45, SD = 2.46); t(19) = -5.57, p < .001, d = .96; see Figure 1E) and a significant decrease in perceived anxiety about the issue (week four (M = 4.10, SD = 2.45); baseline (M = 6.00, SD = 2.70), t(19) = 4.79, p < .001, d = .74; see Figure 1F). There were no significant differences between Baseline and Week 1 for any of the six variables (all p>.05).

Analysis of the follow-up data (n = 11) showed that for these children some of the improvements noted at the end of the intervention phase were still present at least 6 weeks post intervention. Significant improvements compared to baseline were found for both closeness to the goal (t(10) = 5.41, p < .001) and frequency of negative behaviour (t(10) = 4.45, p < .001), but not intensity (t(10) = 2.25, p = ns), understanding (t(10) = 1.32, p = ns), anxiety (t(10) = 2.22, p = ns) and severity of the negative behaviour (t(10) = 2.60, p = ns).
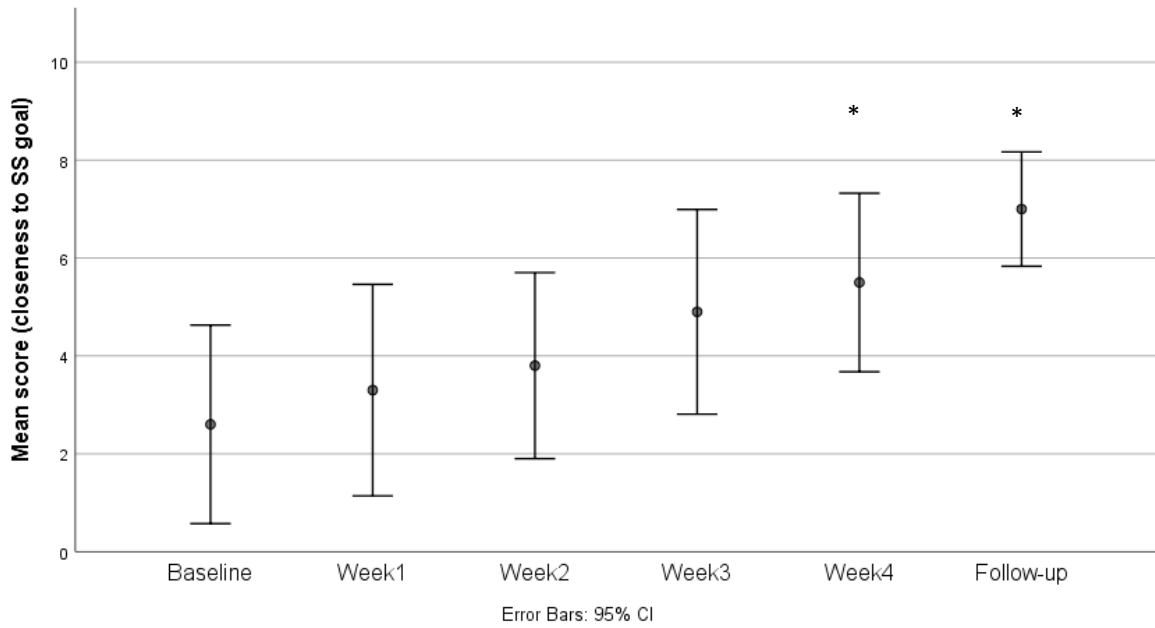
*Significantly different to baseline score (Bonferroni correction p < 0.008)

