Autistic peer-to-peer information transfer is highly effective

Catherine J Crompton, Danielle Ropar, Claire VM Evans-Williams,
Emma G Flynn, Sue Fletcher-Watson

Introduction: Autism spectrum disorder (hereafter "autism" (Kenny et al., 2016)) is clinically characterised by lifelong impairments in social and communication domains, the presence of restricted and repetitive behaviours, and sensory perceptual features (APA, 2013). A large body of research indicates that autistic people struggle with attributing mental states to others and identifying social cues such as basic and complex facial emotions (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997), tone of voice (Rutherford & Baron-Cohen, 2002), sarcasm (Persicke, Tarbox, Ranick, & Clair, 2013), and social faux pas (Baron-Cohen, O'Riordan, Stone, & Jones, 1999) compared with non-autistic people, resulting in difficulties in social interactions.

However, non-autistic individuals have communicative difficulties when interacting with autistic individuals. Non-autistic people struggle to identify autistic mental states (Edey, Cook, Brewer, & Johnson, 2016), identify autistic facial expressions (Sheppard, Pillai, Wong, Ropar, & Mitchell, 2016), overestimate autistic egocentricity (Heasman & Gillespie, 2018), and are less willing to socially interact with autistic people (Sasson et al., 2017). Thus, although non-autistic people are generally characterised as socially-skilled, these skills may not be functional, or effectively applied, when interacting with autistic people. This bi-directional disconnect in communication and understanding between autistic and non-autistic people has been labelled the "double empathy problem" (Milton, 2012, Milton, Heasman, & Sheppard, 2018). One implication of the "double empathy problem" is that if autistic "social impairments" result from a mis-match between autistic and non-autistic populations, they may disappear in within-group interactions. Thus, predictions based on clinical definitions of autism about autistic-autistic interaction would be that they would be non-functional or ineffective, and in contrast, predictions based on the Double Empathy theory about autistic-autistic interaction would be that they would be successful and positive. However, to date, there is no experimental evidence directly testing whether autistic-autistic interactions are successful.

Recent research has found that autistic people prefer interacting with other autistic people, and experience close social affiliation with them (Crompton, Fletcher-Watson & Ropar, 2019; Morrison et al., 2019), and has begun to examine the mechanisms that underlie this preference. Autistic people are, by definition, more familiar with autism, and are more accurate at correctly detecting the intentions of autistic people than non-autistic people (Heasman & Gillespie 2018; Sheppard et al., 2016). Autistic people report exhibiting fewer autistic traits when interacting with other autistic people compared with non-autistic people (Gernsbacher, Stevenson & Dern, 2017) and are less deterred by negative first impressions of autistic adults in deciding whether to later socialise with them (Debrabander et al., 2019). Additionally, autistic interactions follow a distinctive pattern of intersubjectivity, which while unconventional by non-autistic standards, function effectively to facilitate mutual understanding (Heasman & Gillespie 2019b). Collectively, this evidence suggests that autistic interactions may be unique, but similarly facilitative of communication as non-autistic interactions. However, to date, not research has looked at information transfer as a measure of communicative success, contrasting how autistic and non-autistic people share information with their autistic and non-autistic peers.

This study directly compares how autistic and non-autistic people interact when in matched (same diagnostic status) or mixed (autistic with non-autistic pairs, in an information-sharing context. Aligned with the double empathy theory, we hypothesised that information transfer would yield higher fidelity for sequences of matched pairs (whether all autistic or all non-autistic), and that there would be poorer quality information transfer for mixed pairs of autistic and non-autistic people. We also hypothesised that, alongside information transmission, self-rated rapport would be higher for matched pairs (whether all autistic or all non-autistic), and that mixed pairs would experience lower interactional rapport.

Information transfer was operationalised using a 'diffusion chain' technique (Bartlett, 1932) (Figure 1) which involves examining the fidelity of information as it is passed along linear "chains" of participants. By assessing and analysing the rate which information degrades along the chain, the efficacy of information transfer can be explored (Mesoudi & Whiten, 2008). This type of diffusion chain paradigm is novel to the field of autism research.

