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Interpersonal similarity of autistic traits predicts friendship quality

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> *ἐρωτηθεὶς τί ἐστι φίλος, ἔφη, «μία ψυχὴ δύο σώμασιν ἐνοικοῦσα».*
> ".when he was asked what a friend is, he said 'one soul dwelling in two bodies'.
> **Diogenes Laërtius on Aristotle**

Abstract

Autistic traits are known to be associated with social interaction difficulties. Yet, somewhat paradoxically, relevant research has been typically restricted to studying individuals. In line with the 'dialectical misattunement hypothesis' and clinical insights of intact social interactions among autistic individuals, we hypothesized that friendship quality varies as a function of interpersonal similarity and more concretely the difference value of autistic traits in a dyad, above and beyond autistic traits *per se*. Therefore, in this study, we used self-report questionnaires to investigate these measures in a sample of 67 neurotypical dyads across a broad range of autistic traits. Our results demonstrate that the more similar two persons are in autistic traits, the higher is the perceived quality of their friendship, irrespective of friendship duration, age, sex and, importantly, the (average of) autistic traits in a given dyad. More specifically, higher interpersonal similarity of autistic traits was associated with higher measures of closeness, acceptance and help. These results, therefore, lend support to the idea of an interactive turn in the study of social abilities across the autism spectrum and pave the way for future studies on the multiscale dynamics of social interactions.

Key words: autism; friendship; dialectical misattunement hypothesis; second person neuropsychiatry; double empathy problem; interpersonal similarity

Introduction—from individual traits to interpersonal attunement

Autism spectrum condition (ASC) has been described as a pervasive developmental condition, which is characterized by difficulties in social interaction and communication, as well as restricted interests and/or sensory behaviors (cf. Lord *et al.*, 2020). Recent predictive processing theories (e.g. Van de Cruys *et al.*, 2014; Lawson *et al.*, 2014) view core autistic difficulties as a result of inflexible updating of expectations. This recasts ASC as a deficit of information processing in individual brains. While touching upon social aspects (e.g. Sevgi *et al.*, 2020), these predictive processing accounts still view ASC from an individualistic perspective: the deficit lies exclusively within the autistic individual.

However, the view of ASC as a mere disorder of the individual has been increasingly questioned. For instance, it might be more precise to think of the social difficulties autistic persons typically face as a two-way complication, rather than reduce them a priori to autistic traits *per se* (cf. the double empathy problem; Milton, 2012). Indeed, autistic atypicalities can be seen as a different way of making sense and interacting with the world (cf. De Jaegher, 2013; Hellendoorn, 2014; Fuchs, 2015). Atypicalities or even disorders of social interaction also exist to varying degrees and define other conditions. Notably, transdiagnostically observed social difficulties that are characteristic of psychiatric disorders are more likely observed or may only manifest in real-time social interactions (cf. Schilbach, 2016). Synthesizing predictive processing and intersubjective approaches, the 'dialectical misattunement hypothesis' has reviewed ASC as a cumulative interpersonal mismatch of prediction and interaction styles (Bolis *et al.*, 2016; Bolis and Schilbach, 2017, 2018). These prediction and interaction styles are defined as a set of prior expectations and reaction patterns a person develops in interaction with the world and others across multiple timescales.

In a nutshell, misattunement has been described as disturbances of the dynamic and reciprocal unfolding of social interactions (Bolis *et al.*, 2017). More concretely, two reciprocally linked processes have been thought of being at play: at the collective level, weak interpersonal coupling leads to increasing interindividual incompatibilities in generating and expressing (social) expectations, while at the individual level, such diverging expectations lead to weak coupling with others in social interactions. Coupling can be technically thought of as 'the amount of influence that a system's variables have on another's parametrical conditions' (De Jaegher and Di Paolo, 2007). Critically, these processes can increasingly enhance each other in a feedback loop fashion, where—even minor—changes at one level result in corresponding changes at the other one and vice versa. This type of misattunement manifests not only in clinical populations, but also to varying degrees in so-called neurotypical groups across various timescales (Bolis *et al.*, 2017). For instance, such a misattunement may unfold across the timescale of a single dialogue, during a social relationship or even throughout the development of a child.

On the other hand, dialectical attunement can be thought of as a set of multiscale and inextricably linked processes of attuning to one another and the environment in and through social interactions (cf. Vygotsky, 1980; De Jaegher and Di Paolo, 2007; Bolis, 2020; Bolis and Schilbach, 2020). To elucidate different levels of attunement, let us imagine two illustrative scenarios. First, a person, in deciding about what to wear for going out that night, checks current temperature out at the balcony. The person sees that most people on the street are lightly dressed and eventually decides against wearing a coat despite feeling a cold breeze.

Such decisions, especially when reinforced by persistent cultural norms, can even form stable personal habits beyond awareness. In a second scenario, two skilled tango dancers implicitly anticipate each other's moves and act accordingly, largely beyond the timescale of conscious reflection, as conscious movement monitoring in this case could actually lead to weaker interpersonal coupling.

While interpersonal (mis)attunement may encompass aspects of both similarity and complementarity, in this study, we focus on the former. Indeed, we suggest that a certain level of similarity is crucial for two persons to be able to attune to each other, such as sharing common ground (e.g. culture and language) and channels of communication. In this light, diverse autistic traits can be viewed as differently tuned channels of communication, which, if not taken into account, can lead to multiscale interactional mismatches and eventual lower satisfaction in interpersonal relationships. However, contrary to an apparently persistent misconception, such dissatisfaction should not be a priori attributed to the autistic persons themselves, as this might primarily be a dynamic product of interpersonal misattunement in a neurotypical world.

In fact, interactional and relational quality appears interrelated with interpersonal similarity even with regard to brain function. For instance, not only short-term shared psychological perspectives (Lahnakoski *et al.*, 2014) and motor synchrony (Dumas *et al.*, 2010), but also longer-scale perceived closeness (Bevilacqua *et al.*, 2019), type of relationship (Pan *et al.*, 2017) and distance of a relationship within a social network (Parkinson *et al.*, 2018) appear to be reflected by similarities at the level of brain function. For instance, interpersonal neural similarity has found to be exceptionally high in friends when viewing audiovisual movies, while that similarity decreases as the distance of the relationship within the social network increases (Parkinson *et al.*, 2018). More concretely, these effects are more prominent in brain regions involved in attentional allocation, narrative interpretation and affective responding, such as the nucleus accumbens, amygdala, putamen, caudate nucleus, the right superior parietal cortex and regions in the inferior parietal lobe, possibly implying interpersonal similarity in friends specifically with regard to attention, interpretation and emotionally reactivity to the environment. Interestingly, such similarity does not appear to be visible at the level of intrinsic functional connections during rest (McNabb *et al.*, 2020) but, rather, only presents itself when participants are exposed to social situations or stimuli.

This interrelation of interpersonal similarity with interactional and relational quality extends beyond brain function. For instance, interpersonal synchrony in real-time social interactions has been shown to enhance affiliation (Hove and Risen, 2009; Miles *et al.*, 2009). Additionally, similarity of social skills has been found to be positively related to interpersonal attraction (Burleson and Samter, 1996). Furthermore, homogeneity of student roommate dyads has been indicated as beneficial to the relationship quality, at least during the first weeks of cohabitation (Faso *et al.*, 2016). The abovementioned examples resonate well with the principle of 'homophily', according to which 'contact between similar people occurs at a higher rate than among dissimilar people' (McPherson *et al.*, 2001). Notably, this sort of processes might have been present early in human history (Apicella *et al.*, 2012) as well as in our close primate relatives which also tend to form friendships based on interpersonal similarity (Massen and Koski, 2014).

