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Physiological synchrony is associated with attraction in a blind date setting

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Humans are social animals whose well-being is shaped by the ability to attract and connect with one another, often through brief interactions. In addition to physical features, a choreography of movements, physical reactions and subtle expressions may help promote attraction. Here, we measured the physiological dynamics between pairs of participants during real-life dating interactions outside the laboratory. Participants wore eye-tracking glasses with embedded cameras and devices to measure physiological signals including heart rate and skin conductance. We found that overt signals such as smiles, laughter, eye gaze or the mimicry of those signals were not significantly associated with attraction. Instead, attraction was predicted by synchrony in heart rate and skin conductance between partners, which are covert, unconscious and difficult to regulate. Our findings suggest that interacting partners' attraction increases and decreases as their subconscious arousal levels rise and fall in synchrony.

In our modern world where millions of people meet online before interacting face to face, the question of what defines attraction has never been more relevant. Physical attractiveness is often valued as one of the most important characteristics of a potential partner[1]. Yet, research demonstrates that judging a potential romantic partner based on written or visual stimuli (for example, personal ads or photos) does not predict attraction during a first date[2]. This is because, in a social situation, aside from static facial features and the conversation, non-verbal dynamics such as eye gaze, facial expression and body posture plays a key role. Importantly, research has begun to acknowledge that what people really seek in a partner is a 'gut feeling of connection' expressed as a sensation in the body[3,4]. This type of attraction is difficult to regulate, fake or put into words yet seems to be a major force that often overrides rational decisions when it comes to partner selection. Despite its importance, what sparks this feeling between people remains one of the unsolved mysteries of science. To understand how a romantic spark between people develops, we developed a blind date experiment. Using state-of-the-art technology, including eye-tracking glasses linked to physiological measures, this experiment aims to elucidate the non-verbal and physiological signals that predict attraction between strangers.

Early-stage romantic attraction is sometimes referred to as passionate love[5]. A first date provides an excellent scenario in which to test how attraction develops[6]. We hypothesize that, if a gut feeling of attraction truly exists (beyond the perceiver's projection of infatuation by the perceiver onto the other), there must be a physical manifestation of interpersonal attraction in the real world of behaviour. One possibility is that the feeling of attraction between people is achieved on a level where it is not obvious. According to the somatic marker hypothesis, emotional reactions have strong somatic components[7]. These somatic components mark the occurrence of important events through a parallel somatic–visceral response. In return, bodily information provides feedback perceived as a gut feeling that shapes perceivers' cognition and behaviour. Through subtle changes in the face and body, changes in physiological arousal can become visible to others, allowing physiological synchrony to emerge. In this way, physiological responses can potentially contribute to social perception and provide input for romantic decisions. In line with this hypothesis, recent advances in methodologies have begun to uncover that, during social encounters, partners tend to synchronize on physiological levels[8,9]. This type of subconscious synchrony is reflected in the correlation between people's continuous measures of autonomic nervous system such as heart rate (HR) and skin conductance (SC)[8]. Crucially, in established couples, the level of synchrony has been associated with the amount of time the couples have spent together[10], the ability to identify the emotions of one's partner[11] and the couples' romantic satisfaction[12–14].

The function of physiological synchrony is not well understood, but similar to motor mimicry (for example, facial expression mimicry), it may help people to align emotionally[15,16]. Specifically, physiological synchrony might be a result of the biologically mediated tendency to adapt to incoming social information[16,17]. In support of this theory, our previous research has shown that synchrony in autonomic signals (SC and pupil sizes) predicts trust and successful cooperation[18,19], which are crucial components underlying attraction[20]. Physiological synchrony also seems to increase with familiarity and during intimate moments such as direct eye contact[21] and touch[22]. Taken together, prior literature agrees that physiological synchrony might be a precursor of deeper emotional understanding[11,22]. We elaborate on this theory further and hypothesize that this type of affective alignment might be particularly meaningful for early romantic development.

To define what drives the feeling of attraction, we built a dating laboratory outside of the regular laboratory setting, at different social events, where meeting a new person is most natural (Fig. 1). Males and females (140 participants), who had never met before, entered the dating cabin and sat at a table. A visual barrier initially occluded their view of each other, but then opened for three seconds, allowing them to form a first impression of their partner. The barrier then closed, and participants rated their partner on attraction (0–9 point scale). This baseline measure of initial attraction

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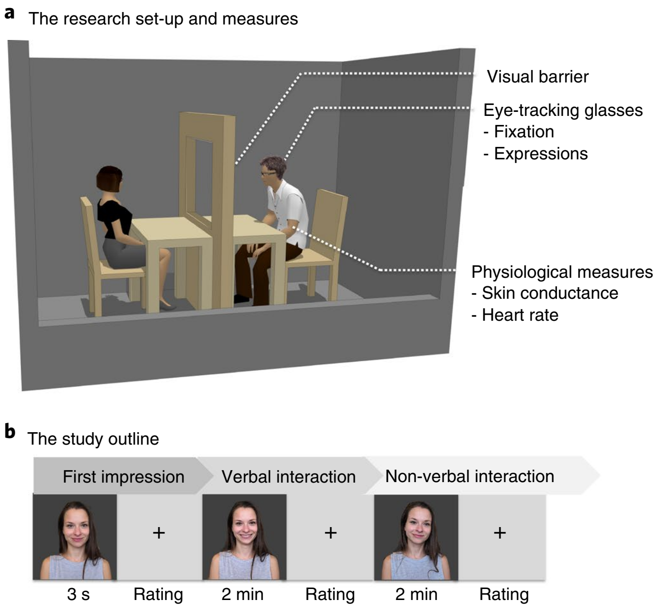

Fig. 1 | Experimental set-up and outline. a, The experimental set-up was situated in a habitable container. Inside the cabin, there was a table with two chairs on opposite sides. A white barrier with a fixation cross was placed in the middle of the table, preventing the dyad from seeing each other and controlling the dating interaction types. Participants were instructed to remain silent until they heard pre-recorded instructions via a speaker. Throughout the experiment, Tobii eye-tracking glasses measured participants' gaze fixations and expressions while participants' physiology was recorded with two BIOPACs. **b**, Experimental outline. To collect baseline physiological measures, participants looked at the fixation cross on the closed barrier for 30 s. The barrier opened for 3 s, and participants saw each other for the first time (first impression). After that, the barrier closed and post-first impression physiological measures were collected during another 30 s fixation period. Subsequently, participants rated their partner on attraction. Two additional interactions followed, each preceded by 30 s closed-barrier baseline (the barrier closed). During verbal interaction, the visual barrier opened and participants were instructed to talk freely with their partner for 2 min. During non-verbal interaction, participants were instructed to look at each other without talking for 2 min. After each interaction, the barrier closed and participants rated their partner on the same scales. The order of verbal and non-verbal interaction was counterbalanced **c**, Pre-processing pipeline. (i) Two groups of independent coders rated behavioural expressions, and mapped eye gaze fixations on pre-selected areas of interest. (ii) Gaze fixations and expressions were time locked and synchronized with physiological measures (HR and SC) using customized scripts. (iii) Video visualizations were created. (iv) The physiological data were further pre-processed using our PhysioData Toolbox[56] and down-sampled to 100 ms windows for (v) windowed cross-lagged correlation analyses[24] before they were (vi) regressed with attraction ratings.

was then followed by one verbal and one non-verbal interaction of 2 min each (the order of which was counterbalanced). After each interaction, the barrier closed and participants rated their partner on the same scales again. At the end of the experiment, participants could decide whether they wanted to go on another date with their partner. We anticipated (a) that dating partners would synchronize on multiple levels of expression including motor movements (facial expressions, nodding and gestures), gaze (face-to-face contact) and physiology (synchrony in HR and SC). Although each of these modalities has different characteristics and the literature uses a variety of terms to describe them ('mimicry', 'physiological linkage' and 'gaze reciprocity'), for the purpose of consistency, we refer to synchrony in gaze and expressions as 'mimicry' whereas mirroring of unconscious physiological signals will be referred to as 'synchrony'. We further predicted that (b) the strength of HR synchrony and SC synchrony would be predictive of attraction over the course of the date. Specifically, we expect that moment-to-moment physiological synchrony will correlate with moment-to-moment affective dynamics that are predictive of the quality of the interaction[18].