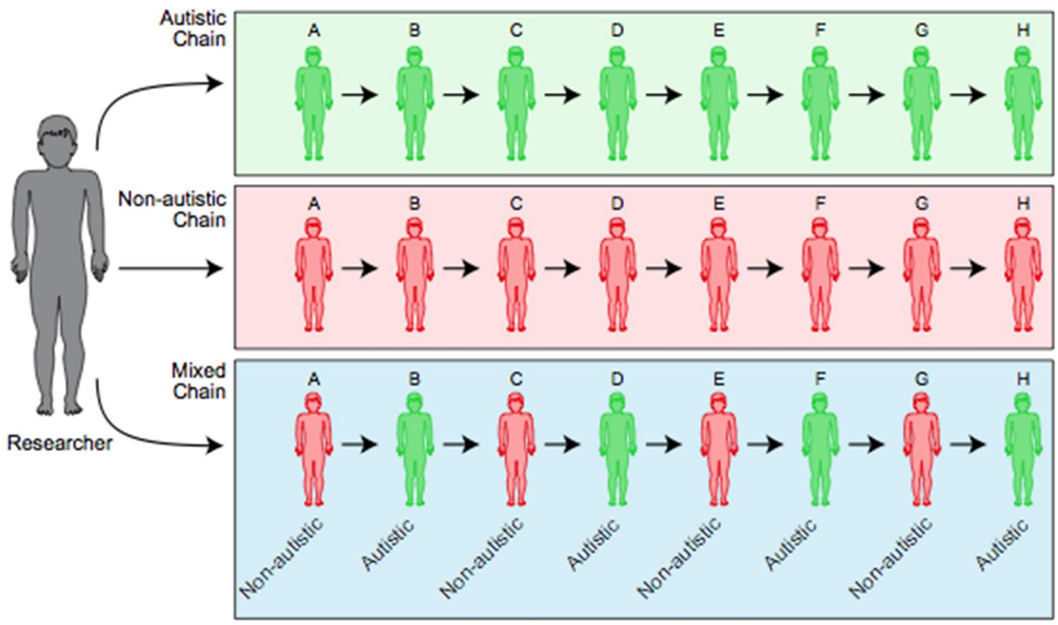

Figure 1: Illustration of the diffusion chain technique

Methods

This study was carried out in accordance with the British Psychological Society's Code on Human Research Ethics. Experimental procedures were reviewed and approved by the University of Edinburgh Psychology Research Ethics Committee, and all participants provided written informed consent prior to participating in the study. Participants were remunerated for their time.

Study design: The paper describes a between-groups experimental study, comparing information sharing outcomes using a diffusion chain paradigm, comparing autistic, non-autistic, and mixed groups.

Participants: 72 adult volunteers participated, with 24 adults in each of the autistic, non-autistic, and mixed sets. G*power was used to run a prospective power analysis, indicating 95% power to detect a medium effect of 0.5 at the standard 0.05 alpha error probability with a sample size of 66. To allow us to have an even number of 8-person diffusion chains in each group, 72 participants were recruited through community networks, social media, and local autism organisations.

The three groups were matched on age, gender, years of education, and IQ (Tables 1a and 1b). All spoke English to a native level and did not have a clinical diagnosis of social anxiety disorder. All non-autistic participants scored less than 32 on the Autism Quotient (AQ), indicating low levels of autistic traits (Baron-Cohen., Wheelwright, Skinner, Martin & Clubley, 2001). All autistic participants were either clinically diagnosed (n = 29), or if self- diagnosed (n = 3) they scored above 72 on the Ritvo Autism-Aspergers Diagnostic Scale- Revised (RAADS-R)[26]. A RAADS-R score of above 65 is consistent with a clinical diagnosis of autism[26]. In addition to this, all self-diagnosed autistic participants scored above 32 on the AQ[25] indicating high levels of autistic traits (Baron-Cohen et al., 2001). Participants also completed the Wechsler Abbreviated Scale of Intelligence II (WASI-II), (Wechsler, 2011), a measure of IQ, with all participants scoring within a typical range. Demographics for the autistic and non-autistic participants are reported in Tables 1a and 1b)

Table 1a: Descriptive statistics (Mean (Standard Deviation) on demographics by diagnostic status, using independent t test and Fisher's exact test comparisons.

