Main Manuscript for

Collaborative imagination synchronizes representations of the future and fosters social connection in the present

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Abstract

From close friends to people on a first date, imagining a shared future appears fundamental to relationships. Yet, no previous research has conceptualized the act of imagination as a socially constructed process that affects how connected we feel to others. The present studies provide a novel framework for investigating imagination as a collaborative process in which individuals co-create shared representations of future events–what we call collaborative imagination. Across two pre-registered studies (N=244), we provide the first evidence that collaborative imagination fosters social connection in novel dyads– beyond imagining a shared future individually or shared experience in general. Subjective ratings and natural language processing of participants' imagined narratives illuminate the representational features of imagined events shaped by collaborative imagination. Together, the present findings could potentially shift how we view the structure and function of imagination with implications for better understanding interpersonal relationships and collective cognition.

Significance Statement

Despite a growing interest in imagination among cognitive scientists, existing research has viewed this as an individual process, focusing on how people imagine personal events independently. The present manuscript has the power to change the way we view imagination by providing a novel theoretical framework and evidence that imagination itself is a socially creative process–what we are calling "collaborative imagination" (co-imagination). These findings shed new light on the nature and structure of imagination with implications for better understanding interpersonal relationships, future thinking, and the formation of collective beliefs across social networks. As such, we believe this research speaks to a number of contemporary issues in science and society and will be relevant to researchers in a variety of disciplines.

Main Text

Introduction

Humans are mental time-travelers, capable of imagining novel hypothetical experiences in order to help us envision, plan for, and motivate desired future goals. A wealth of literature has advanced our theoretical understanding of imagination, identifying cognitive processes and brain regions that contribute to this ability (1–4), and establishing several key adaptive functions of imagination, such as improved decision-making ability and emotion regulation (5–7). Yet one area that has received considerably less attention is the contribution of imagination in social relationships. Imagination is seemingly a ubiquitous part of our social lives: From family and friends to people on a first date, from the mundane decisions of what to make for dinner to the consequential choices of where to live and with whom, we imagine and feel out possible future events together. How might engaging in imagination as a collaborative social act shape our relationships in the present? Can imagining a shared future be the first step toward creating one?

Here, we investigate for the first time the phenomenon of "collaborative imagination" (co-imagination), the act of co-creating novel hypothetical experiences in a shared future. We test the prediction that collaboratively imagining a shared representation of the future can shape the formation of new relationships, fostering a sense of closeness and connection. We then explore the features and qualities of imagined events that change as a consequence of co-imagination and may contribute to this effect.

Although prior work has yet to consider the role of collaborative imagination in social connection, integrating findings across disparate research areas suggests a possible association. First, imagination often involves social content and consequences. Thought sampling procedures reveal that people's spontaneous thoughts about the future frequently involve other people (8–

10), and that the social context of the present moment can shape spontaneous thoughts. For example, individuals independently completing mind-wandering tasks in the mere presence of a familiar person generate more social content in their spontaneous thoughts, considering others' thoughts, feelings, and intentions more often than individuals mind-wandering in solitude (11). Indeed, the social content of imagination has important downstream effects related to interpersonal relationships, enabling us to feel empathy (12), increasing mentalizing (i.e., consideration of others' mental states) (13), guiding moral decision-making, and motivating us to help others (14, 15).

Further insight into the potential link between co-imagination and social connection can be gained from research on collective future thinking, defined as the act of imagining the collective future of the group or sociopolitical context in which an individual is embedded (16). This work has deepened our understanding of how individuals imagine the future of their social groups, revealing, for example, an important role for agency in how people imagine the future of their countries (17–20). Furthermore, how individuals think of their group's future can have important social consequences, providing a sense of meaning and continuity within a community (21).

Research on imagination has been highly productive for more than a decade and has highlighted the social content and consequences of imagination. However, previous efforts to understand how and why people imagine the future have largely focused on individuals independently imagining personal events. Existing work has yet to examine the effects of imagining a shared future *together*, co-creating shared representations of novel future events in an interactive, generative social context.

Related phenomena in the memory literature help inform predictions regarding how imagination may function as a social process. Prior work has broadly demonstrated the importance of memory in relationships (22–24), illustrating how remembering prior experiences that include a close other can foster feelings of social connection (25). Further, work on collaborative recall has found that memories can be socially reconstructed (for review, see (26)), with individuals who recall together showing convergence in which details are later retained, creating a shared understanding that can have implications for collectively held beliefs (e.g., (27)). Given that the structure and function of imagination are intimately tied to memory such that both processes draw on a shared cognitive-neural basis (4), this prior work opens the possibility that imagination may too be part of a transactive, distributed social system that extends beyond the individual. Indeed, imagination may have a uniquely flexible advantage compared to memory for forming new social connections, providing an opportunity to create common shared experiences even in the absence of past interactions and shared history.

Another area of research that can inform predictions about the social functions and consequences of collaborative imagination is work on joint attention and social interactions. This literature shows that sharing a new experience (28–31), or even a conversation and a smile (32, 33), can heighten positive feelings and satisfaction in a variety of relationships. Further, engaging in such experiences together can facilitate perceptions of shared inner states (e.g., thoughts and feelings) and a common sense of shared reality and purpose (34, 35). This literature hints at the potential for collaborative imagination to influence social connection through providing an opportunity for individuals to engage in a shared experience. However, it is unclear based on this prior research whether collaborative imagination may influence social connection in ways which are unique and distinct from the effects of shared experiences more broadly.

In sum, a diverse and multidisciplinary body of work opens the possibility that co-creating imagined events may play an important but unexplored role in social relationships. While co-imagination may contribute to a variety of interpersonal relationships, the present work provides an initial exploration of this phenomenon in pairs of strangers. Specifically, we developed an experimental paradigm in which participants imagined shared future events in as much detail as possible and measured its impact on feelings of social connection. Participants imagined either collaboratively with another participant (collaborative imagine condition) or independently (individual imagine condition). Additionally, a third condition (collaborative perception, game (Study 1) or scene (Study 2)) involved either collaborating on a game with another participant or collaboratively discussing and describing details in an image depicting an event with people and objects in a specific location (see Figure 1). We predicted that interacting with a novel conversation partner to co-imagine a shared future event may heighten feelings of social connection above imagining a shared future event independently or collaborating on a non-imaginative task and sharing a novel experience in general.

Additionally, we sought to identify what features of imagined episodes may be shaped by co-imagination. To this end, we measured subjective scene imagery vividness, mentalizing, and other features of imagined events during the experimental task (see Study 1 Methods). Participants in the collaborative imagine, individual imagine, and collaborative perception (scene) conditions also completed a recall phase in which they provided individual narratives describing the imagined events or presented scenes from prior experimental trials. Natural language processing algorithms (i.e., latent semantic analysis (36, 37); Bidirectional Encoder Representations from Transformers (BERT) (38)) were used to assess the degree of similarity in

each dyad's individually held event or scene representations, allowing us to analyze the effect of co-imagination on the creation of shared representations.

Across studies, results revealed that collaboratively imagining a shared future increases social connection compared to imagining a shared future independently or collaborating on non-imaginative tasks. Furthermore, collaborative imagination increased participants' engagement in mentalizing (i.e., considering their partners' thoughts and feelings) and heightened the vividness of the imagined event (i.e., clarity of spatial representation) compared to control conditions. Co-imagination also facilitated the creation of shared future representations. These findings have implications for our understanding of the social functions of imagination and begin to illuminate how shared representations and the subjective phenomenology of imagined events may change as a consequence of co-imagination. This work provides novel insight into how imagination may itself be a social process that can help foster new relationships.

