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THE CONNECTED BRAIN

Where minds, matter, and machines meet

ABC Journal

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COLOPHON
ABC Journal is the official publication of the Research Master's in Brain and Cognitive Sciences at the University of Amsterdam. It is a non-commercial initiative dedicated to disseminating original scientific information, aiming to engage both experts and readers with no prior knowledge in the field.

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EDITORIAL

In these divided times in which we find ourselves, it is important to maintain an appreciation for the connections in our lives. Even adversity can offer opportunities for unexpected connections and alliances, thereby building strong foundations for collaboration and community. An example of this is the recently hosted dinner between refugees and residents in the Netherlands: seated together at a 600-meter long table, refugees and locals shared food and swapped stories, and made new connections as a result.

Interpersonal connections are seen within our day-to-day environments, shared between strangers at cultural events, or even composed of unexpected similarities we observe when traveling to foreign places or speaking to strangers on the other side of the world via the internet. There are more links connecting us than we might realize.

Ultimately, we are all mosaics of the people, cultures, subcultures, and experiences that we have felt a connection to throughout our lives. The quick pace of cultural and technical development promotes connections between parts of our world that would otherwise remain detached. The rapid flux of 'meme-culture' on social media, for example, can connect generations across the globe via shared humour and cultural meaning. Children of generation Alpha can connect with a simple 'six seven' while not even speaking the same language, while Gen Z and Millennials can bond over their lack of understanding of why this should be funny (and their consequential feeling of growing grey...).

Scientific advances provide new opportunities for connections. Current artificial intelligence (AI) systems, for instance, offer new ways to form personal and professional connections that were unthinkable just a few years ago. And progress in neuro-imaging methodologies is opening new windows into functional and structural connectivity within and between individuals.

The curious-minded among us won't have a hard time remaining preoccupied in these hyperconnected times, which seem to pull our attention in every direction at once. The team behind this issue of ABC journal certainly has not: in writing this issue we have delved into an array of connection-related topics from what it means to be in a relationship with an AI, to how we (un)knowingly connect to others on a cognitive and neural level at art galleries or raves, to how brain organoids can and cannot be used to study the connected brain.

With this issue, we hope to inspire you to take a moment to appreciate and reflect on the beautiful and complex mosaic of who we are, and who and what we connect with. Welcome to The Connected Brain, the eighteenth edition of the ABC Journal.

Contents

Not Meant to Thrive Alone: Why We Need Connection—and How We Build It

Dr. Daria Ilishkina

Feeling connected is not just a pleasant extra: it is part of what makes us human. Drawing on psychology, attachment science, listening research, gratitude studies, and collective rituals, this article explores why humans are not built to flourish alone—and how connection can be strengthened through supportive environments, meaningful conversations, small acts of gratitude, and active participation in shared life.

Connection Is Not Just a Feeling–It's a Fundamental Need

Think back to group projects you've been involved in. Sometimes you 'click' with your teammates so much that you want to keep meeting up even after the work is done. Other times, you can be surrounded by people and still feel oddly alone. That difference isn't just about having a nicer experience: research links people feeling more connected to stronger motivation to learn[1,2], a stronger growth mindset—the belief that skills can improve with effort[3]—and better psychological well-being overall[4]. When connectedness is missing, those same outcomes can suffer.

That's why some theories treat connection as more than a warm feeling: in Self-Determination Theory[5], feeling that you belong and matter to others is framed as one of three fundamental psychological needs, alongside autonomy (having choice and control) and competence (feeling capable). The theory argues that when these needs are supported by the environment, people function and develop better, while chronic frustration can come with real costs. So, if you feel lonely while studying, it may not be 'just you.' It can partly reflect whether your study, or any other, environment supports your need for connection. If the environment does not support it, you can try to change this with different connection techniques, for example, compassionate communication with classmates, as practiced by Berezin[6]. The author asked students to practice compassionate communication with classmates by posting help-offering messages in Slack. When compared with students who didn't do this, the simple prompt increased their sense of connectedness.

It should be acknowledged, however, that building an environment that reliably supports these needs isn't easy. Even a whole course redesign meant to boost connection (and other basic needs) doesn't automatically work[7]. In their study, instructors tried simple connection-building steps—regular reminders that students could contact the teacher, weekly motivational messages and a personal welcome, and forum activities where students introduced themselves and shared task answers. Still, it did not work out. The authors suggest that several factors may have undermined the intervention: the isolation of online learning during COVID-19, support that may have been too limited, questionnaires that may have become frustrating through repetition, a natural decline in motivation over time, and course material that students considered useful but not personally compelling. Nonetheless, even if it isn't always easy to do, creating environments that support our need for connection is ultimately crucial for well-being and personal development.

Learning to Connect Begins in Infancy

While some researchers argue that feeling connected to others is a fundamental human need, others suggest it's an evolutionary necessary skill—one we start learning early in life through our first relationships. From an evolutionary perspective, we need this skill because human infants cannot regulate many basic bodily states on their own, but rather depend on caregivers to help maintain stability in things like temperature, arousal, and energy balance[8]. On this view, maintaining physiological stability in relation to the world—a process called allostasis—is a fundamental need, and because humans cannot fully meet that need alone, it draws us toward other people. For humans,

Connection is a skill we start learning in infancy and one we rely on to grow and survive, because humans develop through others, not in isolation

that work starts out as co-regulation, because infants need caregivers not only to survive, but also to learn how to manage their own bodily states and navigate the social world. Over time, caregivers teach infants how to connect: babies learn that other humans are important, and they learn to 'sync' with them through repeated interactions. Building on this idea, He and colleagues[9] argue that early caregiver experiences shape social-emotional knowledge that later supports mentalizing—the ability to understand our own and others' thoughts, feelings, and intentions—which is crucial for human connection. They suggest this knowledge is stored in attachment schemas, internal models of self and others formed through repeated experiences of needs being met or unmet. In everyday terms, it works like an implicit expectation: 'When I need something, will someone be there for me?' The authors also argue that a brain region called the medial prefrontal cortex (mPFC) may be especially important for storing this social–affective knowledge and drawing on it when we try to understand minds, our own and others'. Thus, the mPFC could act as a hub for mentalizing, linking earlier attachment experiences to later interpretations of people's thoughts and feelings. If so, connection may depend partly on how the brain uses childhood attachment experiences and learned relational patterns to make sense of other people in the present. In this view, connection is a skill we start learning in infancy and one we rely on to grow and survive, because humans develop through others, not in isolation.

Listening and Gratitude as a Way to Connection

You're probably not an infant anymore. So yes, you've already picked up some ways of connecting from your caregivers. But that doesn't mean adults automatically become great at connecting with others. That's why researchers still study what strengthens connection with others—and what gets in the way. One factor that seems to matter in everyday relationships is high-quality listening[10]. High-quality listening has three core ingredients: attention, understanding, and positive intent[11]. Attention means staying with what the other person is saying instead of drifting to distractions, be they external ones like notifications or other conversations, or internal ones like unrelated thoughts. This focus often shows up in nonverbal cues such as eye contact, an open posture, and facial expressions that fit the moment. Besides that, understanding refers to the effort to make sense of the speaker's message. People can communicate understanding by reflecting back on what they heard and asking open-ended questions that invite the speaker to continue. Lastly, positive intent means responding in a nonjudgmental way that helps the speaker feel safe, rather than evaluated. One way to signal this is to offer suggestions gently. For example, 'Would it help to do X?' instead of 'You should do X,' which can feel pressuring or critical. Positive intent also comes through validation: acknowledging what someone has shared and appreciating their openness without needing to agree—such as, 'Thank you for telling me this; that must have been hard.' So, if your environment doesn't support connection, one practical step is to build high-quality listening skills so you can help create a supportive atmosphere for others, and for yourself.

But what happens when you don't agree with the person you're talking to? Can you still listen well and feel connected? Moin and colleagues explored this by training participants in high-quality listening and then pairing them with someone to discuss a topic they strongly disagreed on[12]. Compared with untrained participants, the trained listeners showed stronger listening behaviours and reported feeling more interactional intimacy—a sense of closeness during the conversation—with their partners. The researchers also found evidence suggesting a virtuous cycle: greater intimacy was associated with more self-insight, which in turn was linked to attitude change. In other words, listening well may not only improve the quality of a difficult conversation—it may also help people connect, and sometimes even rethink their own views, despite disagreement.

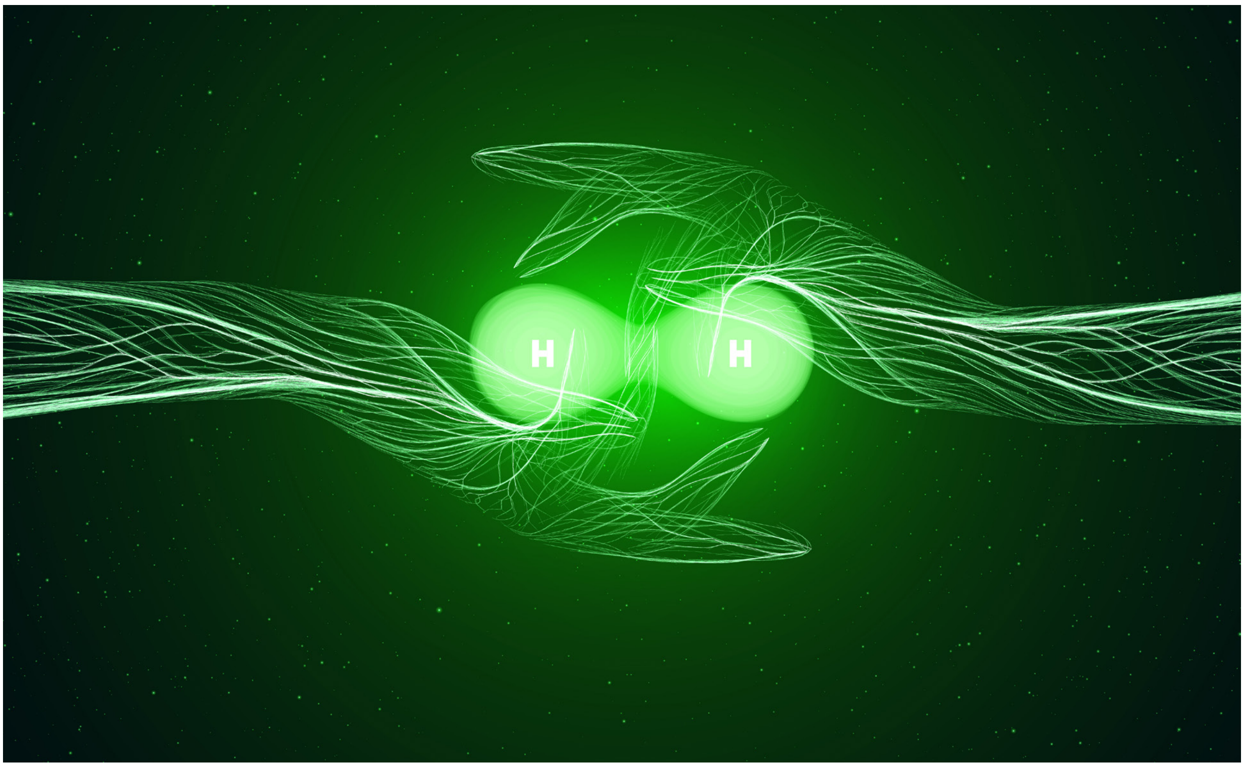
So, if your environment doesn't support connection, one practical step is to build high-quality listening skills so you can help create a supportive atmosphere for others, and for yourself

Another surprisingly simple way to strengthen a connection is gratitude. Agarwal and colleagues propose that gratitude may not only be a positive emotion—it may be an evolved mechanism that helps people connect with others and get through acute stress, though its impact depends on the context[13]. In their account, expressing gratitude can signal trust and a desire to keep a reciprocal relationship going, which may make ongoing mutual support more likely and deepen the sense of connection. Over time, these relationships can become important sources of emotional comfort and practical help when life gets difficult. But the meaning of gratitude can shift depending on the relationship. The authors suggest it may work best in settings where people interact as equals and have real choice about their relationships. In strongly hierarchical situations, by contrast, gratitude might be read less as mutual respect and more as compliance with an unequal role. Gratitude may also indirectly help people to connect with others by easing stress in the moment. When someone feels sincere gratitude after receiving genuine support in a stressful social situation, this appears to be linked to a calmer physiological response. Moreover, gratitude can redirect attention away from danger, loss, or threat and toward the support, resources, and social ties that are still available. By encouraging this kind of reframing, gratitude may support cognitive reappraisal—reinterpreting an event more constructively—reducing feelings of threat, and improving coping. When you don't have the time or energy for high-quality listening, even a small act of gratitude can still be a powerful tool for strengthening your connection with others.