	Non-autistic	Autistic	Comparisons
Age	36.31(13.00)	37.36(12.59)	t(69.93) = 0.35, p = 0.73
Gender	29 F, 7M	28F, 5M, 3 NB[b]	Fishers exact test p = 0.24
Years of Education	17.74 (1.81)	17.19 (2.45)	t(64.44) = -1.07, p = 0.29
IQ – WASI-II[a]	115.86 (10.71)	115.64 (17.03)	t(58.92) = -0.67, = 0.95
Autism Quotient	13.67 (5.87) Range = 3-28	36.78 (6.60) Range = 25-47	t(69.07) = 15.69, p< 0.0001
Age of Diagnosis	N/A	30.66(11.81)	N/A

[a] Wechsler Abbreviate Scale of Intelligence -II [b] Non-binary

Table 1b: Descriptive statistics (Mean (Standard Deviation) on demographic for assigned sets, using Kruskal Wallis Chi Square, ANOVA, and Fisher's exact test comparisons.

	Non-autistic	Autistic	Mixed	Comparisons
Age	37.92 (14.39)	37.33(13.13)	35.25 (10.76)	X^2 (2) = 0.27, p = 0.87
Gender	21F, 3M	18F, 3M, 3NB[b]	18F, 6M	Fisher's exact test p = 0.17
Years of Education	17.83 (1.52)	17.44 (2.80)	17.12 (1.98)	X^2 (2) = 1.83, p = 0.40

IQ – WASI-II[a]	115.04 (11.78)	114.42 (16.89)	117.79 (13.62)	F (2,69) = 0.38, p = 0.68
Age of Diagnosis	NA	30.55 (12.72)	30.89 (10.20)	X^2 (1) = 0.36, p = 0.85

[a] Wechsler Abbreviate Scale of Intelligence -II [b] Non-binary

Procedure:

Diffusion chains: The experiment took place in a research suite at the Division of Psychiatry at the University of Edinburgh. Seventy-two participants were divided into three equal sets: non-autistic (N), autistic (A), and mixed (M). Each set was divided further into three diffusion chains of eight people: nine diffusion chains in total. Each of the nine diffusion chains were run on separate "Research Days", which eight participants attended at a time. Participants were assigned to one of nine Research Days based on their diagnostic status (autistic or non-autistic), age, gender, and years of education.

Participants were part of 8-person chains, where either all participants were autistic, all were non-autistic, or four were autistic and four non-autistic. In this last case, the chain alternated between the two, starting with a non-autistic participant. Each of the chains were ordered in ascending age order, to minimise any potential effects of age-related memory decline, with minimal switches by gender (see Supplementary Table 1). Participants were aware whether they were in an autistic, a non-autistic, or a mixed chain. Participants did not meet before the study started, and were isolated in separate rooms throughout the study, except when participating in the diffusion chain.

The story used in the diffusion chains was a 30-point story, which followed a bear on a surreal adventure (Crompton & Fletcher-Watson, 2019). The story was designed to be difficult to predict, and did not include any inherently social aspects. The story had a Flesch- Kincaid

Grade Level of 4.4, equivalent to age 9-10 reading level, and a Flesch Reading Ease score of 90.1; a score of 60 or more is considered easy to read [27-28].

The researcher read the story to the first participant (A). The researcher left the room, and a second participant (B) entered. A then recounted the story to B. A left the room, and a third participant (C) entered. B then recounted the story to C, and so on, to the eighth participant (H). The eighth participant recounted the story aloud alone. Participants waited in separate rooms for their turn, to avoid contamination during the information sharing. All mixed chains started with a non-autistic participant. Diffusion chains were video recorded for scoring purposes. Participants' final score corresponded to the number of story details they had passed on to the next person in the chain.

Rapport: After completing the diffusion chain, participants indicated their feelings of rapport with their neighbours in the chain using a 100-point scale with five dimensions: ease, enjoyment, success, friendliness, and awkwardness (reverse scored). The five dimensions had a Cronbach's alpha of 0.71, and so were summed to create a single scale of interactional rapport. Subsequent Bayesian analyses were calculated in JASP[29].

Results: Initial pre-registered (Crompton & Fletcher-Watson, 2019) analyses tested for chain-type differences in the overall number of story details (out of a total of 30, averaged across all participants in each chain type regardless of position) recalled using ANOVA, revealing significant group differences ($F(2,69) = 4.60$, $p < 0.05$). Post-hoc contrasts indicated that the non-autistic and autistic chains did not differ from each other ($Mean_N = 12.40$, $SD_N = 5.28$; $Mean_A = 12.96$, $SD_A = 5.31$ Tukey HSD $p = 0.92$), though both groups recalled significantly more details than the mixed chains ($Mean_{A\text{-}N} = 8.92$, $SD_{A\text{-}N} = 4.34$; Tukey $HSD_{N\,\&\,A\text{-}N}$ $p = 0.04$, $Tukey_{A\,\&\,A\text{-}N}$ HSD $p = 0.01$).