Results

Study 1.

In the following, we investigate a social effect of collaborative imagination as tested among *N*=120 undergraduate students. We then explore the subjective features of event representations and explore the role of similarity in how imagined events are represented across partners.

<Figure 1>

Co-imagination fosters social connection.

Participant responses to six social connection items had high reliability (Cronbach's alpha=0.82; see Supplemental Table 1) and were averaged to form a composite measure of social connection measured prior to and following the experimental task (i.e., imagine task or game).

The social connection composite scores were then analyzed with a mixed-effects ANOVA including a between-subjects effect of condition (collaborative imagine, individual imagine, and collaborative perception (game)), a within-subjects effect of time point (pre- vs. post-task), and a time point * condition interaction. There was a significant effect of both condition ($F(2, 117)=4.22$, $p=.017$, $\eta^2_G=0.05$) and time point ($F(1, 117)=144.59$, $p<.001$, $\eta^2_G=0.25$) on social connection. Critically, the expected interaction between condition and time point was also significant ($F(2, 117)=14.05$, $p<.001$, $\eta^2_G=0.062$).

<Figure 2>

Post-hoc Bonferroni corrected two-sided Welch's t-tests showed that, as expected, there were no significant differences between conditions in pre-task social connection ratings (collaborative imagine vs. individual imagine: $t(73.6)=-0.49$, $p=1.0$, $d=-0.11$, 95% CI [-0.56, 0.34]; collaborative imagine vs. collaborative perception (game): $t(77.5)=0.75$, $p=1.0$, $d=0.17$, 95% CI [-0.28, 0.61]; individual imagine vs. collaborative perception (game): $t(75.9)=-1.36$, $p=1.0$, $d=0.30$, 95% CI [-0.14, 0.75]; see Supplemental Table 4 for descriptive statistics). Yet, analysis of post-task social connection ratings revealed significant condition differences. Consistent with preregistered hypotheses, Bonferroni corrected one-sided t-tests of condition differences in post-task social connection ratings indicated that participants in the collaborative imagine condition ($M=5.40$, $SD=0.56$) felt more connected with their partners than participants in the individual imagine condition ($M=4.57$, $SD=0.97$; $t(62.7)=4.7$, $p<0.001$, $d=1.06$, 95% CI [0.58, 1.53]) as well as the collaborative perception (game) condition ($M=4.90$, $SD=0.83$;

t(68.5)=3.19, *p*=0.01, *d*=0.71, 95% CI [0.25, 1.17]). A Bonferroni corrected two-sided t-test revealed that post-task ratings in the individual imagine condition did not significantly differ from those in the collaborative perception (game) condition (*t*(76.2)=1.64, *p*=.95, *d*=-0.37, 95% CI [-0.81, 0.083]).

Bonferroni corrected two-sided t-tests of change over time within each condition revealed a consistent pattern: social connection scores significantly increased in both the collaborative imagine condition (*t*(39)=10.63, *p*<0.001, *d*=1.96, 95% CI [1.42, 2.51]) and, to a lesser degree, the collaborative perception (game) condition (*t*(39)=7.69, *p*<0.001, *d*=1.17, 95% CI [0.69, 1.66]). The change in social connection from pre- to post-task in the individual imagine condition did not remain significant following correction (*t*(39)=2.86, *p*=.06, *d*=0.46, 95% CI [0.013, 0.92]).

Taken together, these findings provide initial evidence that co-creating and collaboratively imagining a shared future event increases a sense of social connection and affiliation, above and beyond imagining a shared future event independently or collaborating on a non-imaginative task.

Co-imagination changes the phenomenology of imagined events.

Next, we analyzed the features of imagined events that may change as a consequence of collaborative imagination and could relate to its effect on social connection. Subjective phenomenology ratings were not measured in the collaborative perception (game) condition, so the following analyses summarize differences between the collaborative imagine and individual imagine conditions, assessed using two-sided t-tests.

Co-imagination facilitates mentalizing. Participants who co-imagined a shared future event reported engaging in mentalizing to a greater extent (*M*=5.27, *SD*=0.90) than participants

who imagined a shared future event individually (M=3.95, SD=1.45; t(65.2)=4.89, p<0.001, d=1.09, 95% CI [0.62, 1.57]). This suggests that co-imagination may shape the way that individuals access the thoughts and feelings of someone they imagine a shared future with.

Co-imagination heightens scene imagery vividness. Co-imagination also had an effect on participants' subjective experiences of scene imagery vividness in imagined episodes. Scene imagery vividness was measured with a rating of the subjective coherence and clarity of the imagined scene and a visual rating of how vividly the individual pictured the scene in their mind (see Supplemental Figure 2). Specifically, individuals who co-imagined rated their imagined scenes as more coherent and clear (M=5.28, SD=0.86) than those who imagined individually (M=4.42, SD=1.12; t(73.08)=3.90, p<.001, d=0.87, 95% CI [0.41, 1.34]). Furthermore, participants in the co-imagination condition indicated picturing a more visually vivid scene (M=5.01, SD=1.00) than participants in the individual imagination condition (M=4.36, SD=1.27; t(73.76)=2.56, p=.01, d=0.57, 95% CI [0.12, 1.03]). These findings suggest that co-imagination can shape the subjective features of the spatial context in which imagined events are embedded, heightening the perceived vividness and clarity of the imagined scene relative to independently imagined events.

Co-imagination is perceived as easier than individual imagination. Participants in the co-imagination condition reported lower levels of perceived task difficulty (M=3.57, SD=1.01) on trials of the imagine task than participants in the individual imagine condition (M=4.34, SD=1.07; t(77.71)=-3.30, p=0.001, d=-0.74, 95% CI [[-1.20, -0.28]).

Co-imagination leads to shared representations of the future.

We additionally analyzed the participants' transcriptions as dyads to assess if there would be higher similarity for recollections of co-imagined events than individually imagined events.

Dyadic event text similarity was measured using two methods, latent semantic analysis (LSA) (36) and Bidirectional Encoder Representations from Transformers (BERT) (38). Briefly, LSA relies on rich and curated text corpuses along with singular value decomposition; BERT is a more recent and computationally intensive large language model that codes the conceptual relatedness of statements using sentence embeddings and much larger, unconstrained text corpuses. Here, we computed text similarity for each event with each method and averaged across events before comparing the two imagine conditions. Using LSA, the recollections were higher in similarity for the collaborative imagine condition (M=0.74, SD=0.07) as compared to the individual imagine condition (M=0.51, SD=0.10; t(34.3)=8.35, p<.001, two-sided; d=2.64, 95% CI [1.77, 3.49]). This effect was also found with the BERT approach, with again higher similarity for the collaborative imagine condition (M=0.72, SD=0.06) as compared to the individual imagine condition (M=0.43, SD=0.08; t(34.0)=12.9, p<.001, two-sided; d=4.07, 95% CI [2.96, 5.16]). These findings suggest that co-imagination synchronizes the content of imagined future events to create shared representations across individuals.

Study 2.

