Interactional beings: the power of automatic mimicry and nonverbal cues in shaping human-human and human-robot naturalistic interactions

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CHAPTER 8

General Discussion

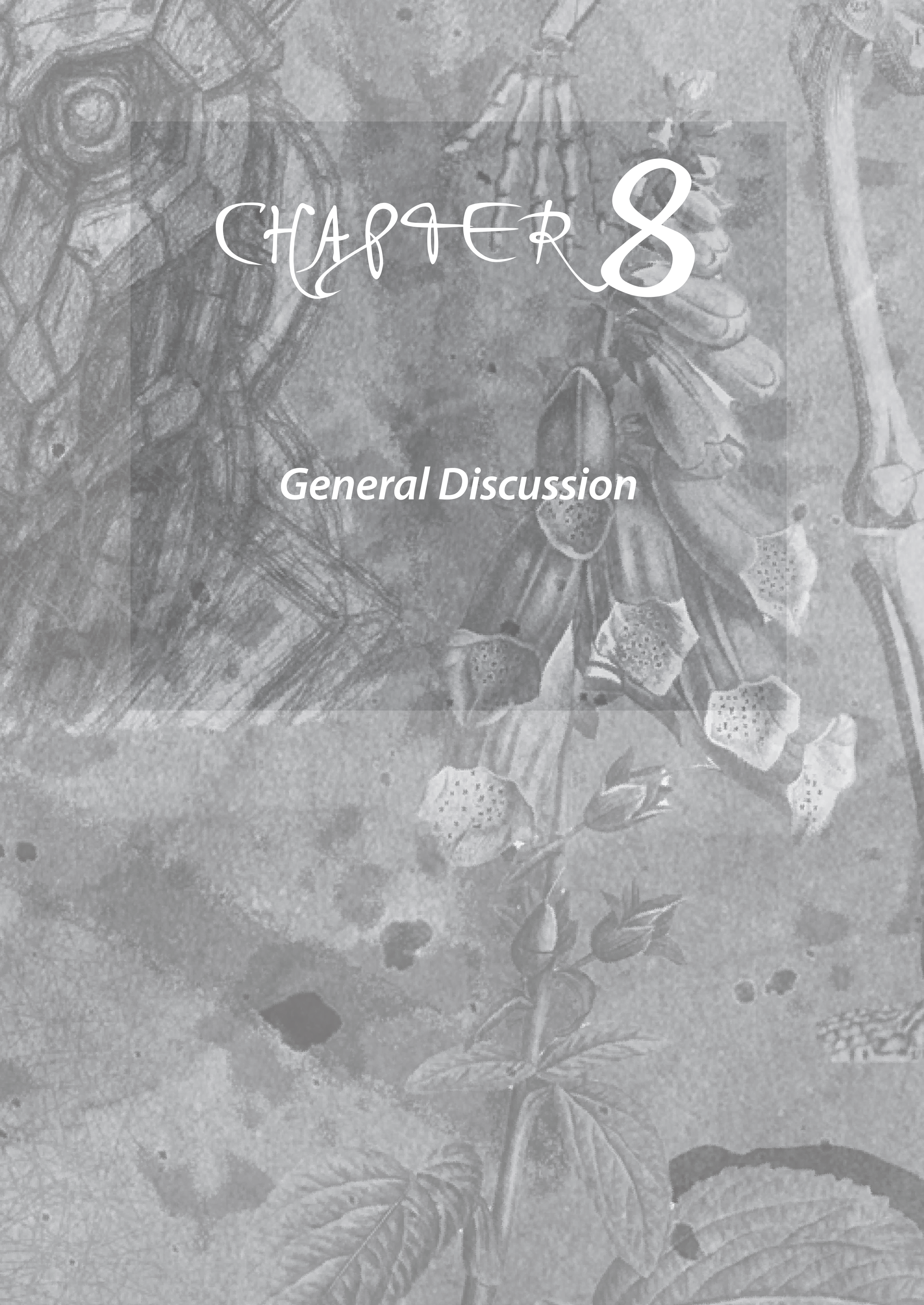


Table 2: Overview of the methodology and key findings/conclusions in each chapter

	Method	Key findings
2	Theoretical review and conceptual framework on automatic mimicry and predictive processing	• Mimicry is not solely affiliative; it occurs for positive, negative, and context-dependent expressions in humans and non-human animals • Mimicry does not always depend on an affiliative goal, and it provides adaptive benefits for the mimicker beyond social bonding • Mimicry may act as a predictive mechanism to anticipate others' actions and predict the environment
3	**Sample**: N=122 (56 females); M age = 21.47 ± 4.24; participants paired in same-sex dyads **Task**: Repeated Trust Game with fixed roles (trustor vs. trustee); trustor received no feedback **Conditions**: Face-to-face vs. Face-Blocked **Measures**: trust and reciprocity scores, skin conductance level (SCL) synchrony, synchrony lag, facial expressivity	• SCL synchrony was higher and its values were more normally distributed (lag centered around zero) in the face-to-face condition compared to face-blocked • Participants were overall more expressive in face-to-face; positive/affiliative expression more frequent in this condition; negative/controlled affect more common in the face blocked. Facial expressivity was not linked to SCL synchrony • Trustor investments were only marginally higher in face-to-face, with an order effect: trust increased when face-to-face followed face-blocked, but remained stable in the reverse order • Trustees reciprocated more when face-to-face • SCL synchrony did not predict trust. Unexpectedly, higher synchrony predicted lower reciprocity only in the face-to-face condition • The negative synchrony-reciprocity link was strongest at low trustor arousal, weaker at average, and absent at high arousal
4	**Sample**: N= 27 (19 females); M age = 21.57± 3.40; participants were paired with a same-sex confederate **Task**: Repeated Trust Game against a confederate; participants always in the role of the trustor **Conditions**: (I) Pre-recorded video, (II) Video call, and (III) Face-to-face. **Self-report**: State-Trait Anxiety Inventory scores; Interpersonal Reactivity Index **Measures**: trust scores, mimicry of target behaviors (yawning, scratching) and control behaviors (lip biting, face-touching);	• Participants mimicked more during face-to-face and video call interactions than during pre-recorded video, with surprisingly no difference between face-to-face and video call • Target behaviors were mimicked significantly more than lip-biting, but did not differ from face-touching • Overall, scratching was the most mimicked behavior, followed by face-touching, yawning, and lastly lip-biting • Empathy levels and trait anxiety were not associated with mimicry • Trust was higher in face-to-face and video-call interactions than in the pre-recorded condition, with no difference between face-to-face and video call • Mimicry was only marginally negatively associated with trust

