Comparing Self-Other Distinction Across Motor, Cognitive, and Affective Domains

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Correlational Clustering Reveals Motor-Cognitive vs. Affective Self-Other Distinction with Domain-General Contribution

Abstract

The self-other distinction (SOD) is a process by which humans disentangle self from other-related mental representations. This online study investigated two unresolved questions: whether (1) **the same** processes **underpin SOD** for motor, cognitive, and affective representations and (2) **SOD** overlaps with domain-general cognitive control processes. Participants (*N* = 243) performed three SOD tasks (motor: automatic imitation inhibition [AIT]; cognitive: visual perspective-taking [VPT]; affective: emotional egocentricity bias [av-EEB] tasks) and two cognitive control tasks (Stroop and stop-signal reaction time [SSRT] tasks).

The study employed multiple correlation analyses, hierarchical clustering, and multidimensional scaling as exploratory data analysis methods to uncover patterns and groupings within the data. Related to the first question, correlation analyses showed no associations among the motor, cognitive, and affective SOD indexes. Similarly, distinct SOD clusters emerged in the hierarchical clustering dendrogram, indicating clear separations among SODs. However, the results of multidimensional scaling suggested a tendency towards two clusters, as evidenced by the proximity of VPT and AIT indexes in relation to EEB indexes on the MDS graph.

Related to the second question, AIT spatial laterality and Stroop domain-general cognitive control confounded AIT and VPT indexes, albeit slightly differently depending on the analysis method used. SSRT showed neither associations with SODs nor with other domain-general indexes.

These findings underscore the complexity of SOD processes and highlight the importance of considering methodological nuances in data analysis.Moreover, these results have notable implications for basic and applied research, e.g., in the domain of clinical disorders affected by deficiencies in SOD.

Keywords: self-other distinction; cognitive control; visual perspective-taking; automatic imitation; emotional egocentricity bias

Public significance statements

The self-other distinction, an ability to disentangle self- from other-related mental states, is a multifaceted and complex phenomenon. This study highlights that individuals may employ different mechanisms depending on the context, whether it involves motions, cognitions, or emotions. By acknowledging the situational variability in **the** self-other processing, we can better tailor interventions and strategies across different contexts.

1. Introduction

Social cognition comprises multiple processes that enable human beings to successfully navigate the social world (Frith, 2008). During an interaction, individuals are prone to share the mental state of people around them, allowing them to sense the state they are currently in (for reviews: (Eddy, 2022; Lamm et al., 2016; Steinbeis, 2016). For example, observation of someone in pain reactivates in a person neural structures involved in first-hand pain (Lamm et al., 2011; Rütgen et al., 2015). This sharing between representations of self and other occurs not only in the domain of emotions but also in the **motor** (for review: (Brass & Heyes, 2005; Heyes, 2011) and cognitive domains (i.e., non-affective mental states; for review: (Decety & Sommerville, 2003). Parallel to this self-other sharing, humans possess a complementary process, **the** self-other distinction (SOD), to disentangle self- from other-related representations (Decety & Sommerville, 2003; Lamm et al., 2016; Steinbeis, 2016). Without this ability, an excessive resonance with others in, e.g., the emotional domain, would result in increased personal distress and reduced empathic concern towards others (Eddy, 2022). The present study aims to advance the current understanding of SOD by addressing two debated research questions.

Research question 1: ***Regardless of the number or nature of the processes underpinning SOD, are these the same processes for cognitive, affective, and motor mental representations?***

Three strands of SOD research have investigated three types of mental representations: motor, cognitive, and affective representations. Motor SOD research is led by the finding that observing an action (motor content) spontaneously induces a tendency to imitate that action (for review: (Heyes, 2011). Motor SOD supports the inhibition of these imitative tendencies (Brass et al., 2009). Cognitive SOD research is dominated by investigating processes related to a mental switch between self and other persons' perspectives (e.g., how individuals represent other persons' viewpoints; for review: (Quesque & Brass, 2019; Steinbeis, 2016). Affective SOD research often relates to empathy research, where SOD allows the empathizer to recognize that their own affective state has been caused or influenced by the one of another person (for review: (Lamm et al., 2016; Vignemont & Singer, 2006).

The experimental measures of motor, cognitive, and affective SOD have in common to contrast performance between congruent and incongruent conditions. In the congruent condition, self- and other-related mental representations match (e.g., both experiencing positive stimulation). In the incongruent condition, self- and other-related representation states are conflicting or opposite (e.g., negative stimulation for self, positive for other).

Neuroimaging studies found involvement of the temporoparietal junction (TPJ) for motor, cognitive, and affective SOD, albeit with some localization differences (Brass et al., 2009); but see (Bukowski, 2018; Darda & Ramsey, 2019; Silani et al., 2013); for review: (Eddy, 2016; Quesque & Brass, 2019).

