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Smiling synchronization predicts interaction enjoyment in peer dyads of autistic and neurotypical youth

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Abstract

Autistic youth often experience challenges in interactions with neurotypical peers. One factor that may influence successful interactions with peers is interpersonal synchrony, or the degree to which interacting individuals align their behaviors (e.g. facial expressions) over time. Autistic and neurotypical youth were paired together into three dyad types: autistic participants paired with autistic participants (AUT-AUT), autistic participants paired with neurotypical participants (AUT-NT), and neurotypical participants with neurotypical participants (NT-NT). Dyads participated in a free conversation task and a video-watching task. We tested whether smiling synchronization differed between AUT-AUT, AUT-NT, and NT-NT dyads. We further tested if smiling synchronization predicted youth-reported interaction enjoyment. AUT-NT dyads had significantly reduced smiling synchronization compared with NT-NT dyads. Smiling synchronization also predicted multiple aspects of participant-rated interaction enjoyment, such as the desire to interact with the peer partner again, above and beyond the overall amount of smiling in the interaction. These findings indicate links between smiling synchronization and interaction enjoyment for autistic and neurotypical youth. Identifying opportunities to synchronize or share positive affect in interactions may promote more enjoyable interactions for both autistic and neurotypical youth.

Lay abstract

For autistic and neurotypical youth, having positive social interactions with other youth is an important part of well-being. Other researchers have found that one factor that can make people feel like social interactions have gone well is synchronization. Synchronization happens when peoples' body movements and facial expressions align while they're interacting. We focus on smiling synchronization here because other studies have found that when neurotypical individuals synchronize their smiles more in a social interaction, they say they enjoy that social interaction more. However, no studies have directly tested whether smiling synchrony influences social interaction enjoyment in autistic and neurotypical youth. We measured smiling synchrony in pairs of interacting autistic and neurotypical youth who were meeting each other for the first time. Some pairs were autistic youth interacting with other autistic youth (autistic with autistic participant pairs), some pairs were autistic youth interacting with neurotypical youth (autistic with neurotypical participant pairs), and other pairs were neurotypical youth interacting with neurotypical youth (neurotypical with neurotypical participant pairs). We found that autistic with neurotypical participant pairs had lower smiling synchrony than neurotypical with neurotypical participant pairs. Youth who were in dyads that had more smiling synchrony said they enjoyed interacting with their partner more and that they wanted to interact with their partner again. Our research shows that smiling synchrony is one part of interactions between autistic and neurotypical youth that influences how well youth say the interaction went. Identifying natural opportunities for autistic and neurotypical youth to share positive feelings could be one way to promote positive social interactions between autistic and neurotypical youth.

Keywords

adolescents, autism spectrum disorders, behavioral measurement, school-aged children, social cognition and social behavior, social interaction, synchrony

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Introduction

Successful social interactions with peers are crucial to mental health and well-being for adolescents (Alsarrani et al., 2022; Orben et al., 2020; Van Harmelen et al., 2017). Autistic adolescents often experience challenges in interactions with peers, which has a negative impact on their well-being, including their mental health (O'Connor et al., 2022; Storch et al., 2012). Traditionally, the challenges that autistic individuals experience in peer interactions have been examined from an individual-level perspective—understanding challenges in social interactions as the result of the autistic individual's autistic traits. However, more recent scholarship has demonstrated the importance of shifting focus to the level of the dyad and understanding autistic challenges in peer interactions as a result of the interplay between the autistic individual and their interaction partner (Bolis et al., 2018; Bottema-Beutel, 2017; Davis & Crompton, 2021; De Jaegher, 2013; Milton, 2012; Milton et al., 2022). This shift to a dyad-level understanding of social interaction challenges provides novel insight into mechanisms of peer interaction success in autistic and neurotypical individuals.

One construct that captures the interplay between interacting individuals is interpersonal synchrony. Here, interpersonal synchrony is defined as the moment-to-moment alignment of interacting individuals' behaviors. Humans naturally synchronize their behaviors with their social partners from the earliest days of life (Condon & Sander, 1974; Feldman, 2007). Synchronization can be examined with respect to behaviors from a variety of domains, including facial expressions, body movements such as nodding, shrugging, or overall postural shifts, and/or physiological measures such as heart rate or skin conductance (Feldman et al., 2011; Louwerse et al., 2012; Palumbo et al., 2017).

Multiple meta-analyses of studies with neurotypical individuals have provided convergent evidence that the degree of synchrony between individuals predicts positive interaction outcomes like interaction enjoyment and feelings of closeness (Mogan et al., 2017; Vicaria & Dickens, 2016). These relations between synchrony and interaction enjoyment are present in initial interactions between previously unacquainted individuals. The degree of synchrony of positive facial expressions, such as smiling, predicts enjoyment and feelings of connection in an initial "getting-to-know-you" interaction with a novel peer partner (Cheong et al., 2020; Golland et al., 2019). Together, these studies provide evidence that the degree of synchrony in interactions between unfamiliar individuals predicts enjoyment of the interaction.

Given the relationship between synchrony and interaction success in neurotypical individuals, interpersonal synchrony may be an important mechanism leading to social interaction challenges between autistic and neurotypical individuals. Across a variety of behaviors and contexts, the amount of synchrony in interactions between autistic individuals and neurotypical individuals is reduced compared with the amount of synchrony in interactions between two neurotypical individuals (Bloch et al., 2019; McNaughton & Redcay, 2020; Murat Baldwin et al., 2022). Interactions between an unfamiliar (presumed neurotypical) experimenter and autistic youth have reduced smiling synchrony compared with those with neurotypical youth, and these reductions in synchrony predict reductions in parent-reported social functioning (Zampella, Bennetto, & Herrington, 2020). However, whether this reduced synchrony in facial expressions predicts interaction outcomes like interaction enjoyment is unknown as these relations have not been directly tested in neurotypical and autistic youth. Testing these relations is a key factor in determining the role that synchrony plays in social challenges between autistic and neurotypical individuals.

