Personality and Individual Differences 219 (2024) 112478

Contents lists available at ScienceDirect

Personality and Individual Differences

journal homepage: www.elsevier.com/locate/paid

The « jingle-jangle fallacy » of empathy: Delineating affective, cognitive and motor components of empathy from behavioral synchrony using a virtual agent

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ARTICLE INFO

Keywords:
Empathy
Synchrony
Non-verbal interactions
Human-computer-interactions

ABSTRACT

Empathy is a multidimensional construct, which has been subject to many conceptualizations (affective, cognitive, and motor components). The present investigation delineated relationships between empathy facets, using questionnaires and a motor task measuring synchrony, a non-verbal component of social interactions. Participants ($N = 276$) completed self-report trait measures of affective, cognitive and motor empathy. A subsample ($N = 202$) executed synchronous movement with a virtual agent driven by a dynamical model of behavioral synchrony. Confirmatory Factor Analyses (CFA) revealed associated, yet distinct constructs of affective and motor empathy, distinguishing somatic and kinesthetic facets. Synchrony scores were associated with affective and cognitive empathy, highlighting the role of the capacity to experience and predict others' emotions and mental states for behavioral synchrony. Yet, synchrony scores were negatively associated with kinesthetic empathy, stressing the distinction between self-report measures of motor empathy from effective behavioral synchrony. These findings support a convergence of empathy and synchrony research fields to better understand their respective contribution in non-verbal social interactions.

1. Introduction

Empathy is a multidimensional construct incorporating affective and cognitive components (typically studied together), alongside less studied motor empathy components. Similarly, behavioral synchrony can be studied as a spontaneous or volitional motor component of social interactions, yet these are often conflated in the literature. Whilst theoretical accounts suggest an overlap between the neurocognitive architecture involved in empathy and synchrony, empirical evidence remains scarce. The gaps between different theoretical and empirical observations mapping the various conceptualizations of empathy and synchrony, challenge a comprehensive understanding of their associations. Consequently, there is a need to investigate the various components of empathy and synchrony simultaneously. The present study addresses this gap by disentangling the association between affective, cognitive and motor empathy, and testing their association with a synchronization task using a virtual agent.

1.1. *Disentangling facets of empathy and synchrony*

Various conceptualizations of empathy exist, most of which depart from its original conceptualization associating body sensations with aesthetic experiences (Lanzoni, 2018). Empathy is nowadays considered an umbrella term, encompassing affective facets, referring to the shared experience of others' emotional states, and cognitive facets, associated with the attribution of independent mental states to self and others

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https://doi.org/10.1016/j.paid.2023.112478
Received 17 August 2023; Received in revised form 31 October 2023; Accepted 2 November 2023
Available online 12 December 2023
0191-8869/

(Decety & Jackson, 2004). However, diffuse conceptualizations of empathy within widely used psychometric assessments further challenge the emergence of a unified framework (Hall & Schwartz, 2019). For example, the experience of emotional sharing or self-other overlap associated with affective empathy can be further divided into subcomponents, such as emotional contagion associated with mirroring others' emotions restricted to acquaintances (i.e., “proximal” responsivity) or to fictional character (i.e., “peripheral” responsivity; Davis, 1983; Reniers et al., 2011). Similarly, the delineation of cognitive empathy from other mental capacities remains disputed, with some authors restricting the concept of cognitive empathy solely to the understanding of emotional states, whilst others extend it to the understanding and knowing of others' thoughts (i.e., Theory of Mind), both associated with the capacities to distinguish self from others (Dvash & Shamay-Tsoory, 2014; Reniers et al., 2011). The conflation of the different definitions led to a « jingle-jangle fallacy » in the empathy research field, whereby researchers are using the same label to describe different concepts (jingle) or different terminologies for referring to the same concept (jangle) – see Heym et al. (2019).