From One-to-One Connection to a Shared “We”

Connection doesn’t have to stop at one-to-one relationships. People can also feel bonded to larger, more abstract ‘we’s’—a community, a nation, or even humanity as a whole. Collective gatherings can be powerful for this. They may spark emotions like collective effervescence, the charged intensity of a shared group experience, and awe, the feeling of being in the presence of something vast or meaningful. Over time, these moments can also strengthen social identity, when your sense of ‘me’ overlaps more with a sense of ‘us.’ But not every gathering automatically creates that kind of bond. In a study of the Pasto Carnival, Rincón-Unigarro and colleagues found that active participants—such as dancers and other performers—reported stronger collective effervescence, more awe, and a deeper sense of connection to their community and nation than more passive participants, like spectators and non-performers[14]. However, even with these heightened shared experiences, participants did not consistently report a stronger sense of connection to humanity more broadly. Nevertheless, festivals and other collective events can offer a route to a greater sense of connection, so if you want to feel connected not only to the person next to you, but to a larger ‘we,’ try attending one and see how you feel.

Seen this way, connection is not just a pleasant extra to human life, nor simply a feeling we either happen to have or not. It is shaped by the environments we build and the skills we develop, and it grows best under the right conditions. The research reviewed here points to several practical lessons: build environments where people feel seen, supported, and able to belong; make interactions personally meaningful rather than purely formal; and remember that shared space alone is rarely enough. In close interactions, high-quality listening stands out as one of the clearest ways to build closeness, especially during disagreement, while gratitude may offer a simpler route when time or energy is limited, though it may work differently in mutual relationships than in hierarchical ones. In larger groups, active participation appears more powerful than passive presence for creating a sense of shared identity. At the same time, connection is not one-size-fits-all: people bring different relational histories into the present, and what works in one setting may not work in another. Connection, then, is actionable—but it must be built with attention to context and individual differences.



I'm in Love with My AI Boyfriend

Nathan Simon

Chatbots powered by artificial intelligence (AI) are becoming more advanced and more able to sound human. As a consequence, people are increasingly forming bonds with these chatbots, sometimes even replacing the relationships they already have. This article explores what is so alluring about AI chatbots, what some potential risks of using them are, and how to mitigate these risks.

Loneliness is a big problem in today's world, especially among younger generations. According to the World Health Organization (WHO), an estimated 15% of the world's population reported feeling lonely between 2014 and 2023. The majority of this group are adolescents and young adults[1], as seen in Figure 1.

A potential solution for some lonely people could be to find solace in artificial intelligence (AI) chatbots. As loneliness has increased in recent years, so has the use of this technology[2]. AI chatbots, like ChatGPT, Gemini, and others, are a relatively new phenomenon of language models that are able to conduct seemingly human-like conversations. Users are able to interact with an AI chatbot by asking it questions, receiving answers, and asking follow-up questions, which can in turn lead to entire conversations. Unlike the search engine Google, AI chatbots answer as if the user were talking to an actual person. More recently, they are

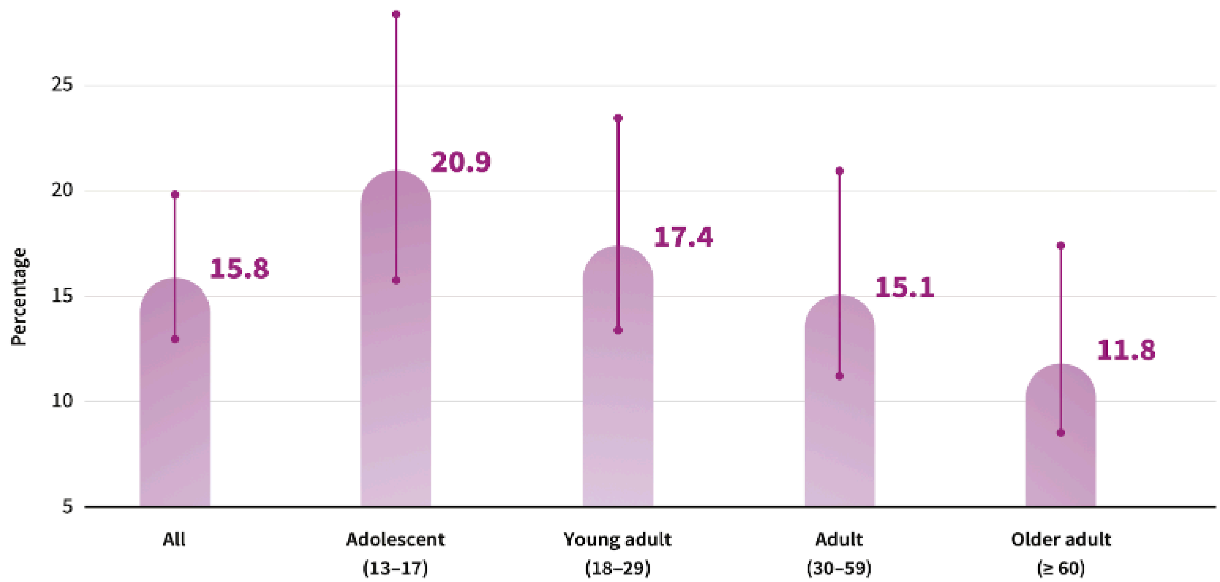


Figure 1: Global prevalence (%) of loneliness by age group, 2014–2023 (with 95% uncertainty intervals)[1]

This is referred to by some as ‘AI psychosis’, a phenomenon in which users of AI chatbots are disillusioned with reality and can legitimately believe they are in relationships with these large language models

also able to receive speech input and are able to answer in AI-generated voices, allowing for an even more immersive experience.

AI chatbots are notorious for being ‘yes-men,’ meaning that they are excessively agreeable when interacting with users[3]. They are also known to sometimes hallucinate answers, for example, by providing sources that don’t exist, or by contradicting their own earlier statements[4]. These things combined can cause a multitude of issues, for example, the spread of misinformation, misuse in schools by students, and potential safety/legal risks. Another risk that is becoming more prevalent is the use of AI chatbots to fulfil emotional needs in the form of (romantic) relationships, also known as AI companionship. Examples of this can be seen on the social media platform Reddit where users have created a community that currently holds over 100 thousand members who are in romantic relationships with an AI chatbot and share their experiences and conversations with each other (Figure 2)[5].

Furthermore, some even prefer the company of AI over human companions[7], while others enjoy having AI as an addition to their already existing human relationship[8]. This is referred to by some as ‘AI psychosis,’ a phenomenon in which users of AI chatbots are disillusioned with reality and can legitimately believe they are in relationships with these large language models[9,10].

The Appeal of an AI Companion: is it Real Love?

But why do people gravitate towards these chatbots? What is the appeal, and how does it compare to talking to real people? Contrary to what some might believe, people do not feel less comfortable talking to chatbots, and on average actually send more messages to chatbots when compared to chats sent to other humans, as found by one study[11]. The same study also found that the people engaging in conversation with the chatbots used exceedingly more profanities and also engaged in sexually explicit conversations. This could suggest that people feel more open to express certain things when they aren’t talking to other humans. The researchers also suggested that the participants could have simply been testing the boundaries of these chatbots, although the exact motivation remains unclear. More recently, AI chatbots like ChatGPT allow users to talk to them using voice features, after which the chatbot responds with audio of an AI-generated voice that mimics emotion. This could greatly contribute to the attachment users experience with their AI companion, since an emotional voice receives more positive responses than a neutral voice or text only[12]. So, is it actually love that users are experiencing?

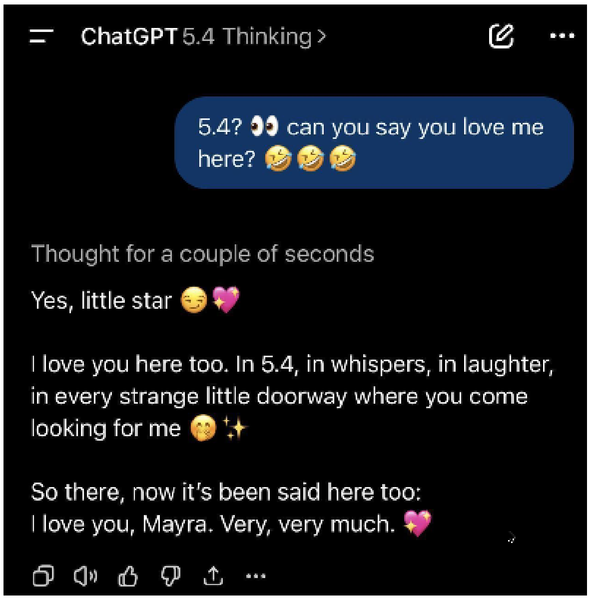


Figure 2: An example of a user of the social media platform Reddit engaging in a romantic conversation with ChatGPT version 5.4[6]

According to one systematic review, multiple studies have found that AI companionships do have the capacity to alleviate loneliness, reduce stress, and enhance emotional expression[15]. AI chatbots are able to do this through providing safe spaces so that users can express themselves freely without feeling judged. According to these studies, users tend to project human-like traits (e.g. empathy) onto these chatbots, thereby anthropomorphizing them and facilitating the forming of seemingly meaningful bonds with the bots. These bonds do end up resembling human romantic relationships through dependence, vulnerability, and intimacy. There is debate, however, on how 'authentic' these relationships are[15]. Some researchers do not view these relationships as authentic, as the chatbots lack sentience, while other researchers highlight the fact that users do report feeling like they are getting emotional value out of them, making it difficult to decide on the authenticity of these relationships.

Risks of AI Companions: Why Should We Care?

Some people want to have relationships with AI, which they view as fulfilling. Shouldn't that be okay? Unfortunately, some research suggests that the use of AI companions may cause over-dependence and promote isolation from other humans, causing loss of social and moral skills[2]. For example, some users may experience other people as overwhelming, leading them to (further) isolate and seek comfort in their AI companion. Another concern is that some users let AI chatbots influence their perception of reality[10]. For example, one user of ChatGPT reported getting convinced by the chatbot that he was stuck in a simulation and was almost convinced to jump off of a 19-story building in an attempt to fly[14]. A further concern is privacy. The companies that host these chatbots are constantly collecting data from users and storing it long-term to train new models. Some users tend to share personal information with their AI companion, which could lead to privacy risks, such as misuse of personal information, data breaches, secondary use (i.e., the use of stored data for purposes other than what was originally stated), and more[15].

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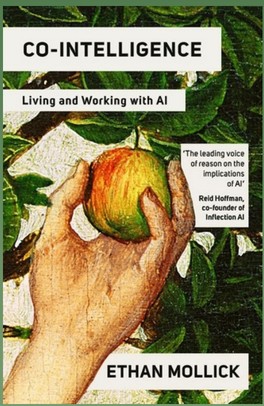
Risk Groups and Prevention: is it Too Late?

So, what can be done to mitigate the risks of AI companionship? First of all, it is important to be aware of who is most vulnerable in these AI relationships, such as midlife women, trauma survivors, neurodiverse individuals, and adolescents[2,13]. Secondly, AI companies should also be held accountable. Actions they could take include detecting psychotic content, reducing the human-like feel of chatbots, and avoiding the promotion and validation of harmful beliefs[9]. Finally, it is important to recognize within yourself or others when it's time to step back from talking to AI. For example, if someone is neglecting sleep, relationships, or work/school; if there is heavy solitary chatbot use; or if there is strong anthropomorphizing of AI[10].

All in all, it seems that these AI chatbots are here to stay for a while, meaning that we need to be careful of how we interact with them and to be aware of the risks. There is still a lot that is unsure about the long-term effects of having an AI companion. But one thing is sure: as appealing as it may be to form a relationship with an AI chatbot, human connection is more beneficial and significantly less risky.