So far, similarities in theories, operationalizations, and neural correlates of motor, cognitive, and affective SOD suggest **similar processes** underpinning SOD for the three types of mental representations. Yet, the few studies which addressed this question reported inconsistent findings (Bukowski et al., 2021; Guzman et al., 2016; Qureshi et al., 2020; Santiesteban et al., 2012; Tomova et al., 2014; Tomova et al., 2019).

The inconsistent findings raise at least three possible scenarios:

1. researchers compare**d** many underpowered studies,
2. the measurement tools of **the** self-other distinction **were** built so that they **fail to capture the underlying shared processes**,

3. the self-other distinction processes for motor, cognitive, and affective mental representations **may appear functionally similar but are not underpinned by the same shared processes**.

For example, related to the second scenario, different neural activations found across the tasks might stem from input or other contextual differences and **do not necessarily rule out the existence of shared processes across the three domains**.

The answer to research question 1 is thus debated, but there is little systematic research on this topic.

Research question 2: ***To what extent domain-general processes confound SOD(s)?***

Another intriguing question is what role domain-general processes, which help individuals overcome similar computational challenges in non-social situations, play in SOD. In other words, is SOD achieved solely through processes specialized for social cognition, or do domain-general processes also contribute, and to what extent, in addressing these challenges?

Similar computational challenges result from the fact that in both kinds of situations individuals have to detect and resist an interference. A prominent example from a non-social domain is the Stroop task (Stroop, 1935), in which participants are instructed to react to the words' color and not words' lexical meaning. In the incongruent trials, the color and the meaning do not correspond, causing a struggle with conflict detection and inhibition. Same domain-general cognitive control processes might account for conflict detection and inhibition in the social domain, in which participants detect and resist an interference between their mental state and the mental state of another social agent.

The question of domain generality is particularly debated in cognitive SOD with level-1 visual perspective-taking tasks (VPT; level-1 refers to inferring whether someone sees an object or not). Specifically, it is still debated whether VPT performance necessarily involves inferring an actual mental state (Schurz et al., 2015) or if it is the product of a domain-general mechanism named submentalizing (Cole et al., 2016; Conway et al., 2017; Furlanetto et al., 2016; Marshall et al., 2018; Santiesteban et al., 2014, 2017; Vestner et al., 2022); for review: (Heyes, 2014; Quesque & Rossetti, 2020); meta-analysis: (Holland et al., 2021). Studies have empirically supported both positions, leading to contradictory results (but see (Bukowski et al., 2015; Bukowski & Samson, 2021; Samson & Apperly, 2010) for an intermediary position).

The debate also exists in research on motor SOD. There, it was shown that generalized visuospatial effects may confound automatic imitation (Ramsey, 2018; Shaw et al., 2017). Spatial confounding occurs when changes in task performance are influenced by the task-irrelevant match (or mismatch) between the laterality of the expected response and laterality of the stimulus (Cooper et al., 2013). Recent meta-analyses, including fMRI studies (Cracco et al., 2018; Darda & Ramsey, 2019), supported the generalist view, according to which this paradigm involves general processes to a greater extent than aspects specialized for social cognition.

At last, SOD and tasks of the cognitive control contrasting incongruent to congruent conditions typically activate the TPJ, with however some socio-cognitive versus cognitive control differences (Bukowski & Lamm, 2020; Schuwerk et al., 2017).

Hence, similarities in theories, operationalizations, and neural correlates of SOD and cognitive control raise the debate about whether and to what extent domain-general processes support **the** self-other distinction(s) (Happé et al., 2017; Heyes, 2014; Quesque & Rossetti, 2020). **Our second research question is phrased more broadly than question 1. We foresee**

at least two different scenarios: 1) any shared processes identified in Q1, if they exist, are used for wider cognitive control processes; alternatively, 2) each SOD may rely to a different extent on domain-general processes.

The present study

The aim of the present study **was**, first, **to identify whether processes underpinning cognitive, affective, and motor self-other distinction overlap.** Second, whether **the** self-other distinction(s) **is, to a larger extent, a process involved in interference resolution used for broader cognitive, social, and non-social computational challenges? An early theoretical paper that emphasized the potential advantage of considering self-other distinction across the three domains comes from Eddy (2022). Our study is the first to** empirically investigate these two questions through multiple *correlation analyses, hierarchical clustering,* and *multidimensional scaling*. **To this aim, we** concurrently examined performance-based measures of motor, cognitive, and affective SOD and domain-generality in a well-powered within-subject experimental design.

For this purpose, we used three well-established self-other distinction tasks (motor SOD: (Sowden & Catmur, 2015); cognitive SOD: (Samson & Apperly, 2010); affective SOD: (Von Mohr et al., 2020), and two control tasks, targeting individual differences in domain-general cognitive control (Stroop task, (Stroop, 1935); Stop-Stimulus-Reaction-Time task, (Logan & Cowan, 1984; Verbruggen et al., 2019). For the motor representations, we used a task version, which explicitly disentangles general spatial congruency from automatic imitation (Sowden & Catmur, 2015).

2. Methods

2.1. Data Collection

We ran a pilot test between September and October 2020. The data collection took place between November and December 2020.