Figure 1A: Goal-based measure: Mean score for closeness to the SS goal (0 = goal not met; 10 = goal reached). Comparisons made between Baseline and Week 4, as well as Baseline and Follow-up.
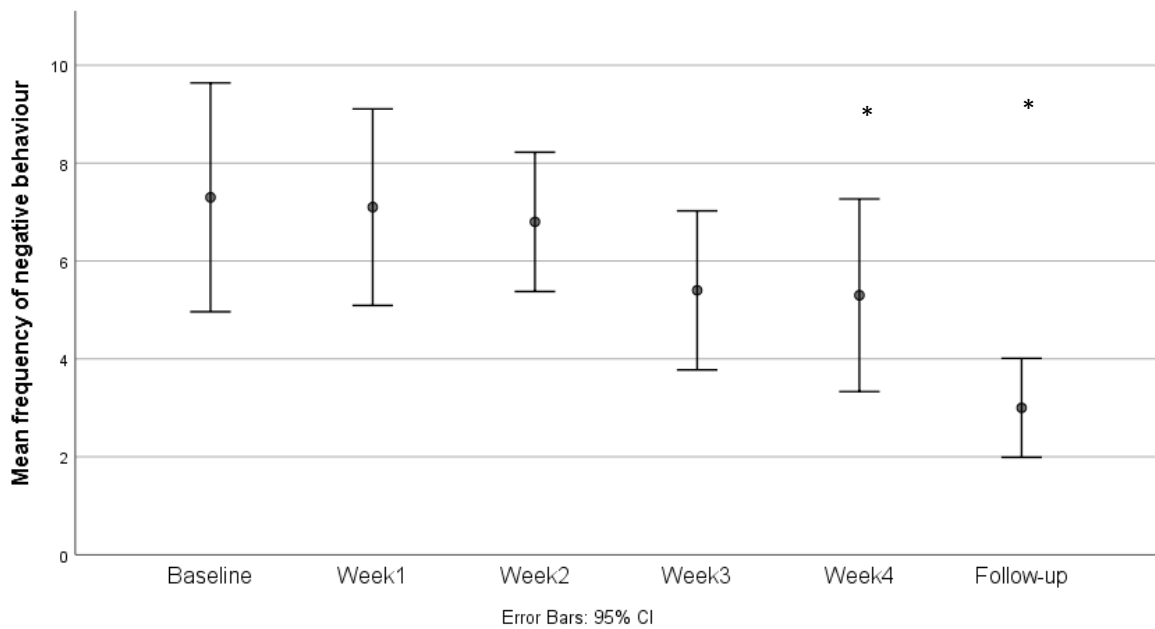
*Significantly different to baseline score (Bonferroni correction p < 0.008)

Figure 1B: Mean score for frequency of negative behaviours. <mark>Comparisons made between Baseline and Week 4, as well as Baseline and Follow-up.</mark>

Error Bars: 95% CI
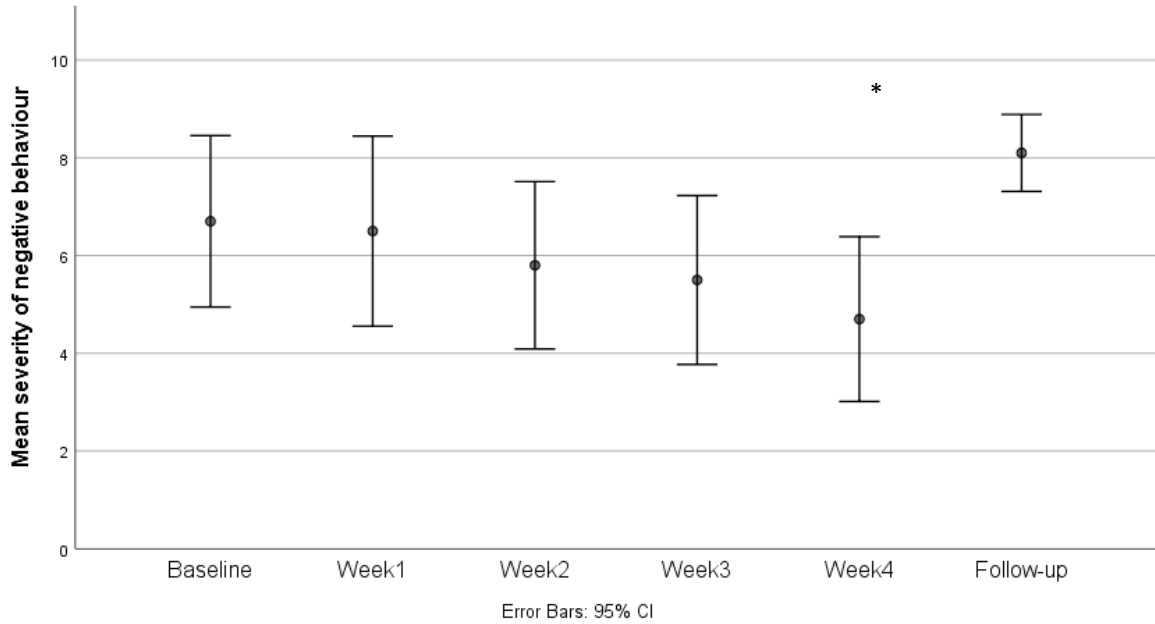
*Significantly different to baseline score (Bonferroni correction p < 0.008)