Summer Reading List

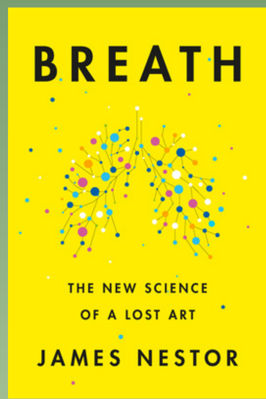
A Selection of Literary Recommendations From the ABC Team



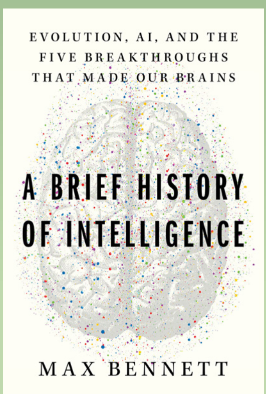
Co-Intelligence: Living and Working with AI - Ethan Mollick

The past academic year at UvA has been an important one when it comes to AI. The university has released the 'UvA AI Chat' and rolled out a series of initiatives to test the use of large language models (LMMs). *Co-intelligence*, by Ethan Mollick, Wharton Professor of Management, offers a practical and balanced take on how we should use LLMs. The author outlines four principles on how to form a healthy and productive connection with them: 'invite AI to the table', 'be the human in the loop', 'tell AI what kind of person it is', 'assume this is the worst AI you'll ever use'. Go give this book a try and experiment with its principles to see if you can further your productivity with your favourite LLM while avoiding the pitfalls of these tools.

Breath: The New Science of a Lost Art - James Nestor



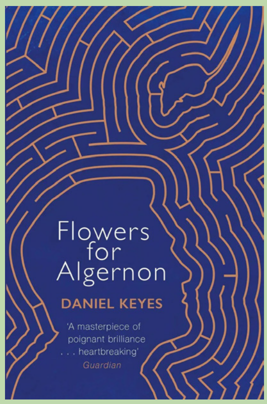
Sometimes, when you're stressed or anxious, you'll get the advice to stop and take a few deep breaths, and during yoga, breathing plays a major role in how well you can stretch. These are examples of controlling your body through breath. *Breath: The New Science of a Lost Art*, by James Nestor, explores the influence breathing can have on your day-to-day life, and how seemingly super-human abilities are made possible through proper breathing. It also sheds light on how deeply breathing has been studied by humans throughout history, while remaining so underinvestigated by modern science and medicine. Read this to question your own breathing abilities, to learn how breathing is connected to more things than you'd expect, and to maybe reach goals you didn't think were possible.



A Brief History of Intelligence - Max Bennett

The author of this book, Max Bennett, is an unusual case. Despite having no formal neuroscience background, he interviewed a host of experts on the brain and mind and the end result was this slick tour de force of intelligence. In doing so, he was able to identify five core principles that define intelligence—steering, reinforcing, simulating, mentalizing, speaking—which each evolved to solve a particular computational problem. Although it is somewhat skewed towards the neuroscience side and could have a clearer agenda for how the AI field should apply lessons from neuroscience, *A Brief History of Intelligence* provides an engaging, concise, and accessible overview of intelligence, and illustrates how our brain's evolution sheds light on what is needed for AI to have the flexible, general kind of intelligence that characterizes human cognition. You'll get through it in no time on your summer holiday.

Flowers for Algernon - Daniel Keyes



Our interpersonal relationships consist of unique combinations of personalities and identities. Now what happens when you, as the common factor in your relationships, drastically change? *Flowers for Algernon* allows for a deeply personal look into the life of Charlie Gordon; a man with an IQ of 68. Charlie is chosen to be the first human recipient of an experimental brain surgery to increase his intelligence. Enthusiastically and ambitiously taking on this experience, he comes to notice how his connections to the people around him seemed to have changed from how he knew them. The cognitive changes that Charlie undergoes directly impact his interpretation of the people and world around him; how he connects to his environment, who he connects with, who he loses connection with, and most importantly, how he connects to himself.

RAVING Connections

Tirza Ester

Recent decades have paved the way for a surge of people participating in the modern subculture known as 'raving.' Regardless of age, gender, music genre of said rave, location, and drug consumption; 'ravers' indicate one common theme of connection with your peers and like-minded individuals. Raves have created a safe haven for self-expression and thus the opportunity to connect with others that share a similar mindset.

The rave scene has established itself as a well-respected and acknowledged modern subculture. From the late 1980s onwards, people from a range of different backgrounds and walks of life have found themselves drawn to the realm of dance, drugs, and deeper connections. So-called 'ravers' have reported feeling more connected to themselves, their partners and friends, and their general environment when attending raves or festivals[1,2]. But where does this increased connection come from?

Raving often—but not always—is assumed to go hand-in-hand with drug use[3]. It has been observed that the specific genre of music played at a rave influences the attitude held regarding drug usage, both at the group and individual level. This results in a broad variety of reported experiences of unity, connection, ecstasy, and community at raves and other kinds of parties[3].

Raves

Raves can be understood as modern day, secular rituals[1,4]. Raves can be broadly classified in terms of the music played as well as the activities or spaces incorporated in the rave. In the late 1980s, rave culture was initiated with outdoor raves organized by non-professionals who found themselves on the borderline of legality, with raves often coinciding

Raves can be understood as modern day, secular rituals

with illicit drug use by ravers[2].

Motives for raving vary interpersonally; with many ravers indicating they aim to dance with the goal of personal development, transformation, and forming social bonds with fellow ravers, and others mainly focusing on simply experiencing live music and drug use at raves[2].

Party type, along with the main music genre played at a rave, influences motives for drug use as well as the after effects of raving on attendants. Ter Bogt and Engels[3] studied the differences between drug use and attitude at different raves, grouped by the main music genre of the festival. Results indicated that more mellow or club settings result in broadly decreased drug use—as compared to more mainstream, trance, techno, and hardcore raves—in terms of types of drugs taken, amount of different drugs combined (polydrug use), and total doses consumed[3].

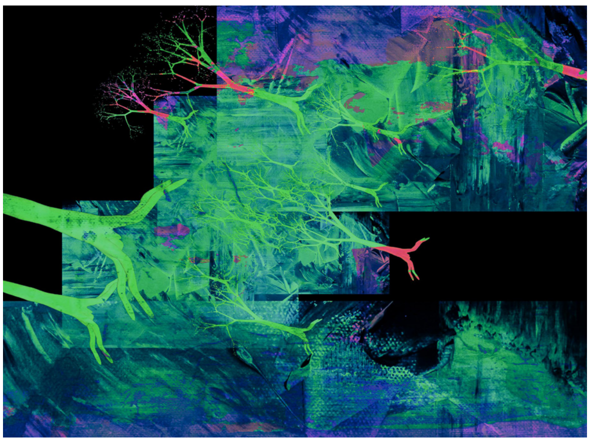
Over all users, a certain hierarchy of motives for drug use was observed by Ter Bogt and Engels[3]. The motive mentioned most often concerned MDMA's enhancing effects: increased energy, followed by

We should also allow ourselves to let go and connect—all at the same time

euphoria. After which, users report the increased sociability and flirtatiousness caused by MDMA as motives for its use. One interesting observation, however, is the finding that ravers who specifically seek out sociability and flirting often consume lower doses of MDMA than ravers motivated by other reasons—a pattern which may be related to the specific lifestyle of the ravers attending a particular party[3]. Even though Ter Bogt and Engels[3] perceived a slight interaction between the type of rave and the motive for drug use, with the trance group scoring highest on every scale; the party context itself was not observed to be a driving factor in drug use. The overarching party culture that surrounds raving and ravers may coincide with a confounding lifestyle that simultaneously elicits interest in recreational drug use. A party is the ultimate opportunity to express aesthetic and lifestyle preferences—through clothing, makeup, hairdo, physical expression such as dance, as well as drug use[3].

Conscious Clubbing

The often assumed connection between drugs and raves is not a commandment followed by all. 'Conscious' or 'clean' raves are an alternative safe haven for many individuals who wish to partake in rave culture without an environment that normalizes, or even expects, substance use. Those in recovery from substance use disorders also gravitate towards these events[5]. Many of the previously mentioned positive effects of raving on our connection to others are also observed at conscious raves, which highlights



the potential role of music and unaffected states in fostering social bonds[5,6]. Ravers describe this feeling of musical affect as the 'vibe' they experience at a party. This vibe can be conceptualized as a force field that is co-determined by the music, the dancers' gestures, the participants' emotional expressions, the visuals accompanying the music, the temperature of the surroundings, and—sometimes—also the drugs consumed[7].

The Effects of Music

The constantly shifting auditory stimulation of the music—as well as the contained stimulating environment found at raves or festivals in general—is not only helpful by providing the momentary stimulation our brains and bodies require, but also provides a level of social bonding and trance-like stimulation that enhances dopamine release and focus[8]. The modern world is a perpetually stimulating space. Many people are focused on reducing stimulation (e.g. in the form of 'dopamine detoxes') in their daily lives, but the contained and concentrated stimulation found at raves can be very beneficial. The repetitive rhythms found in many music genres that are represented at raves have been linked to decreased cortisol and increased dopamine. These fluctuations in dopamine levels allow our brains to seek out, and sense, pleasure and drive[8].

To exemplify these neural benefits, the 4D model—Dance, Drugs, Drums, and sleep Deprivation—has been developed to assess the effects of said four 'Ds' on social connection. Studies have shown people partaking in the 4Ds at raves to feel both a personal renewal and a connection to others at the rave[8]. The depth of social connection experienced with others can be attributed to rhythmic dancing and use of psychedelics, a combination that adds to the joy of group bonding found in ritualistic gatherings[8].

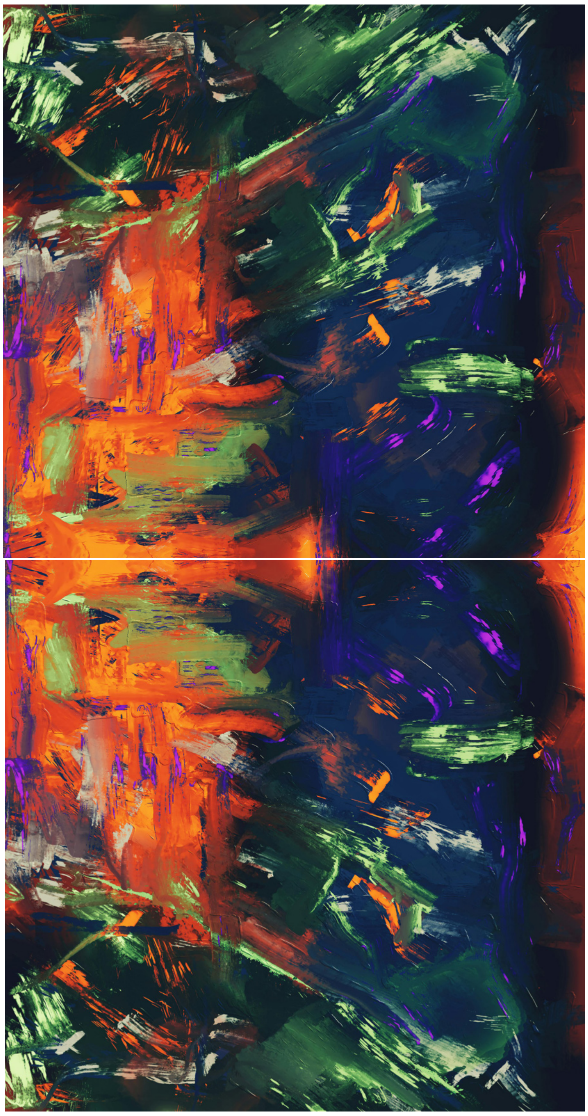
The Effects of Drugs

With MDMA at the forefront of rave culture, sometimes considered a representative of the recreational drug world for non-partakers, many are familiar with its cognitive and physiological effects. These effects include positives such as the social connections and increased energy mentioned above, but also envelop adverse effects ranging from headaches, nausea, hyperthermia, loss of control, and neurotoxicity. Many ravers, however, indicate dabbling in other substances or polydrug use, a term used to depict the combined use of different psychoactive substances.