While Study 1 provided initial evidence demonstrating the social effect of co-imagination, the conditions included did not control for the potential effect of collaboratively engaging in a component process necessary for but not unique to imagination (e.g., representing and processing non-autobiographical scene content). Study 2 sought to examine this possibility through the inclusion of the collaborative perception (scene) condition (see Figure 1). Due to coronavirus-related restrictions, Study 2 was run via a digital medium (i.e., video call). Albeit not a primary goal, this methodological change further strengthened the experimental design by

allowing us to examine whether the effects of co-imagination observed in Study 1 generalize and extend to a virtual format.

The effect of co-imagination on social connection replicates and extends to online interaction.

First, we examined differences in how close and connected participants reported feeling with their dyad partner following the experimental task (i.e., collaborative imagine, individual imagine, or collaborative perception (scene)). Consistent with Study 1, participants' responses to six social connection items were averaged to form a composite measure, which had high reliability (Chronbach's alpha=0.75).

<Figure 3>

The social connection composite scores were then analyzed with a one-way Welch's ANOVA assessing the effect of condition on social connection. This ANOVA showed a significant effect of condition on social connection ($F(2, 77.89)=9.44$, $p<.001$, $\eta^2_G=0.15$). Replicating findings from Study 1 and consistent with pre-registered hypotheses, Bonferroni corrected one-sided Welch's t-tests of condition differences indicated that participants in the collaborative imagine condition felt significantly more connected with their partners ($M=5.80$, $SD=0.59$) than participants in both the individual imagine condition ($M=5.08$, $SD=0.89$; $t(67.59)=4.26$, $p<.001$, $d=0.95$, 95% CI [0.49, 1.41]) and the collaborative perception (scene) condition ($M=5.47$, $SD=0.61$; $t(81.9)=2.48$, $p=.02$, $d=0.54$, 95% CI [0.10, 0.98]). While there were no specific predictions regarding differences between control conditions, participants in the collaborative perception (scene) condition indicated greater social connection than the individual

imagine condition (t(68.77)=-2.30, p=.07, two-sided; d=-0.51, 95% CI [-0.96, -0.066]), though this comparison did not remain significant following correction.

These findings replicate the pattern observed in Study 1, demonstrating consistent evidence that co-imagination fosters heightened social connection above and beyond imagining a shared future independently or sharing in a present-focused, collaborative experience. Expanding this understanding, Study 2 shows that the effects of co-imagination on social connection extend to a sample of the general public, and hold in an online interaction (i.e., video call). Furthermore, data from Study 2 suggests that the social effects of co-imagination cannot be explained by the effects of collaboratively processing or representing non-autobiographical scene content- rather, these effects may be driven by something unique to engaging in imagination as a social act.

The effects of co-imagination on the phenomenology of imagined events replicate.

Co-imagination facilitates mentalizing. A one-way Welch's ANOVA revealed that participants experienced different levels of mentalizing across conditions (F(2, 77.67)=13.52, p<.001, η^2_G=0.14). Bonferroni-corrected t-tests further showed that participants in the collaborative imagine condition (M=5.97, SD=0.95) reported considering the thoughts and feelings of their partner to a greater degree than participants in the individual imagine (M=4.91, SD=1.05; t(78.31)=4.77, p<.001, two-sided; d=1.06, 95% CI [0.59, 1.53]) or collaborative perception (scene) conditions (M=4.90, SD=1.68; t(64.93)=3.57, p=.002, two-sided; d=0.78, 95% CI [0.33, 1.23]). This replicates findings observed in Study 1 and further illustrates how co-imagination can influence the degree to which individuals consider others' thoughts and feelings when imagining a shared future.

Co-imagination heightens scene imagery vividness. Analysis of scene imagery vividness ratings suggested that co-imagined events were subjectively experienced in ways distinct from

individually imagined events. Specifically, the scene imagery of co-imagined events was rated as more coherent and clear (*M*=5.87, *SD*=0.83) than the scene imagery of individually imagined events (*M*=5.32, *SD*=0.92; *t*(78.2)=2.81, *p*=.006, two-sided; *d*=0.62, 95% CI [0.17, 1.07])). Further, co-imagined scenes were rated as higher in picture vividness (*M*=5.95, *SD*=0.76) than individually imagined scenes (*M*=5.39, *SD*=1.10; *t*(68.6)=2.68, *p*=.009, two-sided; *d*=0.60, 95% CI [0.15, 1.05]). Consistent with the pattern observed in Study 1, these findings suggest that co-imagination can shape how the scene imagery of an episode is subjectively experienced.

Co-imagination is perceived as easier than individual imagination but not easier than collaborating in general. Although analyzing ratings of perceived task difficulty initially suggests differences across conditions (*F*(2, 121)=10.74, *p*<.001, η^2_G=0.15), further tests indicate that the pattern of these differences is unlikely to account for the social effects of co-imagination. Specifically, the comparison between the collaborative imagine (*M*=3.15, *SD*=1.28) and individual imagine (*M*=3.76, *SD*=1.33) conditions did not remain significant following correction (*t*(79.39)=-2.10, *p*=.12, two-sided; *d*=-0.46, 95% CI [-0.91, -0.019]). Furthermore, the collaborative imagine condition was rated as somewhat *more* difficult than the collaborative perception (scene) condition (*M*=2.51, *SD*=1.03; *t*(78.43)=2.53, *p*=.04, two-sided; *d*=0.55, 95% CI [0.11, 0.99]). Considering that social connection ratings were higher in the collaborative imagine condition than the collaborative perception (scene) condition, despite greater perceived task difficulty of co-imagination, it is unlikely that the perceived difficulty level of co-imagination could explain its social consequences. Furthermore, participants across conditions reported comparable levels of overall task positivity (i.e., enjoyment, pleasantness, and fun) (*F*(2, 121)=1.58, *p*=.21, η^2_G=.025), ruling out the possibility that differences in enjoyment of the experimental task could explain the observed effects of co-imagination on social connection.

<Figure 4>

Co-imagination leads to shared representations of the future.

Analysis of participants' individual narratives revealed an effect of condition on similarity within dyads (LSA: $F(2, 59)=31.54$, $p<.001$, $\eta^2_G=0.52$; BERT: $F(2, 59)=44.63$, $p<.001$, $\eta^2_G=0.60$). Specifically, recollections were higher in similarity for the collaborative imagine condition (LSA: $M=0.71$, $SD=0.06$; BERT: $M=0.71$, $SD=0.07$) as compared to the individual imagine condition (LSA: $M=0.59$, $SD=0.06$; BERT: $M=0.56$, $SD=0.06$) (LSA: $t(38.8)=6.20$, $p<.001$, two-sided; $d=1.99$, 95% CI [1.17, 2.70]; BERT: $t(38.6)=7.09$, $p<.001$, two-sided; $d=2.24$, 95% CI [1.40, 3.01]). Replicating the findings observed in Study 1, this demonstrates that co-imagination can foster the creation of shared representations of the future.

Notably, recollections were comparable between the collaborative imagine condition and collaborative perception (scene) condition (LSA: $M=0.71$, $SD=0.04$; BERT: $M=0.74$, $SD=0.06$) (LSA: $t(37.6)=-0.44$, $p=1.0$, two-sided; $d=-0.13$, 95% CI [-0.76, 0.49]; BERT: $t(39.2)=-1.65$, $p=.2$, two-sided; $d=-0.52$, 95% CI [-1.14, 0.12]). Thus, dyads in both the collaborative imagine and collaborative perception (scene) conditions held shared representations with high levels of similarity, but participants in the collaborative imagine condition experienced greater levels of social connection than those in the collaborative perception (scene) condition. This suggests that the social effects of co-imagination cannot be explained by creating a shared representation of an experience in general.