In fact, friendship, dubbed as the 'hallmark of human behaviour' (Brent *et al.*, 2014), can be considered as a paradigmatic case of real-life interpersonal attunement. Increasing the

chances of survival and reproductive success, friendship is of paramount importance for both humans and other social animals (cf. Massen and Koski, 2014). Indeed, this importance manifests itself across various aspects of human life (Güroğlu et al., 2008): from aspects of mental and physical health, such as psychosocial functioning, stress as well as depression reactivity, general well-being and even the risk of developing a common cold (Hartup, 1996; Cohen et al., 2003; Heinrichs et al., 2003; Rockhill et al., 2007; Street et al., 2007; Schilbach, 2016; Lamblin et al., 2017) to actual morbidity and mortality (Waxler-Morrison et al., 1991; Giles et al., 2005; Holt-Lunstad et al., 2010; Steptoe et al., 2013). Friendship and social connection in general appear tightly interconnected also with brain structure and function (cf. Lamblin et al., 2017). For instance, the diversity of social contacts and the reported quality of these relationships have been associated with grey matter volume of the amygdala, areas adjacent to the superior temporal sulcus (STS) and the medial prefrontal cortex (mPFC; Bickart et al., 2012; Kanai et al., 2012b; Lewis et al., 2011; Von der Heide et al., 2013; Lamblin et al., 2017).

In spite of these insights about the importance of interpersonal attunement and especially friendship, as well as its interrelation with interpersonal similarity, research targeting the autism spectrum has predominantly taken an individualistic approach to study social abilities and difficulties. This is problematic, because clinical insight and preliminary empirical evidence point toward the need for an interactive and relational turn in autism research (cf. Gallagher, 2004; De Jaegher, 2013; Schilbach et al., 2013; Schilbach, 2016; Bolis et al., 2017; Milton et al., 2020). Furthermore, a comprehensive understanding of interpersonal (mis)attunement might remain practically intractable until the diversity of social interaction partners is systematically considered—e.g. across dyads and groups of varying similarity, such as homogeneous dyads of either only neurotypical persons or persons with the same condition, compared with heterogeneous (mixed) dyads (Bolis et al., 2017).

A recent review by McNaughton and Redcay (2020) has focused on the important topic of interpersonal synchrony in autism and reports 25 relevant studies. However, only one of these has explicitly addressed interpersonal similarity by including both homogeneous and heterogeneous dyads (Wadge et al., 2019 on 'communicative misalignment'). To the best of our knowledge, three other studies have recently reported using a similar approach to investigate aspects of peer-to-peer information transfer, non-verbal interpersonal synchrony and first impressions providing complementary but also contradictory insights (Crompton et al., 2019; Georgescu et al., 2020; Morrison et al., 2020). While these studies constitute an important development, certain limitations, in particular with regard to sample and effect size, render the results inconclusive.

In this study, we attempt to go beyond the individual, leveraging real-life friendship as a paradigmatic case of real-life interpersonal attunement and its relation to interpersonal similarity, measured by means of self-reported autistic traits. To this end, we investigate the correlation of dyadic similarity, operationalized as dyadic mismatch (i.e. difference scores) of autistic traits and friendship quality. As friendship duration, age, sex and the (average) autistic traits of the dyad can potentially affect friendship quality scores, we controlled for each of these influences. We hypothesized that irrespective of friendship duration and the average autistic traits of the dyad, the perceived quality of friendship in a given dyad would be negatively correlated with the dyadic difference score of autistic traits.

Methods

In this study, we adapted the Friendship Quality (FQUA) Scale (Thien et al., 2012) in order to deploy it for measuring the impressions of a specific relationship between adults—as opposed to the original version that targeted general impressions of a student about all their friendship relations (cf. Supplementary data for the adapted FQUA Scale). More concretely, apart from the dyadic average of overall quality of friendship (i.e. mean of FQUA values of both persons; on a scale of 1–6), we also calculated the impressions of two friends about each other with regard to safety, closeness, acceptance and help. The latter subscales have been thought of reflecting levels of confidence or trust relied on the friend, attachment by them, social as well as emotional acceptance and mutual help in sustaining the friendship (cf. Thien and Abd Razak, 2013). Additionally, we measured both individual autistic traits (i.e. in a scale of 0–50; Baron-Cohen et al., 2001) and dyadic mismatch thereof (i.e. absolute value of the autism-spectrum quotient [AQ] difference between the two persons of a dyad).

Subsequently, we analyzed both the individual autistic traits and the dyadic mismatch thereof in the context of the friendship aspects mentioned above by means of one-sided Spearman bivariate correlation analyses. Bonferroni correction was used to correct for multiple testing within each of our investigations. In all cases, we performed permutation-based statistical tests, implemented over 10 000 iterations. Put simply, we constructed null distributions of correlations through a data-driven approach. That is, we implemented a random permutation of the observations within one of the two variables before calculating the value of a correlation, repeating over 10 000 times. This yielded a null distribution, i.e. a set of correlation values that are expected to emerge out of chance, even when two variables have no statistical interrelation.

We operationalized dyadic similarity as a dyadic mismatch of autistic traits, namely the difference value within a given dyad and associated friendship quality as the average within a given dyad. To maintain consistency and avoid dependency pitfalls in the analysis of individual traits, we calculated correlation coefficients and P-values after randomly selecting one of the two persons for each dyad. The reported values are the average over 10 000 iterations of this analysis step. Subsequently, to provide a test of the difference between two correlations we randomly subsampled 20% of both variables within a given test and compared correlation values over 10 000 iterations.

In our study, 144 neurotypical adults were recruited, forming 72 same-sex dyads of friends (consistent with previous relevant research, e.g. Berry et al., 2000; Wainer et al., 2013). Five dyads were excluded from the analyses because individuals in these dyads had either a family or a romantic relationship with each other. The duration of friendships at the point of measurement ranged from 0.25 (3 months) to 30 years ($M = 6$, s.d. $= 6.1$). The meeting frequency varied from a few times per year to daily. Participants' ages ranged from 19 to 50 years ($M = 25.5$, s.d. $= 4.8$, 34 female and 33 male dyads). More details about the distributions, statistics and raw values of the primary variables of this study (i.e. friendship quality and duration, as well as individual and mismatch of autistic traits) are presented in Figure 1.