The recent development of embodied approaches in empathy research has attracted research interest around motor-related components of social interactions. For example, Blair (2005), suggested the inclusion of motor empathy as a specific subcomponent, referring to the tendency to synchronize or imitate others' behaviors. However, synchrony and imitation are two different constructs, whereby synchrony refers to the tendency for temporal matching and imitation to spatial matching. Synchrony and imitation are often conflated, and can be spontaneous, without necessarily requiring volitional processes (Varlet et al., 2011), which also challenges the establishment of a unified taxonomy of motor components of social interactions (Ayache et al., 2021; Dumas & Fairhurst, 2021). Therefore, it remains to clarify how the affective and cognitive facets of empathy can be mapped onto various components of motor empathy. Furthermore, it remains to be clarified whether self-reports of being in synchrony map onto effective behavioral synchrony. Indeed, a study by Matthews et al. (2022) pointed out the potential gap between the “feeling” of synchrony and the “being” in synchrony. Consequently, this study focused on the specific association between self-report measures of affective, cognitive and motor empathy with effective behavioral synchrony measured through a synchronization task.

1.2. Neurocognitive components of empathy and synchrony

Different theoretical models propose an overlap between empathy and synchrony mechanisms. Whilst ideomotor theories suggest the action/perception matching system as a central mechanism for affective empathy and motor synchrony - associated with experience of self-other overlap (Gallese, 2001; Preston & De Waal, 2002), this sole neurocognitive architecture sustaining mirroring behaviors is insufficient to explain cognitive facets of empathy. Neurodevelopmental models stress the capacities for self-other distinction in monitoring self and others' perspectives (Decety & Jackson, 2004). Similarly, the capacity to synchronize movement with others requires mismatch detection between oneself and others' movements (Knoblich et al., 2011; Shamay-Tsoory et al., 2019). Altogether, these models suggest that empathy and synchrony share a common neurocognitive architecture (i.e., the action/perception matching and mismatch detection systems). However, it remains to be clarified to what extent affective, cognitive and motor empathy facets overlap with syncrony.

Empirical evidence remains scarce, typically entangling empathy and synchrony with attachment theories (Feldman, 2012; Preissmann et al., 2016) and social influences (Levy & Bader, 2020; Wiltermuth, 2012), challenging a clear delineation of their respective contribution in human-human interactions. Recent approaches in social neurosciences advocate the use of virtual agents as experimental tools providing replicable and more parsimonious models of the mechanisms underlying social interactions (Dumas, 2011; Pan & Hamilton, 2018). However, here it remains to be clarified whether virtual agents are suitable for studying human-human interactions (Fernández Castro & Pacherie, 2021). Consequently, a systematic investigation of the association between empathy facets and synchrony using a virtual agent was conducted.

1.3. Goal and hypotheses

To address these research questions, this study firstly aimed to test different theoretical models of empathy delineating empathy facets by means of questionnaires measuring affective, cognitive and motor empathy (Koehne et al., 2016; Raine & Chen, 2018; Reniers et al., 2011). Secondly, the associations between empathy components and synchrony were investigated using a virtual agent driven by the Haken-Kelso-Bunz model of synchrony (Dumas et al., 2014; Haken et al., 1985). According to the developmental model of empathy by Decety and Jackson (2004), a positive association between self-reported affective and motor empathy facets would be expected, considering their putative shared reliance on the action/perception matching system (Gallese, 2001; Preston & De Waal, 2002). According to theoretical models of synchrony (Knoblich et al., 2011; Shamay-Tsoory et al., 2019) and observations in laboratory settings (e.g., Koehne et al., 2016; Novembre et al., 2019), cognitive facets of empathy should be associated with effective behavioral synchrony measured by explicit instructions to synchronize with a virtual agent, stressing the role of predicting other's movement for achieving synchrony. Finally, following Matthews et al. (2022)'s observations, this study aimed to explore the potential gap between self-reported measures of motor empathy (i.e., “feeling” of being in synchrony) and effective behavioral synchrony.

2. Methods

2.1. Participants

Participants ($N = 277$) were recruited on the MTurk and Prolific online platforms, from December 2020 to July 2021 and compensated $5.00 for their participation. One participant was excluded due to failure to complete an attentional test. Consequently, a sample of 276 participants (163 men and 113 women; US residents, mean age 34.40 ± 10.68 years) was included for the psychometrics analyses. Due to technical incompatibility with some web browsers, the dataset including the behavioral task was restricted to 202 participants (113 men/89 women; US residents, mean age = 34.17 ± 10.98 years). These were included in the statistical analyses assessing the association between empathy facets and behavioral synchrony.