Regression analysis was carried out to investigate whether number of details recalled deteriorated at a comparable rate for the three chain types (Figure 2, see Supplementary Figure 1 for individual chains). Predictors were chain- type (autistic, non-autistic, and mixed, with non-autistic as the reference group), and position in the chain (1-8), and included an interaction of chain type and position in chain. Individual data were entered without first being averaged across three chains of the same type. There was a steeper decline for the mixed chains (b=-6.04, SE=1.32, p<.0001), while autistic chains' recall did not differ to that of chains of non-autistic people (b=0.13, SE = 1.32, p=0.93), see Table 2. Position also significantly predicted the amount of information recalled (b=-2.15, SE=0.18, p<.0001), and together chain- type and position accounted for 85% of the variance in amount of information recalled ($F(5,66) = 77.05$, $p < 0.0001$, $R^2 = 0.85$). Additionally, a significant interaction between being in an mixed chain and the order of participation was found, indicating that the rate that detail recall deteriorated in the mixed chains was significantly faster ($b = 0.57$, $SE = 0.26$, $p < 0.05$). Thus, autistic and non-autistic chain-types do not differ in their information sharing abilities, and selective penalties for information transfer occur when there is a diagnostic mismatch.

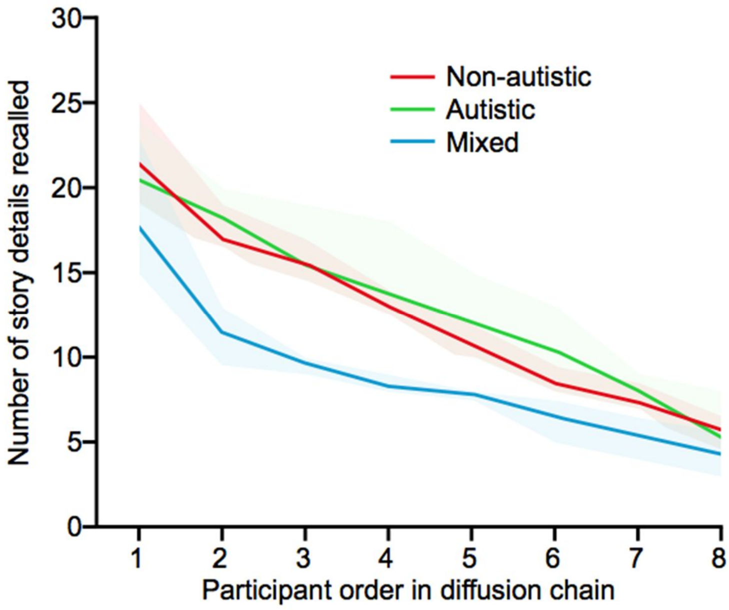

Figure 2: Mean and range of story details (out of 30) transferred in the diffusion chain, by group and position.

Table 2: Regression of the effect of chain type and order in chain on overall accuracy of data transfer between participants

	Estimate	Std Error	t	p
Intercept (Non-autistic chains)	22.10	0.94	23.61	<0.0001*
Main effects				
Group: Autistic chains	0.13	1.32	0.09	0.9251
Group: Mixed chains	-6.04	1.32	-4.56	<0.0001*
Order in chain	-2.15	0.18	-11.63	<0.0001*
Interactions				
Group: autistic * order in chain	0.09	0.26	0.37	0.71
Group: mixed * order in chain	0.57	0.26	2.17	0.03*
Residual standard error: 2.08 on 66 degrees of freedom. Multiple R-squared = 0.85; adjusted R- squared = 0.84. F statistic: 77.05 on 5 and 66 DF, p-value: < 0.0001				

As shown in Figure 2, the mean number of details recalled by the first person in an mixed chain was lower than for other chains. Supplementary Table 2 describes the first participant in each diffusion chain, alongside the number of details shared with the next person in the chain. This reduced recall early in the chain disadvantaged subsequent people in the chain, in terms of their score on our “number of details recalled” measure, since they had less information available to recall. To account for this, data were converted into percentages by calculating the proportion of details recalled relative to number of details recalled by the first person in each diffusion chain, and not the number of details in the initial story. Thus the first participant in each chain would have a proportional score of 100% and each subsequent participant’s score was calculated as a proportion of this (Figure 3).