Participants were recruited as part of a larger suite of behavioral experiments through online advertisements and public leaflets in Munich, Germany. More specifically, interested potential participants were invited to visit our site at the Max Planck institute of Psychiatry together with a friend of their
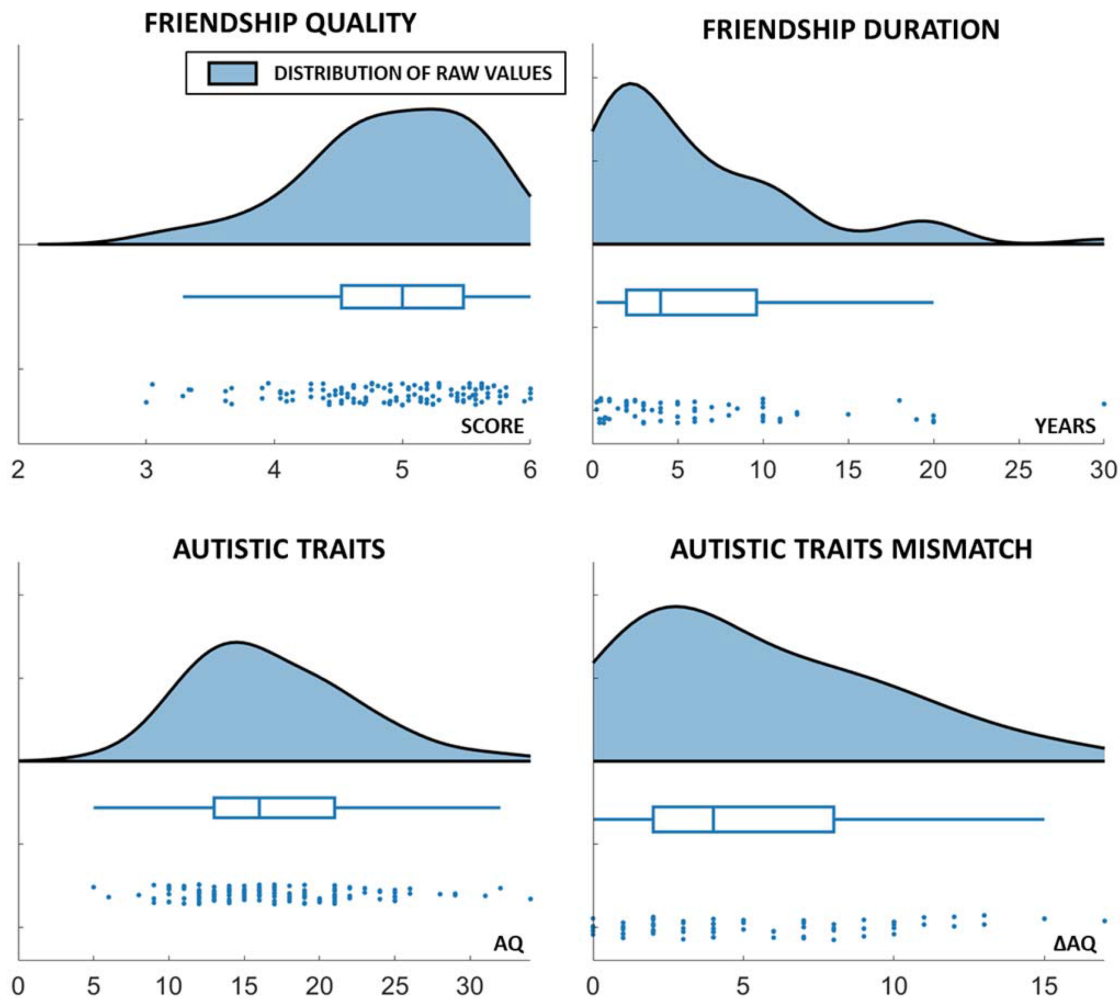
Fig. 1. Primary variables of the study: friendship quality, friendship duration, individual autistic traits and the mismatch of autistic traits (interpersonal difference of individual traits). Dots denote actual raw data, boxplots display sample median alongside interquartile range, while distribution 'clouds' portray a smoothed version of the histogram (cf. rain cloud plots; Allen *et al.*, 2018).

choice. Our study was approved by the institutional ethics committee of the medical faculty at the Ludwig Maximilian University of Munich. All participants read and signed a declaration of consent, which was obtained according to the Declaration of Helsinki. Participants also read detailed information about the course of the studies, including potential side effects and safety aspects, as well as written instructions for the different measurements performed during the studies.

Results

To test our hypothesis, we first calculated the correlations between the autistic and friendship measures for both the dyadic mismatch (i.e. difference value) and individual autistic trait measures (corrected threshold $p_t = 0.0125$, via dividing the standard threshold by the number of comparisons, i.e. 4). Dyadic mismatch of autistic traits (Figure 2, right) was found to be negatively correlated with both the dyadic average of friendship quality $(r(65) = -0.40, p < 0.001)$ and friendship duration $(r(65) = -0.37, p = 0.002)$. In contrast to this, individual autistic traits (Figure 2, left) did not significantly correlate with either friendship quality $(r(65) = -0.18, p = 0.075)$ or friendship duration $(r(65) = 0.01, p = 0.52)$.

Importantly, the partial correlation between the dyadic mismatch of autistic traits and both the dyadic average of friendship quality $(r(65) = -0.32, p = 0.004)$ and friendship duration $(r(65) = -0.39, p < 0.001)$ remained statistically significant even after controlling for the dyadic average of autistic traits. In addition, to evaluate the reliability of the correlation differences between the dyadic and the individual autistic traits, we calculated the difference between correlation coefficients in random subsamples of the data (i.e. 80% over 10 000 iterations). This showed that the friendship quality was more strongly correlated with dyadic mismatch than individual autistic traits in 87.3% of the cases (Figure 3, left). In the case of friendship duration, the dyadic mismatch of autistic traits was more strongly correlated than individual autistic traits in 98.5% of the cases (Figure 3, right). Furthermore, correlations of dyadic *vs* individual autistic traits were higher with both friendship quality $(\Delta r(65) = 0.23, p = 0.07)$ and friendship duration $(\Delta r(65) = 0.37, p = 0.006)$, yet only the latter case was statistically significant within our sample size.

Notably, while duration and quality of friendship were positively correlated $(r(65) = 0.36, p = 0.002)$, the partial correlation between the dyadic mismatch of autistic traits and friendship quality remained statistically significant even after controlling for the duration of friendship
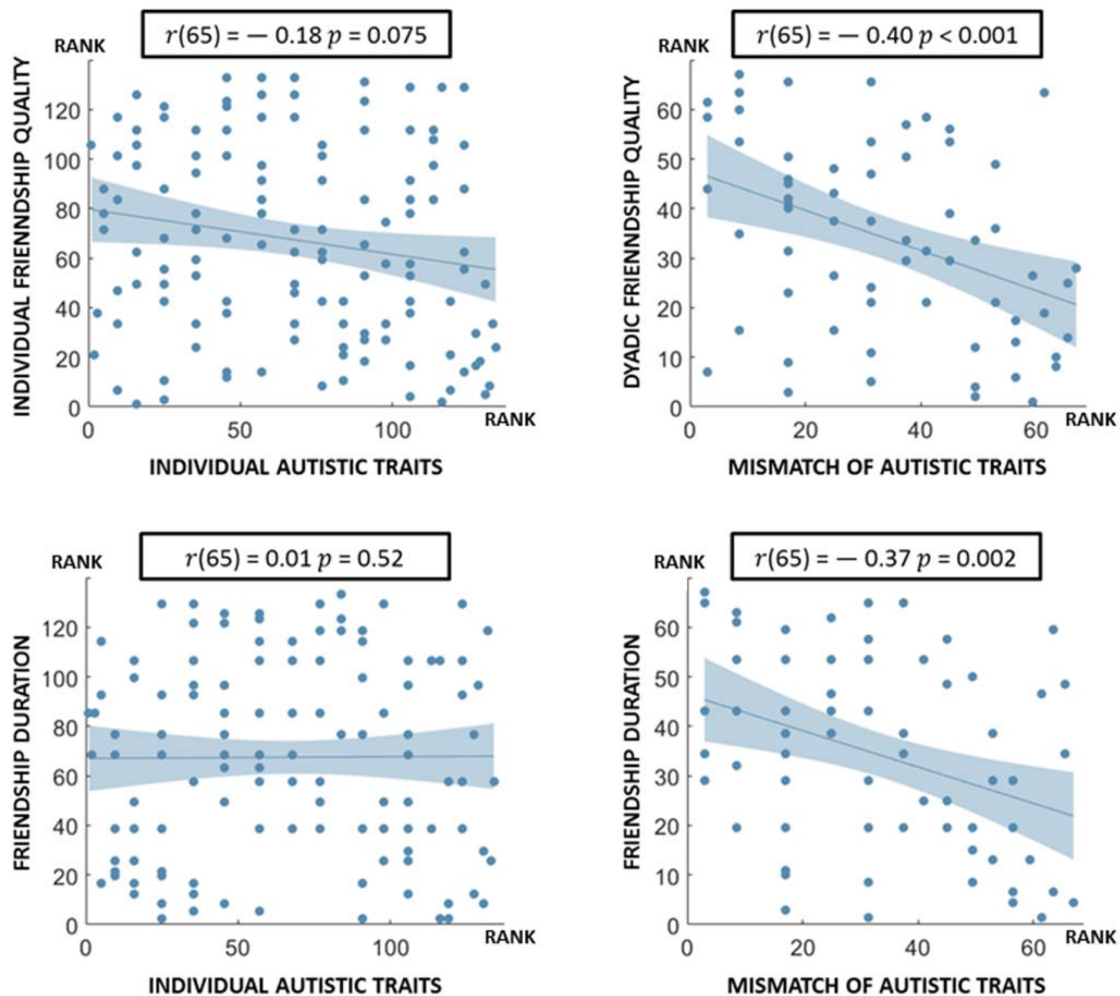
Fig. 2. Friendship (in rank values; vertical axes) and autistic traits (in rank values; horizontal axes): Interrelations of individual autistic traits (left column) and dyadic mismatch thereof (right column) with friendship quality (top row) and friendship duration (bottom row). Dyadic mismatch of autistic traits negatively correlated with both friendship quality and duration, while individual autistic traits did not significantly correlate with either of the friendship measures. Individual friendship quality refers to each individual's impressions, while dyadic friendship quality to the average impressions within a given dyad. Please note there is only one value for each dyad in the pairwise mismatch measures, while individual traits are plotted for each participant. Regression lines and the 95% confidence bands were drawn with the bounded line toolbox (Kearney, 2020).