2.2. Procedure

Participants provided their informed consent on Qualtrics and completed relevant demographics followed by the empathy questionnaires. Then, participants were automatically redirected to the website hosting the behavioral synchrony task and instructed to synchronize their movements with the virtual agent. Finally, participants were redirected to another Qualtrics survey, with additional measurements not reported in the present manuscript. The total procedure took between 15 and 20 min - see Fig. 1 for graphical representation and for full description see: https://osf.io/9z4kh/.

2.3. Empathy questionnaires

Trait empathy measures included the Questionnaire of Cognitive and Affective Empathy (QCAE; Reniers et al., 2011), comprising 31 items, divided into cognitive and affective subscales: (1) *Perspective Taking* defined as “putting oneself in another person's shoes to see things from his or her perspective” (e.g., *I am good at predicting how someone will feel*)

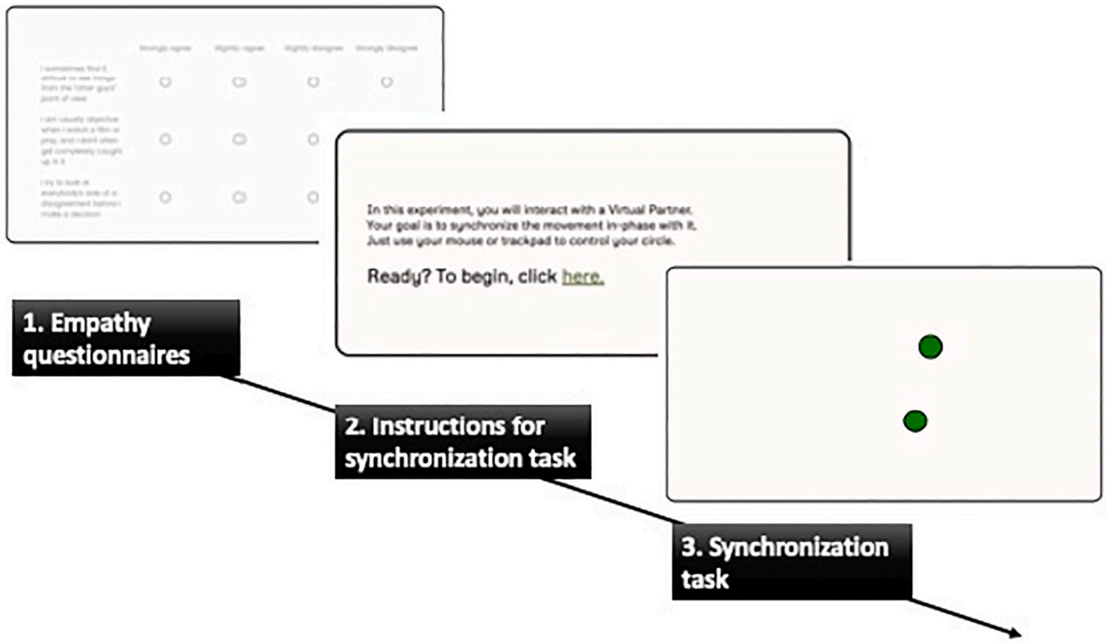

Fig. 1. Graphical representation of the experimental procedure.

and (2) *Online Simulation* characterized by an effortful attempt to put oneself in another person's position by imagining what that person is feeling (e.g., *I always try to consider the other fellow's feelings before I do something*), together measure cognitive empathy (3) *Emotion Contagion* refers to the automatic mirroring of the feelings of others (e.g., *I am inclined to get nervous when others around me seem to be nervous*); (4) *Proximal responsivity* to the responsiveness aspect of empathic behavior such as when witnessing the mood of others in a social context (e.g., *I often get emotionally involved with my friends' problems*), and (5) *Peripheral responsivity* for responses to fictional or detached context (e.g., *I often get deeply involved with the feelings of a character in a film, play or novel*), together measure affective empathy. This questionnaire displays good internal consistency (i.e., Cronbach's alphas, α, ranging from 0.65 to 0.85 across the five subscales) and overcomes limitations from previous empathy questionnaires conflating empathy with its outcomes - see Reniers et al. (2011). However, the QCAE does not contain items measuring motor empathy. Hence, additional questionnaires were administered.