2.2. Sample

The study sample was recruited via The Vienna CogSciHub: Study Participant Platform of the University of Vienna (https://cognitivescience.univie.ac.at/services/study-participant-platform/). Potential participants, recruited via the *hroot* recruitment tool (Bock et al., 2014), received the link to the online platform of the study, where they underwent a screening process by filling out a short questionnaire. The exclusion criteria were: (a) age under 18; (b) left-handedness according to the Edinburgh Handedness Inventory (EHI, (Oldfield, 1971); (c) color blindness; (d) hearing impairment; (e) psychological, psychiatric, or neurological disorders; (f) substance abuse; and (g) poor German skills. Participants received either partial monetary compensation based on 10 euros per hour if the study was not completed or 30 euros for completing all tasks. The study was conducted according to the Declaration of Helsinki (1964) and its later amendments, and was approved by the Ethical Board of the University of Vienna, Faculty of Psychology (EK reference number 00577, amendment 5 to project 00412).

Three hundred fifty-eight (N = 358, see **2.5.1** for power considerations) participants registered in the study, out of which n = 310 finished at least one task. In each task, we had to exclude participants who either made too many errors **(>20%)**, experienced technical difficulties, violated the model's assumption, **or explicitly stated in writing at the end of the task that they did not understand the instructions or were not concentrated.** The final sample comprised n

= 243 individuals who completed all five tasks. The majority of the sample self-identified as women (*n* = 198), had university entrance qualifications (*n* = 158; *n* = 59 completed their bachelor's degree) and were of Austrian nationality (*n* = 135; *n* = 72 Germany). The sample mean age was 23.47 (*SD* = 5.17, age range: 18 - 64).

2.3. Tasks

The online study consisted of **the** three self-other distinction tasks, two control tasks, and one survey, presented in a randomized order.

With regards to the control tasks, the Stroop task is a classic measure of inhibitory cognitive control and has a long-standing tradition of being used in the context of automatic imitation inhibition (Brass et al., 2005; Heyes, 2011; Santiesteban et al., 2012). We chose a version with manual responses, though researchers debate for decades whether different response modes (manual vs. vocal) produce similar effects (Parris et al., 2019; Simon & Sudalaimuthu, 1979). While there can be some differences, we decided that the manual response mode aligns better with the cognitive and motor demands of other RT paradigms in our study (e.g., in terms of task complexity and response mode, such as pressing or lifting a key).

The Stop-Signal Reaction Time (SSRT) task measures the ability to inhibit a prepotent response, i.e., how quickly an individual can inhibit an initiated action. The Stop-Signal Reaction Time (or variations of it) has been often used as a control task in the context of visual perspective taking (Qureshi et al., 2020). To avoid overburdening our participants and to ensure our results are contextualized within the existing literature, we chose these two tasks as our control measures.

The practice trials, attentional and technical checks, and further additional details for every task can be found in supplementary materials (**SM**).

2.3.1. Automatic Imitation Inhibition Task. The automatic imitation inhibition task (AIT) measures **the** self-other distinction processes for motor mental representations (Brass et al., 2009; Sowden et al., 2016; Sowden & Catmur, 2015). We used a version proposed by Sowden and Catmur (2015) to isolate imitative congruency from the confounded effects of spatial congruency.

The participants placed the index and middle fingers of their right hand on the keyboard (index = N, middle = M). During the trials, they were instructed to lift their fingers in response to a colored cue (group 1: purple = index finger lift, orange = middle finger lift; group 2: vice versa). This cue appeared on display together with the task-irrelevant right or left stimulus hand of a female person lifting the fingers. The stimulus hand was executing the same (imitative congruent) or opposite (imitative incongruent) finger movements (Figure 1). Viewing the hand's movements activates the participants' involuntary imitation tendencies, which need to be inhibited actively in the incongruent trials (Brass et al., 2009). This results in prolonged reaction times and more errors compared to congruent trials, which represent a quasi-imitative reaction (Brass et al., 2009). Spatial congruency was manipulated in an orthogonal manner to imitative congruency, depending on whether the stimulus hand lifted a finger that was on the same (spatial congruent) or on an opposite (spatial incongruent) side of space as the finger to be lifted by the participant.

The experimental part comprised three experimental blocks with 36 trials per block. Within each block, four experimental conditions and two base conditions, with six trials per condition were distributed in a pseudorandomized manner. The stimulus hand movements were manipulated in a 2 (congruency: congruent vs. incongruent) x 2 (spatial vs. imitative) fashion, resulting in four experimental trial types. In the base trials, the stimulus hand (right or left) was not performing any movement. The task took approximately fifteen minutes to complete.