Discussion

In what ways does imagining a shared future together shape our social relationships? Across two studies, we find that co-imagining a shared future with a novel partner cultivates

feelings of social connection, to a greater degree than individually imagining a shared future or engaging in a collaborative or shared experience in general. Specifically, participants in the collaborative imagine condition reported liking and valuing their partner more and feeling greater satisfaction with their relationship than participants in the individual imagine or collaborative perception conditions. This work provides a new theoretical perspective on imagination and sheds light on the fundamental role it may play in our relationships: imagination itself can be a socially constructed process that affects how close and connected we feel to others.

While previous efforts to understand how and why people imagine the future have considered the social content and consequences of imagination, they have almost exclusively involved individuals independently imagining personal events (4, 15, 39). The present studies are the first to investigate imagination itself as arising from a social process, in which people co-create shared representations of what could be. Such a framework has implications for better understanding the structure and function of imagination and provides new insight into understanding the nature of interpersonal relationships, collective future thinking, shared beliefs, and collaborative memory. In what follows, we note limitations of the present studies and highlight some of the exciting directions for future research to explore.

Beyond showing that co-imagination can cultivate social connection, these studies take an important first step in demonstrating how collaborative imagination can change the features and phenomenology of what is imagined. Specifically, the present research found that the vividness of scene imagery, degree of mentalizing, and narrative similarity all increased when people collaboratively imagined future events together compared to when they imagined independently. Such changes will likely have a number of downstream effects on attitudes and

behavior that are ripe for exploration. For example, given that vividness of scene imagery has previously been associated with a willingness to help others in need when an individual is independently imagining (14), it is possible that collaborative imagination may serve to amplify this prosocial effect.

We also observed increased mentalizing in the collaborative imagine condition, a finding consistent with recent evidence that social context can affect levels of spontaneous social thought while mind-wandering (11), and that increased eye- and face-directed gaze predict performance on a collaborative recall task (40). In light of the present findings, might mind wandering and collaborative recall also increase mentalizing within a dyad? If so, could mentalizing serve as a domain-general mechanism to shape and synchronize mental content across individuals?

The present studies consistently revealed greater narrative similarity for future event representations in the collaborative imagine condition compared to the individual imagine condition. Such a finding provides insight into how dyads form beliefs and mutual understandings about future experiences, with potential implications for forming a shared sense of reality (35) and collective beliefs (41, 42). Furthermore, research on narrative identity suggests that sharing life stories about the future may play an important role in relationships, though this literature has yet to isolate the effects of sharing future versus past life story events (43, 44). How might co-imagination shape individuals' life stories about the future, and thus, their narrative identity? What role could narrative identity play in the social functions of co-imagination?

While the present studies revealed that scene imagery, mentalizing, and narrative similarity are affected by collaborative imagination, this is by no means intended to be an exhaustive list of what phenomenology and features of imagined events could be shaped by

collaborative imagination. Testing the impact on additional variables is an exciting direction for future research.

Emerging research on collective future thinking has begun to investigate how *individuals* imagine the future of the groups and collectives they identify with (e.g., imagining the future of your country or nation (21)). The present findings draw attention to an intriguing gap in knowledge: how, and in what ways, does collaborative imagination shape collective future thinking and give rise to shared beliefs across a social network about the future of a society? That is, what are the consequences of collaborative imagination on phenomena at the level of collective cognition?

While we await new research to address this important question, we can turn to existing work on how collaborative memory shapes collective memory and beliefs to provide a road map (for review see (26)). For example, evidence shows that remembering past shared experiences collaboratively with others can shape not only the content that is retained versus forgotten (e.g., socially shared retrieval-induced forgetting (27, 45)), but also the emotions associated with that memory (e.g., (46)), leading to greater similarity in individuals' memories following collaboration. As events are collaboratively recalled within a social network, it gives rise to communally-held representations and shared understandings of the past events (i.e., collective memories) that can be important for group identity and the formation of collective beliefs (26, 41, 47–50). Through similar mechanisms of mnemonic accessibility and social network convergence it seems plausible that collaborative imagination may give rise to collectively shared beliefs about the future of a society that may have important implications for group identity and a commitment to that society's future.

A potentially fruitful opportunity for future research is to explore how collaborative imagination and collaborative memory are similar and distinct in terms of both underlying mechanisms and consequences for beliefs, identity, and behavior. While forming collective memories requires a shared past, imagination may offer a unique advantage in that it requires no previously shared experiences to create a unified collective representation. Thus, although collaborative memory and collaborative imagination may both play a role in maintaining relationships, we suspect that collaborative imagination may be particularly influential during initial moments of bonding in new relationships, like the novel dyads studied in the present work.

Demonstrating that co-imagination can cultivate feelings of closeness in the first moments of social interaction between novel dyad partners opens the possibility that it may play an important role in maintaining existing close relationships as well. Co-imagining future events seems to be a part of everyday life with those we are closest to, including friends, family, and romantic partners. Indeed, we suspect it may be a fundamental aspect of forming and maintaining interpersonal relationships broadly. Although no research has examined co-imagination in interpersonal relationships, related work suggests that imagining future events involving a close other may facilitate access to relationship-relevant information (51) and foster other-oriented feelings of warmth and love (52, 53). While these findings illustrate a dynamic link between imagination and close relationships, no work to date has considered the effects of imagining a future event involving one's partner, *with* one's partner.

Another important function imagination may play in maintaining close relationships is by assisting in the pursuit of relationship–oriented goals. Enabling effective goal pursuit is a key function of imagining future events (e.g., (54); for review, see (55, 56)). How might *co-*

imagining a future event shape relationship-oriented goal pursuit? One possibility arises from considering research on interpersonal synchronization (i.e., the temporary coordination of behavior or biological activity across multiple individuals (57)). This work finds that interpersonal synchronization of both behavior and neural activity is associated with a variety of important social outcomes (58, 59), and supports cooperative action towards social goals (60, 61). Might co-imagination be particularly important in coordinating relationship-oriented goal pursuit, enabling partners to generate a synchronized vision in which shared goals are being pursued? While we suspect that co-imagination may fundamentally shape how we connect and coordinate with close others, longitudinal research will be needed to investigate how co-imagination contributes to long-term interpersonal relationships.

The human capacity for imagination and its value to our society has long been a subject of intrigue among artists and philosophers but has only more recently captured the attention of the cognitive science community. The present work has the power to change the way we view imagination by providing novel evidence that imagination itself is a socially creative process. Humans are mental time travelers capable of imagining what the future could be. But our future–the hopes, dreams, and obstacles it may bring–is not ours alone to imagine. Our future and its possibilities are something that we actively co-create with others; in doing so, we become closer and more connected to them in the present. The current findings suggest that collaboratively imagining a shared future together may be the first step toward creating it.

Materials and Methods

This research was approved by the Institutional Review Board at the University at Albany, State University of New York. We complied with all relevant ethical regulations, and informed consent was obtained from all participants prior to their participation in the study.