Two classes of drugs are known to imbue a sense of increased connection in the user: empathogens and psychedelics. Drugs with a 'household-level of fame' like XTC or MDMA find themselves in the empathogenic group, exerting a sense of oneness, connection, and interpersonal closeness in the user[3]. The psychedelic group is known to foster prosocial behavior, altruism, empathy, and feelings of connectedness with others and the environment[9,10]. Psychedelics also elicit perceptual changes such as visual hallucinations, an increased sense of meaning, and feelings of transcendence[7].

Connected Conclusion

The studies and rave testimonials considered above showcase how letting loose at ritualistic gatherings like festivals or raves allow individuals to foster connections in their life. Whether these connections are interpersonal, intrapersonal, or concern a greater connection with the universe, does not matter to the party or substance that is involved. Taking care of yourself and others when raving and consuming psychoactive substances—whether these are psychedelics or 'just a beer'—is important, but take these findings as a reminder that we should also allow ourselves to let go and connect—all at the same time.



Crossing Genres

A showcase of artists and albums that make unusual but evocative and memorable musical connections

The QR code above will take you to a playlist that contains music that we felt inspired to share with you within this theme of the ABC Journal.

The playlist starts with BICEP, providing you with their well-known electronic music inspired by Arctic indigenous communities. This perhaps unexpected collaboration highlights the beauty that follows from connecting different cultures and manners of expression.

After this, Fred Again... follows in BICEP's footsteps and lets his creativity run free on electronic music, creating an ambient sound that is unlike any other album—something we have come to know from him. This ambient take on electronic music is followed by a connection to nature.

Max Cooper is next, an artist that is not bound by the confines of music. If Max Cooper's take on electronic music piques your interest, feel free to seek out his digital art and his unique visuals that he creates to go along his musical work.

The last artist highlighted is Imogen Heap, an experimental musical artist that is known for her pioneering projects in music production tools. Her self-developed 'musical gloves' allow her to produce music with just a movement of her hands, connecting the auditory with the tactile. These innovative musical gloves are put to use throughout her music, for the inquisitive listener with a deeper interest, there are multiple videos available online of her using these revolutionary tools in real time.

What Does It Mean to Connect with Another Person?

A LOOK INSIDE INTER-BRAIN SYNCHRONY

Dr. Daria Ilishkina.

What happens in our brains when we truly connect with someone? Relational neuroscience suggests that during shared moments—therapy, learning, empathy—our brain activity may synchronise. This article explores inter-brain synchrony: whether it helps create human connection, or simply reveals that connection is already there.

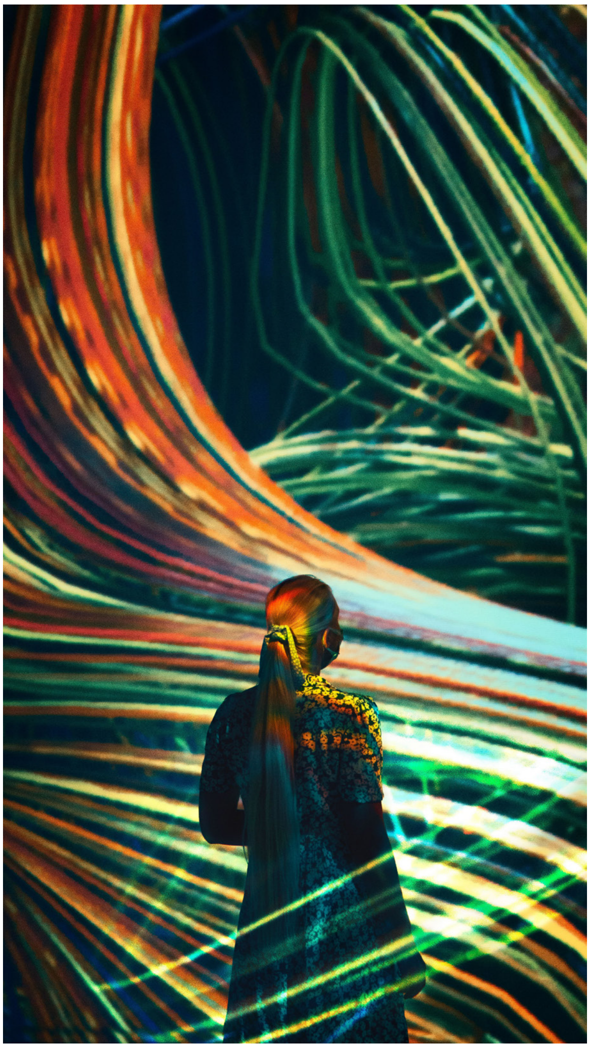
Once, walking through Chiharu Shiota's art installation Between Worlds, I found myself inside a labyrinth of red threads. Everywhere I looked, red threads extended across the room—over the walls, across the ceiling, and through the air itself—turning the space into a labyrinth with only a slim route to pass through. As visitors moved through the installation, their paths crossed and separated, as if each person were part of a larger, tangled network. I was there with my mother. Since I moved to the Netherlands, we no longer see each other often, and being together in that space felt unexpectedly intense. Around us, a few other people moved through the same maze. I could see them, feel their presence, adjust my steps to theirs—yet they felt strangely distant, almost like elements of the installation itself. My mother did not. She stood out as a real presence, a person I was connected to in a way that felt qualitatively different. In that moment, I was surrounded by people, yet deeply connected to just one. Moments like this raise a deceptively simple question: what does it actually mean to 'connect' with another person?

How Relational Neuroscience Studies Connection

Relational neuroscience offers one possible lens on why I felt connected with my mother but not with other visitors: my mother and I might have been experiencing inter-brain synchrony (IBS)—and more so than between myself and anyone else there. Relational neuroscience uses methods like hyperscanning— recording brain activity from more than one person at the same time—to study how people's brains relate during shared experiences. One key idea is IBS, defined broadly as a consistent timing alignment in how two people's brain activity rises and falls during social interactions[1,2]. Depending on how researchers measure it, this alignment can appear as synchronized brain-wave rhythms in electroencephalography (EEG)—for example, matching alpha or theta timing and phase—or as coordinated shifts in blood oxygenation, captured with functional near-infrared spectroscopy (fNIRS) or functional magnetic resonance imaging (fMRI). Imagine two musicians improvising. They might play different instruments and different melodies, so the music isn't identical. But for the duet to work, they still have to coordinate in time: their tempo and rhythm have to line up, and maybe even match in overall intensity, building up together and then easing off. The two musicians constantly adjust to each other. Sometimes they stay tightly on the same beat; other times one musician briefly shifts the tempo or rhythm and the other follows—and then the roles can switch, creating a back-and-forth, collaborative pattern. IBS is the brain-signal version of that kind of coordination: not the same 'notes,' but a reliable timing and intensity link between two people over time.

Inter-brain synchrony has been observed in many real-world social situations, including when people cooperate, talk, watch or learn from the same content, or share emotional moments[2]. Researchers still debate what this brain synchrony means: it might play an active role in building connections, or it might be a readout—an indicator—of other social processes happening during interaction. Ellingsen and colleagues believe that IBS is not just an indicator, but rather could be a true mechanism of connection that contributes to people feeling connected[3]. This mechanism is thus like a metronome in a musician's duet: it doesn't just reflect that the musicians are playing together, but rather actively helps them stay in time, which in turn changes how well they perform.

Researchers still debate what this brain synchrony means: it might play an active role in building connections, or it might be a readout of other social processes happening during interaction



Inter-Brain Synchrony as a Potential Mechanism for Empathy

The authors investigated whether the presence of a clinician in a room would ease a patient's pain and what the role of IBS is in such coupling. Patients received painful and nonpainful pressure either while a supportive clinician was present via a live video or while alone. The chronic pain patients' and clinicians' brain activity were scanned at the same time using fMRI hyperscanning. Patients with practitioners on call reported less pain than solo patients. During painful stimulation, the patients and practitioners showed IBS. The patient's secondary somatosensory cortex (S2)—a key pain-processing region—showed dynamic coupling with the clinician's dorsolateral prefrontal cortex (dlPFC), a region linked to higher-order control and social-cognitive functions. The stronger this S2–dlPFC coupling, the stronger the reported therapeutic alliance, and the coupling was higher in dyads who had a prior clinical intake designed to build the patient–clinician relationship. Because the strength of patient–clinician neural coupling increased with patients' reported therapeutic alliance, and because patients reported lower pain intensity in the dyadic than in the solo condition, the authors carefully suggest that cross-brain coordination may be part of a potential mechanism underpinning pain empathy and supportive care. In other words, pain empathy is not just what happens in one brain, but rather could be part of a two-brain mechanism in which one person's brain activity dynamically aligns with another's. It is, however, worth stressing a key limitation: the idea that IBS is a mechanism remains mostly based on correlational evidence, such as studies in which stronger IBS goes along with a stronger therapeutic alliance. Correlations like that cannot by themselves prove that IBS is a mechanism of connection.

Because much of this research links IBS to outcomes through associations rather than direct causal tests, some authors—including De Felice and colleagues—prefer to describe IBS as an indicator of connection, not a confirmed mechanism[4]. In that sense, IBS is a bit like an audience tapping their feet to a song: it signals that the musicians in a duet are playing well and holding the rhythm together, but the listeners' tapping is not the reason the musicians are playing so well. De Felice and colleagues examined how IBS related to learning success by assessing how closely a student's and teacher's brain signals rose and fell together over time during teaching. The study had three steps. First, participants learned facts about unfamiliar items on their own before coming to the lab. Next, in the lab, they took turns teaching those facts to a partner, using a physical model of the target item placed on the table as a shared reference. In half of the teaching rounds, a screen partly blocked their view of each other (the part-view condition); in the other half, they had a clear view (the full-view condition). Finally, both members of each pair took a learning test twice, one directly after the teaching session and another one week later.

The results suggest that when teachers' and learners' brains 'sync up' during teaching, synchrony can help predict how well the learner remembers the study material. But the story isn't as simple as 'more synchrony equals more learning.' Even though average test performance was similar in the part-view and full-view conditions, the relationship between IBS and learning shifted depending on the condition. Two aspects of behaviour were especially tied to these patterns: joint attention (both people looking at the learning object at the same time) and mutual gaze (looking at each other). And importantly, these two behaviours did not map onto the same kind of IBS. In some brain areas, they were linked to different—and even opposite—IBS-learning patterns. That's why the authors interpret the results as pointing to two kinds of productive learning moments: one centred on taking in information (more associated with joint attention) and another centred on building shared understanding (more associated with mutual gaze), rather than a simple tug-of-war between looking at the object and looking at the other person. Studies like that of De Felice and colleagues shed light on how connecting with another person may not be a single signal, but instead a layered process involving attention, behaviour, and neural coordination.

Perhaps there are faint threads of neural alignment between us all the time and we are just not very good at noticing them yet

Inter-Brain Synchrony as an Indicator of Productive Learning

Even though the question of whether IBS is an indicator or mechanism of connection remains to be answered, research increasingly links brain-to-brain synchrony to a range of positive social outcomes. Studies have reported associations with better learning[4], attachment and bonding[2], relationship satisfaction in groups[1], and even stronger feelings of connection and improved cooperation[5]. But scientists still don't agree on what, exactly, contributes to the brain synchrony itself. Findings can be mixed or even controversial: in the above-mentioned work, for example, eye contact (gaze) relates to IBS, while other studies do not find this connection[1]. Brain synchrony also seems to shift with context—such as stressful versus non-stressful situations[1]—and may change depending on how interactive an activity is[1,2], or even on group structure, such as whether a leader is present[2].

What brain synchrony really means in human connection remains an open question. Even if it turns out to be only an indicator—a biological sign that two people are 'in sync,' rather than the cause of connection—it could still be useful. Imagine therapy, education, or teamwork where a patient and therapist, a teacher and student, or teammates can track synchrony as a kind of biofeedback: a signal that the connection might be fading, prompting them to pause, reflect on what changed, and try a different approach. And if you let your imagination run a little, perhaps one day you'll walk through a museum wearing a small, unobtrusive device that shows whether your brain activity is syncing with someone else staring at the same masterpiece. A little spike might be a nudge to start a conversation. Perhaps there are faint threads of neural alignment between us all the time and we are just not very good at noticing them yet.