Table 2: continued

	Method	Key findings
5	**Sample**: N = 320 (online); Dutch: n=158 (96 females), M age= 32.2 ± 13.7; Japanese: n=162 (83 females), M age = 33.6 ± 10.7 **Task**: Implicit Association Test (IAT) measuring human–robot associations via speeded categorization of words and pictures (humans, virtual avatar, robots); Exp. 1 used same-culture faces, Exp. 2 used cross-cultural faces. **Self-report**: Negative Attitudes Towards Robots Scale (NARS) **Measures**: IAT D-score (implicit attitude); NARS subscale scores (explicit attitudes)	• Japanese participants reported overall more positive attitudes towards artificial agents than Dutch participants. The effect was driven by Subscale 3 (emotions) in Exp. 1, and Subscale 1 (social interaction) in Exp. 2 • Both Japanese and Dutch participants showed a slight implicit preference for humans over robots and avatars. No difference between nationalities or between robot vs. avatar IAT scores was observed • No robust effect of robot body type on implicit attitudes; a small preference for human-like robots was found only for Dutch participants in Exp. 1 • Explicit and implicit attitudes were positively correlated only for Dutch participants (higher NARS = stronger implicit human preference). No significant correlations were found for Japanese participants
6	**Sample**: N=275; European: n = 96 (lab), n = 104 (general public), 122 females, M age = 25.84± 9.19; Japanese: n = 75 (lab), 36 females, M age = 22.40±5.30; participants were paired with a same-sex confederate **Task**: Modified Coin-Toss Game reporting correct/incorrect predictions for monetary reward **Conditions**: Three agent types (human, virtual human-like avatar, physical machine-like robot) × two pupil sizes (large vs. small). **Self-report**: rating of agency, experience, and attractiveness of the agents **Measures**: Dishonesty, physiological arousal (pupil diameter), fixations, self-report rating	• European participants were more honest towards humans than avatars and robots; Japanese participants showed no difference across agent type • Dishonesty towards avatars was modulated by pupil size in a culturally-specific way: Europeans lied more to avatar with large pupil size, Japanese lied more to avatar with small pupil size. No pupil effect for humans or robots • Pupil dilation responses differed by agent type (decreasing before avatar decisions, increasing before human decisions), but did not explain cultural differences in dishonesty • Europeans looked slightly longer at the avatar with large pupil size, while Japanese gaze did not vary; controlling for fixations did not explain pupil-size effects
7	Theoretical opinion paper	• The opinion paper proposes a bottom-up evolutionary perspective for social robotics that focuses on robot-robot interaction • We report efforts from the literature on evolutionary robotics and multi-agent hormonal modulation to reveal emergent social behavior in artificial systems • We encourage more dialogue between biology, robotics, and neuroscience to help us understand more about the evolution of social behaviors through robots

The goal of this dissertation was to investigate whether and how nonverbal cues and their mimicry shape various forms of prosocial behavior, and how these effects depend on the interaction context and the specific cues involved. Is mimicry always prosocial, or does its influence vary with the type of interaction or the meaning of the cue mimicked? Do nonverbal cues and mimicry operate similarly in digital or human-robot interaction? And what role does cultural background play in shaping these processes? I addressed these questions through an interdisciplinary lens, combining empirical investigation in a series of naturalistic studies with diverse samples and settings, as well as a theoretical review and a perspective paper. Over six chapters, I trace the effects of nonverbal cues and their mimicry from direct human-human interactions to video-mediated communication, and finally to interactions with artificial agents. Together, they provide direct contributions to the current literature on automatic mimicry, cross-cultural emotional processing, and culturally-sensitive agent design. In the remaining section, the main findings from both conceptual and empirical work are integrated (Table 1), and their theoretical implications and methodological considerations are discussed. The final section highlights the limitations of the present work and outlines directions for future research.

Theoretical implications

Beyond the affiliative and prosocial nature of mimicry

Most theories explaining automatic mimicry have framed its function in affiliative or prosocial terms. As in, mimicry serves as a tool to affiliate with others (Lakin & Chartrand, 2003). Despite their distinctions, these accounts converge on a common theme: mimicry is bound to affiliative contexts, goals, or prosocial outcomes (Hess & Fischer, 2022; Lakin et al., 2003; Wang & Hamilton, 2012). This view has been supported by studies showing that mimicry is more frequent in affiliative contexts (Lakin et al., 2003; Seibt et al., 2015), stronger for affiliative compared to non-affiliative expressions (Olzanowski & Topilo, 2024), more common towards ingroup members (van der Schalk et al., 2011a), and predictive of prosocial and affiliative outcomes (Wessler et al., 2024).

The empirical findings of this dissertation challenge this established view, aligning with the emerging consensus that mimicry does not invariably yield prosocial outcomes (Mayo et al., 2021; Palumbo et al., 2017; Wood et al., 2021). In **Chapter 3**, physiological synchrony during a trust game was not associated with greater reciprocity from the trustee; on the contrary, higher synchrony predicted less reciprocity. In addition, synchrony was not associated with the trustor's investment. This suggests that autonomic mimicry in our experiment did likely not reflect a drive to prosociality or cooperation. **Chapter 4** showed again no evidence for a uniformly positive effect of mimicry. Motor mimicry of stress-related or ambiguous behaviors (e.g., scratching, yawning, lip biting) did not increase trust. No overall positive effect of mimicry on trust emerged, and if anything, the data hinted at a marginal negative effect. While this effect was non-significant, likely due to the small sample size, it is nevertheless worth mentioning because this could be functional too: negative signs are picked up and the interaction is ended before more time and energy has been wasted.

These findings converge with research showing that mimicry, across levels, is not uniformly affiliative or prosocial. Rather, as I argue in **Chapter 2**, its effects may vary depending on the cue involved and the broader social context. For instance, mimicking a smile fosters attraction and trustworthiness (Arias-Sarah et al., 2024; Fasya et al., 2024), whereas attending to or mimicking an angry facial expression promotes aversion and avoidance (Campellone & Kring, 2013; van der Velde et al., 2010). At the autonomic level, the mimicry of pupil dilation is associated with higher trust (Kret & De Dreu, 2019; Prochazkova et al., 2018a), while mimicking pupil constriction – which may signal disengagement or boredom – correlates with decreased trust (Kret & De Dreu, 2017; Wehebrink et al., 2018a). Autonomic synchrony can also heighten in both cooperative, competitive, and stressful situations (Danyluck & Page-Gould, 2019; Spapé et al., 2013; Vanutelli et al., 2018), potentially reflecting both cooperation and tension (Behrens, Snijdewint, et al., 2020; Mønster et al., 2016). Additional results from **Chapter 3** further corroborate this perspective: the negative association between synchrony and reciprocity emerged only when trustees attuned to trustors with low arousal, remained significant at average arousal, and disappeared entirely at high arousal. This suggests that synchrony may amplify and transmit states across partners regardless of whether those states are positive or negative (Wood et al., 2021). The very fact that humans mimic negative, neutral, or ambiguous expressions and synchronize on negative affective states suggests that automatic mimicry may not be restricted to positive expressions, situations, or goals.

Comparative research on non-human animals reinforces this point. Behaviors such as yawning or scratching, which are often overlooked in human research, are highly contagious and phylogenetically conserved across species. Yet, their valence is highly dependent on the context in which they occur. It was precisely this contextual flexibility that motivated the choice of yawning and scratching as target behavior in **Chapter 4**. Contagious scratching, for instance, increases in potentially stressful contexts (e.g., the presence of an unfamiliar conspecific) (Feneran et al., 2013) but can also occur in positive situations like play (Neal & Caine, 2016). Similarly, contagious yawning has been linked both to social bonds (Norscia & Palagi, 2011) and to stress (Paukner & Anderson, 2006), with evidence suggesting that its meaning may also vary across different displays (Leone et al., 2014). **Chapter 6** further underscores the contextual flexibility of nonverbal cues: the same cue – large pupil size – elicited different behaviors in Japanese and European participants. If identical cues can trigger divergent responses depending on factors such as group membership or cultural background, it is reasonable to expect that the mimicry of these cues will also vary accordingly. Collectively, these findings suggest that ***what*** we attune to, and in which context, may matter as much as the fact that we attune at all.

Mimicry as a tool to predict the (social) environment

Considering the evidence in the literature and the findings in the dissertation, the question that motivated **Chapter 2** was: if humans also mimic negative expressions and in negative contexts, why do they do so? It cannot solely be to affiliate. Beyond the fact that mimicry occurs for negative expressions and in conflicting situations, I argued that emotional expressions, which are often (but not always!) the subject of mimicry, serve crucial adaptive purposes for the expressor. For instance, the facial configuration associated with disgust, characterized by a wrinkled nose and raised upper lip, functions to limit the intake of poisonous substances in the nose and throat (Curtis et al., 2011). The widened eyes typical of fear are advantageous to enhance the visual field and facilitate the detection of potential threats in the environment (Susskind et al., 2008). Comparable adaptive functions can be found in antipredator vigilance behaviors (Iki & Kutsukake, 2021): individuals scan the surrounding environment to detect potential threats coming from predators or conspecifics (Favreau et al., 2010). If expressions carry adaptive value for the sender, then mimicking them may provide parallel adaptive benefits for the observer (i.e., detecting threats more effectively).