The KinEmp, comprising of 9 items, assesses the spontaneous tendency to mimic facial expressions, body gestures or bodily sensations (e.g., *I often feel my own body tensing up when talking to somebody who is tense*). The original version of the KinEmp displayed good internal consistency with Cronbach's alphas, α, of 0.71 (Koehne et al., 2016). Finally, the Cognitive Affective and Somatic Empathy Scales (CASES; Raine & Chen, 2018) is composed of 30-items, assessing positive and negative components associated with cognitive, affective, and somatic facets of empathy. The Somatic subscale (10 items) of the CASES is conceptualized as a self-report measure of positive (e.g., *Seeing others laugh makes me laugh too*) and negative motor components of empathy (e.g., *My heart beats faster when I see a scary TV show*). Designed for children and adolescents, this questionnaire has been recently expanded to the adult population (Raine et al., 2022). The original version displayed good internal consistency with Cronbach's alphas, α, of 0.78.

All items were scored on a 4-point Likert scale (1 = strongly disagree to 4 = strongly agree) to harmonize with the initial scoring of the QCAE and scores on the subscales were calculated by summing the respective items.

2.4. Behavioral synchrony

Participants were instructed to move in synchrony with the virtual agent's movement, represented as a green sphere moving on participants' screens, for a duration of 30 s. Participants were randomly assigned to different experimental conditions: *Cooperation*, where the participant and virtual agent shared the common goal of being in synchrony or *Competition*, where the participant and the virtual agent had antagonistic goals, where the virtual agent was programmed to be in asynchrony (or anti-phase). This was implemented by manipulating the parameters of the Haken-Kelso-Bunz for assessing the influence of shared and antagonistic goals on participants' perception of the virtual agent, however, these results are not pertinent to the current hypotheses and hence not reported in the present manuscript - for a full description, see: https://osf.io/9z4kh/.

2.5. Data analyses

Analyses were computed on R (RStudio Team, 2020) and Python (Van Rossum & Drake, 1995). The psychometric properties of the questionnaires were checked using Cronbach's alpha. Pearson's correlations measured the associations between QCAE subscales, KinEmp and CASES. In contrast to Exploratory Factor Analysis (EFA), which does not assume pre-existing assumptions regarding latent variables (i.e., factors), Confirmatory Factor Analyses (CFA) were conducted using Structural Equation Modeling (SEM), with the R package lavaan (Rosseel, 2012) for testing factor structures suggested by theoretical models of empathy (Decety & Jackson, 2004). Considering potential inconsistencies across studies and populations, it was initially established whether a 5- or 2-factor structure for QCAE better fitted the data (Myszkowski et al., 2017). Then, models including motor empathy were tested. Chi-square tests ($\chi 2$) were performed to test whether kinesthetic and somatic empathy are distinctive or similar constructs by either adding them as unique motor empathy constructs (7-factor model) or combined motor empathy constructs (6-factor model).

Synchrony scores were computed by subtracting the relative phase between participants' and virtual agent movements using Hilbert transformation (see formula in Baillin et al., 2020). Synchrony scores ranged from 0 (no temporal matching) to 1 (perfect temporal matching).

Visual inspection of the synchrony scores revealed a bimodal distribution and Shapiro-Wilk Test confirmed that synchronization scores significantly deviated from a normal distribution ($W = 0.90$, p-value < 0.001). Consequently, non-parametric tests were used for synchronization scores comparisons across conditions and for correlations with empathy subscales. Scripts and datasets are available in OSF: https://osf.io/9z4kh/.

3. Results

3.1. Descriptive statistics and correlations for scales

Consistencies of the scales and subscales were deemed adequate (Cronbach alphas >0.60), apart from the QCAE subscale *Peripheral Responsivity*, displaying low Cronbach alpha (0.52). An examination of the mean inter-item correlations (0.21) revealed that item 17 had low correlations with items 11 and 29. Removing this item improved slightly the subscale consistency (0.57) and mean-inter items correlations (0.30). The QCAE subscales were significantly and positively correlated apart from *Peripheral Responsivity*. The affective QCAE subscales were positively correlated with KinEmp and CASES. Despite a moderate positive correlation between KinEmp and CASES, only the latter was significantly positively associated with the cognitive subscales *Online Simulation* and *Perspective Taking* - for descriptive statistics and subscales correlations, see Table 1.