Figure 1C: Mean score for severity of negative behaviour. <mark>Comparisons made between Baseline and Week 4, as well as Baseline and Follow-up.</mark>

*Significantly different to baseline score (Bonferroni correction p < 0.008)

Figure 1D: Mean score for intensity of negative behaviour. Comparisons made between Baseline and Week 4, as well as Baseline and Follow-up.

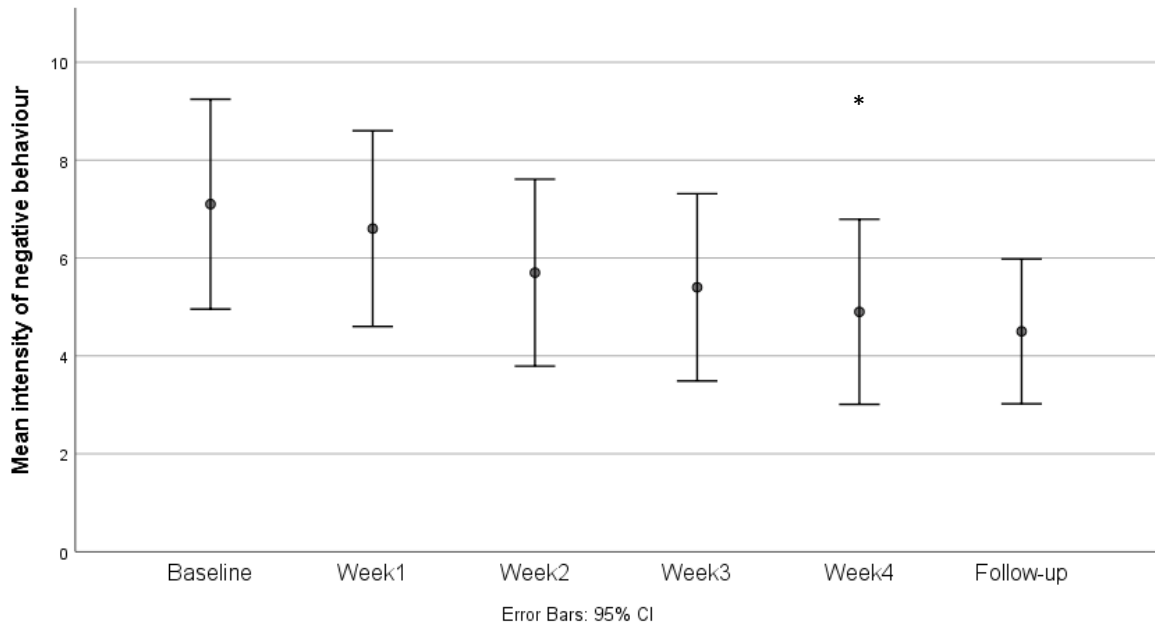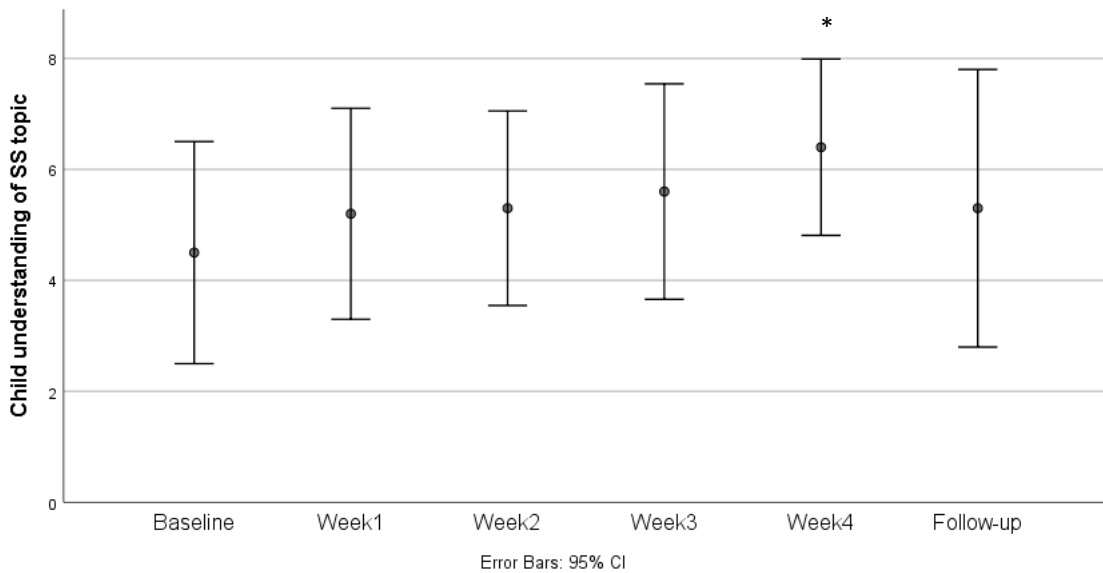
*Significantly different to baseline score (Bonferroni correction p < 0.008)