The alignment of neurotypes between two interacting individuals may be an important factor in the enjoyment of the interaction and degree of synchrony displayed. Several recent studies have demonstrated that people interacting with someone of the same neurotype (i.e. autistic with autistic (AUT–AUT), neurotypical with neurotypical (NT–NT)) enjoy their interaction more than people interacting with someone of a different neurotype (i.e. autistic with neurotypical (AUT–NT); Crompton, Ropar, et al., 2020; Morrison et al., 2020; Rifai et al., 2022). Similarly, dialectical misattunement theory predicts that individuals who are more similar in their prediction of each others' actions (e.g. individuals with the same neurotype) will have interactions that are more synchronous than interactions between individuals who are more dissimilar in their predictions (e.g. individuals with different neurotypes) (Bolis et al., 2018). However, the only study known to-date to directly compare synchrony across AUT–AUT, AUT–NT, and NT–NT dyads did not support this prediction; in this study, body posture synchrony in adults engaged in structured conversation tasks was reduced in both AUT–AUT dyads and AUT–NT dyads compared with NT–NT dyads (Georgescu et al., 2020). Therefore, it is important to clarify relations between synchrony and interaction enjoyment across dyad types, to examine if relations may vary depending on the interaction partner's diagnosis.

Adolescence is a particularly important time to investigate the impact of synchrony on peer interaction outcomes in autism. Adolescence is a time period in which peer relationships are taking on increased importance for neurotypical youth (Furman & Buhrmester, 1992; Orben et al., 2020), and when autistic youth experience increasing challenges navigating their social worlds (Picci & Scherf, 2015; Wallace et al., 2017). These social interaction challenges in adolescence can have profound impacts on well-being in adolescence and beyond; positive adolescent peer relationships predict mental well-being for autistic youth

(O'Connor et al., 2022) while negative adolescent peer relationships predict negative mental health outcomes (O'Connor et al., 2022; Storch et al., 2012).

While the majority of work on synchrony in autistic youth has often focused on synchronization between youth and parents or youth and unfamiliar adult confederates (Fitzpatrick et al., 2016; Romero et al., 2018; Zadok et al., 2022; Zampella, Bennetto, & Herrington, 2020; Zampella, Csumitta, et al., 2020), some recent work has examined synchrony and synchrony-related constructs, such as social coordination of movements, in the peer dyad context (Bar Yehuda & Bauminger-Zviely, 2024; Glass & Yuill, 2023; Stoit et al., 2011; Trevisan et al., 2021). Studying synchrony in adolescent peer dyads is critical to understanding the role synchrony plays in those relationships, because findings in adult–youth dyads may not extrapolate to youth peer dyads. For example, youth's facial expression synchrony may differ when the interaction partner is a same-aged peer compared with an older confederate (Ardizzi et al., 2014). Furthermore, adolescence is a time period in which adolescents may also be especially sensitive to synchrony in social interactions (Rauchbauer & Grosbras, 2020), making this developmental period an important time to assess synchrony and its relationships to interaction outcomes in the peer dyad context.

Here, we test the hypothesis that smiling synchrony predicts initial interaction enjoyment, in short getting-to-know-you interactions between neurotypical and autistic youth (8–16 years old). We chose to focus on smiling synchrony based on previous evidence from neurotypical dyads that smiling synchrony predicts positive interaction outcomes such as enjoyment and feelings of connection with a novel interaction partner (Cheong et al., 2020; Golland et al., 2019) and that smiling synchrony may be reduced in interactions between autistic and neurotypical individuals (Zampella, Bennetto, & Herrington, 2020). We predicted that AUT–NT dyads will have reduced smiling synchrony compared with AUT–AUT and NT–NT dyads. We predicted that across dyad type, reductions in smiling synchrony will predict reduced initial interaction enjoyment. Together, these analyses will comprise the first test of smiling synchrony as a predictor of interaction success in interactions between unfamiliar peers in autistic and neurotypical youth.

Method

Participants

A total of 136 participants aged 8–16 years old were recruited from the Washington, D.C. area. Participants were recruited from their participation in previous studies in the lab or through the Simons Foundation Powering Autism Research (SPARK), Facebook advertisements, and outreach at local events. We appreciate obtaining access to recruit participants through the SPARK research match on SFARI Base.

Table 1. Participant race, ethnicity, household income, and parental education.

	Percentage of sample ($n = 136$)
Race	
Asian	1.5
Black or African American	14.7
White	61.0
More than one race	13.2
Missing or did not wish to report	9.6
Ethnicity	
Hispanic/Latino	8.8
Not Hispanic/Latino	80.1
Missing or did not wish to report	11.0
Household income	
Less than US$35,000	2.9
US$35,000–US$75,000	8.8
More than US$75,000	79.4
Missing or did not wish to report	8.8
Highest level of parental education	
Some college	5.1
Technical/AA degree	2.2
College degree	16.9
Some graduate school	12.5
Postgraduate degree	54.4
Missing or did not wish to report	8.8

All participants were native English speakers with a full-scale IQ of 80 or higher as measured by the Kaufman Brief Intelligence Test, second edition (Kaufman & Kaufman, 2004). For autistic participants ($n = 33$), autism diagnoses were confirmed with administration of the Autism Diagnostic Observation Schedule, Second Edition (Lord et al., 2012) by a research-reliable clinician. Neurotypical participants ($n = 103$) were screened and excluded for any neurological or psychiatric disorders, or first-degree relatives with autism or schizophrenia. A subset of participants ($n = 100$) were included in previous analyses on theory of mind in conversations between neurotypical and autistic children (Alkire et al., 2023). Additional information on race, ethnicity, and socioeconomic status for participants is provided in Table 1.

Participants were paired into dyads based on chronological age (within 1 year or grade level) and parent-reported gender. The research team did not inform participants whether or not their interaction partner had an autism diagnosis. However, some participants chose to self-disclose to their interaction partner during their interaction ($n = 2$ autistic participants in AUT–NT dyads, $n = 3$ participants in AUT–AUT dyads, 2 of whom were paired together). Each participant was a part of one dyad. Three types of dyads were formed: autistic participants paired with neurotypical participants (AUT–NT: 19 dyads), autistic participants paired with autistic participants (AUT–AUT: 7 dyads), and neurotypical participants paired with neurotypical participants (NT–NT: 42 dyads). One NT–NT dyad had previously

Table 2. Participant demographics for AUT–NT, AUT–AUT, and NT–NT dyads.