An ANOVA revealed a main effect of chain type (F(2.69 = 11.39, p < 0.001), see Table 2. Post- hoc contrasts again indicated no significant difference between autistic and non-autistic chains ($Mean_A = 63.59$, $SD_A = 24.46$; $Mean_N = 58.60$, $SD_N = 24.40$, Tukey HSD p = 0.12). The mixed chain differed significantly from both non-autistic chains ($Mean_{AN} = 51.91$ $SD_{AN} = 24.54$, Tukey HSD p < 0.05), and autistic chains (Tukey HSD p < 0.001). Regression analysis indicated that there was a steeper decline for the mixed chains (b=-11.41, SE=5.68, p<0.05), while autistic chains’ proportion did not differ to that of chains of non-autistic people (b=5.66, SE = 5.68, p=0.32), see Table 3. Position also significantly predicted the proportion of information shared (b=-10.05, SE=0.79, p<.00001), and together chain-type and position accounted for 87% of the variance in proportion of information recalled ($F(5,66) = 94.50$, $p <$ 0.0001, $R^2 = 0.87$).

Thus, even though the mixed diffusion chains start with a reduced amount of information to transfer, this group still share proportionately less of that information through the diffusion chain. In contrast, autistic and non-autistic chains do not significantly differ from one another in the proportion of information shared.

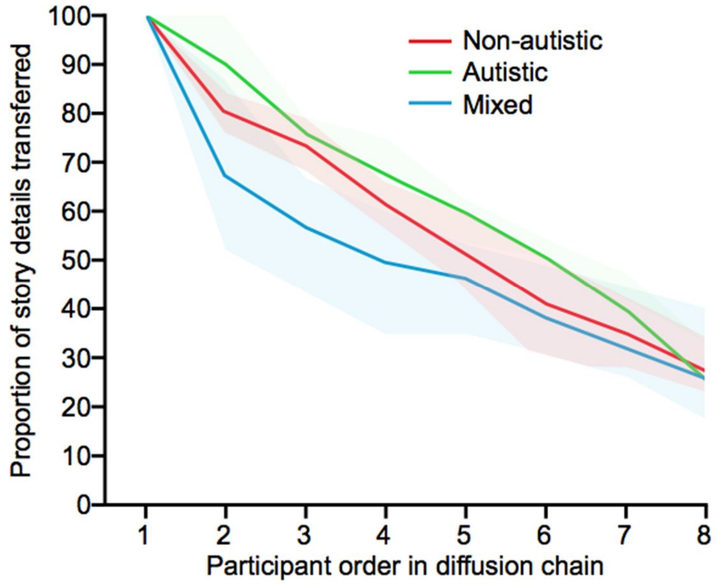

Figure 3: Proportionate mean and range of story details transferred in the diffusion chain, by group and position.

Table 3: Regression of the effect of chain type and order in chain on the proportion of data transferred between participants.

	Estimate	Std Error	t	p
Intercept (Non-autistic chains)	103.81	4.02	25.84	<0.0001
Main effects				
Group: Autistic chains	5.66	5.68	0.99	0.32
Group: Mixed chains	-11.41	5.68	-2.01	<0.05
Order in chain	-10.05	0.79	-12.63	<0.0001
Interactions				
Group: autistic * order in chain	-0.15	1.13	-0.13	0.90
Group: mixed * order in chain	1.04	1.13	0.93	0.35
Residual standard error: 8.93 on 66 degrees of freedom. Multiple R-squared = 0.88; adjusted R- squared = 0.87. F statistic: 94.50 on 5 and 66 DF, p-value: <0.0001				

On completion of the diffusion chain, participants were asked to rate their interactional rapport with each person adjacent to them in the chain, indicating how comfortable they had been during their interactions. Participants rated their rapport both with the person who had recounted the story to them (precede-rapport) and the person they had recounted the story to (succeed-rapport).

Figure 4 illustrates precede and succeed rapport scores by group. Rapport between chains was compared using Bayesian ANOVA using JASP using a default Cauchy prior (0, r = 1/sqrt(2)), and prior odds of 0.59, and using a Bayes Factor of < 6 to make inferences as per our pre-registration, based on Kass & Raferty (Kass & Raftery, 1995). Bayesian ANOVA indicated differences between precede rapport in the three groups (BF_{10} = 71.70, error <0.01%), with post hoc contrasts showing significant evidence that the non-autistic and mixed chains differed (BF_{10} = 62.32, error < 0.001%). Evidence of difference was moderate for the comparison of autistic and mixed chains (BF_{10} = 5.86, error < 0.001), and there was no evidence of difference in precede-rapport between autistic and non-autistic chains (BF_{10} = 0.81, error <0.01). A similar pattern was found for succeed-rapport: with significant evidence of difference between non-autistic and mixed chains (BF_{10} = 6.55, error <0.001), but no evidence of difference between the autistic and mixed group (BF_{10} = 0.57, error < 0.05%) nor between the autistic and non-autistic groups (BF_{10} = 0.67, error < 0.05%).