$(r(65) = -0.31, p = 0.007)$. Furthermore, in order to check whether the within-dyad average value of friendship quality is a representative metric, we also controlled for the differences in ratings between the members of a given dyad, yielding a significant partial correlation $(r(65) = -0.38, P = 0.001)$. Moreover, the partial correlation remained statistically significant after controlling both for age $(r(65) = -0.41, p < 0.001)$ and sex $(r(65) = -0.41, p < 0.001)$. Indeed, the correlation between the dyadic mismatch of autistic traits and friendship quality was not significantly different in the female *vs* the male group of our sample for either the friendship quality $(\Delta r(65) = 0.01, p = 0.97)$ or the friendship duration $(\Delta r(65) = 0.25, p = 0.35)$.

Additionally, to provide a more fine-grained analysis, we subsequently decomposed friendship quality into the subscales of the friendship questionnaire (i.e. safety, closeness, acceptance and help) and repeated the correlational calculations with the dyadic mismatch and individual autistic traits (corrected threshold $p_t = 0.0063$, via dividing the standard threshold by the number of comparisons, i.e. 8). The dyadic mismatch of autistic traits

was found to be negatively correlated with interpersonal acceptance, closeness and help, but not safety at the corrected significance threshold (acceptance: $r(65) = -0.39, p < 0.001$; closeness: $r(65) = -0.34, p = 0.003$; help: $r(65) = -0.38, p < 0.001$; safety: $r(65) = -0.27, p = 0.014$). In contrast to this, none of the correlations between individual autistic traits and the above-mentioned relational factors achieved statistical significance at the corrected significance threshold (acceptance: $r(65) = -0.16, p = 0.1$; closeness: $r(65) = -0.02, p = 0.43$; help: $r(65) = -0.21, p = 0.046$; safety: $r(65) = -0.23, p = 0.031$).

Finally, we calculated correlations of friendship duration and friendship subscales to gain a better insight of the interrelation between these factors (corrected threshold $p_t = 0.0125$, via dividing the standard threshold by the number of comparisons, i.e. 4). Friendship duration was found to be positively correlated with interpersonal acceptance and closeness, but not safety and help at the corrected significance threshold (interpersonal acceptance: $r(65) = 0.41, p < 0.001$; closeness: $r(65) = 0.36$, $p = 0.001$; help: $r(65) = 0.21, p = 0.043$; safety: $r(65) = 0.21$, $p = 0.040$).
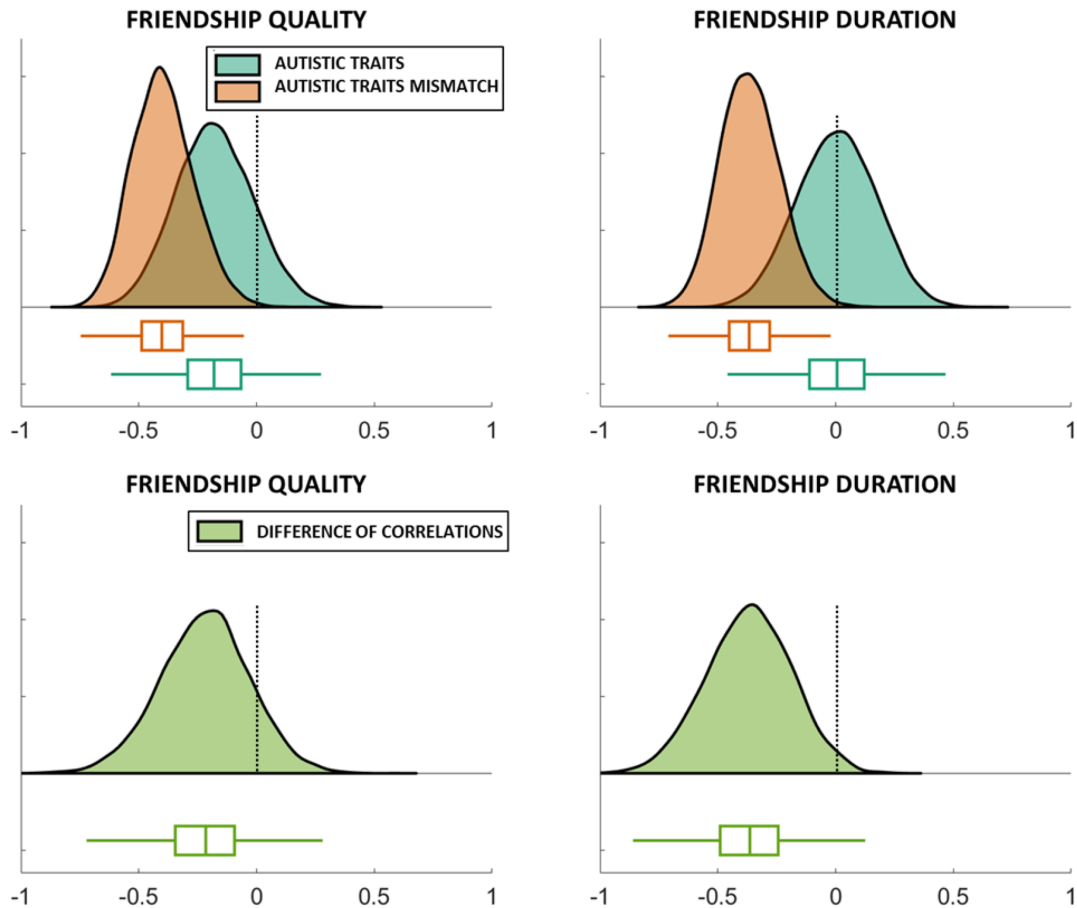
Fig. 3. Bootstrap resampled correlation strengths: dyadic mismatch of autistic traits (r_{dmat};orange) and individual autistic traits (r_{iat}; blue) correlations with friendship quality (top left) and friendship duration (top right). Distributions of correlation difference ($r_{dmat} - r_{iat}$; green) for friendship quality (bottom left) and friendship duration (bottom right). Dotted lines indicate zero level for correlation strength. The autistic trait mismatch correlation distributions (orange, top figures) lie almost completely on the negative side for both the cases of friendship quality and friendship duration. In the majority of resampled datasets, autistic trait mismatch appears stronger correlated with both friendship measures than the autistic traits do (part of the distributions below zero; green; bottom figures). Boxplots display sample median alongside interquartile range, while distribution 'clouds' portray a smoothed version of the histogram (cf. rain cloud plots; Allen *et al.*, 2018).