Dyad type	AUT–NT (19 dyads, 38 participants)	AUT–AUT (7 dyads, 14 participants)	NT–NT (41 dyads, 82 participants)
Parent-reported gender	8 female, 30 male	2 female, 12 male	48 female, 34 male
Mean age (range)	14.0 (9.2–16.9)	12.3 (8.7–15.4)	12.3 (8.7–16.1)
Mean KBIT-2 (range)	120 (89–146)	113 (80–133)	118 (87–142)
Mean ADOS-2 Module 3 Overall Total (SA + RRB) (range)	10 (7–16)	11 (8–16)	N/A

Note: One autistic participant in an AUT–AUT dyad completed Module 4 of the ADOS. Because of the differences in the algorithm between the two modules, only total scores for Module 3 are provided here.

met outside of the study context. This dyad was not included in further analyses, resulting in a full sample of 67 dyads (19 AUT–NT dyads, 7 AUT–AUT dyads, 41 NT–NT dyads; see Table 2). Although samples were intended to be equal across dyad types, data collection was cut short in March 2020 by the COVID-19 pandemic. Therefore, comparisons including the AUT–AUT dyad type are treated as preliminary given the small sample size. All procedures were approved by the University of Maryland Institutional Review Board (Approval No. 733144), and participants and their parents provided written informed assent and consent.

Peer interaction task

The previously unacquainted dyads completed a 25-minute face-to-face interaction as described previously (Alkire et al., 2023). Each participant sat across from each other in a behavioral testing room with cameras capturing a profile view (see Figure 1 for room setup). They completed three activities together: (1) a 5-minute, free conversation activity, (2) a 15-minute, list-making task, and (3) a short, 2 to 5-minute, video-watching task. These are tasks that have been previously used in interactions between autistic individuals and unfamiliar peers (Alkire et al., 2023; Usher et al., 2015). For these analyses, the free conversation and video-watching task were analyzed because they provided structured and unstructured opportunities to elicit emotions, and participants' facial expressions were generally visible.

For the 5-minute free conversation activity, an experimenter invited both participants to sit down in the room and explained that they would do a few tasks together. The experimenter then told the participants: "Before I explain your task, why don't you get to know each other? I'll be back in about 5 minutes." The experimenter left the room and returned after 5 minutes to end the free conversation activity.

The experimenter introduced the video-watching task as follows:

> The next thing you're going to do is watch some video clips together. Feel free to discuss the clips while they're playing or after they're finished. When you are done with each clip, you can press the space bar to advance to the next one. I'll be back in five minutes.

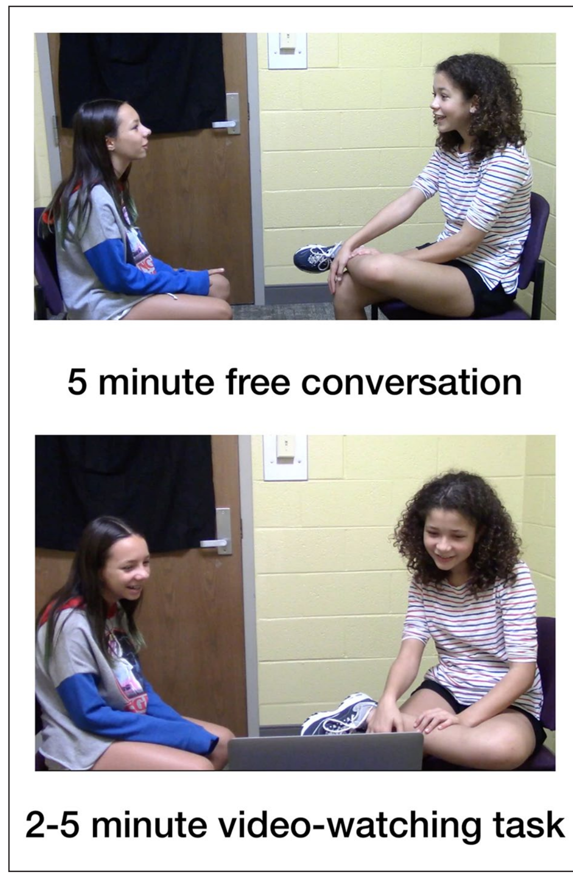

Figure 1. Room setup and participant position for the free conversation and video-watching task. Participants and their parents provided written informed consent for the use of these photographs in this article.

The experimenter put a laptop computer on a small table in front of the participants and left the room (see Figure 1 for room setup). Participants began the video-watching task by pressing the space bar. They watched four short clips, advancing to the next clip at their own pace. Clips were selected based on college student ratings of clips as eliciting positive emotion (baby pig, baby scoring goal) or neutral (tortoise moving, people walking), though the emotion labels may not align with each participant's experience of the clips. The video-watching task ended when participants finished watching all the clips or when 5 minutes had elapsed, whichever came first. The length of the video-watching task did not significantly differ across the dyad types ($F(2, 64) = 1.83$, $p = 0.17$).

Post-interaction questionnaires

Following the paired interaction, participants each completed tasks and questionnaires separately in individual behavioral testing rooms with separate experimenters. Three questionnaires were administered to measure different aspects of interaction enjoyment. The first of these questionnaires was a six-item questionnaire designed to measure interaction quality adapted from previous interaction quality questionnaires (Berry & Hansen, 1996). A score of interaction quality ("Interaction Quality") was created as the raw sum across the six items as has previously been used to measure interaction quality in autistic and neurotypical youth (Alkire et al., 2023; McNaughton et al., 2023). The second was a single sliding scale question (−100 to 100 scale with 1-point increments) administered to measure youth's desire to interact with the same partner again ("Desire to Interact Again"). The third questionnaire was a two-item questionnaire administered to assess youth's enjoyment of watching video clips with their partner and desire to watch more clips ("Video Task Enjoyment"). Additional details on wording of interaction enjoyment outcomes are provided in Supplemental Information. Four participants (1 autistic, 3 neurotypical) did not complete the interaction quality and video-watching task enjoyment questions, and 24 participants (11 autistic, 13 neurotypical) did not complete the desire to interact again slider items, because the questions were added to the study after those participants had completed it or those participants chose to end their visit before completing those questions.

An additional series of questions were designed to assess participants' preferences on the video clips. There were no differences across dyad types on partners' concordance on preferred video clip (see Supplemental Information).