From this perspective, I proposed that mimicry can be understood not only as a route to affiliation but also as a mechanism to ease the prediction of the environment and those around us via sensorimotor simulation. In complex social environments where uncertainty is costly, mimicking others may reduce that uncertainty by fostering shared alignment between individuals and improving predictions about the environment. Mimicking conspecific scratching or fearful expressions, for example, may enhance vigilance (McDougall & Ruckstuhl, 2018; van Berlo et al., 2020), thereby increasing the likelihood of detecting and escaping threats. The same reasoning applies to more positive interactions: rapid facial mimicry of play faces in primates can prolong playful exchanges (Llamazares-Martín et al., 2017; Mancini et al., 2013; Palagi et al., 2019), even if it's preceded or followed by more offensive attack patterns (Cordoni et al., 2024). In this case, through mimicry, individuals may make themselves more predictable whilst easing the prediction of their partner's emotional states, reducing ambiguity and minimizing the risk of escalation into aggression, especially in unpredictable interactions such as play-fight (Cordoni & Norscia, 2024; Facondini et al., 2024). Together, these examples highlight that the predictive account of mimicry offers a comprehensive framework that accommodates positive, negative, and context-dependent expressions.

It is important to note that **Chapter 2** was placed at the beginning of the dissertation because it provides a broad overview of mimicry across modalities, expressions, and species. However, it was written retrospectively, in light of the findings from **Chapters 3–6** and of recent comparative studies converging on similar perspectives (Cordoni et al., 2024; Facondini et al., 2024). As such, the empirical chapter of this dissertation is not designed to provide definitive evidence for the predictive function of mimicry, and in the review, I outlined several ways to test this hypothesis, such as integrating mimicry assessment into experimental studies that test social predictions in interaction (Haroush & Williams, 2015; Morimoto & Fujita, 2012; Waller et al., 2016). The key message, however, is that prediction offers a complementary explanation to affiliation as an ultimate cause for mimicry. Mimicking may help us gather more information about others, ultimately enabling us to navigate our surroundings more efficiently, whether through improving social interactions or avoiding potential dangers. Returning to the "social glue" hypothesis (Lakin et al., 2003), which suggested that mimicry's function shifted from survival to "social survival" (i.e., fostering group affiliation), I believe its original adaptive function may never have shifted at all.

Insights into the mechanism of mimicry

The results of this dissertation also add an important piece to the puzzle of the mechanisms through which automatic mimicry, at different levels, may work. Across experimental paradigms – from face-to-face (**Chapter 3**) to video-mediated interactions (**Chapter 4**) – I observed that the emergence and effects of automatic mimicry are highly sensitive to the interactive nature of the context.

Supporting previous literature (Behrens, Snijdewint, et al., 2020; Tang et al., 2015), in **Chapter 3,** I found that skin conductance synchrony was higher when participants could see each other compared to when visual access was blocked. Temporal lag exploration revealed that while the distribution of synchrony lags was irregular and dispersed in the face-blocked condition, it followed a quasi-normal distribution centered around zero in the face-to-face condition. This indicates that, when mutual visibility was available, synchrony was not only higher but also more stable in time. Visual access thus appears to enhance physiological synchrony, likely by enabling participants to make ongoing, moment-to-moment adjustments to each other's signals. But what exactly are the cues that individuals pick up from one another in these visual exchanges? The data I collected could not provide a definitive answer. When exploring facial expressions, participants were indeed more expressive in the face-to-face condition, particularly on factors related to affiliative smiles, conversational cues, and negative affect. Yet, facial expressivity alone did not correlate with synchrony, suggesting that facial expressions may not be the sole drivers of physiological coupling, and other cues, such as pupil size, may have played a role in fostering alignment among our dyads. The functional relevance of visibility is also reflected in the effect of synchrony on social behavior: in the trust game, skin conductance synchrony predicted trustees' reciprocity, but only in the face-to-face interactions. Even though synchrony ***can*** emerge without visual contact (Ferrer & Helm, 2013), our findings suggest that an interactive context may be essential for synchrony to carry social meaning and inform intuitions.

Motor mimicry exhibits a similarly context-sensitive pattern. In **Chapter 4**, I found that mimicry was significantly reduced in pre-recorded video interactions compared to both video calls and face-to-face interactions. Pre-recorded videos lack the bidirectional exchange of cues that characterizes live interaction, limiting opportunities for moment-to-moment tuning of behavior. Video calls, by contrast, support reciprocation, allowing mimicry even in the absence of physical co-presence. Interestingly, mimicry levels did not differ between video calls and face-to-face interactions. While this diverges from some previous research suggesting reduced communication quality in digital contexts (Duffy & Benotsch, 2025; Fauville et al., 2021), it aligns with multiple studies demonstrating the occurrence of automatic mimicry and emotional alignment between video calls and in-person interactions (Gvirts et al., 2023; Marx et al., 2025). Interestingly, although confederates followed scripted behaviors, they still unconsciously mimicked participants, highlighting the phenomenon's automaticity.

From an evolutionary perspective, these findings are consistent with the notion that mimicry is an automatic, ancient, and conserved mechanism (**Chapter 2**). Even though mimicry likely confers the most evolutionary advantage in physically co-present groups, the automatic tendency to mimic others persists even in contexts where consequences in the immediate social environment are absent, such as viewing strangers on a screen (**Chapter 4**). A trait persists as long as it does not confer substantial fitness costs. That is, even if contagious scratching may be more relevant among physically co-present individuals, the neural and motor system underlying automatic mimicry remains responsive to the perception of these behaviors. This reflects the persistence and flexibility of automatic mimicry even in technologically mediated environments.

The classic explanation for the mechanism of mimicry, the Perception-Behavior Link (Chartrand & Bargh, 1999), proposes that observing someone performing a behavior activates the mental representation of that behavior, which increases the likelihood of mimicking it without awareness. However, such a stimulus-response view may be too simplistic to explain the dynamics observed in this dissertation. Mimicry here did not merely follow the exposure to a stimulus but varied with the interactive affordances of the context. In pre-recorded video interactions, mimicry was substantially reduced relative to both video calls and face-to-face encounters (**Chapter 4**). This suggests that mimicry may depend not just on perceptual input, but on the opportunity for reciprocal exchange. Contemporary models like the Neurocognitive Model of Emotional Contagion (Prochazkova & Kret, 2017a) offer a richer perspective. According to this model, a target's affective state resonates in nonverbal behavior and physiology, which may activate corresponding neural representations in the observer, resulting in motor and autonomic mimicry. Importantly, this process accumulates across modalities – facial, bodily, vocal, physiological – potentially leading to emotional contagion.

In sum, the emergence and effects of automatic mimicry in its different forms appear to be dependent on the availability of an interactive context, even when mediated by digital technologies. The persistence of mimicry even for behaviors that lack immediate adaptive significance – like scratching in video calls – reflects the evolutionary durability and flexibility of these mechanisms.