The benefit of a blind date is that we can observe how attraction between newly met partners develops over time and therefore study the relationship between attraction and synchrony in a controlled way. This carefully designed set-up had several other advantages: First, a blind date setting is a stressful context that likely induces strong physiological reactions, which is a desirable state for physiological synchrony measures. Furthermore, introducing verbal and non-verbal conditions allowed us to separate the influence of non-verbal expressions from verbal expressions on attraction (for details see Supplementary Information). Finally, thanks to the combination of multiple measures and the longitudinal design of our study, we could investigate whether dyads whose synchrony increased over the course of their date became more and more attracted to each other (that is, within-dyad effect predicting attraction over time). Note that, although we measured participants' movements and eye gaze fixations, these visible signals (that humans can reliably perceive) were not the main interest here. Instead, the main aim was to measure the relationship between physiological synchrony and attraction while also accounting for the joint influence of visible signals on individuals' attraction scores. We therefore included multiple synchrony and mimicry measures in the initial model before removing the least important variables through a backward elimination process.

Results

Is there evidence for synchrony? The first hypothesis predicted that dating partners would synchronize on multiple levels of expression including motor movements, gaze and physiology. Specifically, we expected that, if one of the individuals often shows one type of behaviour, for example, looking long into a partner's face, smiling or displaying an increase in physiological arousal, his/her partner

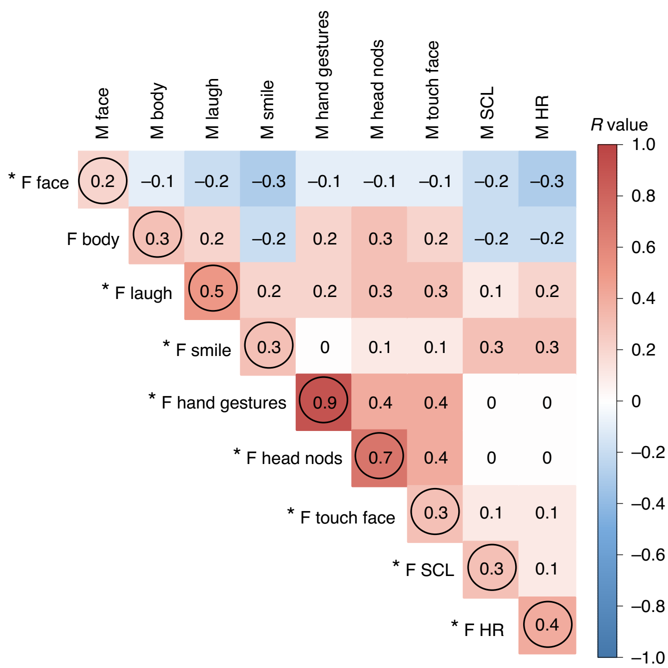

Fig. 2 | Correlation table summarizing associations between real dyad's expressions, eye gaze and physiology across three interaction time periods (based on Spearman's rank-order correlations with false discovery rate correction, $N = 162$). The circled cells depict synchrony types between two interacting partners, and other cells are other, between-partner associations. The asterisks show seven synchrony types that were significantly higher for real couples than for randomly shuffled dyads. The redder the colour, the more positively correlated these variables were. The correlation matrix demonstrates that significant associations occurred on all three levels of expression including males' and females' gaze, motor movements and physiology (one-tailed test). Note that the AOI for eyes was considered too small to be measured accurately in the current research set-up. F, females; M, males; SCL, skin conductance level. The data met the assumptions of Spearman's rank-order correlation tests (Supplementary Fig. S2).

would also show the same behavioural responses. In the first analysis, we tested for evidence of synchrony with a series of Spearman's rank-order correlations with false discovery rate correction, in which we used the proportion of time per interaction that females displayed motor behaviours (expressions, nodding and gestures), duration of eye gaze (looking at partner's face or body) and average baseline change in physiological responses (HR and SC), and correlated these measures with the same behavioural measures of their male partners. This resulted in a correlation matrix (Fig. 2). The circled cells in the Fig. 2 highlight the synchrony types between male and female partners which were the main focus of this analysis. The additional cells are other between-partner associations.

Considering that individuals differ in their level of expressiveness, there is a certain baseline probability that partner's expressions are correlated by chance. To test for the significance of associations above random chance, in a subsequent control analysis, we paired each female with a random male with whom they had not interacted (but who had dated another female). We focus here on the results of the different synchrony types (Fig. 2, circled cells) and show that, for seven out of ten, the correlations between real dyads were significantly higher than the correlations in the randomly shuffled dyads (all Fisher's $Z > 2.3$, $P < 0.05$; Supplementary Table S1). Specifically, we found evidence for synchrony of (i) smiles, (ii) laughs, (iii) head nods, (iv) hand gestures, (v) face-to-face gaze, (vi) HR and (vii) SC. For gaze at partner's body and face touching, the associations were similar across real and randomly shuffled dyads (Fisher's $Z < 0.1$, $P > 0.05$). Thus, these three synchrony types were excluded from subsequent analyses. To predict attraction, in the next model we zoom in on the seven synchrony types that we observed.

Does synchrony strength predict attraction? As expected, attraction fluctuated substantially over the course of the date. While some individuals became more attracted to their partners, others became less attracted (Supplementary Fig. S1). At the end of the date, almost half of the participants (44%) wanted to go on another date with their partner (34% of females, 53% of males), which is a substantial rate considering that couples were paired randomly. However, only 17% of the couples matched and had a mutual wish to date each other again.

Before we examined the effect of synchrony on attraction, we first tested for effects of other factors such as gender, time (first impression, first interaction and second interaction), interaction type (verbal/non-verbal) and interaction order (verbal interaction first/second) on participants' attraction ratings. The multilevel model had the following structure: three time points (level 1) nested in participants (level 2) nested in dyads (level 3). The results of the multilevel linear mixed model showed a main effect of gender ($\beta = 1.12$, $t(324) = 2.60$, $P = 0.009$, CI 0.28 to 1.96), revealing that males were more attracted to females than females were to males. Importantly, the effect of the interaction type (verbal/non-verbal), interaction order, or the two- and three-way interactions between interaction type, interaction order and gender were not significant (all $P > 0.05$; Supplementary Table S2), which implies that the order of verbal and non-verbal conditions did not influence participants' attraction ratings.