Coding procedure for smiling data

Both the free conversation and the video-watching task were coded for smiling to provide data on smiling synchrony in an unstructured context and a structured context intended to elicit emotion. We chose to focus on smiling because of previous work investigating smiling synchrony differences in autism (Zampella, Bennetto, & Herrington, 2020) and work relating positive emotion expressions to social outcome measures in neurotypical individuals (Cheong et al., 2020). The Facial Action Coding System was used to operationalize smiling as the combination of action units 6 (Orbicularis oculi, pars orbitalis, corresponding to cheek raising action) and 12 (Zygomaticus major, corresponding to lip corner pulling action) (Cohn et al., 2007). Videos were coded for the presence or absence of smiling for each participant in each moment of time across the recording.

Videos were coded by a primary and secondary coder in Datavyu (Datavyu Team, 2014). In line with video coding recommendations, the primary coder coded all videos for both tasks, while the secondary coder coded 25% of the videos for each task (Chorney et al., 2015). Interrater reliability was calculated for the time smiling for each participant for each task as the ICC(C,1) (Koo & Li, 2016). For both tasks, smiling coding reliability was in the moderate-to-good range (video-watching task: ICC(C,1) = 0.737, free conversation task: ICC(C,1) = 0.756), therefore the values for the primary coder were used in analyses.

To examine whether overall amount of smiling in the two tasks differed across dyad types, two one-way ANOVAs were conducted with dyad type (AUT–AUT/AUT–NT/NT–NT) as the between factor and (1) total time smiling in the free conversation task, and (2) total time smiling in the video-watching task as outcomes of interest.

Synchrony quantification

To account for the nonparametric, categorical nature of the coded smiling data, cross-recurrence quantification analysis (CRQA) was performed to quantify recurrence patterns between the two individuals' time series (Coco & Dale, 2014). Briefly, CRQA allows for determination of the degree of co-occurrence between the two time series, with higher values indicating more smiling occurring at the same time for the dyad, and lower values indicating less co-occurrence. CRQA was performed on frame-by-frame smiling data at a range of lags of ±2 seconds to account for coordinated smiles that do not occur at the exact same moment. To obtain a value of smiling synchrony for each dyad, the cross-recurrence values were averaged across the range of lags. This mean recurrence value was then square-root transformed to account for non-normality.

Synchrony was calculated separately for the free conversation and video-watching task. A synchrony value was calculated for a dyad if each participant's face was visible above 80% of the time in the video recording and if each participant smiled at least once. For the video-watching task, 59 dyads (37 NT–NT dyads, 18 NT–AUT dyads, 4 AUT–AUT dyads; Table 3) were included in the synchrony analyses, with 1 AUT–AUT dyad excluded for being out of the video view, and 7 dyads excluded for one or both participants not smiling (4 NT–NT, 1 NT–AUT, 2

Table 3. Participant demographics for AUT–NT, AUT–AUT, and NT–NT dyads included in video-watching task synchrony analyses.

Dyad type	AUT–NT (18 dyads, 36 participants)	AUT–AUT (4 dyads, 8 participants)	NT–NT (37 dyads, 74 participants)
Parent-reported gender	6 female, 30 male	2 female, 6 male	48 female, 26 male
Mean age (range)	13.9 (9.2–16.9)	11.7 (8.7–14.9)	12.3 (8.7–16.1)
Mean KBIT-2 (range)	120 (89–146)	107 (80–132)	118 (91–142)
Mean ADOS-2 Module 3 Overall Total (SA + RRB) (range)	10 (7–16)	10 (8–14)	N/A

AUT–AUT). Data exclusion was different across the dyad types for the video-watching task, with proportionally more AUT–AUT dyads excluded than AUT–NT and NT–NT dyads (χ^2 (2, N=67)=7.36, p=0.03). For the free conversation task, 46 dyads (33 NT–NT dyads, 9 NT–AUT dyads, 4 AUT–AUT dyads; Supplemental Table 7) were included in the synchrony analyses, with 5 dyads excluded for being out of the video view (2 NT–NT, 2 AUT–NT, 1 AUT–AUT) and 16 dyads excluded for one or both participants not smiling (6 NT–NT, 8 NT–AUT, 2 AUT–AUT). Data exclusion was different across the dyad types for the free conversation task, with proportionally more AUT–NT and AUT–AUT dyads excluded than NT–NT dyads (χ^2 (2, N=67)=7.10, p=0.03). Because of the high rate of data loss for the free conversation task, analyses are presented in Supplemental Material (Supplemental Tables 7–11, Supplemental Figures 2–4).

Statistical analysis for smiling synchronization in the video-watching task

To test the hypothesis that the dyad types differ in levels of smiling synchronization in the video-watching task, a one-way ANOVA was performed with dyad type (AUT–AUT/AUT–NT/NT–NT) as a between factor and smiling synchrony in the video-watching task as the outcome of interest. Follow-up independent sample *t*-tests were performed to determine which dyad types differed.

To test if synchrony occurred at levels significantly above chance, time series from interacting dyads were randomly scrambled in time and compared with "true" time series from those dyads. Briefly, the smiling time series for each partner during the video-watching task was randomly scrambled frame-by-frame. From these scrambled time series, a pseudo synchrony value was calculated as the mean cross-recurrence value across a 2-second lag window as described above in section "Synchrony quantification." Three paired *t*-tests were used to determine if true synchrony values differed from time-scrambled pseudo synchrony values for each dyad type (i.e. NT–NT true synchrony vs NT–NT pseudo synchrony, AUT–NT true synchrony vs AUT–NT pseudo-synchrony, AUT–AUT true synchrony vs AUT–AUT pseudo synchrony).

To test the hypothesis that synchrony predicts interaction enjoyment, multilevel models were used to account for shared variance in the reports of interaction enjoyment between dyad members and to appropriately partition the variance at the individual and dyad levels. Three models were run for the three relevant interaction enjoyment outcomes of interest: (1) interaction quality, (2) desire to interact again slider question, and (3) video-watching task enjoyment. Smiling synchronization during the video-watching task was the predictor of interest, and dyad was included as a random intercept. Age, gender, and total amount of smiling in the interaction were included as covariates, and dyad type and its interaction with smiling synchrony was included in a follow-up model to assess differences in relations between synchrony and interaction enjoyment across dyad types. To account for multiple comparisons across the three interaction enjoyment outcomes, Benjamini–Hochberg correction procedures were used. Analyses were performed in R (R Core Team, 2020) using the lmerTest package (Kuznetsova et al., 2017).