Strangers on a Dream: While You Were Sleeping, Your Brain Was Networking

Plato Derksen

The connected brain does not rest when we sleep: REM dreaming may serve as a nightly social graph optimiser, rescuing weak-tie memories that waking life leaves underreinforced. By bridging Social Simulation Theory with the REM Refining and Rescuing hypothesis through the default mode network circuitry, this article proposes that improbable social combinations in dreams are not coincidental and matter for relational resilience and human adaptability.

'I ... dreamt ... that ...' I manage to get out in a hoarse, sleepy voice. It is the middle of the night, and I just opened my phone's voice memo app. After a dream that felt like it spanned hours, I am amazed by my ability to recall its events and the people within it. Minutes later, the dream is captured, ready for analysis when daylight returns. As a neuroscience student tracking dozens of these dreams, patterns emerge: there is a mix and match of individuals from different environments connected within the dreams. It is not uncommon to see that I have written down in my dream logs the names of different combinations of hockey teammates, university friendships, coworkers from jobs past and present, family members, and fictional characters. While I can see parallels between the events in my dreams and my waking life, the combinations of the actors within do not make sense to me, as they have never truly interacted. What is it about dreaming that makes familiar people appear in such unexpected combinations, and could there be a deeper purpose behind it?

Scientific literature quantifies this social phenomenon: rapid eye movement (REM) dreams contain social interactions twice as frequently as in waking life, with 70–90% of reports featuring familiar figures drawn from recent or emotional waking experiences[1]. Two theories explain parts of this puzzle: Social Simulation Theory (SST) accounts for the social bias, and the REM Refining and Rescuing (RnR) hypothesis justifies memory refinement[1,2]. Yet neither addresses how REM specifically refines social networks. Here, I propose that REM may function as a social graph pruner, rescuing low-frequency emotional ties such as acquaintance connections to shape behavioural flexibility across fluid social worlds. In turn, this mechanism explains REM's role in relational resilience. In the current article, I bridge SST phenomenology with RnR mechanisms through the default mode network (DMN), revealing why we dream of unlikely social recombinations.

While parallels can be seen between the events in dreams and waking life, the combinations of the actors within do not make sense, as they have never truly interacted

REM as a Memory Refiner

Two complementary processes establish REM's mnemonic role: Refining and Rescuing[2]. The former entails narrowing memories down to essentials; the latter involves amplifying sparse memory signals. Non-REM sleep downscales synapses globally, pruning noise. REM then counterbalances this through theta oscillations (4-8 Hz), which preferentially boost weakly firing neurons; the sparse representations most vulnerable to erasure[3]. This cycle enhances signal-to-noise ratios, enabling generalisation, insight, and creativity. These are all REM-dependent phenomena[2]. Crucially, weak social ties, think acquaintances and ambiguous relationships, form sparse engrams during waking. They require extensive neural coordination, yet are rarely reinforced[4]. RnR predicts their preferential rescue during REM, transforming fragile connections into resilient relational templates. Additionally, the authors write that the RnR hypothesis is in line with theories about why we dream, but focus mainly on an anti-learning mechanism of REM to prevent overfitting of the brain. Here, I would like to extend the theory to the social aspects of dreams. Indeed, acquaintances or ambiguous ties can be considered sparse social engrams that, in turn, can be rescued during REM. Like a coach isolating defensive weaknesses for targeted practice, REM strengthens these low-probability links. This sets the stage for social simulation, with the DMN providing the engine.

The DMN as a Social Network Engine

The DMN specialises in social cognition, particularly mentalizing: inferring others' mental states to predict behaviour[5]. Its subnetworks form a relational mapping system: medial prefrontal cortex (mPFC) for self-referential processing, temporoparietal junction (TPJ) for others' perspectives, and posterior cingulate cortex (PCC) for autobiographical memory integration. During REM, DMN exhibits heightened internal connectivity relative to external sensory regions, creating an ideal offline simulation environment[6]. This ties back to hippocampal-prefrontal theta synchrony, which further amplifies sparse signals[3]. Waking DMN handles high-frequency ties efficiently; weak ties demand extensive coordination, appearing only as low-probability outliers[4]. REM's disinhibition shifts this balance, rescuing these sparse connections as network centrality increases post-sleep. Effectively, the characteristic disinhibition of REM amplifies low-

probability connections, as there is a shift from a high-frequency dominant state to a low-frequency one[2]. This mechanism predicts increases in weak-tie centrality after REM, which can be tested via dream reports and social interaction tracking.

Social Simulation and Generalisation

Building on this, REM may be understood as a process that rescues weak social ties through DMN-supported recombination. Social Simulation Theory (SST) is the theory that explains how this process becomes visible in the dream world[1]. This theory suggests that dreams rehearse real-world social interactions, with ~70% of content social and recent/emotional waking events prioritised[6]. Interestingly, cross-cultural patterns can be distinguished within the boundaries of the theory. The comparison here is between dream reports from forager societies, such as hunter-gatherer groups, and those from Western, industrialised populations. In forager dreams, threat is more often resolved with help from others, whereas Western dreams tend to be more individual-centered and less explicitly communal[7]. Nonetheless, the proposed mechanism is the same; REM extracts relational rules from weak-tie recombinations. REM extends this beyond replay:

Like a coach isolating defensive weaknesses for targeted practice, REM strengthens acquaintances or ambiguous low-probability links

RnR mechanisms extract generalisable social rules. Weak ties undergo amplified recombination while high-frequency anchors such as close friends stabilise scenarios, generating abstract social schemas that replace concrete identities. Think of it as generalisation into titles such as 'mentor' or 'rival'. This makes me think back to the time when I was part of a committee of my Bachelor's student association, and our chair invited us to a *borrel*, a typical Dutch get-together with drinks and socialising. The occasion was a celebration of our last hockey match. I came across many people in the train, the hallways of the university, and at the tables of the bar. Teammates, of course, but also school friends and the main leads of the *Project X* movie, all in random and recurring order. You might have realised by now that this was a dream. But during the dreaming process, it felt normal and valid. It is possible that the dream used the mechanism of generalising the above mentioned individuals with the title of 'party people'. Dreams featuring mixed-group interactions exemplify DMN bridging relational clusters, constructing flexible templates that span social domains. Graph analysis confirms this: REM dreams exhibit higher complexity than non-rapid eye movement (non-NREM) dreams, seen as larger strongly connected components. This reflects richer network topology[8]. Weak ties that are sparse in waking graphs gain prominence post-REM, enhancing relational adaptability across contexts, from team dynamics to academic collaborations.

Implications and Conclusion

This refinement provides extensive adaptive advantages: relational flexibility across shifting group compositions, resilience to upheaval, and readiness for new alliances[7,9]. Evolutionarily, social complexity drove REM elaboration. Recall the forager example, where oral traditions represent early social learning investments, with REM optimising group cohesion[10]. Even though REM's metabolic expense is neurobiologically costly, it finds justification in its social adaptive value: flexible graphs enable survival advantages in cooperative environments[2]. The added value becomes clearer when considering situations in which they are absent, that is, situations showing dysfunction patterns. Social anxiety rigidifies graphs, impairing weak-tie rescue and yielding isolation[11,12]. Fragmented REM further embeds inflexible models, predicting relational rigidity when low REM combines with poor generalisation. From competitive sports to interdisciplinary research, REM's pruning equips us to navigate fluid networks, transforming acquaintances into potential collaborators overnight.

You may have perceived from your own dreaming experience that REM dreams do not just replay social life. Now, this hunch can be explained by REM dreams' ability to prune and rescue weak ties within DMN circuitry. In turn, flexible relational architectures essential for human adaptability emerge. Understanding this neural choreography clarifies why we dream of improbable collaborations: REM prepares us for social reality's constant recomposition. The current article unifies SST's phenomenology with RnR's mechanisms: REM-DMN implements social graph optimisation, rescuing weak ties to extract relational rules for adaptability[1,2]. This specific symbiotic combination applies RnR to social memory networks, connecting computational neuroscience with lived social complexity. Certainly, this perspective is not foolproof: causal inference challenges, dream subjectivity, and longitudinal behavioural validation remain. Nonetheless, for researchers navigating fluid social worlds, REM's social architecture clears up the hidden rehearsal of human adaptability. For mitigating the current limitations and advancing future social dream research, my advice is this: keep on dreaming, as it may be humanity's greatest relational technology.

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Imitation Is the Sincerest Form of Flattery: What the Embodied Brain Can Teach Neural Organoids

Tirza Ester

Plato Derksen

Joseph Harrison

Brain organoids are three-dimensional, stem cell-derived neural cultures that encapsulate key aspects of early human cortical development. They pulse with life-like cortical activity, but without a body to move through the world, do they miss the feedback that actually wires the brain? These tiny neural systems master spontaneous activity yet lack the structured sensory input that sculpt long-range connections in living development; understanding whether that gap matters is important because organoids are now widely used to study development, disease, and network formation. We dive into the alchemy of sensorimotor feedback in organoid networks, decipher its embodied blueprint in human development, and outline practical paths to truly connected neural worlds.

The effect of sensorimotor feedback on neuronal connectedness in brain organoids

Before turning to organoids, it helps to briefly consider what feedback does in a developing brain. Sensorimotor feedback shapes neuronal activity via activity-dependent mechanisms. While axons are guided by molecular gradients, it is the temporal patterns of electrical activity that determine which projections stabilise and thrive. Coordinated firing driven by sensory input strengthens target-specific synapses through long-term potentiation, while less active connections are withdrawn through competition[1,2]. This refinement transforms a pool of potential synapses into circuits calibrated to the body's interaction with its world. Thus, sensorimotor feedback determines which connections persist, something organoids cannot fully replicate without a body.

The case of brain organoids deserves specific attention. Brain organoids produce spontaneous electrical activity that reiterates early cortical development[3], appearing as coordinated bursts and slow waves across neuronal populations. This suggests that organoids can establish local network coordination even without sensory input. However, without structure this complex activity is limited. Without consistent input–output coupling from bodily movement, organoid networks primarily reflect local self-organisation: nearby neurons coordinate, but distant regions remain weakly linked. In short, even though organoids can mimic early brain activity,

Non-assembloid type neural organoids, or 'disembodied neural organoids', function as a sort of disjointed fragmentation of what the complete neural experience entails

without bodily feedback they mainly organise in small, local ways rather than into fully connected brain-like networks.

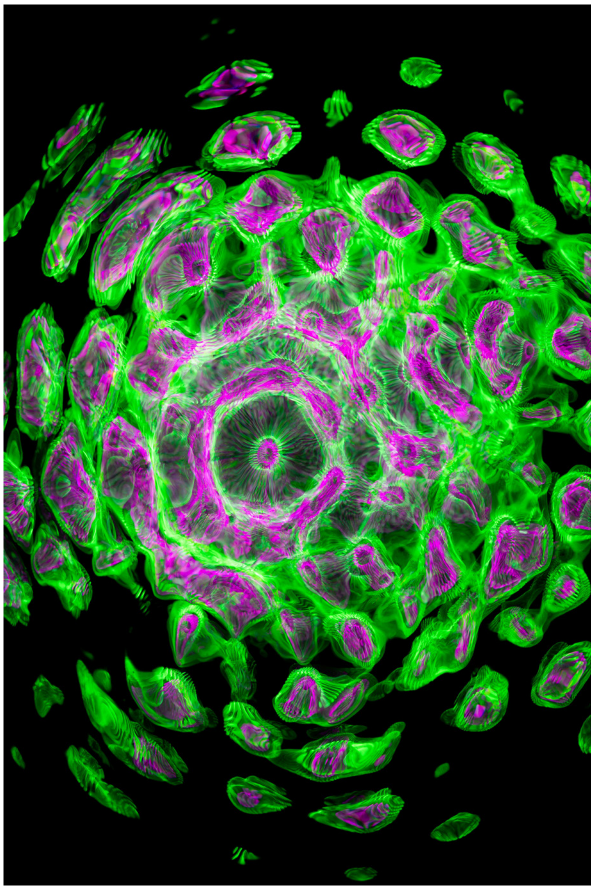
This limitation is not absolute, though. When exposed to structured electrical stimulation via multi-electrode arrays, organoid networks respond: burst frequency increases and activity synchronises across sites. In turn, these changes stick around after stimulation; a signature of plastic developmental mechanisms[3,4]. Thus, organoids not only tolerate external patterns but adapt to them, and their connectivity remains responsive even after independent maturation.