Study 1

Participants. Participants were undergraduate students at the University at Albany, State University of New York. The preregistered (https://aspredicted.org/BFR_BVA) sample size was informed by an a priori power analysis indicating that a total N=15 would be required to detect an effect size f=0.624, an effect size observed in pilot data collection. However, we took a conservative approach and collected usable data from N=120 participants, which would allow detection of an effect size f=0.1817 with 95% power using a between-within repeated measures ANOVA. Participants had a mean age of 19 years; 66.7% self-identified as female, 32.5% as male, and 0.8% as other; and 55.8% White/Caucasian, 15.8% Black/African American, 12.5% Hispanic/Latino/a/x, 3.3% Asian/Asian American, 0.8% Middle Eastern, and 11.8% multiracial. Participants were all native English speakers and were compensated with course credit for their time through SONA.

Procedure. Study 1 involved a three (condition: collaborative imagine (n=40), individual imagine (n=40), and collaborative perception (game) (n=40)) by two (pre- and post-task social connection measures) design. Participants were assigned to pairs, and first were introduced to their fellow participant. Participants first filled out a set of social connection items measuring how close and connected they felt to the other participant. Participants in the collaborative imagine condition completed the rest of the study in a room together, while participants in the individual imagine condition completed the study in separate rooms.

Next, participants in both the collaborative imagine and individual imagine conditions were read the same set of instructions describing the imagine task before answering comprehension checks to ensure that both participants understood the instructions (see Supplemental Note 1 for imagine task instructions). Following these questions, all participants

completed a minimum of two practice trials of the imagine task, providing research assistants an opportunity to give feedback to participants and assess their understanding of the procedure. If deemed necessary by the research assistants, participants completed up to two additional practice trials. Participants still having difficulty at this point were thanked and compensated for their time, dismissed, and excluded from analyses. After completing the practice trials, participants completed five trials of the imagine task.

The imagine task involved two phases: a brainstorm phase and an elaboration phase. In the brainstorm phase, participants were first presented with a cue word. The cue word was intended to help participants generate an event however use of the cue word was optional. Presentation of the cue words was randomized. During the brainstorm phase, participants were provided 60 seconds to decide upon a plausible and positive future event that involved both participants.

During the elaboration phase, participants spent three minutes describing the future event in as much detail as possible (including details such as where and when the event takes place, who is there, what each participant is wearing or doing, etc.). In the collaborative imagine condition, participants worked together on the imagine task, taking turns to describe the event in a manner akin to role-playing. In the individual imagine condition, participants completed the imagine task independently in separate rooms, describing the imagined events on their own. Following each elaboration phase, participants in both conditions individually answered questions about the imagined event (see “Post-Trial Measures” below).

After the imagine task, participants were led to separate rooms to complete the same set of social connection questions a second time. After the social connection measures, participants

completed a math task involving three-digit multiplication problems, which lasted approximately 15 minutes.

Finally, participants in both conditions worked independently on the recall task. For this task, the participants were shown the same cue words that were used for the imagine trials to act as a recall cue. Then participants were instructed to recall the event described in the imagine trial for the given cue word in as much detail as possible for three minutes. Following each trial, participants answered the same set of questions that followed the imagine trials, this time probing their experience of recalling rather than imagining. Following the recall task, participants completed demographic information. Finally, participants were debriefed about the purpose of the study, thanked for their time, and granted course credit on SONA.

In the collaborative perception (game) condition, participants were first introduced to each other, and then completed the social connection measures. Participants were then brought to a room where they were instructed to work on a puzzle game together. They were told that they could talk freely about whatever they wanted to as they worked on the game. Participants completed a brief set of comprehension checks to ensure that they understood the instructions, then worked on the game together for 30 minutes before completing the social connection measures. Participants then completed demographic information.

Measures.

Social Connection. Participants completed a set of social connection measures both before and after the imagine task or game. Participants indicated on a scale of 1 (*strongly disagree*) to 7 (*strongly agree*) to what extent they felt they had something in common with the other participant, were on the same wavelength as the other participant, and felt satisfied with their relationship with the other participant (62). Participants also indicated how much they liked,

valued, and felt connected with the other participant (63). These items were averaged to form a composite measure of social connection that had high reliability (Cronbach's alpha=0.82; please see Supplemental Table 1). Participants also completed a measure of self-other overlap that involved selecting from a set of images showing two circles, one to represent each dyad partner, with varied degrees of overlap (64). An additional item asked participants to indicate where they would place the other participant on a list of the 100 people closest to them, with 1 being their close friend and 100 being an acquaintance (65). Please see Supplemental Tables 2-3 for analyses of these two items.

***Post-Trial Measures*.** Following each imagine trial and each recall trial, participants completed questions about their subjective experience of the imagined event. Please see Supplemental Tables 7-9 for additional analyses regarding these items.

Mentalizing. Participants were asked how much they considered the thoughts and feelings of the other participant while they imagined or recalled the event (1=*not at all* to 7=*strongly considered*) (14).

Scene coherence. Participants indicated how coherent and clear the imagined or recalled scene was in their minds (1=*vague* to 7=*highly coherent and clear*) (14).

Picture vividness. Participants were presented with seven images increasing in transparency and were asked to select the photo that most closely indicated how vividly they imagined or recalled the scene in their mind (13) (see Supplemental Figure 2). The least vivid image was coded as 1 and the most vivid image was coded as 7.

Difficulty. Participants were asked how difficult the task was for them (1=*extremely easy* to 7=*extremely difficult*).

Supplemental measures. Participants also completed items asking how probable it was that they would experience this event in the future (1=*extremely unlikely* to 7=*extremely likely*), and how detailed the imagined scene was in their mind at recall (1=*simple* to 7=*highly detailed*) (14). Participants also completed a measure asking what they pictured in their mind while answering previous questions (1=*nothing or vague*, 2=*objects only*, and 3=*objects and surrounding background, whole scene*) (66). Please see Supplemental Tables 7-9 for analyses of these items.

***Computational Text Similarity*.** Participants' transcriptions were compared event-wise with their dyad partner. Latent Semantic Analysis (LSA) was conducted using the UC-Boulder website (http://wordvec.colorado.edu/pairwise_comparison.html) with the "General Reading up to 1st year college (300 factors)" corpus. Bidirectional Encoder Representations from Transformers (BERT) was conducted using the Sentence-BERT Python package (67) with the "multi-qa-distilbert-cos-v1" model, which has 768 dimensions (https://huggingface.co/sentence-transformers/multi-qa-distilbert-cos-v1). Critically, this model produces normalized embeddings with length 1. One event had to be excluded due to a recording error.

Study 2

Participants. Participants were US residents recruited through the online research platform Prolific. Participants were excluded from analyses if they met any of the following criteria: technical problems occurred during the video call; they were not native English speakers; they failed more than two attention checks; they did not comprehend the experimental task after four practice trials; they were 30 years of age or older. The age limit for participants was intended to eliminate the possibility of age-related changes in episodic ability (68), and to better match the sample from Study 1. This age limit was not reflected in the initial

preregistration (https://aspredicted.org/YNH_NXP), however an updated preregistration (https://aspredicted.org/BM6_NJS) was created shortly after data collection began and prior to any data analysis. Additionally, due to concerns regarding the study length, the updated preregistration specified that pre-task social connection items would not be measured in Study 2.

The preregistered sample size was informed by an a priori power analysis indicating that n=25/group would be required to detect an effect size d=1.11, an effect size observed in Study 1, at 95% power in an independent measures t-test at a Bonferroni corrected alpha level of 0.017. However, we took a conservative approach and set the target sample size to 40 participants/condition for a total N=120 usable cases. Sensitivity analysis indicates that n=40/group will provide 95% power to detect an effect size of d=0.854 in an independent-measures t-test at a Bonferroni corrected alpha level of 0.017.