Statistical analysis of interaction enjoyment measures

To test for dyad type differences in interaction enjoyment, three linear mixed effects models were run to test differences across the dyad types on each of the interaction enjoyment outcome measures: interaction quality, desire to interact again, and video-watching task enjoyment. Dyad type (AUT–AUT, AUT–NT, NT–NT) was a predictor, and dyad was a random intercept.

Community involvement statement

Community members were not involved in the design, implementation, or interpretation of the study or its results.

Results

Smiling synchronization in the video-watching task

Results of a between-subjects ANOVA indicated that smiling synchronization significantly differed across dyad

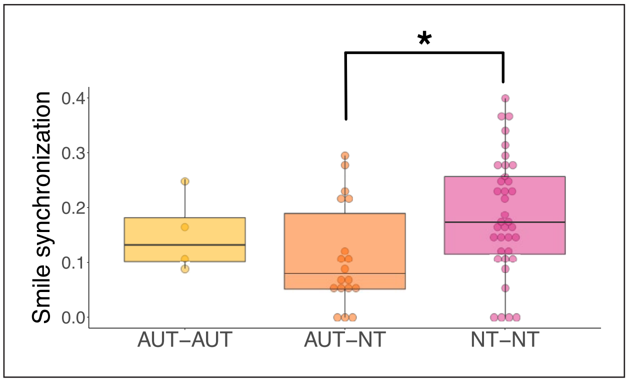

Figure 2. Smiling synchronization differences in the video-watching task across AUT–AUT ($n=4$ dyads), AUT–NT ($n=18$ dyads), and NT–NT dyads ($n=37$ dyads). AUT–NT dyads displayed significantly lower smiling synchronization than NT-NT dyads (*, $p=0.01$), while AUT–AUT dyads did not differ from either AUT–NT or NT–NT dyads.

types ($F(2, 56)=3.30$, $p=0.04$; Figure 2). Planned t-tests were run to compare smiling synchronization during the video-watching task between each of the dyad types. Smiling synchronization in AUT–NT dyads was significantly lower than smiling synchronization in NT–NT dyads ($t(53)=2.53$, $p=0.01$; Figure 2), and smiling synchronization in AUT–AUT dyads did not significantly differ from AUT–NT dyads ($t(20)=0.79$, $p=0.44$) or NT–NT dyads ($t(39)=0.63$, $p=0.53$).

Results of a between-subjects ANOVA indicated that overall amount of smiling did not differ across dyad types ($F(2, 56)=0.72$, $p=0.49$). Overall amount of smiling and smile synchronization were correlated ($r(57)=0.85$, $p<0.001$). When overall amount of smiling was included as a covariate, smiling synchronization differences remained significant between AUT–NT and NT–NT dyads ($t(55)=-3.18$, $p<0.01$). Smiling synchronization marginally differed between AUT–AUT and AUT–NT dyads controlling for overall smiling ($t(55)=-1.76$, $p=0.08$).

To test if smiling synchronization occurred at levels above chance, true synchrony was compared with time-scrambled pseudo synchrony for each of the three dyad types. For all three dyad types, smiling synchronization was significantly above chance (AUT–AUT dyads mean pseudo synchrony value=0.082: $t(3)=4.45$, $p=0.02$; AUT–NT dyads mean pseudo synchrony value=0.079: $t(17)=3.76$, $p=0.002$; NT–NT dyads mean pseudo synchrony value=0.120: $t(36)=8.72$, $p<0.001$) (see Supplemental Figure 1).

To test smiling synchronization in the video-watching task as a predictor of interaction enjoyment, three linear mixed effects models were run with smiling synchronization as a predictor and each of the three interaction enjoyment measures as outcomes (Supplemental Tables 1–3; Figure 3). Age, gender, and overall amount of smiling in the video-watching task were included as covariates. Smiling synchronization did not significantly predict participant-rated interaction quality ($\beta=10.68$, $t(51.99)=1.29$, $p=0.21$; Figure 3(a)). However, smiling synchronization significantly predicted participant-rated desire to interact with the same partner again ($\beta=326.46$, $t(42.58)=2.92$, $p=0.01$; Figure 3(b)). Smiling synchronization also significantly predicted participant-rated enjoyment of the video-watching task with their partner ($\beta=7.52$, $t(52.03)=2.40$, $p=0.02$; Figure 3(c)). Smiling synchronization remained a significant predictor of desire to interact again and enjoyment of the partnered video task when Benjamini–Hochberg correction was applied.

Given the small sample of participants in AUT–AUT dyads ($n=8$), models were also run just with participants in AUT–NT and NT–NT dyads. In this subsample of participants, results were unchanged; smiling synchronization in the video-watching task again significantly predicted the desire to interact with the same partner again and enjoyment of the video-watching task, but did not significantly predict overall interaction quality (Supplemental Tables 4–6). In follow-up models, the interaction between smiling synchronization in the video-watching task and dyad type was also included to test for differences in the relation between smiling synchronization and interaction enjoyment across dyad types, but these interaction terms did not significantly predict any of the outcome measures.

Interaction enjoyment

For interaction quality, AUT–NT dyads did not differ in reported interaction quality from NT–NT dyads ($\beta=0.89$, $t(62)=0.86$, $p=0.39$; Figure 4) or AUT–AUT dyads ($\beta=2.02$, $t(62)=1.25$, $p=0.22$). AUT–AUT dyads also did not differ from NT–NT dyads ($\beta=1.14$, $t(62)=0.77$, $p=0.45$).

For the desire to interact with the partner again, AUT–NT dyads reported a significantly lower desire to interact again than both NT–NT dyads ($\beta=36.79$, $t(54.0)=2.49$, $p=0.02$; Figure 5) and AUT–AUT dyads ($\beta=54.21$, $t(56.1)=2.44$, $p=0.02$). AUT–AUT dyads did not significantly differ from NT–NT dyads in the reported desire to interact with their partner again ($\beta=17.42$, $t(56.3)=0.90$, $p=0.37$).

For enjoyment of the video-watching task, participants in AUT–NT dyads reported a significantly lower enjoyment than NT–NT dyads ($\beta=-1.18$, $t(62)=-2.68$, $p=0.01$; Figure 6). AUT–AUT dyads did not differ from either NT–NT ($\beta=-0.30$, $t(62)=-0.47$, $p=0.64$) or AUT–NT dyads ($\beta=0.88$, $t(62)=1.28$, $p=0.21$).