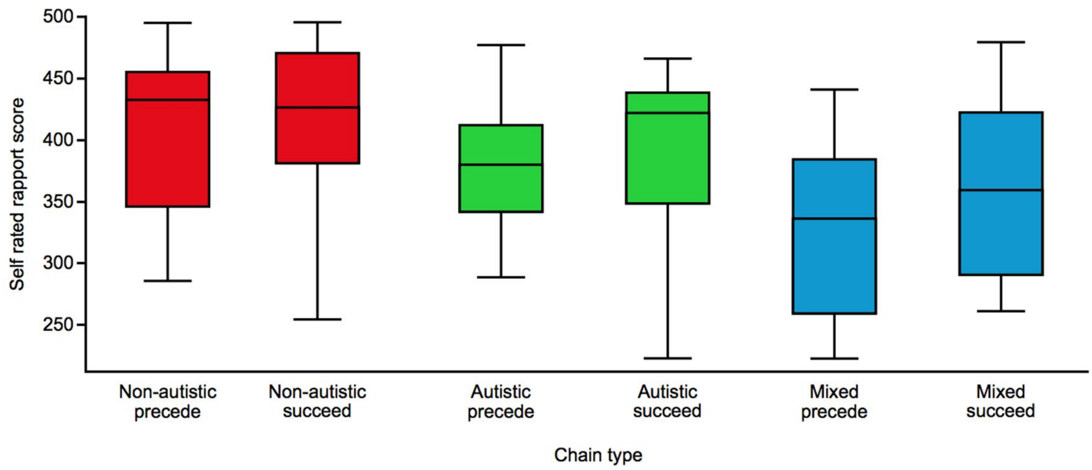

Figure 4: Self rated interactional rapport by chain type and interaction condition.

Within this diffusion chain paradigm, autistic people recall information shared by autistic peers as effectively, as non-autistic people recall information shared by non-autistic peers. Yet, information sharing is significantly poorer in chains of mixed neurotypes. These deficits in information transfer between mixed neurotype groups are accompanied by significantly poorer self-rated interactional rapport.

Discussion: Autism is conceptualised clinically, and in scientific research, by core deficits in social communication, interaction, and emotional reciprocity, deficits in non-verbal communicative behaviours used for social interaction and an absence of interest in peers (APA, 2013). In theory, this should translate into poor information transfer with others. These results, however, are the first empirical evidence that suggest the difficulties in autistic communication are apparent only when interacting with non-autistic people, and are alleviated when interacting with autistic people. This is evidenced by our finding that autistic and non-autistic people do not significantly differ in how accurately they recall information from peers of the same neurotype but that selective difficulties occur when autistic and non-autistic people are sharing information. This occurs alongside significantly lower rapport within mixed groups.

These results challenge traditional assumptions of autistic social impairment. The findings are inconsistent with the social-cognitive deficit narrative of autism. We found a selective breakdown of information transfer and rapport occurred in mixed autistic-non-autistic interactions, indicating that the diagnostic status of an interlocutor plays a critical role in both the quality and enjoyment of and interaction, for both autistic and non-autistic people. The quality of transfer of information within all-autistic chains did not differ from information transfer in all-non-autistic chains, indicating that autistic peoples' abilities to share information and build rapport does not significantly differ from their non-autistic counterparts.

These findings are consistent with prior research indicating that autistic people experiencing close social bonds and empathy with other autistic people, though may experience specific difficulty interacting with non-autistic people (Crompton, Fletcher-Watson & Ropar, 2019; Morrison et al., 2019). This lends additional support to the Double Empathy theory, and suggests that autistic social 'deficits' are better conceptualised as interaction and communicative challenges, operating bi-directionally for autistic and non-autistic people (Milton, 2012; Fletcher-Watson & Bird, 2020). Our data are reminiscent of established effects of in-group/out-group status on imitation, suggesting that autistic people are different without being deficient (Bourgeois & Hess, 2008; Yabar, Johnston, Miles, & Peace, 2006) and have implications for autism diagnosis and post-diagnostic support.