Cultural modulation of nonverbal cues perception in human-agent interaction

Chapters 3-4 highlighted the automatic and functional role of mimicry in human–human interactions, both in face-to-face and digitally mediated contexts. Recent work has extended these ideas to human–robot interaction, showing that when robots or avatars mimic human behavior, they are often judged as more positive, likable, and trustworthy (Fasya et al., 2024, 2025; Sejima et al., 2024). Yet, as reviewed in **Chapter 2**, we know that ***what*** we mimic – such as a smile (Hess & Bourgeois, 2010) or vigilance behavior (Iki & Kutsukake, 2021) – and ***who*** we mimic – such as ingroup ***vs***. outgroup member (van der Schalk et al., 2011) can change the effect that mimicry exerts on the interaction. What happens to "***what***" we mimic when the "***who***" is an artificial agent, perhaps with features that are far from humanoid? Are we sure that we will perceive the same cue (e.g., pupil size) regardless of whether the entity displaying it is human or not? This has crucial implications for the implementation of mimicry in human-robot interaction research: if we do not know how nonverbal cues are perceived when emitted by robots and avatars, we cannot fully understand their impact, and the effects of their mimicry, on (pro) social behavior. Cultural differences are further complicating the matter. Cultural background affect all core domains of this dissertation: frequency and duration of mimicry (Chuang & Fujiwara, 2024; Semnani-Azad et al., 2019), perception of nonverbal cues (Kawahara et al., 2021), prosocial behavior (Hugh-Jones, 2016), and attitudes towards artificial agents (Nomura, 2017). **Chapters 5 and 6**, therefore, shifted focus towards implicit and explicit attitudes towards artificial agents across cultures, and how subtle nonverbal cues, such as pupil size, may shape prosocial behavior in interaction with avatars and robots.

Chapter 5 showed that cultural background not only shapes how artificial agents are evaluated, but also that explicit and implicit measures may diverge (MacDorman et al., 2009). Japanese participants reported overall more positive attitudes towards artificial agents than Dutch participants, particularly concerning emotional engagement and social interaction. Yet, at the implicit level, both groups preferred humans to artificial agents, and neither culture displayed a preference for avatars over robots or for human-like versus machine-like morphology. This dissociation suggests that while cultural exposure may foster explicit acceptance of artificial agents, implicit evaluations may remain more resistant to change, reflecting more rooted default mechanisms of social cognition. Crucially, these differences may matter for how nonverbal cues and their mimicry are processed: if artificial agents are explicitly seen as more social partners (as in Japan), the nonverbal cues they express may be interpreted differently, resulting in mimicry that can be more or less frequent and impactful on behavior.

Building on this foundation, **Chapter 6** showed that subtle cues such as pupil size modulate prosocial behavior towards artificial agents in a cross-cultural fashion. While Japanese participants deceived less when avatars displayed large pupils, consistent with prior findings that pupil dilation can discourage dishonesty (van Breen et al., 2018), European participants showed the opposite pattern. Less exposure to artificial agents may have led them to perceive the avatar as socially inconsequential, and without a physical body, it likely did not appear as a partner who could be harmed (Ahmad & Refik, 2022). According to van Breen et al. (2018), pupil dilation reduces dishonesty only when lying harms the partner; when it does not, large pupils can instead increase defection. Hence, large pupils may signal permissiveness, reducing guilt and facilitating cheating. For Europeans, the avatar's large pupils, combined with its perceived social inconsequence, thus likely acted as a "permission cue." Japanese participants, in contrast, were more honest when the avatar had large pupils. This may reflect greater familiarity with artificial agents, leading them to perceive the avatar as more socially consequential. Another complementary explanation is monitoring: large pupils cansignal attention, increasing the likelihood of a reaction if the individual displaying them is deceived. Cultural familiarity may amplify this effect, such that Japanese participants interpreted the avatar's pupils as "the avatar is watching," whereas Europeans did not. While van Breen et al. (2018) dismissed monitoring as an explanation, more research may be needed to clarify how nonverbal cues like pupil size are interpreted across cultures and contexts.

Theoretically, this has important implications for mimicry (**Chapter 2**). If the meaning of a cue varies by culture and context, then mimicking that cue is likely to have different consequences. Research on how nonverbal cues are interpreted and reacted to across contexts and cultures is, therefore, a necessary precursor to studying their mimicry, ultimately helping us to predict the social effects of mimicry and clarify how mimicry may flexibly support predictive or affiliative functions. Especially in interactions with artificial agents, this would help predict when and how mimicking agent behavior – such as dynamic pupils or other subtle signals – will influence human responses.

Toward a robot-robot interaction

In most social species, much of the social interaction, from the exchange and the mimicry of nonverbal cues to cooperation, happens with conspecifics. While interspecies interactions, with all their facets, exist, the bulk of social behavior mostly occurs within species. This made me wonder about social robots: we aim to build robots that can interact with humans, yet many robots considered "social" – especially those from pop culture that inspired the social robotic field – actually demonstrate social behaviors also through interaction with each other. This sparked my curiosity about the state of research on robot–robot ***social*** interaction. Discovering the work of Prof. Lola Cañamero, I realized that while I'm deeply fascinated by social robotics focused on human-robot interaction, the branch exploring how social behavior emerges among robots themselves is equally captivating. In **Chapter 7**, I briefly sketch what I see as an exciting future for social robotics – one that embraces an evolutionary and interdisciplinary perspective on social behavior in robots.

The attempt to "model sociality" in an artificial entity comes with a basic, yet extremely complicated question: what is sociality even? What are the core mechanisms of sociality, and how do we identify them? We did not presume to answer these fundamental questions but rather aim to spark dialogue and speculate on some initial ideas to explore this complex topic. For instance, a central criterion proposed was that core mechanisms of sociality should be observable across taxa. This could ensure that the mechanisms identified as foundational to sociality are not idiosyncratic to a single lineage or niche adaptation, but instead reflect convergent or conserved biological strategies found across social species. Of course, given evolutionary complexity, it is unrealistic to expect any mechanism in every species within a large taxon like primates. A more precise formulation would be that a candidate mechanism for core sociality should be observable in a wide, representative sample of distantly related taxa, suggesting deep evolutionary roots or strong selective advantages. The requirement for presence in "phylogenetically distant species" highlights mechanisms with ancient origins or independent emergence in evolution. This conversation would hint at solutions repeatedly adapted for sociality, making them strong candidates for building synthetic sociality. Better defining complex social behavior is also important. Complexity here refers to social outcomes like coordinated roles, stable group structures, or cooperation, which can emerge from simple mechanisms – e.g., bacterial quorum sensing (Madsen & Sørensen, 2018) or studies on social amoebas like ***Dictyostelium discoideum*** (Parkinson et al., 2011). Regarding adaptability, while not all social behaviors are universally adaptive (Tian & Liu, 2024), focusing on adaptability emphasizes mechanisms that enhance robustness and flexibility in changing environments without assuming all traits are adaptive. Despite evolutionary robotics' promise to experimentally explore these mechanisms, challenges in scalability, realism, and cross-domain transfer remain. These limitations call for open, interdisciplinary discussion on identifying sociality's fundamental building blocks and investigating them through integrated approaches across biology, robotics, and evolution.

Methodological considerations

The studies in this thesis employed diverse methodologies spanning multiple measurement levels, such as observable behavior (e.g., facial expressions), reaction times, physiological responses (e.g., pupil dilation, skin conductance, heart rate), and self-reported measures (e.g., attitudes, empathy). They involved various participant groups (European and Japanese samples; students and the general public) and took place in different experimental settings, including online platforms, laboratories, and public spaces. Tasks varied as well, ranging from dyadic economic games with naïve participants or confederates to computer tasks. The setups differed in ecological validity, from tightly controlled laboratory environments to naturalistic public data collection. Throughout, I employed numerous manipulations (face-to-face vs. face-blocked interaction, live vs. video calls, different artificial agents, pupil size adjustments) and analyzed multiple outcome measures such as trust, reciprocity, honesty, physiological synchrony, behavioral mimicry, gaze patterns, and questionnaire responses. By applying a range of methods and comparing results across studies, this thesis offers valuable methodological insights and future directions into the study of automatic mimicry and prosocial behavior in naturalistic settings.