Discussion

This study investigated differences in smiling synchronization across dyads comprising autistic and neurotypical youth and tested whether smiling synchronization predicted youth-reported interaction enjoyment during real-world peer interactions. We identified reduced smiling synchronization between autistic and neurotypical youth (AUT–NT dyads) compared with synchronization between neurotypical youth (NT–NT dyads). We further demonstrated that

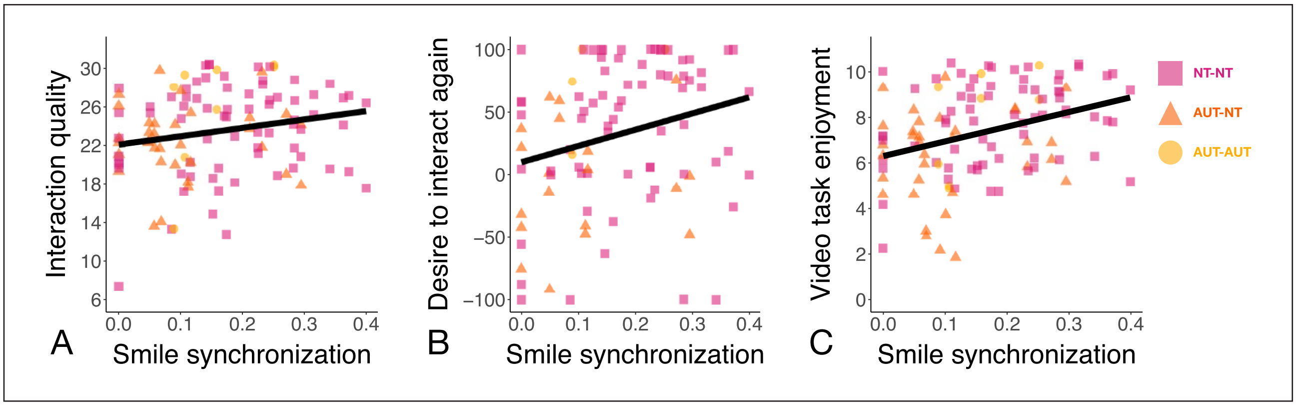

Figure 3. Smiling synchronization in the video-watching task predicted aspects of youth-rated interaction enjoyment. (a) Smiling synchronization did not predict participant-rated interaction quality (n = 114 participants; n = 8 in AUT–AUT dyads, n = 34 in AUT–NT dyads, n = 72 in NT–NT dyads). (b) Smiling synchronization significantly predicted participants' desire to interact with the same partner again (n = 94 participants; n = 5 in AUT–AUT dyads, n = 19 in AUT–NT dyads, n = 70 in NT–NT dyads). (c) Smiling synchronization significantly predicted participants' enjoyment of the video-watching task with their partner (n = 114 participants; n = 8 in AUT–AUT dyads, n = 34 in AUT–NT dyads, n = 72 in NT–NT dyads). Square points indicate a participant in an NT–NT dyad, triangle points indicate a participant in an AUT–NT dyad, and circle points indicate a participant in an AUT–AUT dyad.

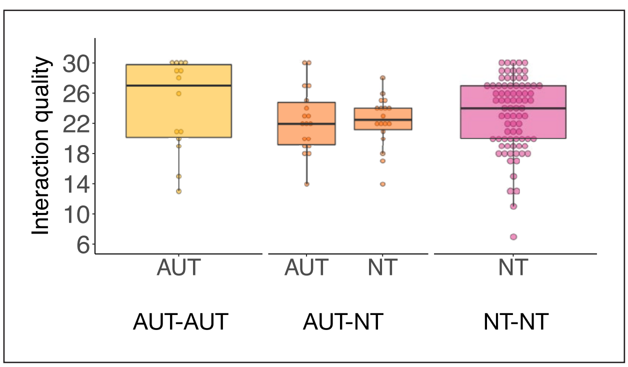

Figure 4. Interaction quality differences across AUT–AUT (n = 14 participants in 7 dyads), AUT–NT (n = 36 participants in 18 dyads), and NT–NT dyads (n = 80 participants in 40 dyads). There were no dyad type differences on participant-reported interaction quality.

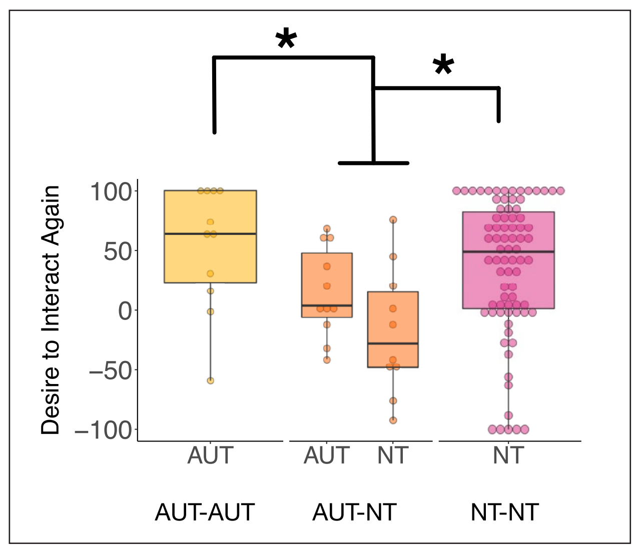

Figure 5. Desire to interact again differences across AUT–AUT (n = 11 participants in 6 dyads), AUT–NT (n = 21 participants in 11 dyads), and NT–NT dyads (n = 78 participants in 39 dyads). Participants in AUT–NT dyads reported a significantly lower desire to interact with their partners again than participants in NT–NT dyads and participants in AUT–AUT dyads (*$p < 0.05$).

higher levels of smiling synchronization predicted multiple aspects of interaction enjoyment, including greater youth-reported desire to interact with a partner again. Finally, we identified dyad type differences in interaction enjoyment, with the AUT–NT dyads differing from other dyad types in their desire to interact again and video-watching task enjoyment. Together, these findings highlight smiling synchronization as one predictor of interaction enjoyment in peer dyads comprising autistic and neurotypical youth.