3.2. Confirmatory factor analyses

For the QCAE, a 5-factor model displayed better fit than the 2-factor model ($\chi2$ (9, 276) = 242.41, $p < .001$). Model comparisons of all empathy scales favored the 7-factor model, separating KinEmp and CASES as unique latent variables alongside the five QCAE variables, over the 6-factor structure combining the two facets into one motor empathy latent variable ($\chi2$ (6, 276) = 150.28, $p < .001$). Finally, considering the positive correlations observed between KinEmp, CASES and the *Emotion Contagion* subscale of QCAE, exploratory analyses compared two further 6-factor models, combining either KinEmp or CASES with *Emotion Contagion*, respectively. Still, these model comparisons favored the 7-factor structure ($\chi2$ (6, 276) = 170.13, $p < .001$ and $\chi2$ (6, 276) = 128.56, $p < .001$, respectively) – see Table 2 for a summary of goodness of fit indexes and Fig. 2 for the final model.

3.3. Zero-order correlations with synchronization scores

Comparison of the experimental conditions did not reveal any significant differences for demographics, QCAE, KinEmp, and CASES subscales nor with synchronization scores across experimental conditions – see Supplementary material for full statistics. The QCAE cognitive facet *Online Simulation* and the affective facet *Peripheral Responsivity* were significantly and positively associated with synchronization scores (with $r(200) = 0.17$, $p = .017$ and ($r(200) = 0.20$, $p = .005$, respectively). In contrast, KinEmp scores were significantly negatively correlated with synchrony scores ($r(200) = -0.14$, $p = .043$). Finally, there were no significant association of synchrony scores with the cognitive facet *Perspective Taking* ($r(200) = 0.01$, $p = .843$), the affective facets *Proximal Responsivity* ($r(200) = 0.04$, $p = .550$) and *Emotion Contagion* ($r(200) = 0.05$, $p = .442$), or with CASES scores ($r(200) = 0.06$, $p = .361$).

Table 2
Summary of goodness of fit indexes for each model tested with CFA and $\chi2$.

	DF	AIC	BIC	$\chi2$	CFI	TLI
2-factor model of QCAE (affective + cognitive subscales)	404	18,298	18,628	1117.5	0.747	0.728
5-factor model QCAE (OS + PT + PE + PR + EC)	395	18,074	18,436	875.1	0.830	0.813
6-factor model QCAE + KineEmp/CASES	1112	30,896	31,482	2377.3	0.732	0.717
7-factor model QCAE + KineEmp + CASES	1106	30,758	31,366	2227.1	0.763	0.748
6-factor model QCAE + KineEmp/EC + CASES	1112	30,916	31,502	2397.2	0.728	0.712
6-factor model QCAE + KineEmp + CASES/EC	1112	30,874	31,461	2355.6	0.737	0.722

Note: **DF** stands for *Degree of Freedom*, **AIC** for *Akaike information criterion*, **BIC** for *Bayesian Information Criterion*, **CFI** for *Comparative Fit Index* and **TLI** for *Tucker-Lewis Index*.

4. Discussion

The present investigation aimed to disentangle the relationship between self-reported traits of affective, cognitive and motor empathy, and their association with behavioral synchrony using a virtual agent. Both the latent structures and inter-correlations amongst the scales suggested that the motor-related empathy subscales KinEmp and CASES represent distrinct constructs and differ from affective and cognitive empathy facets. Moreover, the present study confirmed the association between cognitive empathy and effective behavioral synchrony, replicating findings from human-human interactions to human-virtual agent interactions.

4.1. Disentangling facets of empathy and synchrony

CFA analyses confirmed a 7-factor model, supporting a fine-grained distinction between affective, cognitive and motor empathy dimensions. In line with the first hypothesis, affective QCAE subscales, KinEmp and CASES were positively associated with each other, supporting models of empathy that link the development of affective empathy with mirroring behaviors (Decety & Jackson, 2004). In line with the second hypothesis, cognitive empathy was associated with higher synchrony scores; however, whilst *Online Simulation*, conceptualized as an "an effortful attempt" to adopt another's perspective, displayed a positive association with synchrony, *Perspective Taking*, conceptualized as "intuitive" empathy, was not linked to synchronization. This result, alongside the

Table 1
Descriptive statistics and Pearson's correlations between empathy facets.