Discussion

To empirically examine the dialectical misattunement hypothesis of autistic traits in a neurotypical range, we studied the link between the similarity of autistic traits (operationalized as the dyadic mismatch, i.e. difference value thereof) and friendship ratings in a relatively large sample of same-sex, neurotypical dyads along a continuum of autistic traits. To this end, pairs of friends were invited to complete questionnaires on their individual autistic traits and the quality of their friendship. Subsequently, pairwise correlation analyses were performed between (both dyad-related and individual) measures of autistic traits and ratings of friendship. As hypothesized, the interpersonal similarity (or mismatch) of autistic traits predicted core aspects of friendship quality. Here, it was shown that friendship quality was higher between individuals rating similarly on autistic traits. Importantly, our results also indicate that this positive link between similarity of autistic traits and perceived quality of friendship holds irrespective of friendship duration, age, sex and importantly the (average) autistic traits of the dyad. Further investigation of the key constituents of friendship quality, interpersonal mismatch of autistic traits was found to be negatively

correlated not only with overall quality and duration, but also the subscales of perceived closeness, acceptance and help.

These findings resonate well with clinical insights, recent intersubjective theories as well as preliminary empirical evidence, which emphasize the need for a relational and interactional turn in the research of autism (cf. De Jaegher, 2013; Rolison *et al.*, 2015; Schilbach, 2016; Bolis *et al.*, 2017; Strunz *et al.*, 2017; Heasman and Gillespie, 2018; Milton *et al.*, 2020). Such a development is significant, because the link between autistic traits and the quality of interpersonal relationships has been—somewhat surprisingly—studied from an individualistic perspective. For instance, a seminal study by Baron-Cohen and Wheelwright (2003) tested adults with high functioning autism/Asperger syndrome using the Friendship Questionnaire to explore the extreme male brain theory of autism. This theory predicts that 'on any test of "empathizing", unaffected males will score lower than unaffected females, and performance by individuals with an ASC will be even lower than unaffected males'. Indeed, the study showed that neurotypical females scored highest in the friendship questionnaire, followed by neurotypical males, while autistic males scored the lowest.

Our study goes beyond such an individualistic approach by taking into account how interpersonal similarity along the continuum of autistic traits may influence how we perceive our relations to others. The observed link between interpersonal similarity and friendship quality can be potentially explained on the basis of optimized reciprocal predictions about each other (cf. Friston and Frith, 2015; Bolis *et al.*, 2017; Constant *et al.*, 2020). Predictions about others have been thought of as fundamental in social interactions on both an intrapersonal and interpersonal level (cf. Frith and Frith, 2012; Timmermans *et al.*, 2012). Additionally, making yourself predictable can help increase your chances of continuing to interact with others (Coan and Sbarra, 2015), while potentially decreasing metabolic cost, which has been thought of as a function of prediction error (Theriault *et al.*, 2019). In brief, interpersonal similarity of friends can be considered as adaptive, as it might serve for uncertainty decrease in social interactions by fostering reliability (Massen and Koski, 2014).

Put simply, the role of interpersonal similarity (with regard to autistic traits) in social relationships and interactions is potentially 2-fold: not only does it optimize my predictions about the other, but also it makes me more predictable to the other. This can be thought of as a multiscale process of interpersonal attunement that can promote social cohesion and facilitate communication (cf. Bolis and Schilbach, 2020). Importantly, such an interactional success might be mediated, enhanced and stabilized by rewarding processes along the following lines: as persons become more attuned to each other, the quality of social interaction increases, making communication more rewarding, which in turn enhances interpersonal attraction and motivation to interact with each other, thereby further fostering interactional success and interpersonal attunement in a potential feedback loop fashion (cf. Burleson and Samter, 1996; Schilbach *et al.*, 2013; Bolis *et al.*, 2017). Indeed, a very recent study reported an association between social expectation confirmation and increased activation in brain regions relevant to reward processing, including the nucleus accumbens (Reggev *et al.*, 2020 pre-print).

With regard to ASCs, even minor disturbances in the unfolding of these interactional and relational processes might result in increasingly divergent prediction and interaction styles between the interactors, potentially instigating and perpetuating a vicious cycle of interpersonal misattunement (Bolis *et al.*, 2017). Indeed, some evidence for such interpersonal predictive differences has been found in ASC at both behavioral and neural levels (cf. Balsters *et al.*, 2017; Van de Cruys *et al.*, 2014; Von Der Lühe *et al.*, 2016; Grisoni *et al.*, 2019), which may help explain the development of interpersonal misattunement. For instance, social difficulties in ASC have been connected to differences of social predictive processing within the gyral surface of the anterior cingulate cortex (ACCg; Balsters *et al.*, 2017).

Contrary to the interpersonal similarity of autistic traits, the actual (individual) autistic traits did not significantly predict any of the abovementioned friendship aspects, albeit the correlation coefficient was negative in all measures of friendship quality. With regard to this weak negative interrelation, our results are in line with previous research, which has shown an association between high individual autistic traits and lower general satisfaction about interpersonal relationships, such as increased feelings of loneliness, lower frequency of social behaviors and lower satisfaction when they engage in such behaviors (cf. Reed *et al.*, 2016; De Groot and Van Strien, 2017). Consequently, here, we did not demonstrate that individual traits are irrelevant, but that their impact is too low to be significant in our analyses of

real-life friendships. This shows that future studies might need to focus even more on interpersonal similarity (or mismatch), besides traditional intrapersonal measures.

Clearly, this study has limitations: First, the population sample did not include autistic persons. Therefore, this line of study should be extended by including autistic persons in order to shed light on potential similarities and differences across the whole spectrum of autism conditions. This will be important as while the autism-spectrum model assumes that autism conditions 'lie on a continuum of social-communication skills' (Wakabayashi *et al.*, 2006) and that 'autistic traits are continuously distributed throughout the general population' (Constantino, 2011), other approaches have questioned such a conceptualization (cf. Mottron and Bzdok, 2020).