AUT–NT dyads synchronize smiles less than NT–NT dyads

In the video-watching task, AUT–NT dyads demonstrated significantly reduced smiling synchronization compared with NT–NT dyads. These synchronization differences were observed even though the overall amount of smiling did not differ across dyad types. Reduced smiling synchronization in AUT–NT dyads compared with NT–NT dyads is consistent with previous work demonstrating reduced smiling synchronization in interactions between autistic youth and parents or unfamiliar researchers compared with neurotypical youth (Zampella, Bennetto, & Herrington, 2020). The present work extends these previous findings into the peer dyad context, which is important for understanding how synchrony may function in adolescent peer relationships.

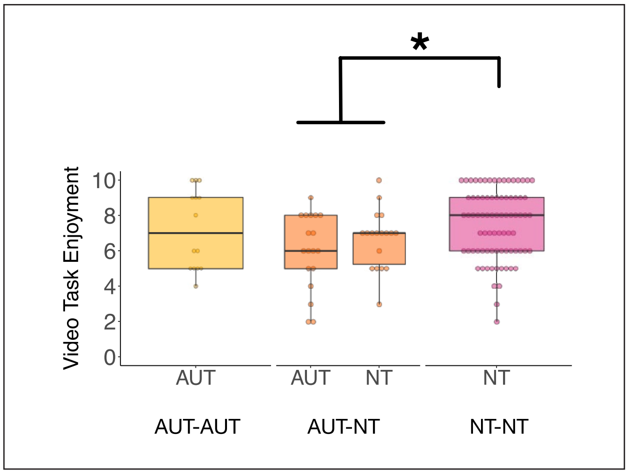

Figure 6. Video task enjoyment differences across AUT–AUT ($n=14$ participants in 7 dyads), AUT–NT ($n=36$ participants in 18 dyads), and NT–NT dyads ($n=80$ participants in 40 dyads). Participants in AUT–NT dyads reported a significantly lower enjoyment of the video-watching task than participants in NT–NT dyads (*$p<0.05$).

This work also aligns with a broader literature of reduced synchrony in AUT–NT interactions compared with NT–NT interactions across a range of domains of synchrony, including synchrony in facial expressions, body posture, and physiology (McNaughton & Redcay, 2020; Murat Baldwin et al., 2022). Reduced synchronization between autistic and neurotypical youth could be a result of many potential mechanisms, including differences in processes such as social attention, multi-sensory processing, action prediction, and action execution between autistic and neurotypical individuals (Bowsher-Murray et al., 2022; McNaughton & Redcay, 2020). These potential mechanisms could be directly tested in further studies.

We did not observe significant differences between AUT–AUT dyads and either AUT–NT dyads or NT–NT dyads, although we did observe marginally greater synchronization in AUT–AUT dyads compared with AUT–NT dyads when controlling for the total amount of smiling. These findings are partly consistent with theories such as dialectical misattunement theory, which suggests that matched neurotype dyads (AUT–AUT, NT–NT) will have more synchronous interactions than mismatched neurotypes (AUT–NT) (Bolis et al., 2018). However, they are in contrast to previous work examining body posture synchrony that identified reduced synchrony between AUT–AUT dyads compared with NT–NT dyads (Georgescu et al., 2020). Given the small sample size in the AUT–AUT group in the current study, comparisons with this group should be taken as preliminary. Therefore, future work could more directly address this prediction with respect to smiling synchrony in larger samples of AUT–AUT dyads.

The synchrony differences across dyad type were observed in the video-watching task context. One limitation of the video-watching task was the design of the task, in which participants could take varying amounts of time to advance to the next clip. This design made it challenging to disentangle if the coordination of smiling between partners reflected smiling synchronization to the shared video stimulus or to each other (e.g. the partner's facial expression, partner's spoken comment) because video timestamps were not aligned across dyads. The observed rates of smiling synchronization could reflect (1) pre-existing similarity in affective response between partners, (2) the mutual and responsive social coordination of smiling, or (3) a combination of both. Future experimental designs could better disentangle these possibilities with task structures that allow for separating pre-existing similarity from responsive coordination with a social partner, such as by including solo viewing conditions to better test the possibility of synchronization reflecting pre-existing similarity in affective response.

Smiling synchronization predicts interaction enjoyment

Increased smiling synchronization significantly predicted increased youth-reported interaction enjoyment across multiple measures, including the desire to interact with their peer partner again and enjoyment of the video task they completed with their partner. Relations between smiling synchronization and interaction enjoyment held when controlling for overall amount of smiling. This finding highlights the importance of synchronization, rather than the amount of the behavior, in predicting interaction outcomes.

This evidence for smiling synchronization predicting interaction enjoyment is consistent with previous work investigating relations between smiling synchronization and interaction enjoyment in neurotypical interactions (Cheong et al., 2020; Golland et al., 2019), extending this work into dyads including autistic youth. We did not observe an interaction between dyad type and synchronization in predicting interaction enjoyment, indicating that relations between synchronization and interaction enjoyment may be similar across AUT–NT and NT–NT dyads. By contrast, some previous work has suggested that the factors that predict interaction enjoyment (e.g. synchrony) may differ across dyad types (Rifai et al., 2022). For example, recent work found relations between increased mimicry to a virtual partner and increased reported affiliation to that partner in neurotypical youth, but did not find the same relation in autistic youth (Tunçgenç et al., 2023). We found no evidence of differences in relations across dyad type, which could reflect the sample size being underpowered to detect an interaction effect, or that previous findings do not hold for smiling synchrony with peers. Further research could examine potential influences of the interaction partner (e.g. live peer partner vs virtual partner), and investigate these relations in larger samples of AUT–AUT dyads to better clarify the role synchrony plays in interaction enjoyment in dyads comprising autistic individuals.

Our study design does not allow us to disentangle the direction of the association between smiling synchronization and interaction enjoyment. Previous work in college students has found that increased initial liking before an interaction predicts increased mimicry during an interaction, which goes on to predict increased liking after the interaction (Salazar Kämpf et al., 2018). In addition, when synchrony is experimentally manipulated in a finger tapping task, inducing synchrony increases interpersonal affiliation (Hove & Risen, 2009). These results suggest reciprocal links between synchronization-related processes and interaction enjoyment. However, these relations may be different for autistic individuals, making it important to more directly test the direction of relations between synchronization and interaction enjoyment for autistic and neurotypical youth in future work.