Having confirmed our first hypothesis that individuals synchronize their behaviours with each other on three different levels of expression, including motor movements, gaze and physiology, our next analysis investigated whether the strength of different interpersonal synchrony types predicts attraction. To quantify synchrony for binary variables (for example, smiling or not), we calculated the proportion of time both participants' reciprocated expressions for motor movements (smiling, laughing, head nods and hand gestures) and gaze fixations (looking at partner's face) while allowing a lag of 5 s (for details see Methods and Supplementary Information). The max 5 s window was selected because it is a frequently used lag in literature focusing on behavioural mimicry (for review see ref. [23]). To calculate the strength of synchrony between continuous physiological signals (HR and SC level), we used windowed cross-correlation analyses[24] (for details see Methods and Supplementary Information).

This resulted in seven synchrony values (synchrony in smiles, laughs, head nods, hand gestures, face-to-face gaze, HR and SC level) for each dyad and time (first impression, first interaction and second interaction). These seven synchrony types were used as predictors of attraction in a multilevel linear mixed model. The multilevel model had the following structure: three time points (level 1), nested in participants (level 2), nested in dyads (level 3). As both the attraction ratings and the synchrony measures were level 1 (repeated-measures) predictors, the longitudinal design of the study implies that we predict the evolution of attraction by the evolution in synchrony over the course of the three time intervals. To account for the dependence of measures within participants, we included a random intercept effect (across participants) and a random slope for time to account for the different trajectories in attraction scores (as outlined above). Apart from different synchrony measures, to control for other variables that may influence attraction, the full model included factors of gender, a dummy variable for interaction type (1 for verbal, 0 for non-verbal), a dummy variable for interaction

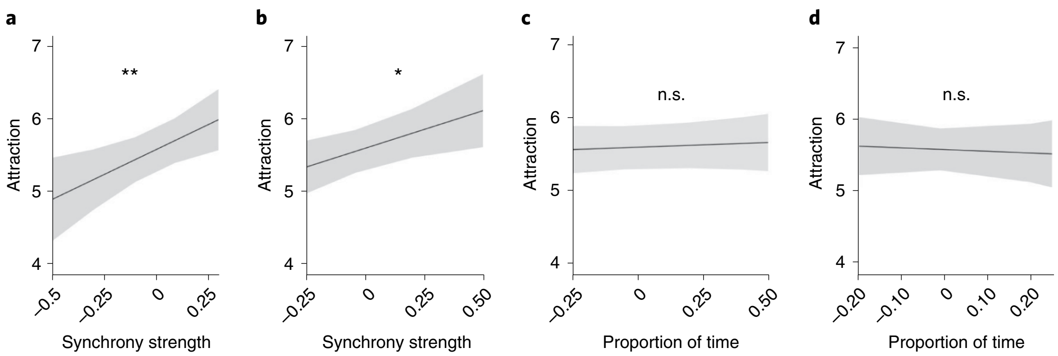

Fig. 3 | Line graphs representing slopes extracted from the multilevel linear mixed model. a,**b**, Attraction based on synchrony of SC level (**a**) and HR (**b**). **c**,**d**, The proportion of time participants' mimicked smiles (**c**) and displayed face-to-face gaze mimicry (**d**) did not significantly affect attraction. The shaded areas represent 95% confidence intervals.

order (verbal first: 1 for yes, 0 for no) and two-way interactions between interaction type and each type of synchrony and the type of interaction × interaction order. The final model was selected with a backward stepwise selection of fixed effects. The variance inflation factor values of the full and final models were all smaller than 4, suggesting that multi-collinearity did not influence our results[25] (for the final and full models see Supplementary Table S3).

The final model (see Methods for the final model equation) showed that attraction was predicted by physiological synchrony between partners. Specifically, the more couples' SC and their HR synchronized, the more attracted participants were to their partner (SC level: $\beta=1.33$, $t(324)=2.67$, $P=0.008$, CI 0.35 to 2.31; HR: $\beta=0.98$, $t(324)=2.34$, $P=0.020$, CI 0.16 to 1.80; Fig. 3a,b). Interestingly, we did not find this association with synchrony in smiles, laughs, head nods, hand gestures or face-to-face gaze (all $P>0.05$; Fig. 3b,c). Moreover, the lack of an interaction between physiological synchrony and interaction type ($P>0.05$; Supplementary Table S3) implied that physiological synchrony had a positive effect on attraction during both verbal and non-verbal interactions. In sum, these data suggest that physiological synchrony explains more variance in attraction than the synchrony of explicit expressions such as smiles, laughs, head nods, hand gestures or face-to-face gaze.

To show an example of what physiological synchrony looks like, we include a video of one couple (Video 1). We selected this video because these two people first met without exchanging any words and, during this non-verbal interaction, their mean attraction score increased. For the selected area of interest (AOI) for the face, see Fig. 4.

Additional control analyses. For a more precise examination of the effect of physiological synchrony on attraction, we conducted three control analyses.

Does within- or between-dyad synchrony predict attraction? First, in the previously described model, the variables for HR and SC level synchrony included within- and between-dyad level variation in synchrony. It is therefore unclear whether couples who are highly attracted to each other synchronize more than those who are not (that is, between-dyad effect), or whether changes in physiological synchrony over time predict attraction changes (that is, within-dyad effect). To disentangle these two types of variation, we computed two variables: (1) between-dyad SCL synchrony: the averaged synchrony level across time points per dyad, and (2) within-dyad SCL synchrony: the deviation in synchrony level (per time point) from the dyad's averaged synchrony level (within-dyad centring). Both variables were included in a multilevel linear mixed model with a three-level structure consisting of three time points (level 1), nested in participants (level 2) nested in dyads (level 3). We also included a random intercept effect (across participants) and a random slope for time.

Results clearly show that the change in synchrony was associated with the change in attraction at the within-dyad level (for both synchrony variables; HR: $\beta=0.94$, $t(324)=2.16$, $P=0.028$, CI 0.10 to 1.78; SC: $\beta=1.30$, $t(324)=2.47$, $P=0.012$, CI 0.28 to 2.31), but there was no effect at between-dyad levels (Supplementary Table S5). Thus, dyads with overall more synchrony were not significantly more attracted to each other (Supplementary Fig. S3). The two main effects for within-dyad SCL and HR synchrony demonstrate that, the more couples became synchronized over the course of the date, the more their attraction increased. It is difficult to speculate whether a larger sample size might potentially reveal that the strength of synchrony also plays a role between dyads. However, both effects are interesting to study on their own as they point out different types of processes that might be going on. Specifically, the here reported finding complements the hypothesis that moment-to-moment physiological synchrony correlates with moment-to-moment affective dynamics that are predictive of the quality of that interaction.

To evaluate the robustness of our data, we considered using additional cross-validation analysis. Specifically, we additionally applied clustered bootstrapping to estimate the confidence intervals of the coefficients. The results of bootstrap analysis show that, after 1,000 permutations, the coefficient of the HR and SC synchrony did not include zero, indicating its stability (Supplementary Table S6). This bootstrap analysis supported that synchrony effects for HR and SC were both robust.