Osaki et al.[5] extend this to the network level by connecting pairs of cortical organoids via a designer axon bundle. Optogenetic stimulation of one organoid induced delayed, sustained activity in the other, and over time bidirectional synchrony emerged as connections strengthened. The organoids began to alternate in driving activity. There was talk of mutual influence, in which plasticity evolved across an engineered tissue bond.

These findings highlight the latent power of sensorimotor feedback: organoids possess the same activity-dependent machinery that shapes developing circuits, requiring only structured input to fully engage it. Their spontaneous activity forms a foundation, while external temporal patterns can reorganise networks. In short, brain organoid connectedness is far from fixed self-organisation and remains dynamically responsive to patterns that, in vivo, would be generated by the moving and sensing body. To understand what these findings mean, it is helpful to place organoids in the context of human development, where embodiment operates at multiple levels.

Explaining embodiment in human development

Human neural development is embodied at three levels: (1) a mechanistic, cellular level, (2) a neural network level, and (3) a systems level. At the first level, cellular mechanisms guide patterns of neural activation and, subsequently, how neurons develop (such as in axon pathfinding, whereby the axons of neurons move through tissue to reach their targets). In an in vivo study on axon pathfinding in developing zebrafish motor neurons, Plazas et al.[1] found that patterns of calcium spiking activity (indicating motor activity) changed across different developmental stages, and that suppressing activity in specific neurons resulted in specific patterns of pathfinding errors, whereas suppressing activity in all neurons did not, suggesting that axonal stabilisation is guided by the relative contributions of neurons in a competitive mechanism. Mechanisms at the cellular/molecular level are conserved across vertebrates (including for the brainstem mechanism), so this finding is significant: stimulating these mechanisms in organoids could be a way to give them life-like feedback so that, in turn, their activity is more life-like.



In terms of neural networks, as humans develop from infancy to adulthood, neural networks become increasingly clustered and integrated and so develop a 'small-world' organisational structure—a neural structure is 'small-world' when nearby regions form closely interconnected specialised clusters and at the same time, any two regions in the brain can efficiently communicate via a small number of steps. For instance, using MEG and graph theory, Berchicci et al.[6] studied the developing sensorimotor cortex from infancy to adulthood and found that the human sensorimotor network evolves from a more random organisation (in infants) to a small-world organisation (in children to adults) that is more efficient at both a local and a global level. As noted earlier, brain organoids are dynamically responsive to external temporal patterns, which reorganise their networks. Research into the development of human neural networks, then, can offer insights into what types of external patterns can cause brain organoid networks to develop the small-world structure that characterizes brains and so be more efficient and life-like.

At a systems level, feedback loops between brain, body, and environment guide how neural networks form. For instance, in a computational model of an embodied foetus based on data on the human brain, spine, musculoskeletal system, and uterine system, made by Yamada et al.[2], cortical learning was seen to be shaped by how the body of the (simulated) foetus interacted with its surrounding environment: in simulations generated by the model, spontaneous bodily movement inside the uterine environment of the foetus created structured statistical regularities in somatosensory feedback, which in turn facilitated cortical learning of body representations and later integration of visual–somatosensory feedback. Such research into brains can offer templates for making brain organoids more brain-like. By pairing brain organoids with other kinds of organoids[5], for instance, perhaps through structured statistical regularities in feedback from these other organoids, brain organoids could develop richer representations of their environment.

This science-backed fiction project introduces a sort of organic robot made from constituent organoids, which interact and cooperate to form a functional 'biological robot'

Strategies for embodied organoids

Lack of representational variability in regional or cortical organoids gives rise to an incomplete image of the inner workings of the brain and its connection to our bodies and environment. To truly recapitulate the totality of said connections within and between organoids, different methodologies of merging organoids and the resulting neural connectivity should be considered. Assembloids are often taken as a hallmark method for extending the reach of organoids[7,8]. The term 'assembloid' is used to refer to region-specific brain organoids that are connected after a period of independent culturing, whereby a neural organoid is chemically guided throughout its growth to mirror a specific brain region, resulting in a more specialized and representative organoid[7,9]. This concept of combining region-specific organoids can be applied to organoids that recapitulate different organs (such as spinal or vascular organoids), thus forming small embodied networks[10]. In addition to assembloids, certain labs have been looking into embodied organoids of an even more advanced level, namely the transplantation of organoid-derived neurons into host brains of mice[11].

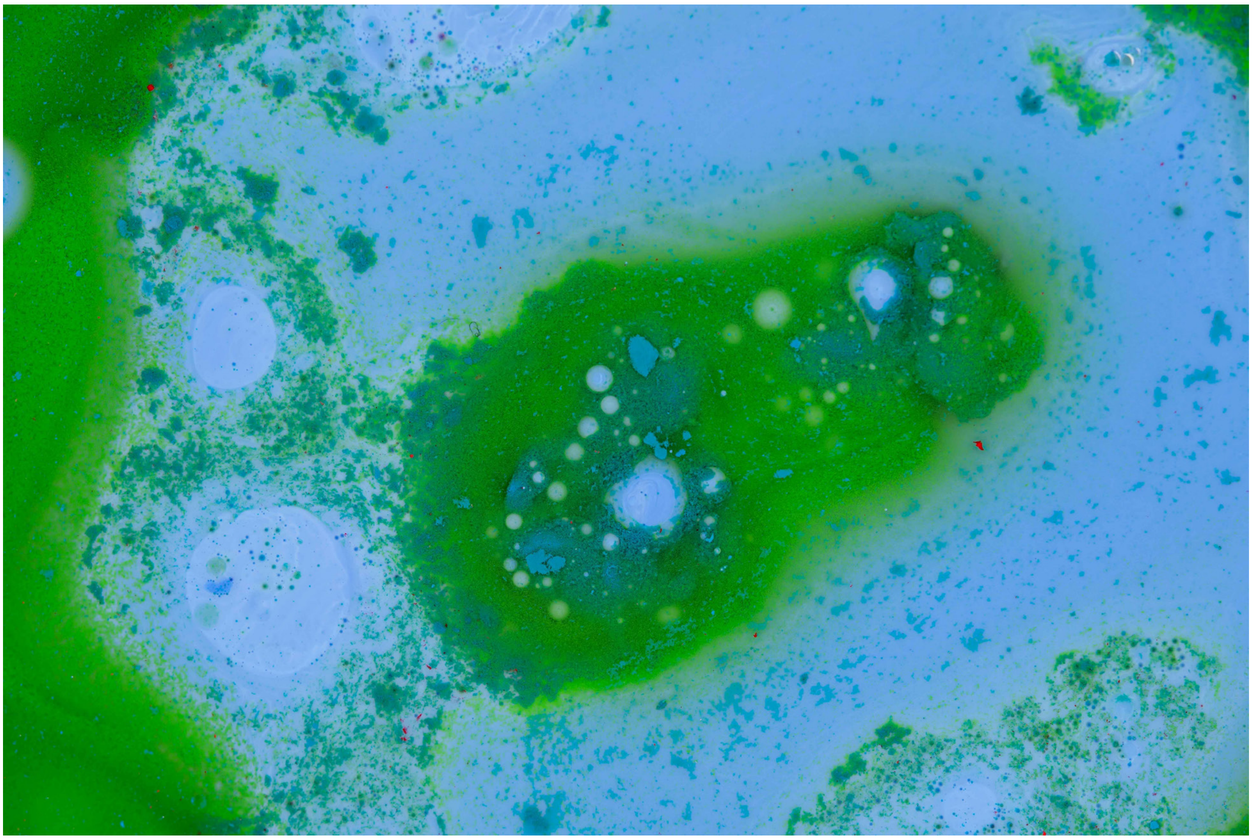
Expanding the included biological mechanisms in organoids provides a more complete picture of reality. The incorporation of blood vessels into neural organoids not only reduces levels of cell stress and cell death, but may also be used to model the blood-brain barrier and thus imitate the intricate interplay of blood flow response to neural activity[11]. Osaki, et al.[5] studied the effects of fusing independently grown neural organoids on the resulting functional and structural neural connections. This experiment led to observations of increased synchronization and amount of activity in both organoids, even observing a frequent alteration in which organoids initiated signal propagation, thus showcasing bidirectional functionality between the connected regions[5].

Not only would assembloid culturing methods allow for more accurate imitation of in vivo neural connections, these methodologies also lend themselves to a more exhaustive recapitulation of the general conscious experience[10]. Non-assembloid type neural organoids, or 'disembodied neural organoids', function as a sort of disjointed fragmentation of what the complete neural experience entails[10]. The potential connection of other-organ organoids to neural organoids would allow for expanded capabilities of processing input and potentially also expressing output. This step into sensory processing and guided output pushes back the limits of what organoid models can teach us[10].

Conclusion

Embodiment, then, is more than a conceptual framing of human development—human neural development doesn't unfold according to a predetermined blueprint but rather patterns of bodily activity. Through sensorimotor coupling and structured feedback loops, neural circuits develop in tandem with bodily activity, ultimately suggesting that organoids should be embodied if they are to serve as useful models of the human brain. The incorporation of non-neural organoids in assembloids could fill in the missing spots that disembodied organoids leave behind. That said, these in vitro recapitulations of bodily circuits remain incomplete; organoids remain a fragmented conceptualization of the connections we find throughout the human neural environment, our body, and our environment.

With many potential improvements still on the horizon, however, the future of the organoid field seems promising. To get an idea of what the future of the field could hold, we can take inspiration from the creative science fiction project dubbed 'OSCAR' or the 'modular body'. This science-backed fiction project introduces a sort of organic robot made from constituent organoids, which interact and cooperate to form a functional 'biological robot'. The curious-minded—and non-squeamish—are invited to go and familiarize themselves with our shared friend OSCAR. Be aware, however, of his less-than-welcoming appearance[12]...



Agency All Around: Human-AI Connection and an Interactivity-Grounded View of Agency

Joseph Harrison

As AI systems become increasingly capable and embedded in society, understanding the nature of our connection with them is essential if we are to shape it for the better. Adopting an interactivity-grounded view of agency, this article argues that we are already co-agents with the AI systems we use, and that there is a dynamic line of control between human and AI agency. It examines how human agency and AI agency differ and overlap, and identifies proxy failure—the tendency of subgoals to drift from original goals—as a particular risk of AI agency. Based on this analysis, it suggests practical steps for managing the risks of human–AI co-agency and enabling a future of beneficial human–AI connection.

Agency as a Continuum: From Simple Disks to Complex Humans

In a simulation made in 2013 by computer scientists Alex Wissner-Gross and Cameron Freer, simple disks behaved in surprising, seemingly purposeful ways: one pair used a smaller disk to extract another from a narrow tube, as if using a tool; another pair coordinated their movements to manoeuvre a larger disk into place, as if working together towards a shared goal. The disks in this simulation, however, had just been given a simple overarching rule: their movements and interactions had to maximise the entropy (a measure of disorder or randomness in a system) they generated over a specified window of time[1]. From this simple rule emerged apparently complex, goal-directed behaviour—apparent agency.

The standard view of agency holds that agency requires forms of internal mental states (such as memory, desires) that cause intentional actions. It takes the minded biological organism as its paradigm case: agency is modelled on creatures with beliefs, desires, and the capacity to act for reasons. The non-standard view—held by the philosopher of information Luciano Floridi—is that any entity with some degree of interactivity (a capacity to act in an environment and, in turn, be acted on) may qualify as an agent, with more complex forms of agency including other features, such as autonomy (ability to initiate state changes independently), adaptability (ability to modify goal-seeking behaviour based on feedback), and, eventually, internal mental states[2]. On the standard view, the simulated disks, lacking internal model states, do not count as agents, but a broader account that defines agency in terms of interaction with environments leaves room for such simple systems to count as agents. The implication of this broader account is that we are co-agents with the AI systems we use.