Also, our correlational analyses manifest potential interrelations between the study's variables, which in cases might be mediated through additional intra- as well as interpersonal factors and thereby should not be taken as implying direct causal relations. This study is primarily grounded in the dialectical misattunement hypothesis (Bolis *et al.*, 2017), which focuses on a potential interpersonal mismatch with regard to autistic traits on the basis of potentially diverse styles of developing and expressing (social) expectations. Notably, interpersonal variability of autistic tendencies has been shown to be largely independent of principal personality dimensions in the general population (Wakabayashi *et al.*, 2006). Here, comparatively studying the contribution of autistic and other so-called personality traits will help further specify the conclusions of this study (Selfhout *et al.*, 2010). Yet, the dialectical misattunement hypothesis could be readily investigated across various other important factors, such as age and gender, but also cultural, socioeconomic and educational background, to name but a few examples (cf. Fong and Isajiw, 2000; Pollmann *et al.*, 2010; Reed *et al.*, 2016).

Additionally, only same-sex dyads of adult individuals were recruited and all participants came from a relatively homogeneous cultural background. Sexual preferences were also not considered, except in dyads where a romantic relation existed. Furthermore, exclusively explicit measures were analyzed at a certain point in time, thereby capturing a static snapshot of the multiscale dynamics of relevant individual and interpersonal processes viewed through the lens of subjective evaluations. Additionally, we only studied dyads that identified as friends and, as such, it is unclear how strongly the similarity of autistic traits relates to the quality of social relationships in other types of situations, such as in romantic relationships or hierarchical organizations, such as certain working places. Finally, a specific validated scale of friendship quality was deployed in order to capture friendship quality and relevant attributes, slightly adapted for use in real-life dyadic relationships of adults. Systematic comparison and integrative use of diverse scales of friendship and broader interactional and relational aspects might further refine relevant insights in the future.

Taken together, our results lend support to the notion of a relational and interactive turn in the research of human behavior, bringing interpersonal similarity and dialectical (mis)attunement into the foreground. Yet, further research is needed to delineate the specific behavioral and neural mechanisms of interpersonal (mis)attunement in social interaction across various groups of individuals. Crucially, future studies should include measurements of real-time social interactions of dyads tested for mismatch of autistic and other factors in order to unveil the processes of interpersonal misattunement and communication success in action. Various forms of

interpersonal psychophysiological attunement could be considered here; from heart rate and brain function coupling to facial expression and linguistic alignment, to name but a few examples (cf. Konvalinka *et al.*, 2011; Fusaroli *et al.*, 2012). Two-person (and collective or social) psychophysiology as well as interpersonal predictive processing appear as promising avenues to this end (cf. Bolis *et al.*, 2017; Bolis and Schilbach, 2017, 2018, 2020; Brandi *et al.*, 2019; Ciaunica *et al.*, 2018; Constant *et al.*, 2020; Dumas, 2011; Dumas *et al.*, 2020; Fotopoulou and Tsakiris, 2017; Konvalinka and Roepstorff, 2012; Milton *et al.*, 2020; Redcay and Schilbach, 2019; Schilbach, 2016; Veissière *et al.*, 2019).

A focus on social interactions between autistic persons will also be of particular relevance: First, tapping into interpersonal mismatch processes might result in a more precise analysis of the mechanisms of communication breakdown. Importantly, it can also help to understand to what extent and how autistic persons among each other are able to communicate effectively, without relying on those processes that appear to be relevant for neurotypical persons. Such an intersubjective research approach aligns with holistic perspectives of impairment as 'profoundly bio-social, that is, shaped by the interaction of biological and social factors, and … bound up with processes of socio-cultural naming' (Thomas, 1999, p. 43; cited in Graby, 2012). Finally, by taking atypical social interaction seriously, in terms of both research and practice, a voice is given to the most relevant part of the population for the endeavor, namely the primarily affected persons themselves. Such a perspective eventually aims at not merely treating the autistic individual, but rather cultivating an interpersonal space where both sides will be able to adapt to the expectations of each other.

Supplementary data

Supplementary data are available at *SCAN* online.

Conflict of interest

None declared.

References

Allen, M., Poggiali, D., Whitaker, K., Marshall, T.R., Kievit, R. (2018). Raincloud plots: a multi-platform tool for robust data visualization. *PeerJ Preprints*, 6, e27137v1.

Apicella, C.L., Marlowe, F.W., Fowler, J.H., Christakis, N.A. (2012). Social networks and cooperation in hunter-gatherers. *Nature*, 481(7382), 497–501.

Balsters, J.H., Apps, M.A., Bolis, D., Lehner, R., Gallagher, L., Wenderoth, N. (2017). Disrupted prediction errors index social deficits in autism spectrum disorder. *Brain*, 140(1), 235–46.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., Clubley, E. (2001). The autism-spectrum quotient (AQ): evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, 31(1), 5–17.

Baron-Cohen, S., Wheelwright, S. (2003). The Friendship Questionnaire: an investigation of adults with Asperger syndrome or high-functioning autism, and normal sex differences. *Journal of Autism and Developmental Disorders*, 33(5), 509–17.

Bevilacqua, D., Davidesco, I., Wan, L., et al. (2019). Brain-to-brain synchrony and learning outcomes vary by student–teacher dynamics: evidence from a real-world classroom electroencephalography study. *Journal of Cognitive Neuroscience*, 31(3), 401–11.

Berry, D.S., Willingham, J.K., Thayer, C.A. (2000). Affect and personality as predictors of conflict and closeness in young adults' friendships. *Journal of Research in Personality*, 34(1), 84–107.

Bickart, K.C., Hollenbeck, M.C., Barrett, L.F., Dickerson, B.C. (2012). Intrinsic amygdala cortical functional connectivity predicts social network size in humans. *Journal of Neuroscience*, 32, 14729–41.

Bolis, D. (2020). 'I interact therefore I am': human becoming in and through social interaction. *Doctoral Dissertation*. Munich, Germany: Max Planck Institute of Psychiatry and LMU.

Bolis, D., Balsters, J., Wenderoth, N., et al. (2017). Beyond autism: introducing the dialectical misattunement hypothesis and a Bayesian account of intersubjectivity. *Psychopathology*.

Bolis, D., Becchio, C., Schilbach, L. (2016). Revisiting psychological definitions at the interface of sociocultural historical theories and predictive coding. *Worlding the BRAIN: Patterns, Rhythms, Narratives in Neuroscience and the Humanities*, 10.

Bolis, D., Schilbach, L. (2017). Beyond one Bayesian brain: modeling intra- and inter-personal processes during social interaction: commentary on "Mentalizing homeostasis: the social origins of interoceptive inference" by Fotopoulou & Tsakiris. *Neuropsychoanalysis*, 19(1), 35–38.

Bolis, D., Schilbach, L. (2018). Observing and participating in social interactions: action perception and action control across the autistic spectrum. *Developmental Cognitive Neuroscience*, 29, 168–75.

Bolis, D., Schilbach, L. (2020). 'Through others we become ourselves': the dialectics of predictive coding and active inference. *Behavioral and Brain Sciences*, 43, E93. doi:

Brandi, M.L., Kaifel, D., Bolis, D., Schilbach, L. (2019). The interactive self – a review on simulating social interactions to understand the mechanisms of social agency. *i-com*, 18(1), 17–31.

Brent, L.J., Chang, S.W., Gariépy, J.F., Platt, M.L. (2014). The neuroethology of friendship. *Annals of the New York Academy of Sciences*, 1316(1), 1.

Burleson, B.R., Samter, W. (1996). Similarity in the communication skills of young adults: foundations of attraction, friendship, and relationship satisfaction. *Communication Reports*, 9(2), 127–39.

Ciaunica, A., Schilbach, L., Deroy, O. (2018). The multisensory base of bodily coupling in face-to-face social interactions: contrasting the case of autism with the Möbius syndrome. *Philosophical Psychology*, 31(8), 1162–87.