Interaction enjoyment differences across AUT–AUT, AUT–NT, and NT–NT dyads

Youth-reported interaction enjoyment differed across the dyad types in distinct ways for each of the three interaction enjoyment measures. Participants in AUT–AUT and NT–NT dyads both reported a greater desire to interact with their partner again compared with participants in AUT–NT dyads, which is consistent with previous findings of higher interaction enjoyment for matched neurotype interactions (i.e. AUT–AUT, NT–NT) compared with mismatched neurotype interactions (i.e. AUT–NT) (Crompton, Ropar, et al., 2020; Morrison et al., 2020; Rifai et al., 2022). These findings also align with autistic testimony of enjoying the company of other autistic people (Crompton, Hallett, et al., 2020). Together, these findings speak against previous hypotheses about reduced social motivation in autistic individuals (Chevallier et al., 2012), and highlight that interaction enjoyment depends on contextual factors, such as the neurotype of the interacting partners (Bolis et al., 2018, 2021; Davis & Crompton, 2021). While beyond the scope of the current project, one mechanism for this increased interaction enjoyment among matched neurotypes may be due to greater understanding between social partners. Specifically, the double empathy problem proposes that in mixed neurotype conversations (i.e. AUT–NT), both autistic and neurotypical individuals demonstrate a reduced ability to take the other's perspective (Milton, 2012; Milton et al., 2022). Future work could examine links between differences in perspective-taking and interaction enjoyment at the dyad level to test these hypotheses.

The mixed pattern of results, with dyad type differences varying across each of the three interaction enjoyment measures, may reflect differences in the underlying constructs of the measures of interaction enjoyment. Specifically, wanting and liking components of reward are neurally and behaviorally distinct (Berridge et al., 2009). Wanting and liking may also be expressed differently between neurotypical and autistic individuals (Keifer et al., 2021). Although the interaction enjoyment measures in the present study were not selected to specifically tap into "wanting" versus "liking," a desire to interact again aligns with "wanting," while reports of interaction quality and enjoyment map more onto "liking." However, the measure of interaction quality used in this study did include an item about desire to interact again (reflecting "wanting") so this divide is not perfect within our measures. AUT–AUT dyads and NT–NT dyads had a higher desire to interact with their partner again compared with AUT–NT dyads suggesting that "wanting" may be especially sensitive to neurotype match or mismatch. Future research should more precisely assess potential "wanting" and "liking" differences in autistic and neurotypical peer dyads. In addition, differences in self-reported enjoyment following the interaction may also reflect differences in initial expectations of interaction enjoyment between the dyad types. Future research could measure expectations of interaction enjoyment and initial impressions of the interaction partner more directly.

Limitations and future directions

The present study has several limitations to consider when interpreting the results. First, because of COVID-19 data collection cut-offs, the sample size was small for participants in AUT–AUT dyads compared with AUT–NT and NT–NT dyads. Therefore, comparisons with this dyad type should be taken as preliminary. Future research in larger samples of AUT–AUT participants will better clarify levels of smiling synchronization and relations with interaction enjoyment in this group. Future research could also incorporate data-driven methods to understand features that best predict interaction enjoyment in AUT–AUT dyads, rather than beginning investigation with features from literature on NT–NT dyads. Furthermore, involvement of autistic individuals as collaborators in the research process and qualitative research with autistic individuals will shed light on autistic individuals' experience of smiling synchronization, as well as other features that may better predict interaction enjoyment in AUT–AUT and AUT–NT interactions.

In addition, the sample of female autistic participants was also small and relied on parent report of participant gender. Previous work has highlighted differences in synchrony between male and female autistic children (Paolizzi et al., 2022), making it important to better understand relations between synchrony and interaction enjoyment for female autistic participants. Furthermore, future research should better characterize gender diversity and examine potential synchrony differences by measuring participant-reported gender and recruiting additional female and non-binary participants. Dyads were same-gender because friendships in adolescence are overwhelmingly between individuals of the same gender (Osgood et al., 2022); future work could also examine synchrony in mixed-gender dyads.

The analysis of the free conversation task was limited by data loss and low smiling rates. Data loss and low smiling rates may have been a result of the free conversation task being unstructured and occurring at the beginning of the social interaction when participants may have been more anxious and smiled less, or the orientation of the participants relative to the video recording for this task making it more challenging to code smiles. Future work could quantify synchrony in a manner that is more robust against low smiling rates, for example, by continuously extracting smile intensity using computer vision methods (Zampella, Bennetto, & Herrington, 2020) rather than the categorical coding scheme used in the present study. Notably, the rate of data loss across the dyad types significantly differed, as AUT–NT and AUT–AUT dyads were excluded from the synchronization analyses for the free conversation task at a higher rate than NT–NT dyads, although among dyads that were included, smiling rates did not differ. Speculatively, this differential rate of data loss could suggest the unstructured context, particularly at the start of an interaction, may elicit less smiling due to greater uncertainty or greater anxiety in some dyads with autistic individuals. This reduced smiling could also indicate that behaviors other than smiling are being used more frequently in this unstructured context, and these other behaviors may be more informative to study to understand how autistic individuals navigate unstructured "getting to know you" conversations. Future work could also examine different features, such as linguistic expressions of positive engagement, as autistic interactions are characterized by different markers of engagement and rapport than non-autistic interactions (Heasman & Gillespie, 2019; Rifai et al., 2022). It is challenging to directly compare results between the free conversation task and video-watching task because of the numerous differences between these contexts. Because the free conversation task and video-watching task were always presented in the same order, task order and task content/structure are confounded when comparing the different pattern of results observed between the two tasks.

Conclusion

We present novel evidence for differences in smiling synchronization between peer AUT–NT and NT–NT dyads and further demonstrate that this synchronization predicts youth-reported interaction enjoyment. These findings highlight the importance of assessing social interactions at the dyad level, as the amount of synchronization and enjoyment of the interaction all differ as a function of dyad type. By including dyads of autistic youth paired with other autistic youth, we are better able to understand the social interaction outcomes as a function of both the individual and their interaction partner. Furthermore, these findings highlight the importance of synchronized affect for interaction enjoyment in dyads including autistic and neurotypical youth. Finding opportunities to promote synchronous positive affect (e.g. shared smiling) for autistic and neurotypical youth could help promote positive social relationships for youth.

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Data availability

The data that support the findings described in this manuscript are available from the corresponding author upon reasonable request.

Supplemental material

Supplemental material for this article is available online.

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