A central methodological theme across these studies is the trade-off between experimental control and ecological validity. A key strength of the studies presented in this dissertation lies in their use of real dyadic interactions. While phenomena such as automatic mimicry and prosocial behavior have often been explored in computer-based tasks (Bourgeois & Hess, 2008; Kret et al., 2015; Murata et al., 2016; Rauchbauer et al., 2016; Sun et al., 2019), conducting research using direct face-to-face (**Chapters 3, 4, 6**) or mediated interactions (**Chapter 4**) allows the investigation within a dynamic, reciprocal context. Live interactions capture the continuous bidirectional flow of social cues – including facial expressions, gestures, and subtle physiological responses – which likely evolved to function with co-present partners. Thus, studying these phenomena in live settings offers a more ecologically valid context that better reflects the interactive and adaptive nature of human social behavior, which may not fully manifest in computer-only paradigms (Reader & Holmes, 2016). At the same time, these studies required a degree of experimental control to ensure standardization and comparability across participants. For instance, participants were often not allowed to talk (**Chapters 3, 4, 6**), interactions followed strict temporal structures (**Chapters 3, 4, 6**), behavior was constrained by specific task instructions (**Chapters 3, 4, 6**), and some manipulations involved artificial stimuli (**Chapter 6**). Although the research extended beyond student samples and prioritized ecologically valid conditions, the studies inevitably retained certain artificial, lab-based features. These constraints facilitated precise measurement and isolation of specific variables but reduced the spontaneity of the interaction and may limit the generalizability of findings to everyday social interactions.

A further methodological consideration in this direction applies to the use of confederates (**Chapters 4, 6**), a technique traditionally employed in mimicry research (Lakin & Chartrand, 2003; Pickering & Garrod, 2007; Wessler et al., 2024). Confederates offer a valuable compromise between ecological validity and control: they allow participants to still interact with a real partner, whilst introducing a level of experimental control that would be impossible in spontaneous dyadic interactions. For instance, in **Chapter 4**, using a confederate allowed us to time-lock the occurrence of specific target behaviors, making it possible to precisely test mimicry rather than rely on chance occurrences. Similarly, in **Chapter 6**, confederates were essential for pupil size to be manipulated. Concurrently, this approach inevitably introduced challenges, since even trained confederate could not suppress their unconscious reaction, such as mimicking the participants back (**Chapter 4**). I attempted to avoid such spontaneous reactions in **Chapter 6** by having confederates wear contact lenses that impaired their vision, making them less able to pick up and mimic subtle cues. This manipulation worked, but it also introduced a new problem: participants often perceived the confederate as odd or unresponsive, which likely altered the flow of the interaction. This highlights both the value and the limitation of confederates: they make it possible to isolate key variables in dyadic interactions, but they also remind us that human behavior cannot be fully scripted without some loss of ecological validity.

An additional issue of **Chapter 4** that may threaten the ecological validity of the study relates to the spatial arrangement: even in the video call condition, participants and the confederate were in the same physical room, separated only by a partition. Although required by logistical constraints, this design choice may have contaminated the manipulation, resulting in the lack of difference between face-to-face and video calls, since sharing an environment is atypical of real video calls. Previous work suggests that scratching contagion may depend on spatial proximity (*Tibetan macaques*: Zhang et al., 2022), while yawning appears less tied to proximity (*gedala baboons*: Palagi et al., 2009; ***wolves***: Romero et al., 2014). Whether similar effects apply in human interactions remains an open question, but my data cannot exclude that sharing an environment could play a role in shaping how behaviors such as scratching and yawning are mimicked.

A methodological innovation of this dissertation lies in the sampling approach adopted in **Chapter 6**. To overcome the frequent critique that psychological research relies too heavily on student populations – who are usually younger, WEIRD (Western, Educated, Industrialized, Rich, Democratic) (Henrich et al.,

2010) – I complemented the lab-based student sample with data collected from the general public. This was made possible through a mobile laboratory (a van equipped for psychophysiological research), which allowed us to recruit and conduct the experiment outside the lab and reach participants across a wider age range. This approach not only broadened the demographic base of our research but also demonstrated the feasibility of implementing technically demanding methods in field settings. However, this choice did not come without challenges. To adapt to the field context, the protocol was shortened: the number of trials of the coin-toss game was halved, and trait questionnaires were omitted. As a result, although the overall number of participants was equivalent across student and general public samples, the effective statistical power of the latter was reduced. This may explain why a significant difference in dishonest behavior, which I would have expected, did not emerge between the two groups. Another point to consider is the educational background of the participants. A frequent critique of the student sample is that, being highly educated, they are also more likely to come from higher socioeconomic (SES) backgrounds. This can create a bias in psychological research, as individuals from lower SES are underrepresented. To address this, I recruited in a more neutral environment, namely, the market of Leiden. Surprisingly, the general public sample was still highly educated – even more so than the student population. This suggests that testing outside the lab does not necessarily guarantee a sampling that deviates from the WEIRD standard: individuals who approach or agree to partake in scientific studies outside the lab may still represent a selective subgroup of society, highlighting the need for additional strategies to ensure more diverse recruitment across socio-economic strata and cultural backgrounds.

Finally, an important methodological aspect worth mentioning concerns the paradigms used to operationalize social constructs such as trust, reciprocity, and honesty. The repeated Trust Game (**Chapter 3, 4**) is a widely used paradigm for studying trust and reciprocity (Cesarini et al., 2008; Innocenti & Pazienza, 2006). Compared to other games where players make a decision simultaneously, the Trust Game has the advantage of reflecting the inherent asymmetry of trust decisions, where one party invests its own resources in the hope that the other party will reciprocate. A crucial methodological choice was that the trustor did not receive feedback about whether their investment was reciprocated, both in **Chapters 3 and 4**. This aimed to prevent decisions from being solely guided by previous outcomes, making the task a closer match to real-life blind trust decisions, where feedback is not immediately available. However, this lack of feedback also changed the reciprocal nature of the task: without knowing if their trust was returned, trustors could not link their intuition to actual (un)trustworthy behavior. Although automatic mimicry between players still occurred in both experiments, it did not guide trustors' decisions, potentially because it lacked predictive utility in this setting (**Chapter 2**). This choice has important implications: while mimicry at different levels may occur without feedback, its influence on social behavior may diminish. Notably, the only other study directly manipulating feedback in a cooperative paradigm found no main effect of feedback on cooperation (Behrens, Snijdewint, et al., 2020), but did not test its moderating role on the synchrony–cooperation link, suggesting a need for future research.

In **Chapter 6**, dishonesty was measured using a modified coin-toss game, a well-established paradigm to investigate lying behavior (Cohn et al., 2022; Greene & Paxton, 2009a). The primary reason for selecting this task is its ability to simulate real-world scenarios where individuals perceive their lies as undetectable (Gerlach & Teodorescu, 2022). This makes the paradigm particularly suitable for the assessment of dishonesty in interactions with both humans and artificial agents, where participants may feel more prone to misreport outcomes without fear of being exposed. In line with previous findings (Shalvi et al., 2011), most participants did not lie maximally but instead displayed moderate dishonesty, suggesting that the paradigm captures a realistic pattern of self-serving yet self-limiting deception. At the same time, the coin-toss game is a non-traceable measure. Hence, I can infer dishonesty at the group level, but it is impossible to determine exactly which specific responses are lies or at what moment participants deceived. This limits the possibility of linking dishonesty to dynamic cues within the interaction, such as subtle nonverbal expressions or physiological changes. Although our manipulation checks confirmed that participants across cultures did lie, the nature of the task constrains the precision with which dishonesty can be linked to interpersonal processes. Future research could benefit from incorporating more traceable dishonesty paradigms (Heyman et al., 2020), which allow for a precise assessment of when and how cheating occurs. To balance the ecological validity of non-traceable tasks with the analytic precision of traceable ones, several methodological innovations might be considered. These include combining traceable and non-traceable tasks within the same study, implementing partial traceability so that at least some instances of dishonesty can be verified, or even employing strategic deception such as telling participants that their behavior is monitored when it is not. Such approaches could help to better disentangle when and why people choose to deceive others, and to more effectively link dishonest responses with observable behavior and physiological measures.

In sum, the methodological innovations of this dissertation, ranging from real dyadic interactions to mobile field experiments, demonstrate the value of combining ecological validity with experimental control. At the same time, challenges such as reduced spontaneity, sampling biases, and task constraints highlight the need for continuous refinement. Together, these considerations point to promising directions for studying social behavior in contexts that more closely mirror everyday life and in more inclusive samples.