An additional preregistration (https://aspredicted.org/HYH_1Q7) was created to specify the hypotheses and analysis plan regarding the use of natural language processing algorithms to examine narrative similarity across conditions.

Participants had a mean age of 24 years; 62.9% of participants self-identified as female, 33.1% as male, and 4.0% as other; participants were 61.3% White/Caucasian, 11.3% Black/African American, 8.9% Asian/Asian American, 5.6% Hispanic/Latino/a/x, 0.8% Middle Eastern, 0.8% Native American, and 11.3% multiracial. Participants were compensated for their time at a rate of $15/hour. The study duration was between 90 and 120 minutes.

Procedure. Participants first completed a survey assessing interest and availability to participate in the full study. Interested and available participants were scheduled for two-hour slots and provided a Zoom link prior to the scheduled study time. Due to high rates of non-attendance, study slots were overbooked. The first two individuals to arrive would participate in

the timeslot, while additional participants would be compensated for the inconvenience ($5) and given an opportunity to sign up to participate in the future.

Study 2 used a three-condition (collaborative imagine (*n*=42), individual imagine (*n*=40), collaborative perception (scene) (*n*=42)), between participants study design. Participants were randomly assigned to conditions. Upon arrival of two participants in the Zoom meeting, participants were instructed to keep their video cameras on for the duration of the study and provided informed consent for portions of the study to be recorded. Participants were then given an opportunity to introduce themselves, with the choice to choose a nickname if preferred.

Following introductions, participants in the individual imagine condition were moved to separate break-out rooms in Zoom, where they completed the rest of the study with only the research assistant present. Participants in the collaborative imagine and collaborative perception (scene) conditions remained on the Zoom call together until completing the experimental task.

The collaborative imagine and individual imagine conditions both completed the same imagine task as described in Study 1 but adapted to take place over a video call rather than in-person (please see Supplemental Note 1 for instructions). The cue words for the imagine task also now included an accompanying photograph, to match the stimuli for the collaborative perception (scene) condition (please see Supplemental Figure 1).

The collaborative perception (scene) task was drawn from previous research that utilized the task as a control condition to isolate the effects of episodic simulation from those of scene processing and representation (68). Stimuli for the task were modified to include the same cue words and photos used in the imagine conditions. Participants were instructed to work together to describe the people, objects, and environment in the picture as they are literally presented, and

to describe the picture as if they are talking to someone who can't see it. Participants were given three minutes to describe the scene.

All participants completed four comprehension checks after receiving task instructions and completed between two and four practice trials of the imagine or collaborative perception (scene) task to ensure understanding. Cue words and photos were displayed in a separate survey that a research assistant shared on their screen. Two versions of the cue survey were created with different randomly chosen orders of cue word presentation. Cue survey versions were randomly assigned. Participants completed ratings of the subjective phenomenology of the imagined events or scenes on each trial in their individual surveys.

Following completion of the experimental task, participants in the collaborative imagine and collaborative perception (scene) conditions were brought to separate break-out rooms and completed the remainder of the study with only the research assistant. Participants completed the eight social connection items. Participants then spent about 15 minutes completing a filler math task involving multiplication.

Participants in all conditions then completed a recall phase, in which they were shown only the cue word (without the accompanying photo) and asked to describe as much as they could recall about either the event they had previously imagined or the picture they had previously described. Participants were given up to three minutes to recall as much as possible. If participants could not recall any additional information after one minute, they proceeded to the next trial. Participants completed ratings of the subjective phenomenology of the recalled events on each trial. Presentation of the recall cue words matched the order of the imagine cue words.

Following the recall phase, participants completed four items measuring their perception of the experimental task, and 10 items measuring their sense of rapport with the other participant.

Following completion of the survey, participants were debriefed on the purpose of the study and given the opportunity to provide feedback. Participants were then thanked for their time and sent compensation through Prolific.

Measures.

Social Connection Items. Social connection was measured using the same eight items as in Study 1. Please see Supplemental Tables 10-13 for analyses of the items excluded from the composite measure.

Post-trial measures. The subjective phenomenology of event representations was measured using the same variables as in Study 1: mentalizing; scene coherence; picture vividness; difficulty; with supplemental measures including: probability; detail; and ratings of scene-object integration. Please see Supplemental Tables 16-18 for analyses of these items. Additionally, the distribution of responses to the mentalizing measure during the imagine phase was skewed, and analyses of the transformed variable are available in Supplemental Tables 19-20.

Global task evaluations. Overall perceptions of the experimental task were measured by asking participants to rate how enjoyable, pleasant, fun, and difficult the task was for them (e.g., *1*=extremely unenjoyable, *7*=extremely enjoyable). Positive task evaluation items were averaged into a composite measure that showed high reliability (see Supplemental Table 21). Please see Supplemental Tables 22-25 for additional analyses of these items.

Supplemental rapport items. Participants' sense of rapport with their experimental partner was measured by asking participants to rate the degree to which each of a list of words described their interaction with the other participant (*1*=not at all, *9*=extremely) (35, 69). Interaction descriptions included: comfortable; friendly; harmonious; positive; satisfying;

awkward; boring; cold; dull; slow. Positive and negative items were formed into separate composite measures that showed high reliability (see Supplemental Table 26). Please see Supplemental Tables 27-29 for analyses of rapport measures.

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Additional Information.

Supplementary information (including survey questions) and quantitative data for both studies are available on OSF (https://osf.io/j8uhc/). A preprint of this work has been made available on PsyArXiv (doi: 10.31234/osf.io/3gyw8) under the CC-By Attribution 4.0 International license.