Does increase in physiological arousal predict attraction? Second, considering that arousal has been linked to attraction, what remains unknown is whether an increase in synchrony of physiological signals is required for attraction to occur. For example, increases in the level of SC and HR may yield similar attraction changes without the need for synchrony: in other words, the relationship between synchrony and attraction discussed above may be an epiphenomenon of increased arousal. If true, this would mean that participants' arousal level alone may predict attraction irrespectively of inter-individual synchrony. To test this, we first computed the mean SC and HR change from baseline and then standardized the responses per participant. In subsequent control analysis, we used the same multilevel linear mixed model with the same structures as in the second analyses, but instead of HR and SC synchrony measures, we used participants' HR and SC (baseline-corrected) changes as predictors of attraction (see Supplementary Table S7 for the model summary and more details). The results show that attraction was not significantly

Fig. 4 | Face and body AOIs. Face masks were drawn by an oval shape which was fitted around the participant's face (keeping the ears and hair outside of the mask). For the body AOI, the body was cropped out with a drawing tool and included the neck and both arms.

explained by individuals' HRs ($\beta = 0.03$, $t(324) = 0.60$, $P = 0.544$, CI −0.06 to 0.12) or SC changes ($\beta = 0.01$, $t(324) = 0.28$, $P = 0.779$, CI −0.01 to 0.02). This result further confirms that attraction could not be solely predicted by the arousal responses of the two individuals, but by the synchrony of arousal between individuals.

Is attraction a valid outcome variable? Third, one may wonder whether we really measured attraction in this study or possibly something else. To control for this possibility, throughout the experiment we also collected other ratings including trust, liking, feeling of connection and 'click'. We also asked whether participants felt awkward or anxious. These scores were then compared with attraction ratings and participants' choice to go on another date (yes/no) with the partner. The results of a principal component analysis showed that attraction was closely correlated with positive factors (for example, liking and connection) and negatively linked with feelings of being shy, awkwardness and low self-esteem (Supplementary Tables S8 and S9). Importantly, among all the collected ratings, the feeling of attraction was the strongest predictor of the decision made at the end of the date to date the partner again ($\beta = 0.62$, $t(324) = 2.53$, $P = 0.013$, CI 0.13 to 1.11; see Supplementary Table S10 for details), giving credence to the solidity of our dependent variable in the previous analysis.

Discussion

Multiple studies have suggested that synchrony on the emotional level promotes connection and affiliation[26], yet the mechanisms mediating the link between attraction and non-verbal communication remained unknown. In this blind date experiment, we measured a whole choreography of movements, gestures and physiological reactions in order to understand how romantic attraction between people develops. In line with existing literature[8,16,27], we observed that people spontaneously synchronized on multiple levels of expression including motor movements, eye gaze and physiological responses. We further demonstrate that attraction was associated with physiological synchrony between partners; this effect persists regardless of whether couples were allowed to speak or had to remain silent. Since we did not find evidence of a significant association between attraction and synchrony in visible expressions (smiling, laughing, direct eye contact, head nods and hand gestures), these results highlight the importance of subconscious physiological coupling in the development of romantic attraction. The current findings are particularly relevant from the perspective of our modern romantic landscape where affective exchange is reduced to quick encounters between strangers. The finding that physiological synchrony predicts attraction between strangers supports existing theory implying that synchrony on an unconscious level plays a key role in the development of human connections[3,4]. These results further showed that visible signals (detectable by humans) were not significantly associated with attraction ratings. However, these findings do not suggest that synchrony in smiling, laughing or face-to-face gazing does not play a role in attraction. Instead, we demonstrate that physiological synchrony is reflective of attraction above and beyond visible signals measured in this study. There are several theoretical and methodological reasons for why physiological synchrony may be superior in attraction detection than visible mimicry or arousal level.

First, mimicry in the form of pure motor imitation has been found to increase liking and rapport between individuals[28]. However, especially at the early stages of dating, humans do not disclose their interest too overtly[29]. Whereas straightforward information exchange would be more evident, research suggests that humans make handy use of a 'backdoor', which offers an option of escape when things do not progress as hoped[30]. For instance, while smiling and prolonged gazing has been proposed to be a sign of affection[31–33], ignoring a partner's gaze and looking away is often a sign too[29]. These behavioural inconsistencies probably relate to the lack of visible synchrony effects on attraction found in this and other experiments (for review see ref. [33]).

Moreover, in contrast to visible synchrony (for example, direct copying of overtly perceived behaviours), physiological synchrony requires both partners' autonomic nervous systems to become simultaneously activated. Considering that such a response is difficult to regulate, we propose that physiological synchrony potentially captures more 'genuine emotional exchange'. In support of this theory, our data demonstrate that couples were often smiling and mimicking each other on a superficial level, yet these visible signals were not significantly associated with attraction (for the analysis of individual expressions see Supplementary Table S8). Yet, when participants' physiological signals aligned, attraction increased during these interactions. The fact that arousal plays a role in sexual attraction has been well established[5,34]. For instance, it has been found that couples who had been watching a high-arousal movie engaged in more affiliative behaviours than did couples who had watched a low-arousal movie[35]. Similarly, people who had just got off a roller-coaster ride perceived a photographed individual as more attractive than people who had been waiting for the roller-coaster ride[36]. Contrary to contemporary theories implying that attraction is heightened by the level of arousal (for example, excitation transfer theory[37]), the current study shows that SC and HR baseline increases were not sufficient predictors of interpersonal attraction during dating interactions. Instead, these results imply that attraction is not as much of an arousal response as the ability of two people to put each other in a similar physiological state (ease or excitement)[38].

One thing that merits discussion is how synchrony relates to romantic relationships over a longer time frame. Seminal studies with married couples measured physiological synchrony while couples argued. In these experiments, physiological linkage was associated with lower marital satisfaction and higher chance of divorce (negative affect)[13,39]. In contrast, in the current study, couples were on a date, which is in essence a positive experience. Consequently, physiological synchrony was predictive of positive affect (attraction). This result aligns with prior research suggesting that physiological linkage can be either good or bad, depending on the environmental context[12]. Although the direction between physiological synchrony and attraction is unclear (synchrony may cause attraction or vice versa), we speculate that the ability to synchronize with others could allow humans to embody the affective experiences of others. The concept of embodied emotions is closely related to the somatic marker hypothesis[7] or to the concept of interoceptive memories[40]. As people perceive another person's smile, blush or pupil dilation, their homeostatic reflexes can be triggered while viewing affects expressed by another individual. In this way, people can emotionally and physiologically align. Therefore, ones' gut feeling about others can be defined as the rapid assessment of the probability of a favourable or unfavourable outcome based on somatic experiences[7]. That is, apart from one's own arousal changes, individuals must be able to assess their own arousal in relation to another person's arousal.

Finally, from a methodological perspective, the reason why physiological synchrony might be a better predictor of interpersonal attraction than physiological arousal is that inter-individual metrics might be better suited to capture/normalize physiological patterns. Recently, research has begun to demonstrate that the unified nature of conscious experience in fact consists of temporally interleaved and highly selective activations in the central nervous system[41]. While SC level and HR responses lack specificity (high arousal can be both pleasant or unpleasant), by tracking the stream of physiological signals between two interacting partners, physiological synchrony incorporates information regarding affective reciprocity. In this way, physiological synchrony could partly account for the social contexts and thus provide better insights into human interactions than the level of arousal alone.