Coan, J.A., Sbarra, D.A. (2015). Social baseline theory: the social regulation of risk and effort. *Current Opinion in Psychology*, 1, 87–91.

Constant, A., Bervoets, J., Hens, K., Van de Cruys, S. (2020). Precise worlds for certain minds: an ecological perspective on the relational self in autism. *Topoi*, 39(3), 611–622.

Constantino, J.N. (2011). The quantitative nature of autistic social impairment. *Pediatric Research*, 69(8), 55–62.

Cohen, S., Doyle, W.J., Turner, R., Alper, C.M., Skoner, D.P. (2003). Sociability and susceptibility to the common cold. *Psychological Science*, 14(5), 389–95.

Crompton, C.J., Ropar, D., Evans-Williams, C.V., Flynn, E.G., Fletcher-Watson, S. (2019). Autistic peer to peer information transfer is highly effective. *Autism*, 1362361320919286.

De Groot, K., Van Strien, J.W. (2017). Evidence for a broad autism phenotype. *Advances in Neurodevelopmental Disorders*, 1(3), 129–40.

De Jaegher, H. (2013). Embodiment and sense-making in autism. *Frontiers in Integrative Neuroscience*, 7, 15.

De Jaegher, H., Di Paolo, E. (2007). Participatory sense-making. *Phenomenology and the Cognitive Sciences*, 6(4), 485–507.

Dumas, G. (2011). Towards a two-body neuroscience. *Communicative & Integrative Biology*, 4, 349–52.

Dumas, G., Gozé, T., Micoulaud-Franchi, J. (2020). "Social physiology" for psychiatric semiology: how TTOM can initiate an interactive turn for computational psychiatry? *Behavioral and Brain Sciences*, 43, E102.

Dumas, G., Nadel, J., Soussignan, R., Martinerie, J., Garnero, L. (2010). Inter-brain synchronization during social interaction. *PLoS One*, 5, 8.

Faso, D.J., Corretti, C.A., Ackerman, R.A., Sasson, N.J. (2016). The broad autism phenotype predicts relationship outcomes in newly formed college roommates. *Autism*, 20(4), 412–24.

Fong, E., Isajiw, W.W. (2000). Determinants of friendship choices in multiethnic society. *Sociological Forum*. 15, 249–71.

Fotopoulou, A., Tsakiris, M. (2017). Mentalizing homeostasis: the social origins of interoceptive inference. *Neuropsychoanalysis*, 19(1), 3–28.

Friston, K., Frith, C. (2015). A duet for one. *Consciousness and Cognition*, 36, 390–405.

Frith, C.D., Frith, U. (2012). Mechanisms of social cognition. *Annual Review of Psychology*, 63, 287–313.

Fuchs, T. (2015). Pathologies of intersubjectivity in autism and schizophrenia. *Journal of Consciousness Studies*, 22(1-2), 191–214.

Fusaroli, R., Bahrami, B., Olsen, K., et al. (2012). Coming to terms: quantifying the benefits of linguistic coordination. *Psychological Science*, 23(8), 931–39.

Gallagher, S. (2004). Understanding interpersonal problems in autism: interaction theory as an alternative to theory of mind. Philosophy. *Psychiatry, & Psychology*, 11(3), 199–217.

Georgescu, A.L., Koeroglu, S., de C. Hamilton, A.F., Vogeley, K., Falter-Wagner, C.M., Tschacher, W. (2020). Reduced nonverbal interpersonal synchrony in autism spectrum disorder independent of partner diagnosis: a motion energy study. *Molecular Autism*, 11(1), 1–14.

Giles, L.C., Glonek, G.F., Luszcz, M.A., Andrews, G.R. (2005). Effect of social networks on 10 year survival in very old Australians: the Australian longitudinal study of aging. *Journal of Epidemiology and Community Health*, 59(7), 574–79.

Graby, S. (2012). To be or not to be disabled: autism, disablement and identity politics. In: Paper presented at the 'Theorising Normalcy and the Mundane' conference. University of Chester, Chester, 27 June.

Grisoni, L., Moseley, R.L., Motlagh, S., et al. (2019). Prediction and mismatch negativity responses reflect impairments in action semantic processing in adults with autism spectrum disorders. *Frontiers in Human Neuroscience*, 13, 395.

Güroğlu, B., Haselager, G.J., van Lieshout, C.F., Takashima, A., Rijpkema, M., Fernández, G. (2008). Why are friends special? Implementing a social interaction simulation task to probe the neural correlates of friendship. *Neuroimage*, 39(2), 903–10.

Hartup, W.W. (1996). The company they keep: friendships and their developmental significance. *Child Development*, 67(1), 1–13.

Heasman, B., Gillespie, A. (2018). Perspective-taking is two-sided: misunderstandings between people with Asperger's syndrome and their family members. *Autism*, 22(6), 740–50.

Heinrichs, M., Baumgartner, T., Kirschbaum, C., Ehlert, U. (2003). Social support and oxytocin interact to suppress cortisol and subjective responses to psychosocial stress. *Biological Psychiatry*, 54(12), 1389–98.

Hellendoorn, A. (2014). Understanding social engagement in autism: being different in perceiving and sharing affordances. *Frontiers in Psychology*, 5, 850.

Holt-Lunstad, J., Smith, T.B., Layton, J.B. (2010). Social relationships and mortality risk: a meta-analytic review. *PLoS Medicine*, 7(7), e1000316.

Hove, M.J., Risen, J.L. (2009). It's all in the timing: interpersonal synchrony increases affiliation. *Social Cognition*, 27, 949–60.

Kanai, R., Bahrami, B., Roylance, R., Rees, G. (2012). Online social network size is reflected in human brain structure. *Proceedings of the Royal Society B: Biological Sciences*, 279, 1327–34.

Kearney, K. (2020). boundedline.m (https://www.github.com/kakearney/boundedline-pkg), GitHub. Retrieved November 2, 2019.

Konvalinka, I., Roepstorff, A. (2012). The two-brain approach: how can mutually interacting brains teach us something about social interaction?. *Frontiers in Human Neuroscience*, 6, 215.

Konvalinka, I., Xygalatas, D., Bulbulia, J., et al. (2011). Synchronized arousal between performers and related spectators in a fire-walking ritual. *Proceedings of the National Academy of Sciences*, 108(20), 8514–19.

Lamblin, M., Murawski, C., Whittle, S., Fornito, A. (2017). Social connectedness, mental health and the adolescent brain. *Neuroscience and Biobehavioral Reviews*, 80, 57–68.

Lahnakoski, J.M., Glerean, E., Jääskeläinen, I.P., et al. (2014). Synchronous brain activity across individuals underlies shared psychological perspectives. *NeuroImage*, 100, 316–24.

Lawson, R.P., Rees, G., Friston, K.J. (2014). An aberrant precision account of autism. *Frontiers in Human Neuroscience*, 8, 302.

Lewis, P.A., Rezaie, R., Brown, R., Roberts, N., Dunbar, R.I.M. (2011). Ventromedial prefrontal volume predicts understanding of others and social network size. *Neuroimage*, 57, 1624–29.

Lord, C., Brugha, T.S., Charman, T., et al. (2020). Autism spectrum disorder. *Nature Reviews Disease Primers*, 6(1), 1–23.

Massen, J.J., Koski, S.E. (2014). Chimps of a feather sit together: chimpanzee friendships are based on homophily in personality. *Evolution and Human Behavior*, 35(1), 1–8.