Limitations and Future Directions

While the studies in this dissertation provide valuable insights into automatic mimicry, perception of nonverbal cues, and prosocial behavior towards human and artificial agents, several limitations should be acknowledged, alongside opportunities for future research.

First, I did not observe robust heart rate synchrony (**Chapter 3**): real dyads did not differ from pseudo dyads. This is not entirely surprising, as synchrony is not expected to emerge uniformly across modalities or across every interaction (Mønster et al., 2016; Wood et al., 2021). However, it raises the important question of whether different contexts may differentially support the emergence of specific types of synchrony, and under what circumstances these influence behavior. Future research should explicitly test how contextual factors shape the conditions under which different forms of synchrony arise. Differently, skin conductance synchrony was instead different between real vs. pseudo dyads, and it was higher in face-to-face compared to face-blocked interactions, but the effect size was smaller than in previous studies (Behrens, Snijdewint, et al., 2020; Tang et al., 2015). This was likely due to the small number of trials in the task. The experiment was co-designed together with colleague Julia Folz, with the explicit goal to test the paradigm both in control groups and clinical populations, including individuals with social anxiety and autism. Consequently, the number of trials was deliberately limited to six per condition. While this inevitably reduced statistical power, the decision was important to keep the study duration tolerable for the clinical sample, but also to minimize monotony and disengagement that could bias behavioral responses (Acconito et al., 2024; Seiler et al., 2022). Future research should replicate the study with a larger number of trials to strike an appropriate balance between ecological validity and sufficient statistical power. A further limitation linked to low statistical power is that motor mimicry of scratching and yawning failed to elicit an effect on trust in this dissertation (**Chapter 4**): the pattern of results hinted at a negative association between mimicry and trust, as I expected, but the effect was only marginally significant. Although the model estimates were robust to clustered bootstrapping, the small sample size in the study remains an important limitation, and invite caution in interpreting not only this finding but also the other effects reported in the chapter. Moreover, I did not perform Bayesian analyses, which in hindsight could have provided a more nuanced estimate of evidence for or against the null hypothesis. Future work with larger samples and Bayesian approaches will be necessary to draw firmer conclusions on the effect of scratching and yawning mimicry on prosocial behavior.

Throughout the dissertation, I investigated different types of automatic mimicry, both at the autonomic and motor levels. A fascinating future avenue would be to investigate how different types of mimicry and synchrony – skin conductance, pupil size, facial expressions – interplay with each other. To my knowledge, only one study investigated how. The initial aim of my PhD project was to explore this interplay; however, the COVID-19 pandemic severely restricted data collection in general, and dyadic studies were particularly affected. Although I could not present these results in this dissertation, I am currently collaborating with colleague Julian Karch to apply vector autoregressive models to the **Chapter 3** dataset, as well as to another dyadic dataset, in order to examine how different processes align or diverge over time. Beyond these, we also encountered several technical challenges. In **Chapter 3**, for example, Julia Folz and I had originally planned to include additional measures (facial electromyography and skin temperature to capture blushing), but these had to be abandoned due to feasibility issues. While we successfully collected real-time pupil dilation data using portable eye-trackers, the recording quality ultimately proved insufficient for reliable synchrony analyses.

The findings of **Chapters 3 and 4** also connect to a broader debate in the literature about the conditions under which mimicry occurs. For instance, a study reported that synchrony affected trust in a design in which participants were doing the same task in separate rooms, and could not see each other at any point (Sun et al., 2019). This raises a fundamental question: if mimicry and synchrony evolved in environments in which individuals are at least co-present, what is the social value of synchrony when no perceptual access to the partner exists? Is this synchronization still a result of the social interaction between participants, or is it a byproduct of doing the same task? Future research could focus more on comparing synchrony levels with and without direct sensory access to dissociate social from non-social effects.

Another promising avenue for research on mimicry is the focus on negative emotional expressions, or negative context, in a more ecological setting. In **Chapter 2**, the literature provides little evidence for mimicry of negative emotional expressions, with scarce and inconsistent findings (Campellone & Kring, 2013; Olzanowski & Topilo, 2024; Rymarczyk et al., 2016) compared to animal studies. One explanation is that such behaviors are metabolically costly (Wood et al., 2016) and therefore less likely to emerge in low-stakes laboratory contexts, where defensive responses are not required. Much of what we know about negative mimicry comes from non-human animal research (P. L. McDougall & Ruckstuhl, 2018b; Pays et al., 2009). In contrast, the human literature has largely focused on affiliative expressions, which are easier to elicit under experimental conditions. We cannot exclude, however, that this asymmetry may reflect a broader bias in the field: with the traditional focus on mirror neurons as a mechanism of empathy, researchers may have inadvertently overlooked their role in more negative emotional contexts (e.g., vigilance, competition). Recent neuroscience findings underline this point: neurons in the ventromedial hypothalamus of mice have been shown to mirror aggressive behaviors both when enacted and when observed (Yang et al., 2023). As such, there is now a broad call for a reassessment of the unidirectional empathy-based model of mirror neurons (Ferrari et al., 2024), as well as for a more thorough investigation of mimicry across negative and positive contexts.

Shifting the focus from mimicry to nonverbal cues, the findings of **Chapter 6** offer valuable reflections. Interestingly, the effect of pupil size that I observed was unique to the avatar. For humans, fixed pupil manipulations via painted contact lenses may have lacked the dynamic changes needed to signal arousal or intent

(Prochazkova et al., 2018b) and could even represent a conflicting cue that violates expectations (Chattopadhyay & MacDorman, 2016). Contact lenses were nonetheless necessary to prevent the confederate from unconsciously mimicking the participant, as shown in **Chapter 4**. For the robot, its stylized, pixelated pupil was not a biologically relevant cue. Initially, I hypothesized that embodiment would make pupil cues effective, but the robot's low morphological overlap may have reduced its perceived similarity to humans. Broadbent (2017) suggests that our tendency to anthropomorphize increases with humanlikeness, supported by evidence that robots with more facial features are perceived as more humanlike (DiSalvo et al., 2002). Moreover, expectation violations, such as observing a mechanical robot or an incongruent android, trigger larger neural prediction errors (Broadbent, 2017). The robot in our study, with square, pixelated pupils, may therefore have failed to generate biologically meaningful signals, highlighting the importance of ecological validity in social signal design. Future research should therefore test dynamic manipulation in human interaction, and systematically vary morphological realism in robots to clarify when and how nonverbal signals become socially meaningful. Another reason could be that participants unfamiliar with the robot might not have known how large or small pupils appear on this platform. Although a post-hoc validation shows that participants on average perceived pupil size correctly, a stronger approach would be to implement a pre-experimental interaction with a neutral version of the target cue. Finally, as you can see in ***Figure 12***, Cozmo's eyes do not exhibit pupil-iris differentiation, raising the possibility that the figures displayed on the robot's screen were perceived as eyes rather than as pupils. This distinction is not merely semantic but has theoretical implications for how the observed effects should be interpreted, given that manipulations of pupil size and eye size may rely on partially distinct perceptual and social mechanisms. Future research could address this limitation by implementing comparable manipulations with human confederates or avatars that vary in eye size rather than pupil size, assessing whether and how this distinction affects behavioral responses.