Figure 1

Timeline of a) an Experimental Trial; b) a Base Trial

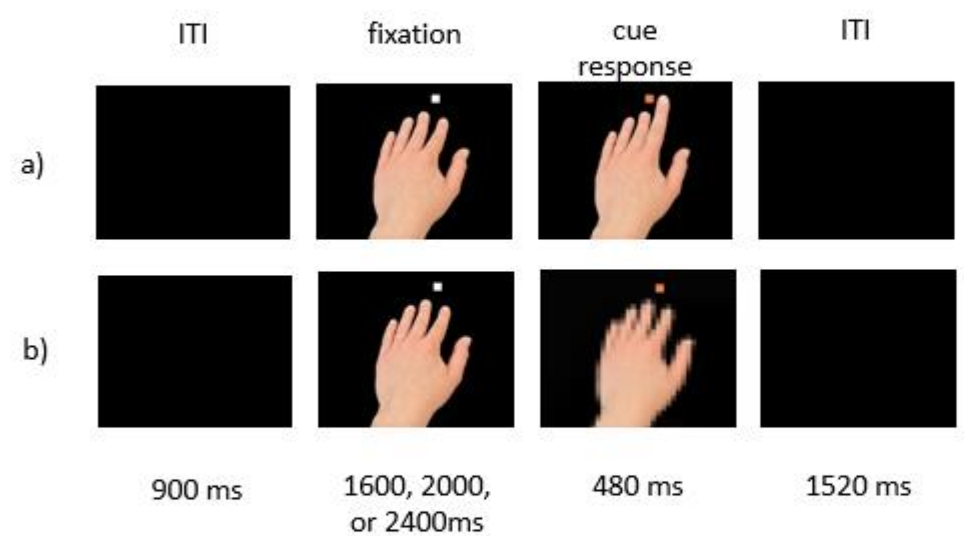

Figure 1: Note. A trial starts with an intertrial interval, followed by a frame depicting a static hand alongside a white fixation square. In the experimental trials (a), the next frame shows a lifted finger. In the base trials (b), the stimulus hand remained static and was additionally pixelated. In this case, an orange fixation square provides a cue for a finger response (group 1: middle finger, group 2: index finger lift). The trial ends with a 1520 ms inter-stimulus interval. The next trial starts only when both N and M keys are pressed. Copyright: adapted from Sowden and Catmur (2015, fig. 1; Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License).

2.3.2. Visual Perspective-taking Task. The visual perspective-taking task (VPT) proposed by Samson et al. (2010) measures **the** self-other distinction processes for cognitive mental representations. The participants placed two fingers on the C and N keys of their keyboard. In every trial, participants adopted either self or other perspective and memorized a digit (0-3) that appeared on the screen. The next frame depicted a lateral view of a room. In the center of this room stood a gender-matched human avatar facing either the right or the left wall. Simultaneously, red discs were displayed on either one or two walls. The participants were instructed to verify if the memorized digit matches the number of the discs the agent (self or other) can see (yes = C, no = N) (Figure 2).

The stimuli were manipulated in a 2 x 2 x 2 fashion (Perspective: Self vs. Other, Congruency: Congruent vs. Incongruent, Match: Matching vs. Mismatching). The matching trials were always associated with a “yes” response, and the mismatching trials with a “no” response. In the congruent condition, the avatar and the participant always saw the same number of discs. In the incongruent condition, some of the discs were not visible to the avatar but were visible to the participant. It was shown that participants could not easily ignore the irrelevant perspective (Samson & Apperly, 2010), resulting in prolonged reaction times and more errors in the incongruent condition compared to the congruent condition. Depending on the cue prompted to take the self-perspective or the avatar’s perspective, the interference on performance due to the conflict of viewpoints is referred to as the altercentric bias or egocentric bias, respectively.

In the main experimental part, there were four blocks, each consisting of 48 trials, along with four filler trials and no feedback. These trials encompassed 24 self trials and 24 other trials, with an equal variation of Congruency and Match trial type. The trials were presented in a pseudorandom order with no more than three consecutive trials of the same type. In the filler trials, no discs were shown on the walls. The task took approximately 22 minutes to complete.

Figure 2

Timeline of an Experimental Congruent Trial

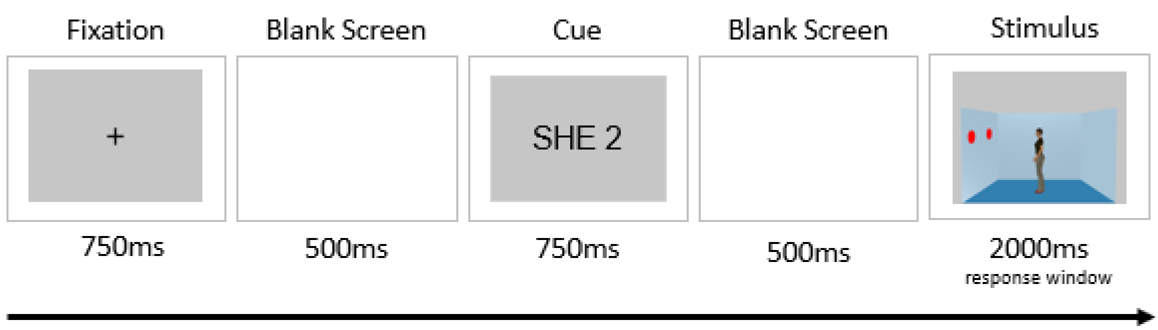

Figure 2: Note. The trial starts with a fixation cross, followed by an inter-stimulus interval (ISI). The next frame indicates to the participants that they have to adopt another person's perspective (she) and memorize the digit 2. After the second ISI, the participant sees a gender-matched avatar (e.g., a woman) facing the wall with the two red discs on it. The correct response is yes since the memorized digit (2) matches the number of discs the avatar can see. In this example, the participant and the avatar see the same number of discs (congruent condition). Copyright: adapted from Samson et al. (2010; stimuli: Samson & Apperly, 2015, figshare).