Figure 1E: Perceived child understanding relating to the topic of the SS. Comparisons made between Baseline and Week 4, as well as Baseline and Follow-up.
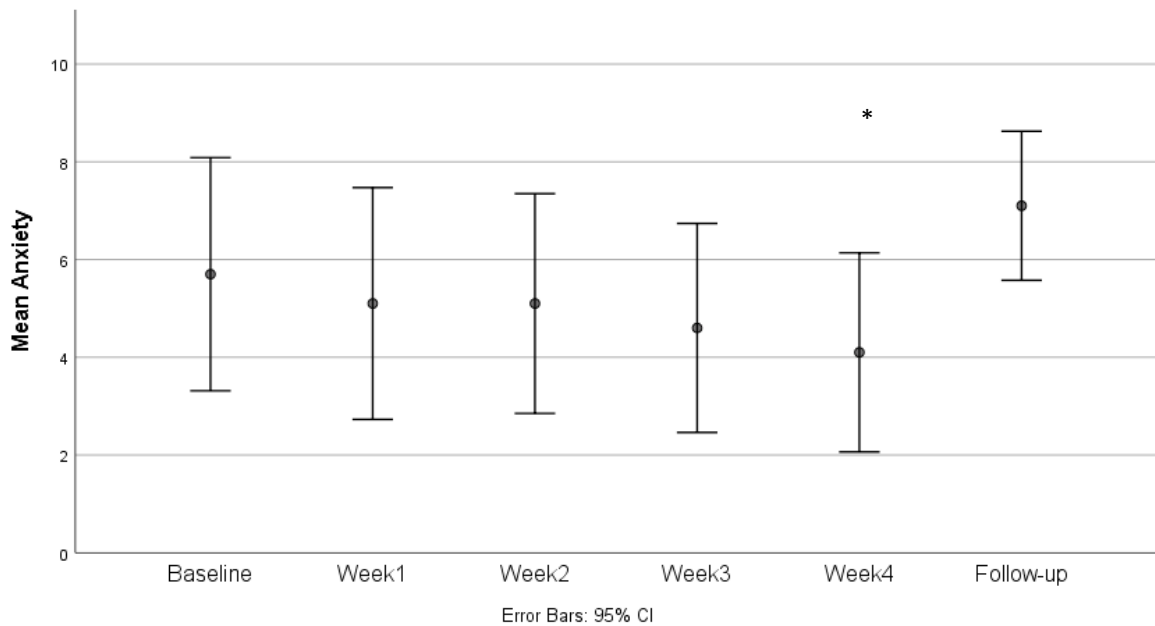
*Significantly different to baseline score (Bonferroni correction p < 0.008)

Figure 1F: Perceived child anxiety relating to the topic of the SS. Comparisons made between Baseline and Week 4, as well as Baseline and Follow-up.