McNabb, C.B., Burgess, L.G., Fancourt, A. et al. (2020). No evidence for a relationship between social closeness and similarity in resting-state functional brain connectivity in schoolchildren. bioRxiv, 788208.

McNaughton, K.A., Redcay, E. (2020). Interpersonal synchrony in Autism. *Current Psychiatry Reports*, 22(3), 12.

McPherson, M., Smith-Lovin, L., Cook, J.M. (2001). Birds of a feather: homophily in social networks. *Annual Review of Sociology*, 27(1), 415–44.

Miles, L.K., Nind, L.K., Macrae, C.N. (2009). The rhythm of rapport: interpersonal synchrony and social perception. *Journal of Experimental Social Psychology*, 45, 585–89.

Milton, D.E. (2012). On the ontological status of autism: the 'double empathy problem'. *Disability & Society*, 27(6), 883–87.

Milton, D.E.M., Heasman, B., Sheppard, E. (2020). Double empathy. In: Volkmar, F., editors. *Encyclopedia of Autism Spectrum Disorders*. New York, NY: Springer.

Morrison, K.E., DeBrabander, K.M., Jones, D.R., Faso, D.J., Ackerman, R.A., Sasson, N.J. (2020). Outcomes of real-world social interaction for autistic adults paired with autistic compared to typically developing partners. *Autism*, 24(5), 1067–80.

Mottron, L., Bzdok, D. (2020). Autism spectrum heterogeneity: fact or artifact? *Molecular Psychiatry*.

Pan, Y., Cheng, X., Zhang, Z., Li, X., Hu, Y. (2017). Cooperation in lovers: an f NIRS-based hyperscanning study. *Human Brain Mapping*, 38(2), 831–41.

Parkinson, C., Kleinbaum, A.M., Wheatley, T. (2018). Similar neural responses predict friendship. *Nature Communications*, 9(1), 1–14.

Pollmann, M.M., Finkenauer, C., Begeer, S. (2010). Mediators of the link between autistic traits and relationship satisfaction in a non-clinical sample. *Journal of Autism and Developmental Disorders*, 40(4), 470–78.

Redcay, E., Schilbach, L. (2019). Using second-person neuroscience to elucidate the mechanisms of social interaction. *Nature Reviews. Neuroscience*, 20(8), 495–505.

Reed, P., Giles, A., Gavin, M., Carter, N., Osborne, L.A. (2016). Loneliness and social anxiety mediate the relationship between autism quotient and quality of life in university students. *Journal of Developmental and Physical Disabilities*, 28(5), 723–33.

Reggev, N., Chowdhary, A., Mitchell, J.P. (2020). *Confirmation of Interpersonal Expectations Is Intrinsically Rewarding*. bioRxiv.

Rockhill, C.M., Fan, M.Y., Katon, W.J., McCauley, E., Crick, N.R., Pleck, J.H. (2007). Friendship interactions in children with and without depressive symptoms: observation of emotion during game-playing interactions and post-game evaluations. *Journal of Abnormal Child Psychology*, 35(3), 429–41.

Rolison, M.J., Naples, A.J., McPartland, J.C. (2015). Interactive social neuroscience to study autism spectrum disorder. *The Yale Journal of Biology and Medicine*, 88(1), 17.

Schilbach, L., Timmermans, B., Reddy, V., et al. (2013). Toward a second-person neuroscience. *Behavioral and Brain Sciences*, 36(4), 393–414.

Schilbach, L. (2016). Towards a second-person neuropsychiatry. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 371(1686), 20150081.

Selfhout, M., Burk, W., Branje, S., Denissen, J., Van Aken, M., Meeus, W. (2010). Emerging late adolescent friendship networks and Big Five personality traits: a social network approach. *Journal of Personality*, 78(2), 509–38.

Sevgi, M., Diaconescu, A.O., Henco, L., Tittgemeyer, M., Schilbach, L. (2020). Social Bayes: using Bayesian modeling to study autistic trait–related differences in social cognition. *Biological Psychiatry*, 87(2), 185–93.

Steptoe, A., Shankar, A., Demakakos, P., Wardle, J. (2013). Social isolation, loneliness, and all-cause mortality in older men and women. *Proceedings of the National Academy of Sciences*, 110(15), 5797–801.

Street, D., Burge, S., Quadagno, J., Barrett, A. (2007). The salience of social relationships for resident well-being in assisted living. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences*, 62(2), S129–S134.

Strunz, S., Schermuck, C., Ballerstein, S., Ahlers, C.J., Dziobek, I., Roepke, S. (2017). Romantic relationships and relationship satisfaction among adults with Asperger syndrome and high-functioning autism. *Journal of Clinical Psychology*, 73(1), 113–25.

Theriault, J., Young, L., Barrett, L.F. (2019). The sense of should: a biologically-based model of social pressure.

Thien, L.M., Abd Razak, N. (2013). Academic coping, friendship quality, and student engagement associated with student quality of school life: a partial least square analysis. *Social Indicators Research*, 112(3), 679–708.

Thien, L.M., Razak, N.A., Jamil, H. (2012). *Friendship Quality Scale: conceptualization, Development and Validation*. Australian Association for Research in Education (NJ1), Paper presented at the Joint Australian Association for Research in Education and Asia-Pacific Educational Research Association Conference (AARE-APERA 2012) World Education Research Association (WERA) Focal Meeting, Sydney, New South Wales, Dec 2-6.

Thomas, C. (1999). *Female Forms: experiencing and Understanding Disability*. Buckingham: Open University Press.

Timmermans, B., Schilbach, L., Pasquali, A., Cleeremans, A. (2012). Higher order thoughts in action: consciousness as an unconscious re-description process. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 367(1594), 1412–23.

Van de Cruys, S., Evers, K., Van der Hallen, R., et al. (2014). Precise minds in uncertain worlds: predictive coding in autism. *Psychological Review*, 121(4), 649.

Veissière, S.P., Constant, A., Ramstead, M.J., Friston, K.J., Kirmayer, L.J. (2019). Thinking through other minds: a variational approach to cognition and culture. *Behavioral and Brain Sciences*, 43, 1–97.

Von der Heide, R., Vyas, G., Olson, I.R. (2013). The social network-network: size is predicted by brain structure and function in the amygdala and paralimbic regions. *Social Cognitive and Affective Neuroscience*, 9, 1962–72.

Von Der Lühe, T., et al. (2016). Interpersonal predictive coding, not action perception, is impaired in autism. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 371(1693), 20150373.

Vygotsky, L.S. (1980). Mind in society: the development of higher psychological processes. Harvard university press. Original work 1930–35.

Wadge, H., Brewer, R., Bird, G., Toni, I., Stolk, A. (2019). Communicative misalignment in autism spectrum disorder. *Cortex*, 115, 15–26.

Wainer, A.L., Block, N., Donnellan, M.B., Ingersoll, B. (2013). The broader autism phenotype and friendships in non-clinical dyads. *Journal of Autism and Developmental Disorders*, 43(10), 2418–25.

Wakabayashi, A., Baron-Cohen, S., Wheelwright, S. (2006). Are autistic traits an independent personality dimension? A study of the Autism-Spectrum Quotient (AQ) and the NEO-PI-R. *Personality and Individual Differences*, 41(5), 873–83.

Waxler-Morrison, N., Hislop, T.G., Mears, B., Kan, L. (1991). Effects of social relationships on survival for women with breast cancer: a prospective study. *Social Science & Medicine*, 33(2), 177–83.