	Mean (SD)	Alpha	OS	PT	PE	PR	EC	KI
Online simulation (OS)	27.24 (4.86)	0.82	–					
Perspective taking (PT)	30.47 (5.36)	0.87	0.66***	–				
Peripheral responsivity^ (PE)	7.73 (1.95)	0.57	0.16**	0.01	–			
Proximal responsivity (PR)	11.65 (2.37)	0.65	0.53***	0.45***	0.33***	–		
Emotion contagion (EC)	11.25 (2.58)	0.75	0.27***	0.23***	0.18**	0.51***	–	
KinEmp (KI)	22.04 (4.56)	0.71	−0.05	−0.02	0.21***	0.23***	0.43***	–
CASES (CA)	29.46 (5.67)	0.83	0.18**	0.16**	0.28***	0.44***	0.48***	0.54***

Note: $*p < .05$, $**p < .01$, $***p < .001$. ^Peripheral responsivity values reported after item 17 removed.

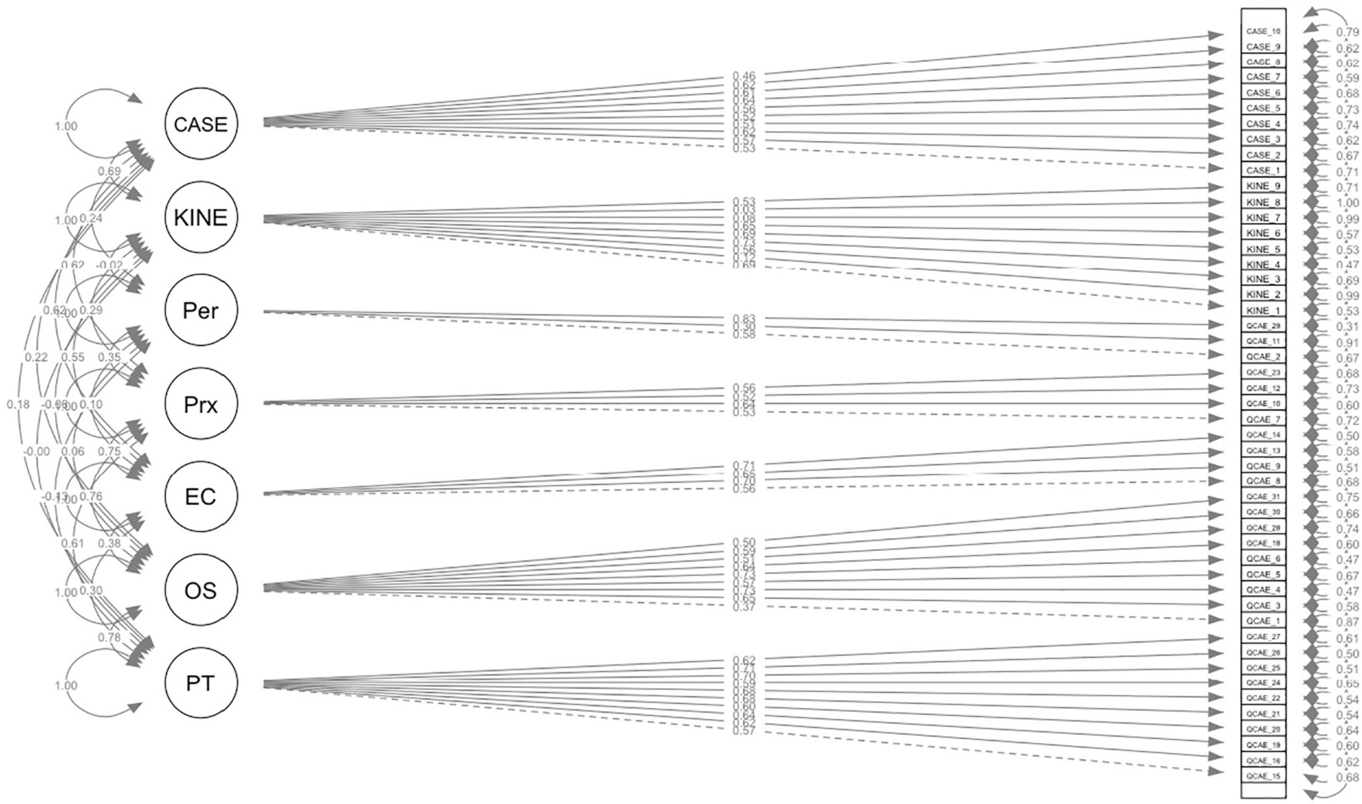

Fig. 2. Graphical representation of the model tested with seven latent factors. Single-headed arrows represent standardized correlations, and double-headed arrows represent covariances.