Relationships between Gray's criteria and effectiveness

The CGAF was applied to all the available data independently by two of the authors. All SS texts were available (n=22) and 18/22 (81.8%) had fully completed corresponding teacher questionnaire data. Results indicate that the majority of Gray's criteria were being followed with adherence rates ranging from 59.1% to 100% for each individual criterion (see Table 3 for full details). However, only 5/18 (27.8%) met every criterion. Each of the SS with complete data (n=18) were given two scores, the first relating to the story writing process (0-9, according to the first 9 criterion), and the second relating the implementation (0-6, according to criteria 10). Mean scores for the story writing process was 8.00 (SD = 1.03; range = 6-9), and 5.11 (SD = 1.32; range = 2-6) for implementation.

Effectiveness was calculated based on the change scores from baseline to week 4 for the goal-based measure (M = 2.50; SD = 2.12; range = -2 - 6) and for understanding (M = 2.20; SD = 1.76; range = 0-

5). Correlations were conducted to investigate the relationship between the two scores generated from the CGAF (SS writing; SS implementation) and effectiveness. Results showed a non-significant negative relationship between the CGAF SS writing score and change on the goal-based measure (r = -0.29, p = ns). This was also the case for SS implementation (r = -0.28, ns). A positive relationship was found between the change in understanding and both SS writing and SS implementation, but these relationships did not reach significance (r = 0.31, ns; r = 0.26, ns, respectively). The relationship between change scores on the goal-based measure and for perceived child understanding was positive but non-significant (r = 0.31, ns).

Relationships between child/intervention characteristics and effectiveness

Relationships between the child characteristics and SS effectiveness scores are presented in Table 4 below (higher mean indicates greater improvement towards goal or understanding, See Table 1 for frequencies of each characteristic). Statistical comparisons were calculated using either independent t-tests or one-way ANOVAs to consider the differences between groups. No statistical differences were found for any of the comparisons.

Qualitative data: Teacher Comments

Teachers were encouraged to write comments in the behaviour diary. They were also asked to provide feedback on why they felt the SS had, or had not been, effective at the end of the study. Negative comments were linked to a range of external factors. These included: absence from school, illness, instability at home and changes to the child's usual school routine.

> *"The child was absent for one week due to illness, reducing the opportunities to use the SS. The school routine had changed due to the time of year – he could not cope with all the changes." Child J*

A mismatch between better understanding but limited behavioural change was also noted.

> *"It was effective in supporting my pupils understanding. He is still struggling to act on advice in the story but he is more able to make a choice." Child P*

Positive comments highlighted benefits relating to: the visual representation of information; the personalised nature of the story to the child; initiation of further discussion; increased understanding and potential to use in collaboration with other techniques.

> *"It was very effective in helping the pupil to understand the situation in a very visual way and give them explicit strategies to change their response to the situation to get a more positive outcome." Child Q*

Discussion and Implications

This was the first study to explore whether digital technology could support the fidelity of SS interventions developed and delivered by educational professionals within a naturalistic school setting. Digital technology has been found to support effective development and delivery of SS within a research context, however, a naturalistic setting has been argued to be essential for establishing ecological validity (Hanrahan et al., under review; Mayton et al., 2013; Styles, 2011). There was initial evidence that digital support did result in greater fidelity, compared to reports from previous studies such as Reynhout and Carter (2009). Also, this is the first study to assess teachers' SS in accordance to Gray's 10 Criteria (Gray, 2010), as opposed to only considering the sentence ratio (Kokina & Kern, 2010; Reynhout & Carter, 2006, 2009; Tarnai, 2012). The development of the Carol Gray Assessment Framework (CGAF) also provides a structure to guide fidelity checks in future studies.