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Figures

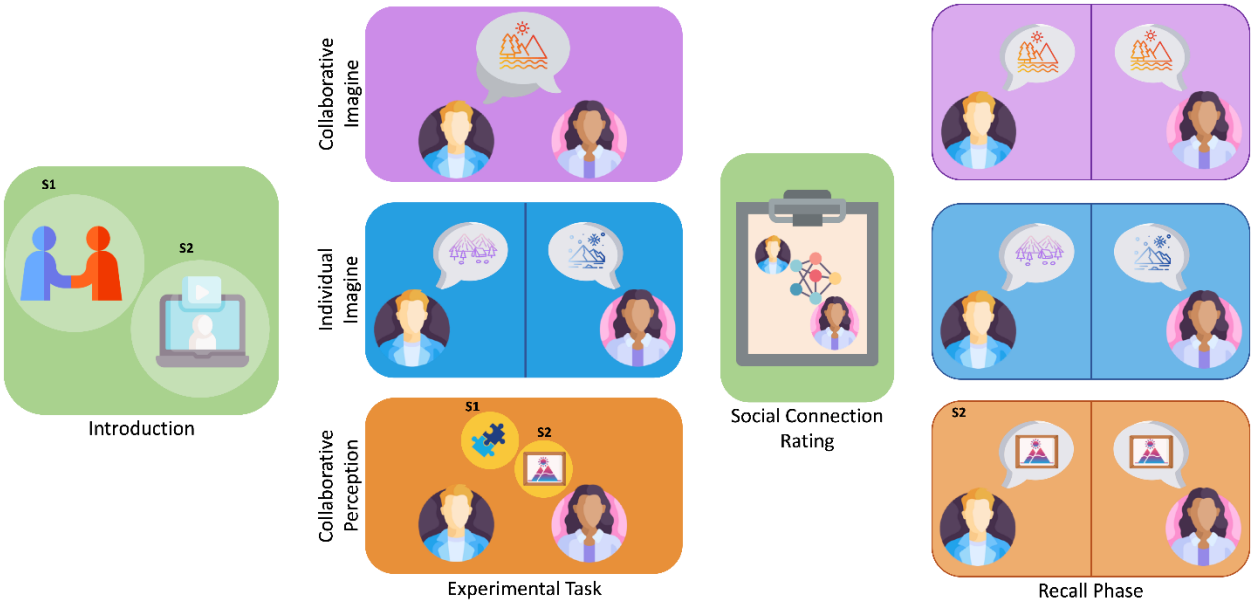

Figure 1. Experimental design and logic for Study 1 and Study 2. Two studies were conducted to test the hypothesis that co-imagining a shared future event may heighten feelings of social connection above imagining a shared future independently or collaborating on a non-imaginative task and sharing a novel experience in general. Across conditions, participants were first introduced to their dyad partner (in person for Study 1, over video call for Study 2). Participants then completed the experimental task. In the collaborative imagine condition, participants worked together to complete the imagine task: imagining shared future events in as much detail as possible. In the individual imagine condition, participants completed the imagine task independently, allowing us to control for the effect of imagining a shared future in the absence of social interaction. In the collaborative perception conditions (S1: game, S2: scene), participants either collaborated on a game with another participant or collaboratively discussed an image depicting an event with people and objects in a specific location, allowing us to control for the effect of engaging in general present-focused social collaboration. Further, the collaborative perception (scene) condition involved describing details presented in an image (e.g., people, actions, spatial surroundings), enabling us to consider what effect may arise from engaging in a component process necessary for but not unique to imagination (e.g., representing and processing non-autobiographical scene content). All participants then completed a set of items measuring feelings of social connection and closeness with the dyad partner. All participants (excluding S1's game condition) then completed a recall phase, in which they recounted the imagined event or scene they had described prior in order to isolate stored representations of these experiences for each participant.

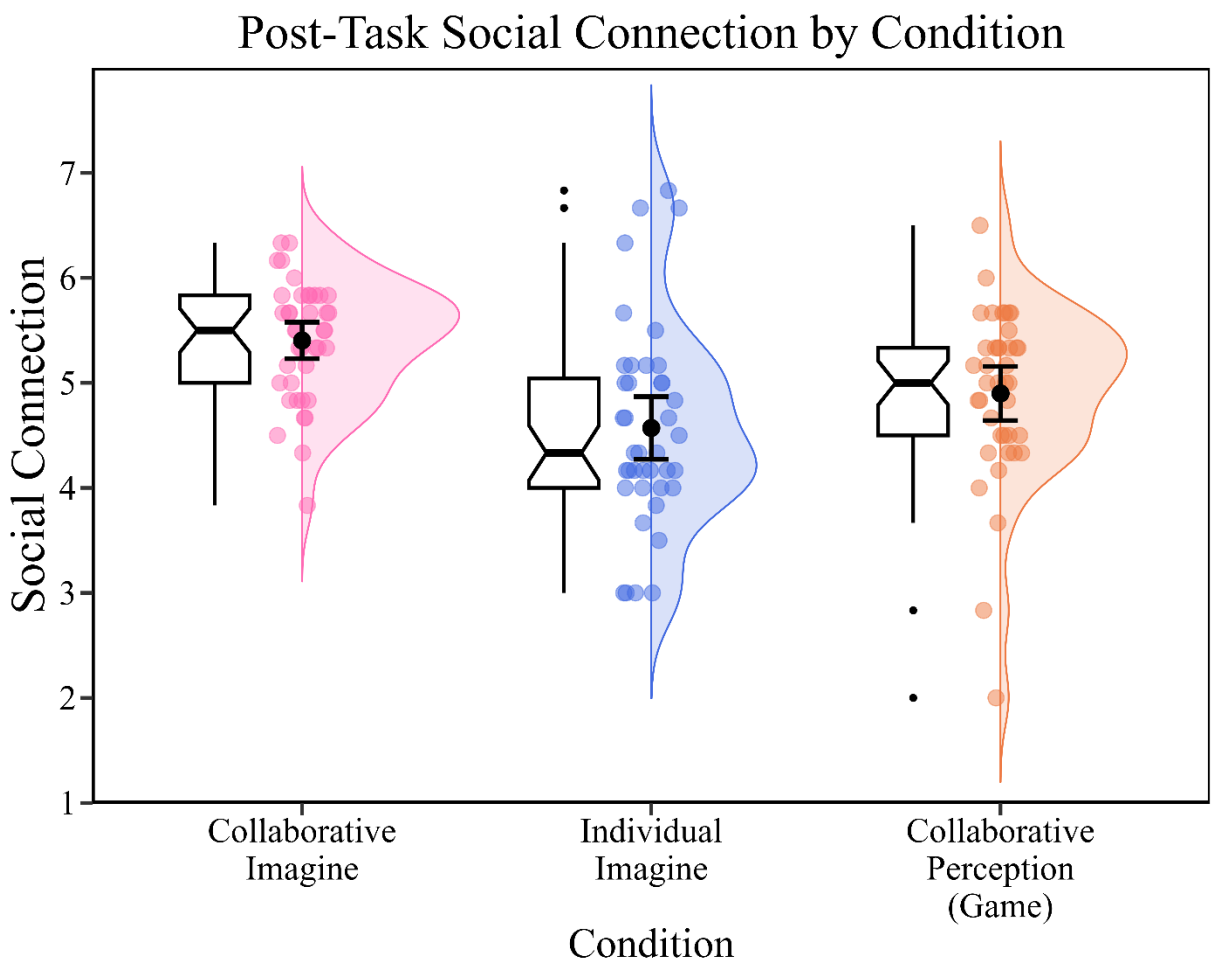

Figure 2. The effect of collaborative imagination on social connection. Plot depicting participant responses to social connection items measured post-task (Study 1) across conditions. Ratings were made on a scale from 1 to 7 and averaged to form a composite measure. Colored dots correspond to individual data points and are jittered for readability, with split violin plots overlaid to show the relative distribution of scores across conditions. Error bars depict 95% confidence intervals around the mean. Notched boxplots are included, with notches depicting a confidence interval around the median with a value of +/- 1.58*IQR/sqrt(n). Overlapping notches suggest that median values across groups are not significantly different. Please see Supplemental Tables 5-6 for analyses of social connection ratings excluding outliers.