2.3.3. Audio-visual Emotional Egocentricity Bias Task. The audio-visual version of the emotional egocentricity bias task (av-EEB) developed by von Mohr et al. (2020) measures **the** self-other distinction processes for affective mental representations. The tasks consisted of five parts: deception, stimuli familiarization, catch trials, manipulation check (described in **SM.3.**), and the main experimental part. In the main experimental part, the task of the participants was to judge the (un)pleasantness of different audio-visual stimuli to which they or another person were exposed. **The stimuli were manipulated in a 2 x 2 x 2 fashion (Perspective: Self vs. Other, Congruency: Congruent vs. Incongruent, Valence: Positive vs. Negative). Congruent trials involved audio-visual stimulation of the same valence for both perspectives, while incongruent trials had the self and the other experiencing audio-visual stimulation of opposite valences. The incongruent trials are typically associated with reduced ratings for the target compared to congruent trials. Each trial was classified as pleasant or unpleasant based on the valence of the stimulation for the target (Self or Other). The valence table for the stimuli is available in SM.3.**

The participants were falsely led to believe that they performed the online task together with another person. In every block, participants adopted either the self or other perspective and, in every trial, rated the pleasantness of the audio-visual stimulation for a given perspective. During the trials, the participants simultaneously heard a sound and saw a picture on the screen. The picture depicted the type of sound to which the paired fake participant was exposed. In the congruent trials, the valence of the audio-visual stimulation was identical for both perspectives. In the incongruent trials, the self and the other experienced the audio-visual stimulation of opposite valence. For the self-perspective, the participants rated the pleasantness of the sound they heard. For the other perspective, the participants had to provide an estimation of how pleasant the sound depicted as the picture was for the other person (Figure 3).

The main experimental part consisted of four blocks (two self and two other blocks) with 16 trials per block presented in a randomized order. From these 16 trials, eight trials were of pleasant valence (four congruent and four incongruent trials), and eight trials were of unpleasant valence (four congruent and four incongruent trials). The participants were asked to judge blockwise the pleasantness of the sound either from their own (self block) or from the other person's perspective (other block) while suppressing an evoked or perceived emotional response of the irrelevant perspective. It was shown (Silani et al., 2013; Von Mohr et al., 2020) that during incongruent trials, the participants struggle to inhibit the tendency to project their own emotional states onto others, a phenomenon referred to as the egocentric bias. For the ratings, we deployed a visual analogue scale ranging from -10 (not at all) to +10 (extremely). The task took approximately 30 minutes to complete.

Figure 3

Timeline of an Experimental Incongruent Self-trial

Figure 3: Note. A trial starts with an intertrial interval, followed by a picture depicting an applauding crowd. The text on the top of the picture indicates that the paired fake participant MAPR82 is listening to sounds associated with this picture (in this case, of a positive valence). The real participant is listening to the sound of a woman being attacked (negative valence), making it an incongruent trial. After 3000 ms, the participant had to rate their feelings induced by the attack audio stimulation (self-rating). Copyright: based on the study by von Mohr et al. (2020, adapted from https://psyarxiv.com/j7vec/, CC0 1.0 Universal).

2.3.4. Stroop Task. The Stroop task (Stroop, 1935) measures the general ability to inhibit prepotent response tendencies (a part of cognitive control). The participants placed their fingers on the predefined keys (left middle = C, left index = V, right index = N, right middle = M). During the trials, they were instructed to press a key in response to the color of a presented stimulus (group 1: red = C, green = V, blue = N, yellow = M; group 2: red = N, green = M, blue = C, yellow = V). The presented stimuli were either color words (RED, GREEN, BLUE, YELLOW) or four X letters (XXXX). In the congruent trials, the color words were written in a matching color (e.g., BLUE printed in blue color). In the incongruent trials, the color of the words did not match their lexical meaning (e.g., BLUE printed in red color). Therefore, in the incongruent trials, the participants had to suppress or actively inhibit a highly automatic response tendency (reading a word), resulting in prolonged reaction times and more errors than in congruent trials (Stroop, 1935). During the baseline trials, the four X letters appeared in one of the four possible colors (either red, green, blue, or yellow).

The participants were instructed to react as fast and as accurately as possible. In the main experimental part, four blocks with 30 randomized trials per block and no feedback were presented (see **SM.4.** for a trial timeline). Out of these 120 trials, 40 were congruent trials, 40 were incongruent trials, and 40 were baseline trials. The task took approximately twelve minutes to complete.