The limitation of this experiment is that there may be other visible signals that we did not test but which could mediate the relationship between physiological synchrony and attraction. Another limitation is that only heterosexual dyads were included in this study. For example, we consider pupil size[19,42] and blushing as likely candidates. In support of this, a recent study showed that humans are able to estimate another person's HR merely by viewing a video recording of a neutral face[43]. Previous studies have argued that our trichromatic vision has evolved to detect emotional states, where most trichromatic apes tend to be bare faced[44]. We therefore recommend future research to investigate the underlying mechanism in more depth and also include homosexual couples. Moreover, since this is one of the first studies that attempted to detect attraction using real-life eye-tracking and physiological measures, we advise researchers to replicate our findings in even more controlled laboratory setting, ideally with a larger sample, before attempting to use these measures in the field.

Overall, the results of this study suggest that physiological synchrony is predictive of attraction even after accounting for participants' mimicry in expressions, face-to-face gaze and mean autonomic nervous system activity. These findings are particularly relevant if we consider the rapid change in our modern dating culture. With the rise of online dating, the pool of potential partners has grown substantially (50 million people date online today)[45] and dating has become a fast and controllable process. We propose that future studies could use modern devices (wireless watches collecting physiology or mobile apps) to assess this non-verbal form of communication. Additionally, state-of-the-art automatic AOI extraction and facial expression detection can greatly elevate the time-consuming process of manual scoring and thereby provide a promising future for studies of real-life interactions. Further understanding of these processes may shed light on the mechanisms by which humans relate to each other during real-life interactions in their everyday natural environments.

In sum, thanks to the unique combination of measures (videos, eye-tracking and physiological measures), we were able to visualize the contagious spread of emotional information that emerges already during first encounters. Our findings suggest that, when interacting partners' subconscious arousal levels rise and fall into synchrony, mutual attraction also changes. Crucially, our findings imply that, on the dyad level, the interacting partners' physiological states synchronize into mutual alignment on a moment-by-moment basis. During these moments, a joint mental state potentially facilitates the feeling of a 'click' and attraction.

Methods

The experimental procedures were in accordance with the Declaration of Helsinki and approved by the Ethical Committee of the Faculty of Behavioral and Social Sciences of Leiden University (no. CEP16–0726/258). Informed consent was obtained from all human participants. Participants did not receive any compensation for taking part in this study. The authors affirm that human research participants provided informed consent for publication of the images in Fig. 1 and Video 1.

Participants. In total, 142 participants were recruited (71 opposite-gender dyads). At the time of data collection, we were not aware of methods to calculate prior power analyses for hierarchical data structures. Instead, we based the sample size on our previous studies, where we used a similar set-up[9,13,46]. Although recent advances would make it possible to conduct a post hoc power analysis, we refrain from this as it greatly depends on the P value of the observed effects. Participants' age ranged from 18 to 37 years (male: M 25.71 years, s.d. 4.639 years; female: M 23.45 years, s.d. 4.265 years). Participants were recruited at three different annual events in the Netherlands: Lowlands (a music festival that takes place in the City of Biddinghuizen, $N=32$), The Night of Arts and Science (a festival that brings art and science together in Leiden, $N=9$) and InScience (a science film festival in Nijmegen, $N=30$). The seating and lighting conditions were very similar across testing sites as we brought our own equipment including the table, chair and lights. As for ambient noise, dyads were always situated in a separate room with minimal ambient noise. To participate in the experiment, participants had to be single and aged between 18 and 38 years and have normal vision or vision corrected by contact lenses (normal glasses could not be worn underneath the eye-tracking glasses). Furthermore, participants could not have or have had any psychological illness, use medication or be undergoing psychological treatment. Using a digital 1PC alcohol tester, we made sure to only include participants who did not exceed a blood alcohol content of 220 μg of alcohol per litre of exhaled breath (the Dutch driving limit). For the behavioural analysis, one dyad was excluded because they were part of camera crew and their interaction was recorded, while in another dyad the male left the experiment prematurely, leaving 69 dyads included in the behavioural analysis. For the physiological analysis, an additional 15 dyads were excluded due to artefacts or missing physiological data, meaning that 54 dyads were included in the physiological analysis. Participants were mostly Dutch (92%) and highly educated. Of the participants, 73% used dating applications (for example, Tinder, Bumble and Happen) and both males and females were looking for a committed relationship (Supplementary Table S11). At the end of the study, out of 138 people, a total of 58 (44%) wanted to date their partner at the end of the date (34% of females, 53% of males), among whom 11 couples matched (17%). Five people did not report. Furthermore, 20 couples (31%) mutually agreed on not being a good match for each other, and in half of the couples (52%) one partner wanted to date their partner but the other did not reciprocate. There were no significant differences between males and females in their level of social anxiety, positive/negative affect or score on the social desire scale (Supplementary Table S12).

Procedure. *Baseline measures.* Participants were screened for exclusion criteria, received information about the study and gave informed written consent. Participants were then asked to fill out some questionnaires to control for psychological factors that could influence a person's ratings of their partner or the general behaviour during social interactions (Supplementary Information). In addition, participants filled out baseline ratings reporting their expectations and standards (for example, how attractive, intelligent, trustworthy and funny their potential romantic partner should be). Participants also rated themselves on the same items on ten-point scales. Two researchers (one for male, one for female participants) attached electrodes measuring HR and SC to the participants' skin. They also helped participants to put on the eye-tracking glasses, which were calibrated afterwards.

Before participants started, there was a 15 min period where they were separated and asked to relax and fill in questionnaires. Then, without seeing their partner, participants were led to the dating cabin: the female first, and after calibration of her equipment, the male partner. Upon eye-tracking and SC calibration, participants were instructed to look at the fixation cross (at the closed barrier), while their baseline (30 s) physiological measures were collected. Participants were instructed to remain silent until they heard instructions via a speaker. Cameras in the glasses recorded video and sound over the whole period of the dating experiment. The visual barrier was opened by being pulled manually by the examiner from the adjustment room.

First impression. The screen then opened briefly (3 s), giving participants a first impression of their partner. After the first impression, participants looked at the fixation cross for 30 s to collect post-first impression physiological measures, after which they rated their partner on the same (0–9) scales as they rated their imaginary or potential romantic partner during baseline. In addition, participants were asked to rate how much they liked their partner and how much they thought their partner liked them. Other questions included how similar they thought their partner was in terms of personality and how much connection, 'click' and sexual attraction they felt between them. After the first impression, two additional interactions would take place (the order of which was counterbalanced).

Verbal interaction. The visual barrier opened and participants were instructed to talk freely with their partner for 2 min. After this interaction, the participant was asked to fill in the same scales as during the first impression, plus rate their impression of the verbal interaction.

Non-verbal Interaction. The visual barrier opened and participants were instructed to look at their partner and not speak for 2 min. Afterward, the barrier closed and participants rated their partner on the same 0–9 point scales. Whether participants began with the verbal or non-verbal interaction was counterbalanced (Fig. 1b). During the final ratings, participants indicated how much they thought the other person liked them and whether they wanted the experimenters to exchange their email addresses. The pairs were also asked to predict whether they thought their partner wanted to exchange email addresses and go on another date. Finally, participants were asked to indicate whether their video recordings could be used for follow-up experiments.