This study raises many questions for future research; for example, would mixed chains may show a different pattern if an autistic participant began the chain? We could hypothesise that the first non-autistic participant in the mixed chain is recalling and sharing fewer details due to an anxiety around how to interact with autistic people, or an intentional oversimplification of information for the perceived benefit of the autistic learner. These effects may or may not be present if an autistic person were the first participant in the chain, and future research may focus on this question. However, if it were the case that non-autistic people oversimplify in an attempt to lower communicative pressures on autistic people, this could have a dramatic impact on autistic peoples' ability to get the information they need from non-autistic people in their day to day life. Future work should focus on understanding information transfer, rapport, and dynamics between mixed pairs and groups, as well as in within autistic groups, to more fully understand the mechanisms underlying autistic social cognition.

This study does have limitations, which could be addressed by future research in this field. Firstly, though fully powered to detect even moderate effects, the sample size was relatively modest, and replications are warranted. Second, participants were aware of the diagnostic status of the person with whom they were interacting, which could have affected their behaviour. However, previous research has shown that when non-autistic people believe they are interacting with an autistic person, they attempt to behave in a helpful way (Heasman & Gillespie, 2019a), and sharing diagnostic information results in greater acceptance of autistic people (Sasson & Morrison, 2017). As such, it may be hypothesised that an even larger effect would be found if participants were blind to the diagnostic status of the others in their diffusion chain. Third, the diffusion chains were not equally divided by gender which may have affected results (Wood, Kendal, & Flynn, 2013). However, the most prominent comparisons of autistic males and autistic females to date have focused on access to diagnosis (Rutherford et al., 2016), co-occurring conditions (Mannion, Leader & Healy, 2013), and behavioural profiles (Kirkovski, Enticott & Fitzgerald, 2013), but not on factors expected to drive this effect, for example recall ability or verbal IQ. Thus, we cannot hypothesise whether the gender distribution in this sample drives the effect via cognitive mechanisms. It is possible that rapport scores and social dynamics could be different within a more mixed or predominantly male sample, for example if autistic males were less likely to camouflage (Hull et al., 2019) and are thus more likely to align with non-autistic expectations of what autism is. While this is a tentative hypothesis, if anything this could lead to an even greater disadvantage in the mixed chains. Fourth, the sample had IQ within the typical range, communicated verbally, and were likely to have received their diagnosis in adulthood given the relatively high mean age of diagnosis. It is not known whether similar effects would be found in autistic people with intellectual disability.

Finally, the Bayesian comparison for rapport did not yield especially high Bayes Factors when comparing autistic and mixed groups. Further work needs to establish the validity and reliability of this effect through replication and across tasks and populations. Specifically, the connection between poor information transfer and lower ratings of rapport bears further scrutiny – does lack of rapport drive the effects we've seen here? Or is the mechanism more behavioural, for example due to mismatches in the type and manifestation of social cues used during the interactional task? Uncovering the mechanism of the effects reported here will have probable implications for our understanding of social cognition and interaction itself (Sheppard et al., 2016).

In addition to these conceptual advances, our findings may also carry relevant practical implications for psychological, psychiatric, and social practice. Confirmation of the finding that autistic social difficulties operate solely across the autistic-non-autistic divide could have profound implications for the classification of autism as a disorder in the Diagnostic and Statistical Manual (APA, 2013). In the meantime, our data suggest that (non-autistic) practitioners supporting autistic people should be conscious of the challenges to information-transfer described here. In the context of rising concern about suicide in autism (Cassidy & Rodgers, 2017) and evidence that "sense of belonging" is a key protective factor against suicide (Pelton & Cassidy, 2017) evidence of improved rapport between autistic people bolsters existing calls for more autistic peer-to-peer support (Iemmi, Knapp & Ragan, 2017). Subsequent research is required to delineate the differences in autistic and non-autistic interaction styles, which will offer practical utility to psychologists, psychiatrists and health professionals, if they can be taught to adapt their communication style to better accommodate people with autism. While replications are warranted, this radical finding challenges the way autism has been characterised for decades, and there are significant and wide-reaching implications for how autistic people are supported in society.