2.3.5. Stop-Signal-Reaction-Time Task (SSRT). The SSRT is a paradigm to measure the inhibition of prepotent response tendencies (similar to the Stroop task). The participants respond with a button press to certain stimuli (go trial) while withholding a response to other stimuli (stop trial). Our task implementation procedure followed the recommendations provided by Verbruggen et al. (2019). The participants placed their fingers on the V and the N keys. During the go trials, they were instructed to press a key in response to a direction indicated by an arrow (V - when the arrow stimulus was pointing to the left, N - to the right). In the stop trials, in which the participants had to inhibit their response tendencies, the arrow turned red after a variable delay period (stop-signal delay [SSD], see **SM.5.** for a trial timeline).

The participants were instructed to react as fast and as accurately as possible. In addition, they were explicitly encouraged not to wait for a stop signal. The stop-signal delay was continuously adapted to an individual reaction time so that a successful inhibition would have been possible in 50% of the stop trials, and the number of go omissions would have been close to 0%. In the main experimental part (after the practice block), four blocks with 64 randomized trials per block and no feedback were presented. Out of these 64 trials, 48 were go trials, and 16 trials were stop trials. The task took approximately twenty minutes to complete.

2.4. Indexes

2.4.1. Automatic Imitation Inhibition Task. Prior to index calculation, we discarded trials that deviated ±2.5 *SD* from the participant's mean RT or were faster than 150 ms.

First, we computed the spatial congruency index for reaction times by subtracting reaction times in spatial congruent trials from the corresponding spatial incongruent trials (Equation 1).

$$\text{AIT spatial congruency index} = \frac{\left(\text{SIIC}^{\text{MeanRT}} + \text{SIII}^{\text{MeanRT}}\right)}{2} - \frac{\left(\text{SCIC}^{\text{MeanRT}} + \text{SCII}^{\text{MeanRT}}\right)}{2} \quad (1)$$

Note. RT = reaction time; SC = spatial congruent; SI = spatial incongruent; IC = imitative congruent, II = imitative incongruent (e.g., SCII – spatial congruent, imitative incongruent trial).

Our data showed (see https://osf.io/nys7q/, *Task Validation*) that spatial incongruence had a stronger interference effect than imitative incongruence. As a result, when struggling to resist the interference due to more dominant spatial incongruence, the participants might have had limited processing resources left to withstand the imitative incongruency. As a result and in contrast to the original study, we further refined the task's indexes by cancelling out the more dominant spatial incongruency. Specifically, we computed the subsequent imitative indexes based solely on spatially congruent trials, aiming to enhance comparability with other SOD measures without a double perceptual conflict.

We computed the imitative congruency index on spatial congruent trials (Equation 2) by subtracting reaction times in imitative congruent trials from the imitative incongruent trials. A higher imitative congruency index indicates reduced self-other distinction.

$$\text{AIT imitative congruency sp index} = \text{SCII}^{\text{MeanRT}} - \text{SCIC}^{\text{MeanRT}} \quad (2)$$

Note. RT = reaction time; sp = index calculated on spatial congruent trials; SC = spatial congruent; IC = imitative congruent; II = imitative incongruent.

In line with Bukowski, Todorova et al. (2021), we calculated the inhibition costs index on spatial congruent trials (Equation 3). The inhibition costs is **the** adjusted self-other distinction score.

$$\text{AIT inhibition costs sp} = \left(\frac{\text{BR}^{\text{MeanRT}} + \text{BL}^{\text{MeanRT}}}{2}\right) - \text{SCII}^{\text{MeanRT}} \quad (3)$$

Note. RT = reaction time; sp = index calculated on spatial congruent trials; BR = base right hand; BL = base left hand; SC = spatial congruent; II = imitative incongruent.

Additionally, to control for a possible speed-accuracy trade-off, we combined **per condition** the reaction times and accuracy (proportion correct) into the "Balanced Integration Score" using the function BIS (Liesefeld & Janczyk, 2019); https://github.com/Liesefeld/BIS). This function was applied to each AIT index, enabling a comprehensive performance evaluation while accounting for potential speed-accuracy trade-offs.

2.4.2 Visual Perspective-taking Task. As in the original study by Samson et al. (2010), we excluded mismatching trials ("no" responses, see **SM.2**, *n* = 24 trials per block). Next, we discarded trials that deviated ±2.5 *SD* from the participant's mean RT or were faster than 150 ms.

First, we computed two biases by comparing the reaction times in the incongruent trials to the congruent trials for the two perspectives (Equations 4, 5). Higher scores indicate reduced self-other distinction.

$$\text{VPT Altercentric bias} = \text{Incongruent Self}^{\text{MeanRT}} - \text{Congruent Self}^{\text{MeanRT}} \quad (4)$$

$$\text{VPT Egocentric bias} = \text{Incongruent Other}^{\text{MeanRT}} - \text{Congruent Other}^{\text{MeanRT}} \quad (5)$$

Note. RT = reaction time.