Follow-up. For ethical reasons, participants' decisions to date their partner again or not were not revealed until the festival was over. Only if both of them agreed to exchange contact information, 1 week after the study they received an email with their partner's email address. They were asked if we could contact them again later to ask if they were still in contact with their partner.

Measures. *Ratings.* Participants filled in ratings before the experiment, after the first impression and after both the verbal and non-verbal interactions. All questionnaires included the same questions about the partner (or during baseline about a potential partner) in which the participant rated: attraction, funniness, intelligence, trustworthiness, similarity in personality, connection, sexual attraction and 'click' on scales ranging from 1 (not at all) to 9 (very). Additionally, during baseline, participants had to indicate how attractive, funny, intelligent and trustworthy they thought they themselves were (0–9 scales). Every questionnaire also contained a mood grid, in which participants had to indicate their level of arousal and the valence of their affect. Participants also rated how shy, awkward and self-confident they were feeling. Furthermore, every questionnaire (except during baseline) included a question asking how much they liked the partner, and how much they thought their partner liked them. Finally, during the first impression and during their last interaction, participants indicated whether they wanted to see their partner again and whether they thought their partner wanted to see them again. As additional control measures for mood and sexual desire, we included the Liebowitz Social Anxiety Scale[47], Positive and Negative Affect Schedule[48] and Sexual Desire Inventory[49] (Supplementary Table S12).

Pre-processing. *Behavioural expressions coding.* The eye-tracking glasses videotaped participants' behaviour, and the eye-tracking fixations were classified by the algorithm in the Tobii Pro Lab software. Four independent raters (two raters for males and two for females) rated participants' expressions (smiling, laughing, head nod, hand gestures and face touching) using Tobii Pro Lab (version 1.5, 5884). The tapes were coded without sound, and coders were blind to participants' ratings. The facial expressions were coded per tenths of seconds, and the frequency of each expression was then averaged per interaction (lasting between 3 s and 120 s). The reliability was then calculated as the percentage agreement between recorded observations. All coders had successfully completed training and reached an agreement ratio of at least 0.70 for all behaviours, except for the open versus closed body position (agreement less than 0.7). Thus, this particular behaviour was dropped from all analyses.

Eye gaze fixation classification. Eye fixations were recorded using Tobii Pro Glasses 2. In the first AOI analysis steps, we instructed the scorers (using Tobii Pro Lab) to draw all visible AOIs including the head, face, eyes, nose, mouth, body, right arm, left arm and background. AOIs were drawn on snapshot images of participants taken at the start of each interaction (1079 × 605 pixels). Upon visual inspection, we considered smaller AOI (eyes, nose and mouth) to be too small to be accurately measured. Thus, we dropped these AOIs from all analyses. In the end, only two masks were used: face and body. Figure 4 shows the size of each mask.

Fixation mapping procedure. Eye gaze fixations were mapped onto areas of interest (partner's face and body) using the 'fixation classification method' implemented in Tobii Pro Lab (version 1.5, 5884) as well as manual mapping. Specifically, the real-world mapping was used in interactions that were static enough. In verbal interactions, real-world mapping could not be done effectively because participants moved a lot during those interactions. For this reason, all verbal interactions were done with manual mapping, whereas real-world mapping was used for static scenes (non-verbal interactions and first impression). This was kept consistent across all participants. Importantly, after fixations were mapped (manually by scorers, or automatically), the fixations were also visually verified by scorers. This was done fixation by fixation to correct for inaccuracies. In addition, to compare the number of fixations classified with real-world mapping versus manual mapping, we did post hoc checks where we selected one subject and re-ran the analysis with manual mapping during the subject's static interactions (first impression and non-verbal interaction). This control check confirmed that manual mapping and real-world fixation mapping produced very similar results (Supplementary Table S13).

The 'I-VT (Attention)' filter (velocity-threshold identification gaze filter) was selected to handle eye-tracking data from the glasses' recordings conducted in dynamic situations. As with facial expressions, the fixation analysis was performed in Tobii Pro Lab using the trackers' native sample rates. Afterwards, the Boolean AOI-hit time series were exported from Tobii Pro Lab and imported into MATLAB, where they were re-sampled into 10 Hz time series for use in the analysis pipeline. This was done to standardize and align all the physiological and behavioural time series, including HR and SC. The 100 ms was based on previous literature measuring synchrony in a variety of physiological measures[18,19,50]. Given that we were interested in slower signals (HR and SC) and not low-latency gaze contingent behaviour, we judged sub-10-ms temporal accuracy as being unnecessary.

Systematic error in gaze position. The validity of eye-tracking analysis depends on the size of the AOIs, the distance from the eye tracker, the systematic error and the mapping procedure. Several actions were taken to account for this: before we conducted the experiment, we did pilot tests. Specifically, we spent a substantial amount of time trying to find a seating position such that participants would be sitting in the centre of their partner's visual field. Subsequently, we brought all equipment, including the dating table, lights and chairs, with us to the testing events at the locations. We also placed markers on the floor for the chairs so that each chair would be positioned in the middle of the table, approximately in the middle of the visual field (as depicted in Video 1). Furthermore, we positioned the fixation cross such that, if participants fixated at the fixation cross, their partner's face would appear behind that cross when the barrier opened. The size of the table was exactly 1 m (100 × 100 cm). So that all participants sat at an equal distance, the research assistant helped participants to their seats so that their face was right at the edge of the table. We also made sure that all participants had the eye-tracking glasses fixated by the rubber band (attached to Tobii glasses). This prevented the glasses from moving too much. Because we recognize the limitations of the eye tracker, as mentioned above, we included only the larger AOIs (face and body; Fig. 4). Finally, to quantify potential errors in calibration, we asked participants to look at the fixation cross before every interaction; having this fixation check before each interaction helped us see if peoples' calibration began to drift. The above-mentioned features of the design helped us to make the systematic error uniform across participants and inspect whether participants fixated at the centre of the marker. Prior to each interaction, we checked whether the eye-tracker needed recalibration or not. In case the eye fixation did not overlay the fixation cross, we re-calibrated. In the post-experiment pre-processing stage, we calculated the remaining small differences in the x and y coordinates between the glasses' fixation and the fixation cross. The AOI masks were then moved by these small differences along the respective x and y coordinate. However, this correction was judged necessary only for six participants, whose inclusion or exclusion did not change the results of our main analysis (Supplementary Table S3).

Importantly, the primary aim of this study was not to analyse intricate gaze behaviour but to measure partners' physiological synchrony while controlling for duration of eye gaze. As such, we estimated that the technical limitations of the glasses with regards to accuracy would be acceptable for our design. This was supported by post hoc control analysis. While there might be a measurable effect, it does not seem to be meaningful in our analysis, and more importantly does not invalidate our findings. For more details about potential deviations in face AOI eye-tracking measures, see Supplementary Information.

Physiological measures. For each participant, electrocardiographic and electrodermal activity data were collected using BIOPAC's ECG2-R and PPGED-R modules, respectively, and an MP-150 system operated using AcqKnowledge software version 3.2 (BIOPAC, Goleta, CA). All raw signals were recorded at 1,000 Hz.