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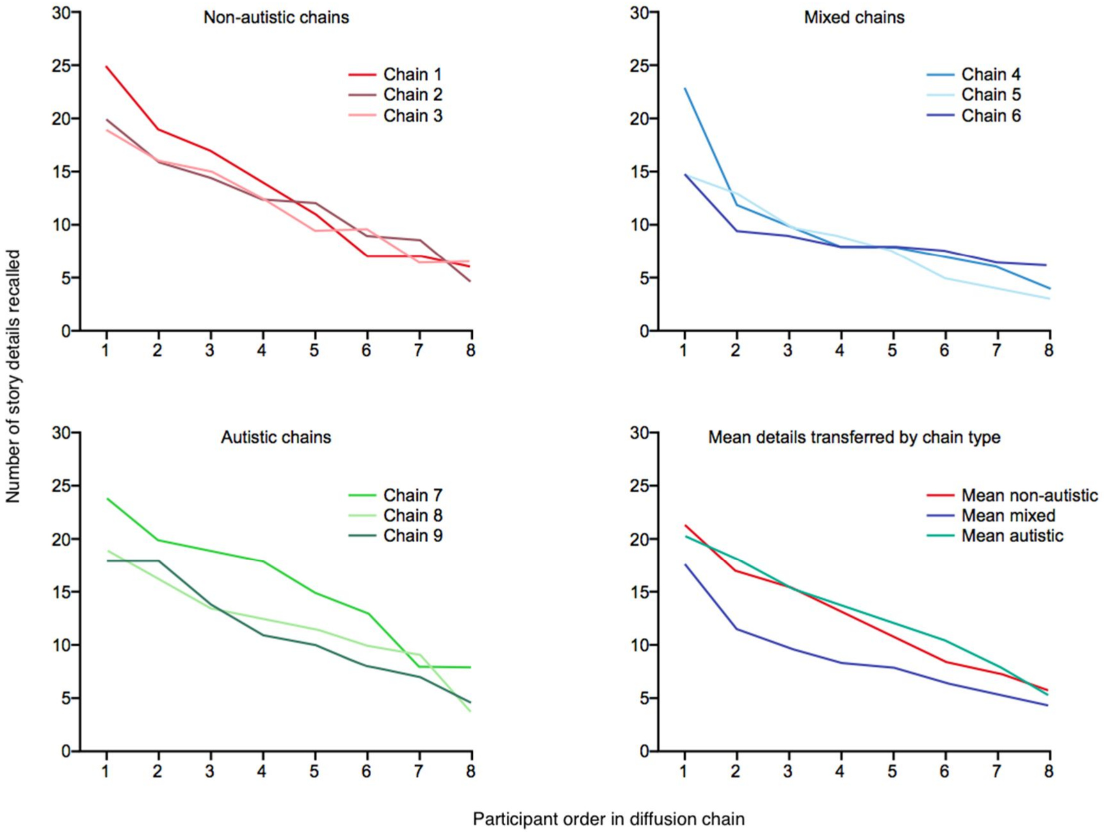
Supplementary data



Supplementary Figure 1: Number of story details shared transferred in the diffusion chain (out of 30) by individual chain and type.

Supplementary Table 1: Description of gender switches in each diffusion chain

Chain	Condition	Gender pattern	N switches
1	Non-autistic	FF-M-F-M-FFF	4
2	Non-autistic	FFFFFFFF	0
3	Non-autistic	FFF-M-FFFF	2
4	Mixed	M-FF-MM-FF-M	4
5	Mixed	FFF-M-FFFF	2
6	Mixed	FF-M-FFFFF	2
7	Autistic	FFFFFFF-M	1
8	Autistic	M-FFFF-NB-FF	3
9	Autistic	FFFF-NB-F-NB-M	4

Supplementary Table 2: Demographics and number of story details recalled by the first participant in each of the diffusion chains.

Chain number	Condition	Autism status	Age	Gender	Years of education	AQ[a]	IQ[b]	Number of story details
1	Non-autistic	Non-autistic	22	F	17	16	117	25
2	Non-autistic	Non-autistic	33	F	17	18	103	20
3	Non-autistic	Non-autistic	21	F	16	11	120	19
4	Mixed	Non-autistic	25	M	20	10	127	23
5	Mixed	Non-autistic	24	F	18	16	108	15
6	Mixed	Non-autistic	24	F	18	8	119	15
7	Autistic	Autistic	21	F	16	25	99	24
8	Autistic	Autistic	20	M	11	27	103	19
9	Autistic	Autistic	19	F	14	34	109	18

[a] Autism Quotient, [b] Full Scale IQ as measured by the WASI