The altercentric bias describes a human's tendency to be influenced by the inferred mental state of others when building judgments about one's own mental state (Bukowski & Samson, 2021). In other situations, individuals sometimes egocentrically build their judgments on their own experience when trying to infer the mental states of those around them (Bukowski & Samson, 2021; Silani et al., 2013).

As in AIT, we calculated **the** adjusted self-other distinction score (VPT conflict index, Equation 6). VPT conflict is the main effect of incongruency and corresponds to the mean of altercentric and egocentric biases.

$$\text{VPT Conflict} = \frac{\left(\text{Incongruent Self}^{\text{MeanRT}} + \text{Incongruent Other}^{\text{MeanRT}}\right)}{2} - \left(\frac{\left(\text{Congruent Self}^{\text{MeanRT}} + \text{Congruent Other}^{\text{MeanRT}}\right)}{2}\right) \quad (6)$$

Note. RT = reaction time.

In the next step, to control for possible speed-accuracy trade-off, we applied the function BIS **per condition** (Liesefeld & Janczyk, 2019); https://github.com/Liesefeld/BIS) to the three VPT indexes.

2.4.3 Audio-visual Emotional Egocentricity Bias Task. In the baseline rating analysis, we aimed to replicate the study design of the original study (Von Mohr et al., 2020). Our results showed stimuli fit for all but one item (**SM.3.**, Table 2). The audio and picture stimuli of bees were rated neutral and not negative as intended. This motivated us to exclude all trials from the main analysis where the bees stimuli were used (25 % of all trials). We calculated several indexes quantifying the ability to correctly distinguish between self and other perspectives, making it comparable with the visual perspective-taking task (Bukowski et al., 2021; Samson & Apperly, 2010).

The altercentric bias is calculated by comparing the ratings in the incongruent trials to the congruent trials in the self condition (Equation 7). Higher biases indicate reduced self-other distinction. The egocentric bias is calculated by comparing the ratings in the incongruent trials to the congruent trials in the other condition (Equation 8).

Note, that in both the AIT and VPT tasks, researchers, including ourselves, have observed that reaction times are typically slower in incongruent trials compared to congruent trials. However, in the EEB task, the incongruent trials are associated with lower (i.e., less extreme) ratings than congruent trials (Silani et al., 2013; Von Mohr et al., 2020). To make the direction of interference consistent across all three tasks, we have reversed the EEB indexes. In practical terms, this means that while the AIT and VPT tasks calculate interference as the difference between incongruent and congruent trials (incongruent - congruent), the EEB task now calculates interference as the difference between congruent and incongruent trials (congruent - incongruent). This reversal ensures that higher EEB index values consistently reflect greater interference, aligning with the methodology used in the other two tasks. This change allows for a more straightforward comparison of results across different experimental conditions.

$$\text{EEB Altercentric bias} = \text{Congruent Self}^{\text{MeanR}} - \text{Incongruent Self}^{\text{MeanR}} \quad (7)$$

$$\text{EEB Egocentric bias} = \text{Congruent Other}^{\text{MeanR}} - \text{Incongruent Other}^{\text{MeanR}} \quad (8)$$

Note. Per condition, we aggregated the mean judgments for pleasant and unpleasant stimuli as follows: [pleasant judgments + (-1) x unpleasant judgments]/2. R = Rating.

As in AIT and VPT tasks, we calculated **the** adjusted self-other distinction score (EEB conflict index, Equation 9). The EEB conflict index is the main effect of incongruency and corresponds to the mean of altercentric and egocentric biases.

$$\text{EEB Conflict} = \frac{\left(\text{Congruent Self}^{\text{MeanR}} + \text{Congruent Other}^{\text{MeanR}}\right)}{2} - \frac{\left(\text{Incongruent Self}^{\text{MeanR}} + \text{Incongruent Other}^{\text{MeanR}}\right)}{2} \quad (9)$$

Note. Per condition, we aggregated the mean judgments for pleasant and unpleasant stimuli as follows: [pleasant judgments + (-1) x unpleasant judgments]/2. R = Rating.

2.4.4. Stroop Task. Prior to index calculation, we discarded trials that deviated ±2.5 *SD* from the participant's mean RT or were faster than 150 ms.

The Stroop congruency index for the reaction times was computed by subtracting reaction times in congruent trials from the incongruent trials (Equation 10). Higher scores indicate a reduced ability to inhibit prepotent tendencies.

$$\text{Stroop congruency} = \text{Incongruent}^{\text{MeanRT}} - \text{Congruent}^{\text{MeanRT}} \quad (10)$$

Note. RT = reaction time.