Overall, after a 4-week intervention period, SS developed and delivered by school staff with the SOFA app were found to have significantly improved the behaviour, understanding and anxiety of autistic children, based on teacher perception. Autistic children demonstrated significant improvement in ratings of closeness to the goal of the SS, a reduction in frequency and severity of negative behaviours, as well as a significant increase in understanding and decrease in anxiety about the topic of the SS. This suggests, that with digital support, SS can be an effective intervention for autistic children within naturalistic settings, without the support of a Researcher. When considering effectiveness at an individual level the change scores from baseline to the end of the intervention phase ranged from minus two to plus six (average: +2.5) on the goal-based measure. This is consistent with reviews of the literature and meta analyses that have highlighted that whilst SS can be effective, there is typically huge variability in effectiveness (Hutchins & Prelock, 2013; Kokina & Kern,

2010; McGill et al., 2015). The present study suggests that digital support for SS can maximise the fidelity of SS within naturalistic school context to raise the effectiveness to be consistent with a research context (Hanrahan et al., under review; Mayton et al., 2013; Styles, 2011).

This effectiveness within a naturalistic setting may be due to the digital support enabling teachers to develop SS in line with the established criteria and/or to implement the delivery of SS in line with the established criteria, although we did not find a relationship between CGAF scores and effectiveness. Whilst only around a quarter of SS met all the criteria, the CGAF scores were relatively high (with means of 8 out of 9 and 5 out of 6) again indicating that digital support can enhance fidelity to a large degree. Limited variance may relate to a lack of a significant relationship between adherence to the criteria and changes in closeness to goal or understanding (from baseline to week 4). It is interesting to note, however, that adherence to Gray's criteria consistently positively correlated with changes in understanding but negatively correlated with changes in closeness to goal (albeit insignificantly, $r \approx$ .3), which has been identified previously (Reynhout & Carter, 2006, 2009; Tarnai, 2012). There was a positive relationship between changes in understanding and closeness to goal but this was not significant. Teachers comments also noted that SS can enhance understanding without improving behaviour on occasion, consistent with Gray's original conception for the focus of SS. This negative relationship may only be the case when there is generally good adherence to the criteria overall, but this is an area that requires further investigation.

At 6-week follow-up without intervention, behavioural improvements were still reported for closeness to goal and frequency of negative behaviour. However, this was no longer the case for ratings of intensity and severity, and for potential related issues around understanding and anxiety. Importantly too, whilst all teachers remained within the 4-week intervention, only around half responded to requests for information at the 6-week follow-up, and this potential bias needs to be borne in mind. The digital support was withdrawn during this 6-week follow up period ensuring the intervention was not re-administered. One benefit of digital supports is their availability and accessibility, and in future it would be possible for teachers to re-administer the intervention as and when it was needed with no additional preparation time. Thus, there are early indications of long-term benefits of SS intervention without the intervention being re-administered but in a completely naturalistic setting, the intervention could be maintained potentially for years, which future research can explore evaluating.

Consistent with Hutchins and Prelock (2013) we did not find any statistical differences relating SS effectiveness with any of the following child characteristics: level of autism, cognitive ability, language ability, reading skills, level of challenging behaviours (noting that some level of language ability was required for the study). For most of the categories (see Table 4) there is a pattern of greater level of difficulty being associated with greater improvements in closeness to goal and understanding (albeit insignificantly). This is consistent with previous research (Kokina & Kern, 2010) and again the digital support may enable future research to explore this empirically. Similarly, there was no significant differences relating to the category of the SS, but the most positive improvements were noted for those stories that targeted improving appropriate behaviour. Qualitative comments from the teachers provided a valuable insight into other factors that impacted on effectiveness, highlighting issues such as school absence, changes in routine, illness and unsettled homelife.

The insignificant findings may relate to there only being 22 autistic children. However, most of the research to date has had very small numbers of participants (Kokina & Kern, 2010; Leaf et al., 2015; Qi et al., 2018). Qi et al (2018) for example in their review identified a maximum number of 6 participants, with an average of 2 participants. Thus, relative to the literature, the present study has enabled statistical comparisons between baseline and week 4 overall, which have been supportive of SS intervention. However, to further identify which features (of the intervention or the child) relate to effectiveness larger numbers of participants will be required. In addition, there was no comparison groups or conditions with which to compare the effects within the present study. This relates to researcher-led protocols which have previously been identified to be effective ('anonymous') and the focus of the present study was to establish whether SS intervention could be digitally supported in a naturalistic setting, which did not have comparison groups or conditions. As the present study has identified that SS can be effective in school settings, future research can both add comparison groups and conditions within a naturalistic setting as well as follow up long term usage 'in the wild' (see above).