CFA analyses further support the distinction between these QCAE cognitive facets. Importantly, this study is in line with results from Novembre et al. (2019), reporting a positive association between behavioral synchrony and the subscale *Perspective Taking* from the Interpersonal Reactivity Index (IRI; Davis, 1983). Items composing this subscale and the QCAE subscale "Online Simulation" are indeed overlapping, stressing the mismatch between IRI and QCAE labels and the risk of "jingle-jangle fallacy" (Heym et al., 2019).

An unexpected association of the affective subscale *Peripheral Responsivity* with increased synchrony was also observed. Interpreted as reflecting affective empathic responses in a detached context (Reniers et al., 2011), this subscale is composed of items from the IRI *Fantasy* subscale - associated with the tendency to "transpose oneself into fictional situations", initially conceptualized as a cognitive facet (Davis, 1983, p.11). Accordingly, *Peripheral Responsivity* displayed indeed positive correlations with the cognitive facet *Online Simulation* (as well as affective facets) though not with *Perspective Taking*, highlighting its associations with motivational and volitional processes. However, its reliability was questionable, echoing previous concerns (Myszkowski et al., 2017), and calls for a revision of this subscale.

4.2. Motor-related components of empathy

In contrast to affective and cognitive empathy, motor empathy has received relatively little attention in the trait empathy literature to date. Despite being moderately intercorrelated, the two scales used for measuring motor empathy emerged as distinct factors and displayed divergent associations with cognitive empathy and behavioral synchrony. Thus, whilst the KinEmp and CASES scales are both conceptualized as reflecting the subjective experience of "motor" components of empathy, they differ in their relationships, stressing the importance of delineating them as distinctive constructs.

The CASES somatic subscale was developed as a self-report measure of motor empathy, based on electrophysiological recordings of muscle and neural activity (Raine & Chen, 2018). This conceptualization of motor empathy is associated with the elicitation of a "motor act" (i.e., smiling when seeing someone happy) or experiencing autonomic bodily responses to emotional cues (i.e., startling when seeing a dog run over). Therefore, the items composing this subscale reflect a conceptualization of motor empathy as body responses to emotional cues, typically associated with tendencies for emotion contagion and mimicry. To date it was unclear, whether this conceptualization of somatic responses to another's affective empathic state requires the mentalization of another's affective state (Heym et al., 2019). Results from the current study suggest that somatic motor empathy, as measured by the CASES subscale, overlaps not only with affective but also with cognitive empathy, and might therefore require mentalizing other's state. Furthermore, the present study substantially extends Raine and Chen's (2018) study, which initially distinguished somatic (i.e., motor component of empathy) from affective and cognitive constructs psychometrically. The current study explored the direct association of these components with effective behavioral synchrony and delineated more distinct facets of motor empathy (i.e., somatic vs kinesthetic), both important for emotional contagion but displaying different associations with synchrony.

In contrast, the KinEmp scale (Koehne et al., 2016) was conceptualized as a self-report measure of kinesthetic empathy, tapping into behavioral synchrony rather than imitation. Accordingly, Koehne et al. (2016) reported higher kinesthetic empathy for dancers with practices requiring synchrony, who also displayed higher scores of affective and cognitive empathy. However, whilst the current study reported an association between kinesthetic and affective empathy, we did not replicate the association between kinesthetic and cognitive empathy. Moreover, in contrast to Koehne et al. (2016), kinesthetic empathy was associated with reduced behavioral synchrony. The differences in findings might be a sampling and/or methodological artifact. The population tested by Koehne et al. (2016) was composed of expert dancers, and the authors used different measures of affective and cognitive empathy, namely the Cognitive and Emotional Empathy Questionnaire (CEEQ), which, to the author's knowledge, has not been published yet. This contradictory outcome calls for future investigations comparing experts (e.g., dancers, musicians) and novice populations to disentangle potential biases in recruitment and capacity to self-report motor abilities.