Related to the human-robot interaction studies of this dissertation (**Chapters 5,6**), a common limitation is that I did not assess participants' prior experiences with artificial agents. This omission is important because previous work demonstrates that prior exposure – whether through embodied interactions or mediated by arts and media – can strongly shape people's attitudes toward artificial agents (Bartneck, Suzuki, et al., 2006; Haring, Silvera-Tawil, et al., 2014). Such experiences may influence explicit reports (Hoffman et al., 2015a), implicit attitudes (Ciardo et al., 2020), and trust towards agents (Rosén et al., 2024). Moreover, people's attitudes, expectations, and fears about artificial agents are rapidly changing, particularly with the release of large language models like ChatGPT in late 2022 and the potential rollout of generative AI (Gen-AI) abilities in robots. Given this rapidly evolving technological landscape, controlling for prior and current exposure and attitudes towards artificial agents should be non-negotiable in all future studies in the field. In addition, it is indispensable to consider these changes when interpreting findings from previous work. The studies in this dissertation were conducted before the widespread launch of these sophisticated AI systems, so caution is needed when generalizing these results to today's context. Caution is advised also when applying previous findings to inform current hypotheses, as the accellerating technological changes, exemplified by Gen-AI, may alter baseline attitudes and perceptions of artificial agents in ways that classical studies from the first decades of 2000 cannot fully reflect.

A further limitation concerns the nature and strength of the stimuli used to assess implicit attitudes in **Chapter 5**. Implicit associations were measured using static images of humans, robots, and avatars, which may not constitute a sufficiently strong or ecologically valid manipulation to elicit robust differences at the implicit level. Human–robot interaction research consistently shows that actual physical presence and real-time interaction with a robot amplify embodiment effects, shaping social responses, attitudes, and behavior in ways that static picture often fail to capture (Deng et al., 2019). From this perspective, the absence of cultural or body type effects in the IAT may reflect limitations of the stimulus modality. While richer stimuli such as videos could, in principle, convey motion, contingency, and expressive dynamics more effectively than static images, their use within an IAT framework is methodologically constrained, as the task relies on rapid categorization, reaction times and numerous trials. Videos, with their variability in duration and content, would which complicates their integration into standard IAT tasks. This limitation reinforces the need to interpret both the significant ***and*** null effects of this chapter with caution and suggests that future studies on implicit attitudes should complement image-based tasks with alternative implicit methodologies that involve embodied interaction or more immersive stimuli.

Alongside experience and beliefs, the physical form of the embodied agents (human-like vs. machine-like) also shapes participants' evaluations (Hameed et al., 2016). In **Chapter 6**, I compared a machine-like robot with a human-like ***virtual*** avatar, thereby conflating embodiement with morphology. As a result, it remains unclear to what extent the observed effects can be attributed to embodiement per se or the specific form the agent takes (e.g., mechanoid vs. humanoid). An important open question for future research is whether participants would have responded differently to a more human-like embodied robot (e.g., Furhat or Pepper) combining physical embodiement with anthropomorphic morphology. Retrospectively, including an additional condition with a more human-like ***embodied*** robot would have helped to disentangle how embodiement and morphology shape the effect of nonverbal cues on behavior, and whether different embodiments enable distinct mimicry processes. This has important implications for mimicry, as agents with different shapes, proportions, and expressive cues may elicit qualitatively different forms of mimicry, or render certain mimicry cues more or less salient. This limitation also raises broader questions about the generalizability of findings across robot platforms. Robots are clearly not a unitary class of objects, and results obtained with a small, mechanoid robot such as Cozmo may not straightforwardly generalize to larger, human-looking platforms. In light of the present findings, morphology, as well as past experiences, beliefs, and attitudes towards agents (Hortensius & Cross, 2018), may be just as important as embodiment for the effectiveness of subtle social signals.

Another perspective that I came to appreciate during my data collection is the value of qualitative insights. Especially for **Chapter 6**, I was present at every data collection session and interacted with every participant. The informal conversations I had after the tasks revealed nuances not captured by questionnaires. Strikingly, these nuances varied cross-culturally. Many European participants described the embodied robot as "cute" or "creepy," often commenting on its appearance. Japanese participants, in contrast, spoke of the robot in more relational or moral terms, for example, worrying about harming it by winning a round or perceiving the experimenter's voice as originating from the robot itself. These conversations also revealed participants' tendencies to occasionally "lie for the good" – for example, deliberately losing a few rounds because repeatedly winning against a human confederate felt uncomfortable. Across studies, I collected similar comments, which I partly noted in the experimental logbook. I often felt these exchanges would have benefited from follow-up semi-structured interviews. Future research could integrate such interviews or mixed-methods approaches more broadly to complement quantitative measures. Quantitative data cannot tell us everything.

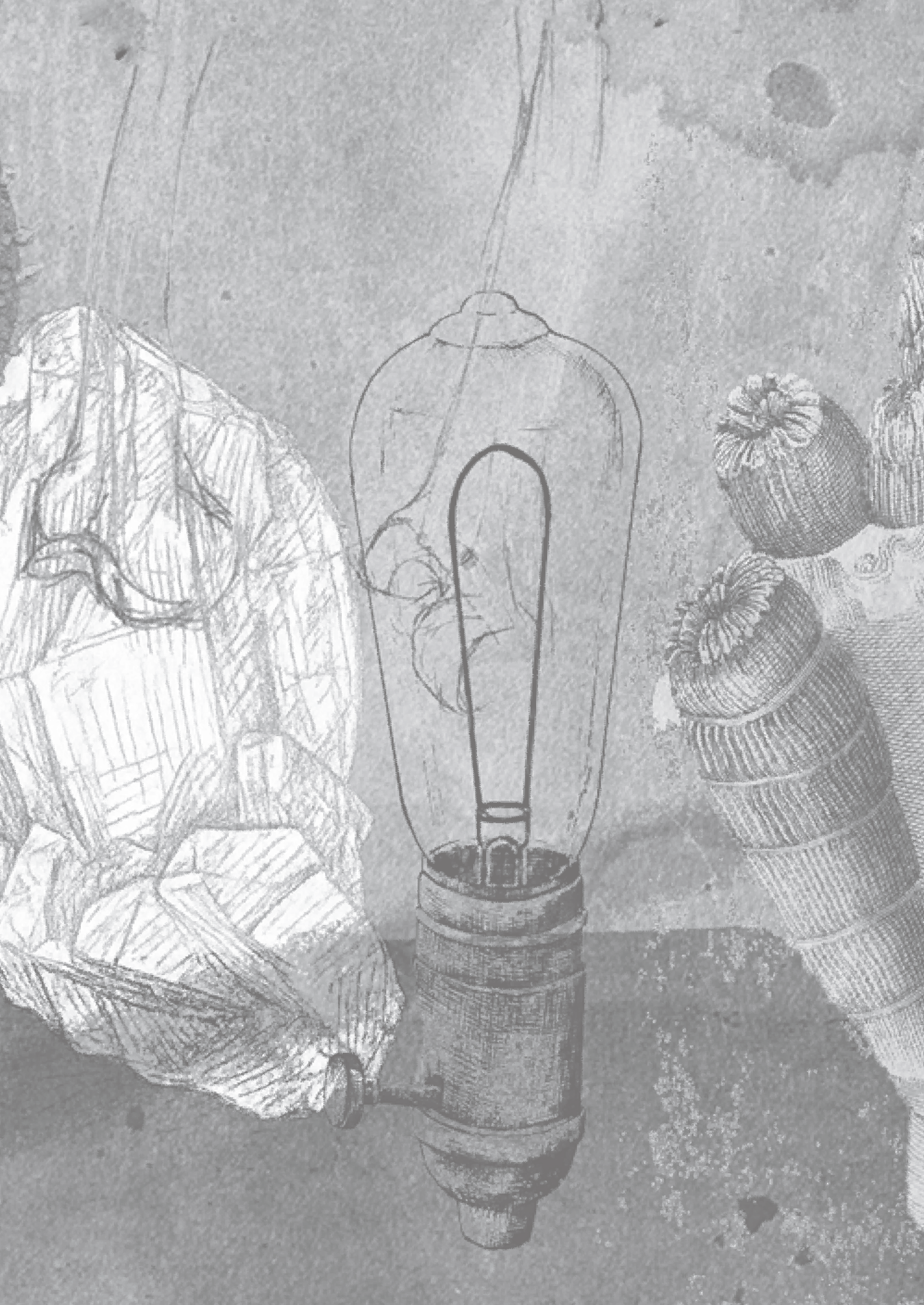
As a general limitation, while **Chapters 5** and **6** incorporated cultural comparisons between European and Japanese participants, the other chapters did not. A persistent challenge in the field is the over-representation of Western samples and the limited inclusion of diverse cultural contexts. Many populations, such as Global South communities, remain largely unexplored. Beyond culture, other demographic factors – including socioeconomic status, education, and age – were not systematically investigated in my studies, yet these variables may critically influence how people interact with both humans and artificial agents. Future research should prioritize more inclusive and diverse sampling to enhance the generalizability of findings. This may be achieved through more targeted sampling methods that ensure representation across underexplored cultural groups, SES, and age ranges, collaboration with local communities and scholars, especially in underrepresented regions, and systematic tracking of participants ' diversity across studies.