SC level pre-processing. Two electrodes were attached on the intermediate phalanges of the index and ring finger of the non-dominant hand. Using the PhysioData Toolbox, the raw SC signal was visually inspected and short-duration artefacts were removed and replaced using linear interpolation (maximum interpolation duration 2 s). Longer invalid sections of data were excluded. The SC signal was then low-pass filtered at 2 Hz to remove high-frequency noise and, for each section of interest, down-sampled to 10 Hz for further analysis.

HR pre-processing. Similarly, the PhysioData Toolbox was used to extract 10 Hz continuous instantaneous heart rate (IHR) signals from the raw ECG signal. This involved bandpass-filtering the raw signal at 1–50 Hz, performing peak detection to find the R peaks, and calculating the interbeat intervals (IBIs). Both the R peaks and resulting IBIs were reviewed visually, and erroneously derived instances of any of the two were removed. The IHR signal, in beats per minute, was then generated from the remaining IBIs using piece-wise cubic interpolation (maximum interpolation duration 2 s). Trials (participants' interaction segments) with less than 30% coverage of the sum of the IBIs relative to the duration of the time signal were excluded. Participants missing more 50% percent of the IBIs were excluded.

Considering that HR and SC are very slow signals, we anticipated that 3 s of first impression might not be enough to capture physiological synchrony. To account for this, in addition to the 3 s of first impression, we also included 30 s of a post-first impression period where participants sat quietly. The synchrony measures were then evaluated across the whole 33 s window.

Data collection and analysis were not performed blind to the conditions of the experiments.

Analysis. *Analysis 1.* We ran a correlation between all measures. This resulted in a large correlation table showing associations between males' and females' expressions, eye fixations and physiological measures as well as female–female and male–male associations showing how non-verbal behaviours and physiological responses relate to each other within participants. Then, in a control analysis, each female was paired with a random male. To test for significance, we compared the correlation coefficients between true couples and randomly matched couples using the 'cocor' package in R Studio[51] with gender as an independent group and a two-sided test with α set to 0.05. Note that the assumption for monotonic relationship is met (Supplementary Fig. S2).

Analysis 2. Before we examined the effect of synchrony on attraction, we first tested whether there was a main effect of other factors on participants' attraction ratings (0–9). The multilevel linear mixed models had the following structure: three time points (level 1) nested in participants (level 2) nested in dyads (level 3). We included factors of gender, time (first impression, first interaction and second interaction), interaction type (verbal/non-verbal) and the order of the interaction (verbal interaction first/second) as well as two- and three-way interactions of gender × interaction type and gender × interaction order.

Quantifying behavioural mimicry. Mimicry is defined broadly as 'doing what others are doing'. This includes mimicry of mannerisms, gestures, postures and gaze movements. Some studies are very loose regarding their definition of mimicry. For instance, mimicry might be defined as any movement following the other person's movement[52,53]. However, we adopt a stricter definition of mimicry where behavioural mimicry occurs when a couple engages in the same behaviour within a short time window, typically no longer than 5 s (for review see ref. [23]). To quantify mimicry for each dyad and interaction, motor movements (smiling, laughing, head nods, hand gestures and face touching) were coded by four independent raters (two raters for males and two for females). Eye fixations falling on pre-defined areas of interests were mapped manually or assisted with the Tobii Pro Lab analyser. Both emotional expression and eye fixation were classified per tenths of seconds as binary variables (1 for occurrence, 0 for no occurrence). We then classified as mimicry when person A directly repeated the same expression as person B within a 5 s window. Specifically, if subject A showed a behaviour and subject B showed the same behaviour at that time point or within a duration of 5 s (50 windows) after the time point, an instance of lagged mimicry was noted. We did the same for person B to A. 'Mutual mimicry' was then calculated by summing the number of mimicries noted from A to B and from B to A, divided by twice the total number of time points. This variable accounted for the proportion of time that both participants displayed mimicry (smiling, laughing, head nods, hand gestures and face touching) and gaze fixations (looking at their partners' face and body) per each interaction. The proportion of mimicry was calculated for each condition (first impression, verbal and non-verbal interaction) resulting in N dyads × 3 conditions for mimicry in smiles, laughs, head nods, hand gestures and face-to-face fixations.

In addition, to compare effects of direct mimicry where person A directly shows the same expression as person B on participants' attraction, we quantified the proportion of time both participants' directly reciprocated expressions (smiling, laughing, head nods, hand gestures and face touching) and gaze fixations (for details see Supplementary Information). Not surprisingly, lagged classification resulted in more data being classified as mimicry compared with direct mimicry measures (Supplementary Table S14). Subsequently, we ran our main analyses again, but this time with lagged mimicry values as predictors of attraction scores. The results (Supplementary Table S3) show that the lagged mimicry and direct mimicry values (Supplementary Table S15) yielded highly comparable results. This made us confident that both lagged and direct synchrony provide very similar information.

Quantifying physiological synchrony. We conducted a lagged windowed cross-correlation analysis to quantify physiological synchrony for the HR and SC level measures separately[24]. The objective of this analysis was to calculate the strength of the association between two time series while taking into account the non-stationarity of the signals and the lag between responses, that is, to consider the dynamics of a dyadic interaction. Non-stationarity is accounted for by breaking down the time series into smaller segments and calculating the cross-correlation of these segments, allowing the correlation to change throughout the time series. There are four parameters to be determined: (1) the length of each segment, referred to as the window size w_{max}, (2) the increment with which the segments are moved along the time series, that is, the window increment w_{inc}, (3) the maximum by which two segments can be lagged from one another, that is, the maximum lag τ_{max}, and (4) the increment by which two segments are lagged from each other, that is, the lag increment τ_{inc}. We determined the parameters following an extensive process by comparing previous studies using similar statistical methods, by looking at what is physiologically plausible given the time course of the physiological signals, and by employing a data-driven bottom-up approach where we investigated how changing the parameters affected the outcomes using a different dataset[54]. Based on these three factors, we set the parameters as follows: a window size of 8 s (160 samples), a window increment of 2 s (40 samples), a maximum lag of 4 s (80 samples) and a lag increment of 100 ms (2 samples). A more detailed description of the analysis can be found in the Supplementary Information. Based on this analysis, we obtained a measure of the strength of synchrony for each interaction per dyad.

Analysis 3. Here, we investigate whether attraction can be predicted by synchrony. In this analysis, we used a multilevel linear mixed model to investigate how different types of interpersonal synchrony impact on participants' attraction ratings (0–9). The multilevel model had the following structure: three time points (level 1) nested in participants (level 2) nested in dyads (level 3). We also included a random intercept effect (across participants) and a random slope for time, but not allowing a correlation between both random effects. The slope for time indicated the evolution of attraction over time. The reason why we did not include the correlation between intercept and slope is because only very small variance was explained by the correlation between the intercept and slope (close to 0). Note that, either way, including/excluding the correlation between intercept and slope does not affect our results. In the model, we included all seven synchrony predictors, including synchrony in (i) smiles, (ii) laughs, (iii) head nods, (iv) hand gestures, (v) face-to-face gaze, (vi) HR and (vii) SC. The full model further included factors of gender, the type of interaction (verbal, non-verbal), the order of interaction (verbal/non-verbal first) and two-way interactions between type of interaction × all synchrony types (smiles, laughs, head nods, hand gestures, face-to-face gaze, HR and SC) and interaction order × interaction type. The final model was obtained by backward stepwise selection of fixed effects. This method first tests interaction terms, then drops interactions one by one to test for main effects. All predictors were centred. To check that multi-collinearity would not confound our results, we calculated the variance inflation factor[55].