Interestingly, the discrepancy between behavioral motor coordination performance and self-reported perceptions of synchrony has been previously observed by Matthews et al. (2022), stressing a gap between effective behavioral synchrony and the "feeling" of synchrony. Thus, being effectively "moved" and being in synchrony should be treated as distinctive constructs. Considering the association between empathy and capacity for self-awareness, that is the capacity to reflect on one's behavior, this finding paves the way for future research investigating the role of self-awareness in behavioral synchrony and its association with empathy deficits (Decety & Jackson, 2004). Finally, although beyond the scope of the present investigation, additional analyses investigating the structure of the KinEmp were conducted considering the low alpha Cronbach value. These analyses showed that some KinEmp items displayed low inter-items correlations (0.09), calling for potential revisions of the scale (see Supplementary material).

4.3. Strengths and limitations

The present results highlight inconsistencies between different conceptualizations of empathy and synchrony, yet they need to be taken with caution. Some of the trait measures of affective and motor empathy displayed questionable psychometric properties, calling for potential revisions of the QCAE and KinEmp (Myszkowski et al., 2017). Additionally, the contrasting findings to Koehne et al. (2016) call for more systematic investigation of behavioral synchrony accounting for sample bias and controlling for the discrepancy between self-reported and effective behavioral synchrony (Matthews et al., 2022). Furthermore, experimental artifacts associated with online data collection cannot be ruled out (i.e., social desirability bias) and replications in laboratory settings are required considering the weak associations observed. Finally, the lack of significant difference between the Cooperation and Competitive condition suggests that the manipulation of the virtual agent behavior may have been too subtle or short for inducing changes in behavioral synchrony scores. Nevertheless, the replication of pre-existing in-laboratory findings is encouraging and suggests that this research question can be investigated using virtual agents, paving the way for more controlled experimental paradigms investigating the dynamics of social interactions.

5. Conclusion

To conclude, this is the first study that attempted to delineate different facets of empathy, including different types of motor empathy, and behavioral synchrony. Firstly, confirmatory factor analyses stress the distinction between all seven facets of affective, cognitive and motor empathy as separate latent constructs. Therefore, although it is tempting to merge facets of empathy, psychometric assessments of empathy traits are better understood as "constellations" (Davis, 1983). Secondly, this investigation provides clear evidence for the proposed theoretical links between affective and motor empathy and confirmed the association between cognitive empathy and behavioral synchrony, suggesting potential joint mechanisms. Thirdly, the novel methodology of testing virtual agents and the replicability of laboratory findings with a virtual agent paves the way for exploring the dynamics of social interaction using an automated agent replicating human behaviors. Finally, the discrepancy observed between self-reported motor empathy (i.e., kinesthetic) and behavioral synchrony highlights the distinction between "feeling" and "being" in synchrony, calling for further investigations of self-awareness in emergent and planned motor coordination.

CRediT authorship contribution statement

Julia Ayache: Conceptualization, Methodology, Formal analysis, Investigation, Data Curation, Writing - Original draft preparation, Visualization **Guillaume Dumas**: Conceptualization, Methodology, Software, Formal analysis, Resources, Data Curation, Writing - Review & Editing. **Alexander Sumich:** Conceptualization, Writing - Review & Editing, Supervision. **Daria J. Kuss**: Writing- Reviewing and Editing, Supervision **Darren Rhodes**: Conceptualization, Supervision **Nadja Heym:** Conceptualization, Methodology, Formal analysis, Data Curation, Writing- Reviewing and Editing, Project administration, Funding acquisition.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent was obtained from all participants included in the study.

Funding

Julia Ayache was supported by the Doctoral Alliance Training co-funded by the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement [801604]. Guillaume Dumas was supported by the Institute for Data Valorization, Montreal (IVADO; CF00137433), the Fonds de recherche du Québec (FRQ; 285289), the Natural Sciences and Engineering Research Council of Canada (NSERC; DGECR-2023-00089), and the Azrieli Global Scholars Fellowship from the Canadian Institute for Advanced Research (CIFAR) in the Brain, Mind, & Consciousness program.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Scripts and datasets are available in OSF: https://osf.io/9z4kh/.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.paid.2023.112478.

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