Finally, across all chapters, I am convinced that the future of this research lies in multimodality. Examining behavioral mimicry, physiological synchrony, and trait-level differences in isolation gives us partial answers, but their interplay – across multiple signals and in real-life contexts – may give us more chances to fully understand the social mechanisms at work. Of course, multimodality comes with significant challenges: colleague Julia Folz and I invested several months developing and testing the setup of **Chapter 3**, which was ultimately possible only with the help of engineer Elio Sjak-Shije. Fortunately, with the rise of second-person neuroscience (Schilbach et al., 2013), such setups will increasingly have a stronger foundation in the literature. This second-person perspective is not entirely new. Early ethological work from the 1960s and 70s already involved careful naturalistic observation of human behavior in social environments (Klein, 2000). In this respect, the recent rise of second-person neuroscience is less a new paradigm than a return to the roots of social research, with the tools and technologies of modern neuroscience and psychophysiology. Sometimes the best future direction is to look back at what was done in the past. My own PhD studies, even when in the wild, are still constrained by experimental control, far from the ecological validity that natural observations offer, and highlight the need to complement free interaction paradigms, multimodal measurement, and diverse participant samples.

Conclusion

This dissertation explored how nonverbal cues and their mimicry influence prosocial behavior across diverse contexts, agents, and cultures. By combining naturalistic dyadic studies, cross-cultural experiments, and human–robot interactions, I critically examined the assumption that mimicry is inherently affiliative. Instead, I propose that its function depends on the specific cue mimicked, the interaction context, and the partner's nature. From trust games with visible versus blocked cues, to comparing face-to-face, video call, and pre-recorded settings, to manipulating subtle pupil signals in humans and artificial agents, the chapters collectively argue for a flexible, context-sensitive understanding of mimicry and nonverbal communication. These findings challenge prior works emphasizing mimicry's prosocial role (Behrens, Snijdewint, et al., 2020; Lakin et al., 2003), framing it instead as a dynamic tool for navigating social interactions and predicting the (social) environment around us. They also add to the growing literature on nonverbal behavior by showing that unconscious cues like pupil size can be interpreted differently depending on cultural background.

Methodologically, the studies advanced beyond computer-based tasks to real dyadic and field experiments for greater ecological validity, though some experimental control limited spontaneity. This trade-off highlights the need for ongoing refinement in social interaction research. Conceptually, the work calls for more empirical study of mimicry's functions, including potential negative effects, and encourages investigating how different types—such as autonomic and motor mimicry—interact to shape social dynamics. Understanding how behavioral, physiological, and contextual factors converge in real time is vital for advancing social cognition models. This multimodal approach represents a promising future direction in second-person neuroscience, deepening insights into human connection mechanisms. Practically, the research informs human-robot interaction by showing that subtle social cues, like pupil size, do not have universal meanings. Their interpretations depend critically on cultural background, agent morphology, and prior experience. This underscores the importance of culturally and contextually sensitive robot designs to effectively engage users and convey emotional signals. Ultimately, I hope this dissertation meaningfully contributes to the literature on automatic mimicry and nonverbal cues across the diverse interaction contexts and partners that our ever-evolving social world has to offer.



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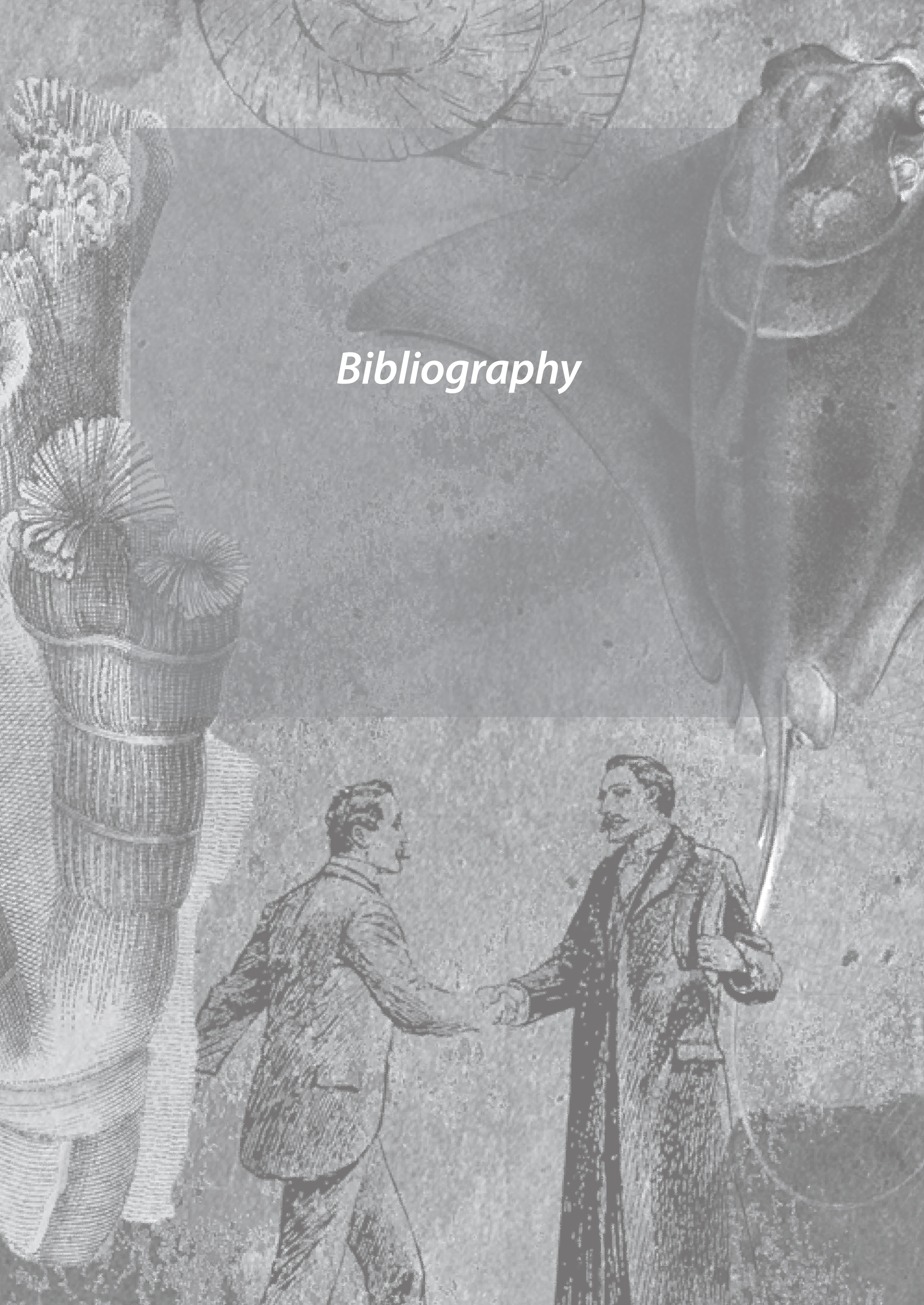

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