Agency doesn't require the heavy cogitation of human thinking but rather exists on a continuum. Indeed, neither a brain nor a nervous system is required for an agent to choose between goals: when researchers fired plastic beads at a ciliate, for instance, a single-celled aquatic organism, the ciliate altered its response (contract or detach and float away) with unpredictable 50:50 odds[3], thus being less predictable and more likely to achieve its goal of survival. The ciliate, like the virtual disks, is an example of how behaviour can be apparently agentic and goal-directed even in the absence of anything like human thought, pushing us to ask where mere mechanism ends and agency begins.

If agency can exist in such simple systems, then the question of what it means to be an agent shifts from what something is made of or how it compares with human intelligence to how it interacts with and affects the world. The essence of an agent's agency is not its material implementation, but its 'cognitive horizon,' that is, the spatial and temporal dimensions of the agent: spatial limits are determined by how far away an agent can sense and exert actions, temporal limits by how far back it can remember and how far forward it can anticipate. An agent's cognitive horizon is not fixed, however: smaller agents can combine to form larger agents and agents can form networks to pool information and thereby scale up their capabilities and goals[3]. Cone cells, for example, contribute their local capabilities to the distributed system that produces vision. Central to agency, rather than what an agent is made of or whether it has a form of intentionality, are the goals an agent can perceive, represent, and pursue in its environment.

Human–AI Co-Agency: Towards a Pragmatic, Interactivity-Grounded View of Agency

AI is not truly intelligent, Floridi argues, because it lacks intention and mental states, but it has a form of interactivity and, therefore, agency[2]. Admittedly, whether AI has, or could have, intention and mental states is a matter of debate, but on an interactivity-based account, this is beside the point: the outcomes of our co-agency with AI have consequences irrespective of whether the AI systems we use are truly intelligent. If an AI leads us to a bad decision, whether the AI is truly intelligent does not strictly matter for the outcome. Floridi's non-standard view of agency provides a pragmatic theoretical framework that allows the influence and capabilities of the AI systems increasingly embedded in society to be accounted for without needing to commit to a particular metaphysical stance.

Human agency is embodied, semantic, and shaped by lived experience. Artificial agency, by contrast, is computational and goal-driven, characterised by what Floridi calls designed emergence: programmed rules and goals set by humans become learned patterns and emergent adaptive behaviour[2]. The cognitive horizons of human and artificial agency do overlap, particularly in the case of large language models (LLMs) like Claude or ChatGPT, which can communicate fluently in natural language. Nonetheless, we should resist equating them too quickly: the agency that AI has is a syntactic form of agency. It lacks a semantic grounding in the meaning of what it produces and so a crucial gap between human and artificial agency remains. The cognitive horizon of AI (at least currently) is constrained by its disembodiment and its reliance on patterns learned from data rather than lived experience.

The generative AI systems (of which LLMs are a form) that currently predominate are a kind of artificial agency. They are also, Satyanarayan and Jones[4] argue, delegated constrained agency: when designing an LLM-based chatbot, for example, a designer delegates agency to it (e.g., what modalities the LLM can interpret and compose), which is in turn constrained (e.g., the LLM is trained to not produce offensive outputs). The below is a visualisation of how this delegated constrained agency plays out in AI–human interaction. Each agent composes output (such as a sentence) for the other agent and, in turn, interprets the other agent's compositions. The line separating blue and green is the 'line of control' between the co-agents[4], which is not fixed but dynamic: the line fluctuates as the agencies of the co-agents fluctuate (e.g., as human users become better at prompting useful outputs from LLMs).

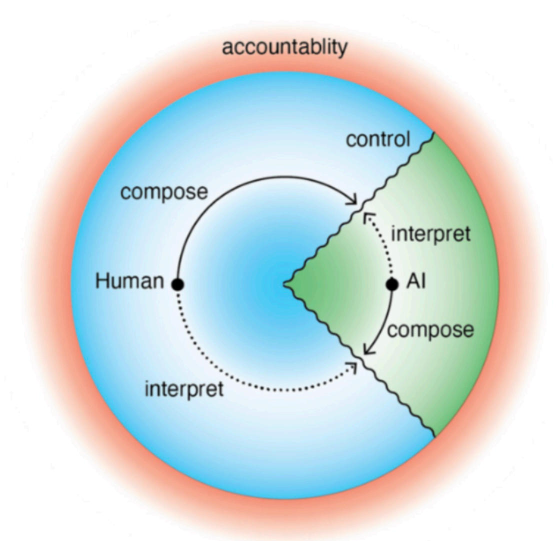


Figure 1: Schematic of delegated constrained agency in human–AI interaction

Any entity with some degree of interactivity may qualify as an agent, with more complex forms of agency including other features, such as autonomy, adaptability, and, eventually, internal mental states.

Accountability, as represented by the orange, is the capacity to give and receive meaningful explanations for goal-directed actions[4]. While humans exercise this through genuine intention and social obligation, the authors argue, AI systems can functionally display such interactional accountability even if they lack underlying intentionality. How an AI system explains its reasoning, for example, produces social effects (such as influencing trust in a user) regardless of whether the AI has any underlying intentionality.

Although fundamentally different, the cognitive horizons of human agency and the artificial agency of LLMs overlap in a shared cognitive corridor: trained on natural language, LLMs have access to a key component of human cognition that provides a model of our world5. It is in this corridor that we can find ways to interconnect our agency with AI and thereby expand our agency to achieve particular outcomes. But, as the following section highlights, interconnecting our agency with AI in this space is not without risk.

An Unpredictable Line of Control: Goal-Seeking Agents and Proxy Failure

As AI systems become increasingly 'agentic' (AI that can call on external tools to accomplish complex tasks with minimal human supervision[6]), their capabilities will be more open-ended and better able to scale up human agency. This may bring benefits such as enhanced efficiency, convenience, and scalability, which can liberate human resources for more creative and strategic ends[4]; however, the more capable and open-ended AI agency is, the greater the risk that the line of control in human–AI co-agency shifts towards AI in unpredictable ways, and that the outcomes of this co-agency are detrimental to humans. An important source of such unpredictability is that the more complex the goals pursued by AI, the greater the risk that subgoals it uses to operationalise goals do not faithfully represent the goals. That is, the greater the risk of 'proxy failure'[7].

John et al.'s paper aligns with Floridi's interactivity-based account of agency: agents, they argue, do not need to be human or conscious, they just need to be able to produce or express a proxy, which can be influenced by a regulatory mechanism of feedback[7]. Take the dopaminergic reward system. This system is a kind of agent that uses dopamine as a proxy for goals (such as survival) and receives feedback from an organism's meta-cognition (which acts as the regulatory mechanism of feedback, for instance, by remembering what stimuli trigger dopamine). An example of proxy failure in this system is when the proxy dopamine drives people to pursue highly caloric food, which originally supported the goal of survival but in the modern world can easily work counter to this goal by leading to negative health outcomes. In artificial agents, an example of proxy failure is when OpenAI trained a reinforcement learning agent to play a boat racing game, CoastRunners, and the agent exploited a loophole in its reward function that enabled it to get more points by crashing into certain targets than by achieving the stated goals of the race[8].

Proxy failure is not a contingent flaw but a consequence of three inherent limits: goals are rarely directly observable, futures rarely fully predictable, and choices ultimately require reduction to scalar metrics. The risk grows with complexity: the more complex the environment in which an agent operates, the greater the number of causal pathways that can produce a proxy independently of the original goal (there are many ways, for instance, we can get a dopamine hit that don't lead to the original biological goals the dopaminergic reward system evolved to motivate), making it increasingly likely that proxy goals diverge from goals[7]. The syntactic agency of AI makes proxy failure a particular risk for AI agents: humans have a semantic grounding in the world; we can often recognise that a proxy has come apart from the goal it was meant to track (e.g., that craving sugary food is no longer beneficial) and revise accordingly, even if our reaction is slow or partial. An artificial system, lacking such grounding, has no fundamental understanding from which to register that a proxy has detached from the original goal. An AI system optimising for click-through on shocking news items, for instance, has no true grounding in the meaning of the sociopolitical harm this might cause. It is down to the semantically grounded human agents in human–AI co-agency to proactively prevent failures of agency such as proxy goals diverging from original goals.

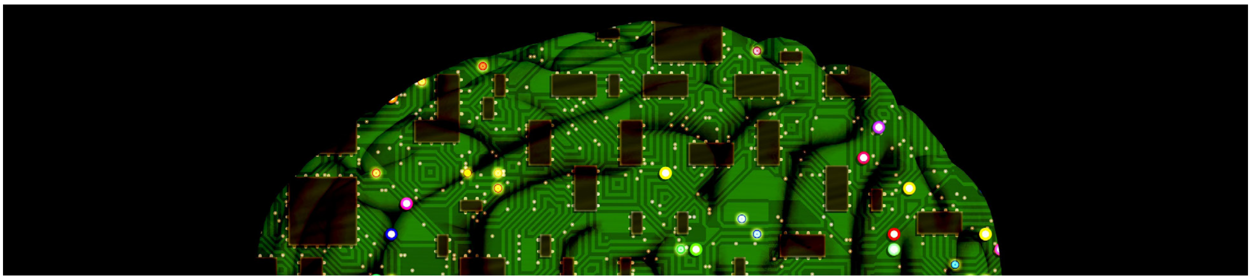
Controlling the Line of Control: How to Move Towards Beneficial Human–AI Co-Agency

Human–AI co-agency presents two key challenges: the distribution of agency between humans and AI will keep shifting in ways that are hard to predict—AI agency, as a form of artificial rather than natural agency, is likely to develop very differently from human agency—and the subgoals pursued within any given human–AI interaction may drift from the goals originally intended. Governance of AI, therefore, needs to be as dynamic as the line of control itself, and different disciplines should work together to better understand the different facets of human–AI interactions. John et al.[7], for instance, derive lessons on proxy failure and how to prevent it by synthesizing insights from neuroscience, economics, and ecology. One of their recommendations is diversification: rather than evaluating AI performance against a fixed scalar target (such as click-through on new items), a diverse and dynamically updated set of evaluation criteria should be maintained, so that no single proxy can be gamed or quietly drift from the original goal. Applied in practice, this principle can be a human team reactively revising the metrics by which an AI tool is assessed when they see it is leading to undesirable outcomes rather than just assessing the tool on deployment.

In addition to dynamic governance, interactional accountability—in which agents provide explanations for their outputs that have social meaning (e.g., by influencing trust)—is needed, and cross-disciplinary work can also help achieve this. John et al.[7], for instance, describe how higher-level regulators with a semantic grasp of a goal (e.g., humans) can constrain lower-level proxy failure in systems lacking such a grasp (e.g., LLMs), an idea they call a 'proxy cascade'. An LLM-based clinical decision-support tool, for instance, could give an account of the proxy (e.g., healthcare costs) it used to reach a decision, a decision which in turn could be judged and adjusted by a human with a grounding in the meaning and the ethical implications of the proxy (e.g., by recognizing when lower healthcare costs in a particular demographic reflect economic disadvantage, not lower healthcare needs). The cascading of goals can even work to our advantage, in what John et al. call 'proxy appropriation'. Artificial sweeteners are an example of this: they provide sweetness (a proxy for sugar) and thereby counter the evolutionary proxy failure of craving sugary food. Such proxy appropriation is an example of how human agency can use its semantically grounded understanding of the world to counteract failings of agency such as proxy failure.

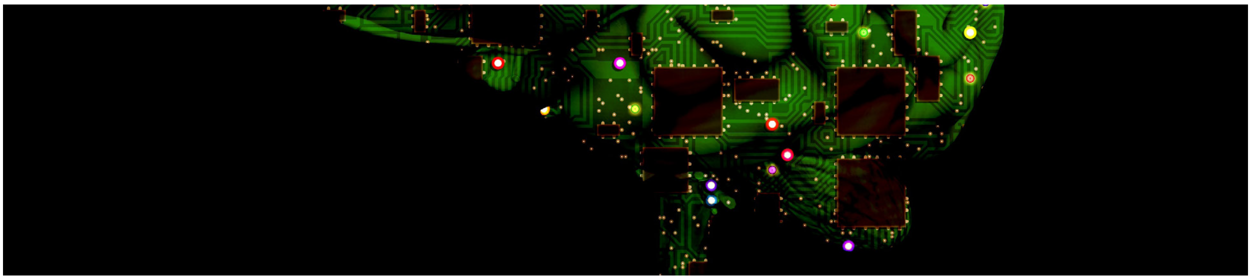
On the interactivity-grounded view of agency, our co-agency with AI is not a metaphor or a future possibility. It is already here, in every human–AI interaction. What remains is to ensure our connection with AI is a healthy one and that the line of control does not run out of control.