A major limitation of this naturalistic study methodology is that teachers provided the evaluations for the SS they developed and delivered. Whilst this is common within naturalistic settings, potential biases in these reports needs to be borne in mind. Previous research has found the weekly teacher questionnaires to be consistent with other measures ('anonymous') and teachers self-reporting on the SS criteria were found to be mostly consistent with independent rating. In addition, most of the ratings

at follow-up were no longer significant highlighting that not all ratings were improvements (albeit on a smaller sample). All the teacher ratings were subjective, however, and the data needs to be considered in this context. The evaluation of the children's capabilities was also a subjective assessment made by the teachers based upon their experience, as it was not possible to formally assess children within this naturalistic context. This methodology has been used within highly varied autistic populations across Europe (see Herrera et al., under review) and, as noted above, was consistent with the literature (Weitlauf et al., 2014). The teachers' qualitative comments also highlighted the additional factors that can impact upon effectiveness of SS within naturalistic settings (e.g. illness, absence from school, change of routines, unsettled home life etc.). Indexing such extraneous factors within future research will further enhance our understanding of causes of the variability within the effectiveness of SS interventions. A further limitation is not knowing the teachers' experiences with other apps or technologies to support autistic children that might influence their ratings. Similarly, due to the naturalistic nature of the study, there may have been variability concerning the amount of direction and prompting provided by the teacher.

In sum, SS is a widely used, and acceptable intervention and this study highlights that significant improvements can be consistently reported in the goals of the intervention for autistic children when teachers are supported with the SOFA app (freely available at sofa-app.org). Within the context of the SS literature this study is one of the largest, but numbers are still too small to consider the impact of child and intervention characteristics fully. To date this has been particularly challenging due to the personalised nature of SS interventions typically lending itself to a multiple case study design. With the use of technology, such as the new SOFA app, this may finally enable larger, better controlled studies to be conducted. In addition, the development of a new framework for assessing adherence to Gray's 10 criteria, will enable future studies to explore the impact of this more fully, enabling a better understanding as to what may be driving effectiveness.

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Table

Child Characteristics	Frequency	Percentage (%)
Educational provision		
Mainstream school	8	36.4
Specialist school/unit	14	63.6
Level of Autism		
None	0	0
Mild	9	52.9
Moderate	8	47.1
Severe	0	0
General Cognitive Ability (intellectual functioning)		
Above average	4	23.5
Average	6	35.3
Mild impairment	3	17.7
Moderate impairment	4	23.5
Severe impairment	0	0
Expressive language skills. Child can talk in:		
Full sentences	14	82.4
Short sentences	3	17.6
Single words	0	0
Non- or minimally verbal	0	0
Receptive language skills. Child can understand:		
Conversations	14	82.4
Simplified short sentences	3	17.6
Single words or symbols	0	0
No/little understanding	0	0
Reading skills		
Fluent	11	64.7
Limited (some skills but not fluent)	2	11.8
Low (pre-reading skills)	2	11.8
None	2	11.8
Level of challenging behaviours		
High	4	23.5
Moderate	5	29.4
Low	6	35.3
None	2	11.8

Table 1. Descriptive Information about the Participants from Teacher Ratings.

Staff Characteristics	Frequency	Percentage (%)
Sex		
Female	14	82.4
Male	3	17.63
Relationship to child		
Teacher	10	58.8
Teaching Assistant	4	23.5
Occupational Therapist	2	11.8
SENCO	1	5.9
Received specific training on SS		
Yes	6	35.3
No	11	64.7
Prior experience of delivering SS		
None	2	11.8
A little	6	35.3
Some	4	23.5
A lot	5	29.4
Prior experience of developing SS		
None	2	11.8
A little	6	35.3
Some	4	23.5
A lot	5	29.4

Table 2. Descriptive Information about the Participating Staff.