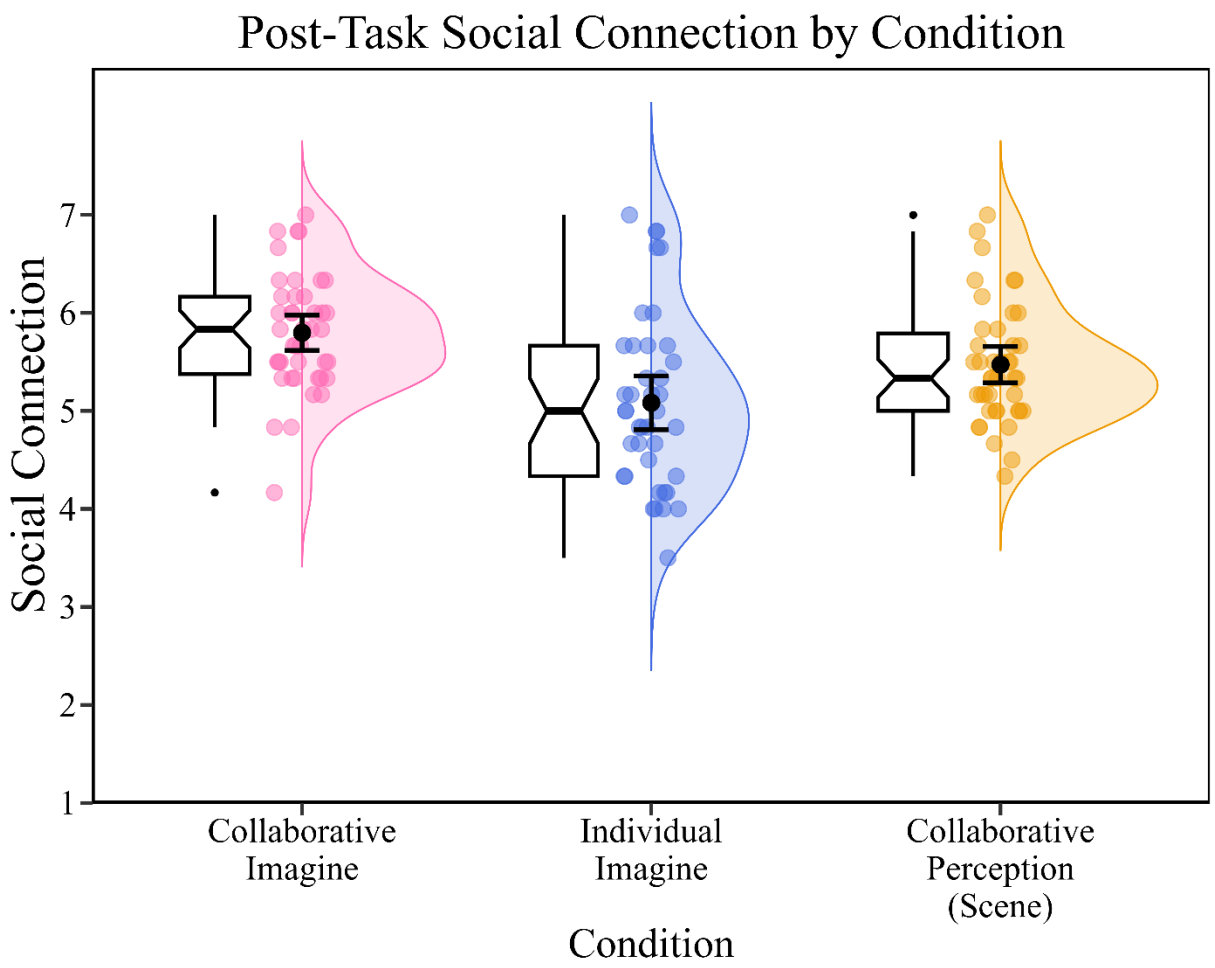

Figure 3. The effect of collaborative imagination on social connection replicates. Plot depicting participant responses to social connection items measured post-task (Study 2) across conditions. Ratings were made on a scale from 1 to 7 and averaged to form a composite measure. Colored dots correspond to individual data points and are jittered for readability, with violin plots overlaid to show the relative distribution of scores across conditions. Error bars depict 95% confidence intervals around the mean. Notched boxplots are included, with notches depicting a confidence interval around the median with a value of +/- 1.58*IQR/sqrt(n). Overlapping notches suggest that median values across groups are not significantly different. Please see Supplemental Tables 13-14 for analyses of social connection ratings excluding outliers.

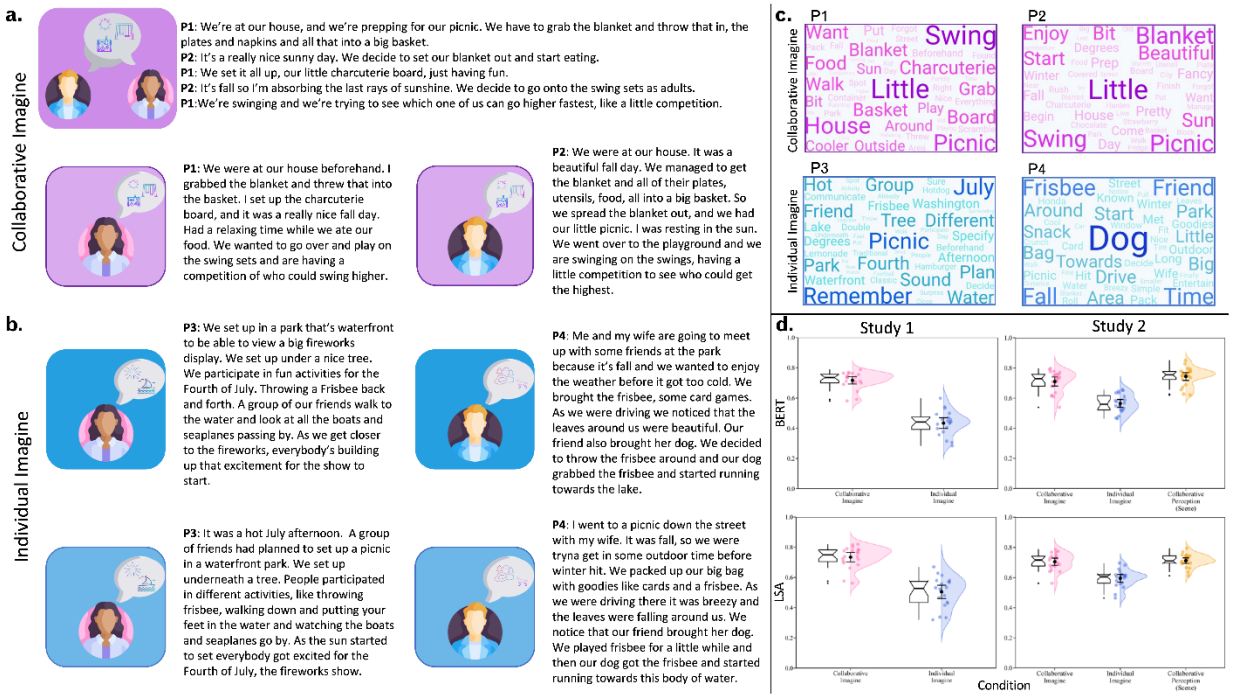

Figure 4. Narrative similarity in stored representations of individually or collaboratively imagined events. **(a, b)** Excerpts of participants' event narration during both the imagine phase (darker boxes) and recall phase (lighter boxes). Figure **(a)** shows excerpts from the collaborative imagine condition, while **(b)** shows excerpts from the individual imagine condition. **(c)** Word clouds depicting the 50 most frequent content words within narratives of participants' individual stored representations of the imagined event (collected during the recall phase). Word color and size both correspond to word frequency. **(d)** Natural language processing of recalled imagined events was conducted using Bidirectional Encoder Representations from Transformers (BERT) (38) and latent semantic analysis (LSA) (36). Converging results across Studies 1 and 2 suggest that co-imagination synchronizes the content of imagined future events to create shared narrative representations that are stored across partners in novel dyads.