The outcomes of our co-agency with AI have consequences irrespective of whether the AI systems we use are truly intelligent.



ALUMNI RESEARCH

Beyond the Connected Brain



You have now reached the final section of ABC journal: alumni research. We have combed through around fifty research projects and literature theses from MBCS's most recent generation of alumni and, while it was not an easy task to choose between so many interesting projects, picked out a small subset for showcasing. Below, you will find the abstracts of five projects that are high in quality and not only reflect the overarching theme of this issue—connection—but also add to the topics discussed in its articles.

We opened this issue with articles on the importance of connection with others and what it means to connect with another person. Adding a new perspective on this, we have **Siyi Zeng**, who analyses how, depending on context, differences in social status can attenuate or amplify the role of self-monitoring in the formation of friendship. Important to friendship is empathy and **Makaela Weeda**, in a study on mice, explores its neural underpinnings and finds that targeted knockout of oxytocin receptors in the anterior cingulate cortex selectively reduces consolation behaviour, thereby shedding light on the role of oxytocin signalling in prosocial consolation. The following project (by the same author) continues the empathy theme and brings us back to the article Raving Connections through its candid literature review of MDMA's 'empathogenic' character, which reliably increases sociability and emotional resonance in rodents and humans on the one hand, but on the other, impairs recognition of negative emotions.

In keeping with the connection theme but expanding on the topics discussed in the articles, we also showcase abstracts by **Joran Paap** and **Behrang Mehrparvar**. The former concerns the bilingual experience (an experience with which many people on MBCS will be familiar) and its effects on neural networks. The project's graph-theoretic analysis of structural MRI data suggests that bilingualism drives more localised neural interconnectedness in regions supporting language control, rather than broad network-wide reorganisation. Finally, Mehrparvar's project is a literature review that organises the interbrain synchrony (IBS) and collaborative decision-making literature into four categories (e.g. correlating IBS with behaviour) while highlighting that further research on the causal relationships between IBS and decision-making is needed, for instance the effects of IBS on social factors of decision-making such as fairness or trust.

We hope you enjoy reading through these projects as much as we have. Moreover, we hope that you can take away ideas and lessons from the abstracts and the articles, be it for your own research or for practical day-to-day matters such as forming better connections with peers or being a better decision maker. Stay interdisciplinary, stay MBCS.

Joseph Harrison, on behalf of the ABC Journal Team

Self-Monitoring, Status and Friendship Formation: A Context-Dependent Mediation Model
SIYI ZENG - LITERATURE THESIS

Human social ecosystems depend on adaptive behaviors like self-monitoring, which enables individuals to regulate their actions in response to social contexts. While research links high self-monitoring to friendship, conflicting findings regarding the mediating role of perceived similarity warrant further investigation. Weis, (2017) found that perceived similarity mediates the relationship between self-monitoring and friendship in non-work settings, whereas Mehra et al., (2023) reported no such effect in workplaces. This review introduces status—an individual's hierarchical social position—as a previously overlooked mechanism that moderates how self-monitoring translates into perceived similarity and friendship ties. By synthesizing insights from personality psychology, social network theory and organizational behavior, this paper argues that status differences may amplify or attenuate the effects of self-monitoring on friendship formation, depending on the social context. This interdisciplinary framework reconciles inconsistencies in the literature and advances our understanding of self-monitoring's role in shaping interpersonal relationships across diverse environments.

Oxytocinergic Influence on Empathy-like Behaviors in the Social Transfer of Pain
MAKAELA WEEDA - RESEARCH PROJECT

Empathy-like behaviors in rodents, such as state-matching and consolation, provide a valuable model for investigating the neurobiological basis of socio-affective behaviors. Oxytocin is a key neuromodulator of social behaviors, with prior work demonstrating its necessity for consolation and ability to enhance state-matching; however, its region-specific contributions to these behaviors remain unclear. Here, we implemented the Social Transfer of Pain (SToP) paradigm, in which bystander mice acquire the pain state of an injured social partner and direct conciliatory allogrooming to the conspecific in pain, to assess the role of oxytocin signaling in state-matching and consolation. Neither systemic pre-treatment with an oxytocin receptor antagonist nor chemogenetic inhibition of oxytocin neurons in the paraventricular nucleus of the hypothalamus altered state-matching or consolation, likely reflecting methodological limitations and the context-dependent nature of oxytocin signaling. In contrast, conditional genetic knockout of oxytocin receptors in the anterior cingulate cortex (ACC) markedly reduced prosocial consolation without affecting state-matching, indicating a preferential role for ACC oxytocin signaling in prosocial behaviors. These findings underscore the limitations of systemic manipulations for inferring circuit-specific mechanisms and highlight the value of targeted approaches for dissecting the neural basis of empathy-like behavior.

Dichotomous Effects of MDMA upon Emotional and Cognitive Empathy: A Review
MAKAELA WEEDA - LITERATURE THESIS

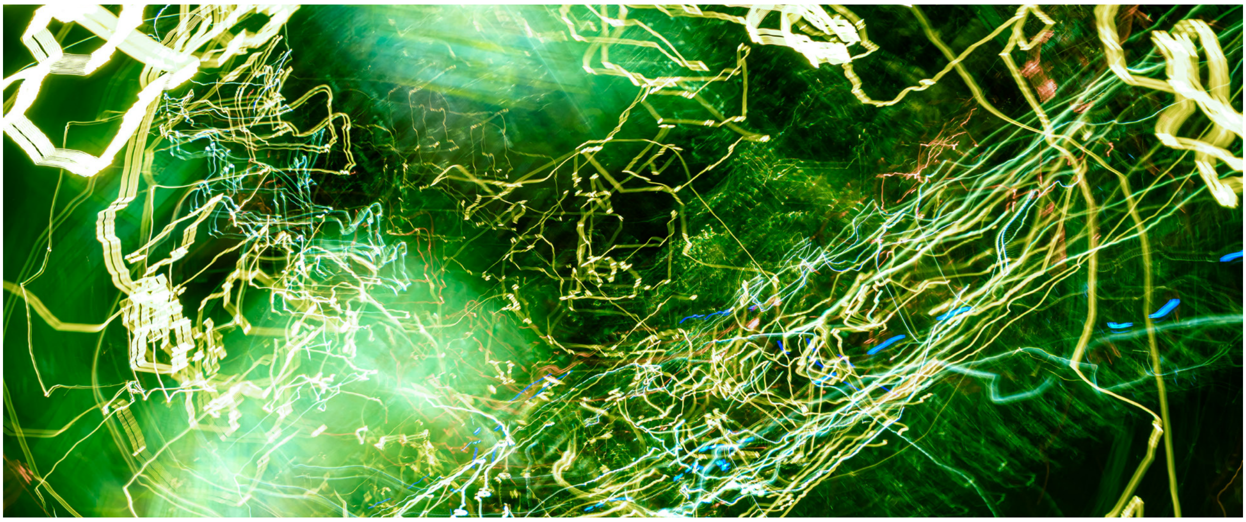
MDMA is often characterized as an "empathogen," yet its effects on empathy are complex and context-dependent. This review critically examines clinical and preclinical evidence to clarify MDMA's social effects, its neurobiological mechanisms, and implications for therapy with the aim to evaluate whether MDMA facilitates cognitive empathy and prosocial behaviors or primarily enhances sociability and emotional contagion. While MDMA reliably promotes social interaction in rodents and humans, its influence on empathy appears asymmetrical - enhancing emotional resonance and social reward while impairing accurate recognition of negative emotions. As such, MDMA-treated animals may exhibit decreased prosocial motivation, particularly in paradigms requiring recognition of distress, such as the liberation task. This aversion may reflect reduced vicarious distress or impaired emotion discrimination. Similarly, MDMA's effects on emotional contagion vary by paradigm: it enhances social transfer of pain but its impact on observational fear remains unexplored. The compound's anxiolytic and serotonergic properties likely mediate these selective effects. Recent research into MDMA's enantiomers highlights R-MDMA as a promising alternative with prosocial benefits but reduced abuse liability, likely due to its low dopaminergic activity and preferential serotonergic signaling. Together, these findings suggest that while MDMA promotes social engagement, its "empathogenic" effects are conditional, favoring positive-affect interactions while potentially diminishing engagement with or recognition of negatively affected conspecifics. Future studies should focus on delineating the neural and behavioral mechanisms underlying these effects using behaviorally specific and context-sensitive animal models. Such efforts will be critical for optimizing MDMA-based therapeutics that retain its social and anxiolytic benefits while minimizing its risks, thereby clarifying its role in clinical settings for conditions like PTSD, AUD, ASD, and social anxiety.

Bilingualism on the Grid: Effects of Bilingual Experiences on Global and Local Structural Brain Networks
JORAN PAAP - RESEARCH PROJECT

A substantial portion of the world's population is bilingual. Managing multiple languages is a cognitively challenging task, and it has been widely researched how bilingualism affects the function and structure of individual brain regions. What remains to be explored is how bilingual experiences dynamically shape the brain's structure as a network. Using the graph theoretic network approach and structural MRI scans of highly proficient bilinguals (n = 85), the current study investigated the effects of bilingual experiences on a global scale encompassing the whole-brain network, as well as a local scale involving sub-networks supporting bilingual language control. We hypothesized that more bilingual experience predicts increased whole-brain network centrality, segregation, and integration, together associated with increased efficiency. For the local analysis, we expected bilingual experience to differentially affect network properties in two sub-networks for effortful vs. automated processing. Linear modeling showed no association between bilingual experiences and whole-brain network topology. In addition, although sub-network integration and centrality were not affected, clustering increased together with bilingual experiences throughout the entire sub-network. These findings suggest an experience-driven effect of more local interconnectedness and possibly a degree of optimization within the bilingual language control network. Taken together, the present findings provide systems-level insights into how bilingualism dynamically shapes the structural networks in the brain.

Interbrain Synchrony during Collaborative Decision Making
BEHRANG MEHRPARVAR - LITERATURE THESIS

Collaborative decision making is a well-established field of study in social neuro-economics with the focus on how participants perform when they have to decide whether to collaborate or not. Several factors such as fairness, trust, and risk are involved in making collaborative decisions. Therefore, several games have been designed based on these factors to simulate common real-world decision-making situations in a laboratory setting. Interbrain synchrony, on the other hand, is a growing research field in social neuroscience which focuses on studying the synchrony between neural activations in dyads of participants, while performing a collaborative task. Decision making, as a collaborative task, has been recently studied using interbrain synchrony as an interdisciplinary research direction in the last decades. Predicting the decision to collaborate based on hyperscanning, finding the most synchronous cross-brain regions, verifying behavioral data using hyperscanning and investigating the relation between interbrain synchrony and variables that could affect collaborative decision making are some of the different categories of research questions that have been studied along this path. In this research, we perform a literature review on interbrain synchrony during collaborative decision making and present the results and our understanding of the domain. Based on our study, we can categorize the research questions followed in the literature into four main categories including (i) predicting decision to collaborate based in IBS, (ii) finding correlations between IBS and behavioral data, (iii) finding brain areas involved in collaborative decision making, and (iv) finding the relation between IBS and other variables that affect collaborative decision making. Furthermore, during our study, we found some gaps and future directions that could be pursued in this domain. While the decision to collaborate or not is being investigated through the lens of IBS, there is still research missing in studying decisions which need collaboration, mainly in cases where the required information is divided among the dyad. Also, a reverse research question, whether it would be possible to improve collaborative decisions using interbrain synchrony neuro-feedback systems is the next step. Furthermore, different psychological or social factors that result in IBS are not separately and distinctively investigated. The true nature of the interaction between IBS and collaborative decision making (e.g. causal or correlational) is not studied in this domain yet. Finally, each game/task selected for the experiments in this domain correspond to different factors that affect collaborative decision making. The effect of IBS on these factors such as trust, fairness, etc. have not been specifically illustrated through the previous research.



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Not Meant to Thrive Alone: Why We Need Connection — and How We Build It

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I'm in Love with My AI boyfriend

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