The equation for the final model. The backward stepwise selection of the full model resulted in a final model where synchrony for SC levels (Synchrony_SCL), HR synchrony (Synchrony_HR) and gender variables were included in a multilevel linear mixed model with a three-level structure comprising three time points (level 1), nested in participants (level 2) and dyad (level 3). We also included a random intercept effect (across participants) and a random slope for time. The slope for time indicated the evolution of attraction over time. We did not allow a correlation between both random effects.

$$i = \text{time}$$

$$j = \text{participant}$$

$$k = \text{dyad}$$

Level 1: time

$$\text{attraction}_{ijk} = \mathrm{b}_{0jk} + \mathrm{b}_{1jk}\,(\text{time})_{ijk} + e_{ijk}$$

Level 2: participant

$$b_{0jk} = \gamma_{00k} + \gamma_{01k}\,(\text{gender})_{jk} + u_{0jk}$$

$$b_{1jk} = \gamma_{10k} + u_{1jk}$$

Level 3: dyad

$$\gamma_{00k} = \pi_{000} + \pi_{001}\,(\text{Synchrony\_SCL})_k + \pi_{002}\,(\text{Synchrony\_HR})_k + \omega_{00k}$$

$$\gamma_{01k} = \pi_{010}$$

$$\gamma_{10k} = \pi_{100}$$

Composite model

$$(\text{attraction})_{ijk} = \pi_{000} + \pi_{001}\,(\text{Synchrony\_SCL})_k + \pi_{002}\,(\text{Synchrony\_HR})_k$$
$$+\pi_{010}\,(\text{gender})_{jk} + \pi_{100}\,(\text{time})_{ijk} + \omega_{00k} + u_{1jk}\,(\text{time})_{ijk} + u_{0jk} + e_{ijk}$$

For details regarding control analyses see Supplementary Information.

Reporting summary. Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

The datasets generated during and/or analysed during the current study are available at DataverseNL: https://dataverse.nl/dataset.xhtml?persistentId=doi:10.34894/RFUGGD.

Code availability

The codes generated during and/or analysed during the current study are available at DataverseNL: https://dataverse.nl/dataset.xhtml?persistentId=doi:10.34894/RFUGGD.

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Author contributions

E.P. conceived the idea. E.P., M.E.K. and F.B. designed the experiment and, with contributions from D.L. and E.E.S.-S., conducted the experiment. E.P., E.E.S.-S. and D.L. performed the analyses and computational modelling with contributions from M.E.K. and F.B.. E.P. wrote the paper with contributions from M.E.K. and F.B. All authors discussed the results and implications and commented on the manuscript at all stages.

Competing interests

The authors declare no competing interests.

Additional information

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Software and code

Policy information about availability of computer code

Data collection	We used the MP150 BIOPAC data acquisition system to wirelessly collect data for the heartrate (ECG), skin conductance (EDA) that were recorded by the software AcqKnowledge 4.4. The Tobii Pro Glasses 2 were used to track eye movements that were preprocessed using the Tobii Lab Pro (version 1.64, 2017). Matlab R2018b (Version 9.5) was used to synchronize the data. Audio stimuli was presented with E-prime (v3.0).
Data analysis	PhysioData Toolbox v0.5.0 , R-studio v1.2.5033 , SPSS (Version 25)

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Behavioural & social sciences study design

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Study description	Quantitative experimental design with dyadic interactions.
Research sample	Our sample size was motivated by those used in previous studies (Reed et al., 2013; Levenson & Gottman, 1983; Thomsen & Gilbert, 1998). In total, 142 participants were recruited (71 opposite-sex dyads). Participants' age ranged from 18 to 37 years old (Male: M = 25.71, SD = 4.639; Female: M = 23.45, SD = 4.265).
Sampling strategy	To determine a medium effect size is not straightforward because, in contrast to simpler models, there are no rule of thumb guidelines for our complex model (e.g., the Cohen's d). By the time of data collection, we were not aware of methods to calculate a prior power analyses for hierarchical data structures. Instead, we based the sample size on our previous studies, where we used a similar set -up (Behrens & Kret, 2019; Kret, Fischer, & De Dreu, 2015), moreover our sample size was motivated by those used in previous studies (Reed et al., 2013; Levenson & Gottman, 1983; Thomsen & Gilbert, 1998). Although recent advances would make it possible to conduct a post-hoc power analysis, we refrain from this as it greatly depend on the p-value of the observed effects.
Data collection	Participants were recruited at three different yearly events in the Netherlands: during Lowlands (a music festival that takes place in the city of Biddinghuizen), The Night of Arts and Science (a festival that brings art and science together in Leiden) and during InScience (a science film festival in Nijmegen). Participants were selected randomly. We used: pen and paper Ratings, Physiological measures, Videos, Eye-tracking.
Timing	Participants were recruited at three different yearly events in the Netherlands: during Lowlands (19-21.August 2016), The Night of Arts and Science (6. September 2016) and during InScience (08 - 12 November 2017).
Data exclusions	To participate in the experiment, participants had to be single, between 18 and 38 years old, had to have normal vision or vision corrected by contact lenses (normal glasses could not be worn underneath the eye tracking glasses). Furthermore, participants could not have or have had any psychological illness, use medication or be undergoing psychological treatment. Using a digital 1PC alcohol tester we made sure to only include participants who did not exceed a blood alcohol content of 220 micrograms of alcohol per liter of exhaled breath (Dutch driving limit). For the behavioral analysis, one dyad was excluded because they were part of camera crew and their interaction was recorded, in another dyad the male left the experiment prematurely; leaving 69 dyads included in the behavioral analysis. For the physiological analysis an additional 15 dyads were excluded due to artifacts or missing physiological data, meaning that 54 dyads were included in the physiological analysis.
Non-participation	In one dyad the male left the experiment prematurely because he needed to use bathroom.
Randomization	participants were not allocated to experimental groups.

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Population characteristics	See above. Participants were mostly Dutch (92%), highly educated, seventy-three percent of the subjects used dating applications (e.g., Tinder, Bumble, Happen) both males and females were looking for a committed relationship (see Supplementary Table 9). At the end of the study, out of 138 people, in total 58 people (44%) wanted to date their partner at the end of the date (34% females, 53% males) from which eleven couples matched (17%), five people did not report. Furthermore, twenty couples (31%) mutually agreed on not being a good match for each other and in half of the couples (52%) one partner wanted to date their partner but the other did not reciprocate. There were no significant differences between males and females in their level of social anxiety, positive/negative affect or score on the social desire scale (Supplementary Table 10).
Recruitment	We are not aware of any selection biases that could have impacted our results.
Ethics oversight	Psychology Research Ethics Committee of Leiden University (Number: CEP16 - 0726/258).

Note that full information on the approval of the study protocol must also be provided in the manuscript.