Intervention Characteristics	Frequency	Percentage (%)
Where was the story read?		
School	18	94.7
Home	1	5.3
How frequently did the child read the story?		
Once a day	8	44.4
Twice a day	3	13.5
Prior to the challenging situation/event	1	5.6
Other	6	33.5
Category of SS		
Reducing negative behaviour	8	36.4
Increasing Positive behaviour	6	27.3
Preparing for change/event; reduce anxiety	8	36.4
Self-report conform to Gray's criteria		
Yes	16	88.9
No	0	0
Don't know	2	11.1
Conform to Gray's criteria*		
Criteria 1: The SS goal	22/22	100
Criteria 2: Two step discovery	20/21	95.2
Criteria 3: Three parts and a title	13/22	59.1
Criteria 4: 'FOURmat'	18/18	100
Criteria 5: Five factors define voice & vocabulary	15/22	68.2
Criteria 6: Six questions that guide story development	22/22	100
Criteria 7: Seven types of sentence	21/21	100
Criteria 8: A GR-EIGHT formula (sentence ratio)	19/22	86.36
Criteria 9: Nine makes it mine	15/18	83.3
Criteria 10: Ten guides to editing & implementation		
Edit	14/19	73.7
Plan for comprehension	15/18	83.3
Plan story support	16/18	88.9
Plan for story review	15/19	78.9
Plan a positive introduction	18/18	100
Monitor	15/19	78.9

*according to Carol Gray's Assessment Framework

Table 3. Characteristics of the SS Intervention

Child/Intervention Characteristics	Effectiveness: Goal[1] M (SD)	Effectiveness: Understanding[2] M (SD)
SS topic		
Reducing negative behaviour	2.43 (2.51)	1.43 (1.23)
Increasing a positive behaviour	3.17 (2.32)	3.50 (1.23)
Preparing for a change/event	2.00 (1.92)	1.86 (2.12)
Complies with Gray's sentence ratio		
Yes	2.41 (2.29)	2.29 (1.61)
No	3.00 (1.73)	1.67 (2.89)
Level of Autism		
Mild	2.50 (2.27)	2.25 (1.98)
Moderate	3.14 (1.86)	2.14 (1.95)
General Cognitive Ability		
Above average	3.25 (1.71)	1.00 (1.41)
Average	1.20 (2.17)	2.60 (2.41)
Mild impairment	3.50 (2.12)	1.00 (0.00)
Moderate impairment	4.00 (1.41)	3.50 (1.29)
Expressive language skills. Child can talk in:		
Full sentences	2.42 (2.01)	1.83 (1.85)
Short sentences	4.33 (1.53)	3.67 (1.53)
Receptive language skills. Child can understand:		
Conversations	2.42 (2.01)	1.83 (1.85)
Simplified short sentences	4.33 (1.52)	3.67 (1.53)
Reading skills		
High/average	2.33 (2.00)	1.22 (1.72)
Limited	2.50 (3.54)	4.00 (0.00)
Low	3.50 (0.71)	3.50 (2.12)
None	4.50 (2.12)	3.50 (0.71)
Level of challenging behaviours		
High	4.00 (1.41)	2.25 (1.71)
Moderate	2.50 (2.38)	3.25 (2.36)
Low	2.50 (2.26)	1.83 (1.72)
None	1.00 (NA)	0.00 (NA)

[1]Closeness to SS goal; [2]percieved child understanding

Table 4: The relationship between teacher reported child characteristics and SS effectiveness based on change scores on the goal-based measure and perceived child understanding.

e-component
Click here to download e-component: Appendix A.docx

Piloting a new digitally-mediated social story intervention for autistic children led by teachers within naturalistic school settings

Highlights

- The first study to explore whether digital technology could support the fidelity of social story interventions developed and delivered by teachers within naturalistic school settings.

- A new assessment framework was developed to enable a measure of social story treatment fidelity according to Gray's 10 Criteria.

- Findings demonstrated that with digital support teachers were able to complete social story interventions to a high degree of fidelity with autistic children within school settings.

- After a 4-week intervention period, the digital social stories were found to have significantly improved the behaviour, understanding and anxiety of autistic children, based on teacher perception.

- Such technology and fidelity measures can now be used within larger, controlled studies, to better explore the impact of child and intervention factors on the effectiveness of social story interventions.