Next, we computed the inhibition costs index (Equation 11).

$$\text{Stroop inhibition costs} = \text{Baseline}^{\text{MeanRT}} - \text{Incongruent}^{\text{MeanRT}} \quad (11)$$

To control for possible speed-accuracy trade-off, we applied the function BIS **per condition** (Liesefeld & Janczyk, 2019); https://github.com/Liesefeld/BIS) to the two Stroop indexes. Note that, due to how the indexes are constructed, the Stroop congruency index closely resembles the altercentric indexes of SOD, while the Stroop inhibition costs index aligns more closely with the conflict indexes of SOD. This aspect has been taken into account when specifying the relevant models for the domain-generality research question.

2.4.5. Stop-Signal-Reaction-Time Task (SSRT). We estimated the SSRT index using the integration method, which, according to Verbruggen et al. (2019), is less biased and more reliable than other methods (e.g., the mean method). The index was calculated with the R Package *SSRTcalc* (*integration_adaptiveSSD function*; (Leontyev, 2021). Adaptive refers to an adaptive method of setting SSD, as in our case (an increase/decrease by 50 ms, depending on whether participants successfully inhibited their prepotent response tendencies in the stop trials or not. In the integration method (Equation 12), SSRT is computed by subtracting the mean SSD from the reaction time on the nth trial, where n is the number of RTs in the RT distribution of go trials multiplied by p(respond|signal). Higher values indicate a reduced ability to inhibit prepotent tendencies.

$$\mathrm{SSRT}_{\mathrm{integration}} = \mathrm{RT}_{\mathrm{nth}} - M_{\mathrm{SSD}} \quad (12)$$

Note. RT = reaction time; Mean = mean; SSD = stop-signal delay.

2.5. Statistical Analyses

2.5.1. Power Consideration. *Correlation analysis:* To ensure stable estimates, the sample size should ideally approach N = 250 (Schönbrodt & Perugini, 2013, 2018). Acknowledging the challenges posed by sample recruitment during the COVID-19 pandemic, our minimum targeted sample size was set at *N* = 150, following Qureshi et al. (2020), while the maximum *N* was capped at 300, consistent with (Shaw et al., 2020). Similar to ours in methodology, these studies investigate the structure of social cognition.

2.5.2. Correlation Analyses. The analyses were run on the final sample of the participants who completed all five tasks (*N* = 243). All indices were standardized before the analyses to reduce the influence of possible outliers.

Related to our main question 1 ***"Regardless of the number or nature of the processes underpinning SOD, are these the same processes for cognitive, affective, and motor mental representations?,"*** we predicted that should the corresponding indexes of SOD performance for motor, cognitive, and affective mental representations measure the same underlying processes, they will significantly correlate with each other.

To investigate this assumption, we clustered indexes into three meaningful groups of indexes:

1. Altercentric indexes: AIT imitative index calculated on spatial congruent trials and controlled for possible speed-accuracy trade-offs (sp-BIS), VPT altercentric bias (BIS), and EEB altercentric index;
2. Egocentric indexes: VPT egocentric bias (BIS) and EEB egocentric bias.
3. Conflict indexes: AIT inhibition costs (sp-BIS), VPT conflict index (BIS), and EEB conflict index.

Regarding our second main question, ***"To what extent domain-general processes confound SOD(s)?"***, we predicted that should the corresponding indexes of SOD performance for motor, cognitive, and affective mental representations measure domain-general processes, they will significantly correlate with the indexes of domain-general cognitive control performance.

To investigate the domain-general SOD hypothesis, we added the cognitive control indexes to the most fitted groups. In the case of the Stroop task, we calculated indexes using a similar approach as in the SOD tasks. As a result, the Stroop congruency index (BIS) fitted best to the altercentric group and the Stroop inhibition costs (BIS) to the conflict group. However, we did not have specific methodological or theoretical justifications regarding the AIT spatial (BIS) and SSRT index classification. Therefore, we added them to all model groups, that is the altercentric, egocentric, and conflict groups and computed the respective correlations.

As a reminder, the spatial congruency index of the AIT task captures the influence on performance caused by whether the laterality of the expected response and laterality of the stimulus match or not (Craft & Simon, 1970; Sowden & Catmur, 2015); the Stroop congruency index measures the interference on performance caused by the stimuli conflict between reading and color perception (Stroop, 1935); the SSRT index quantifies the interference on performance caused by the conflict between expected response and an irrelevant response (Logan & Cowan, 1984; Verbruggen et al., 2019).

For every research question, we adjusted the significance alpha level to control for multiple comparisons. Given the three theoretical clusters (altercentric, egocentric, and conflict), the adjusted $\alpha = 0.017$.

2.5.3. Hierarchical Clustering and Multidimensional Scaling. Hierarchical clustering and multidimensional scaling are exploratory data analysis methods to identify and visualize patterns and groupings within the data. In the present paper, these two methods have been applied to the scaled data to reduce the influence of potential outliers.

Hierarchical clustering proceeds successively by merging smaller clusters into larger ones (Halkidi, 2009). The results of this process can be visualized in a dendrogram-a tree of clusters-which shows how the clusters are related (Halkidi, 2009). Longer branches represent a greater dissimilarity, while shorter branches represent a greater similarity between the clusters. Clusters that merge earlier (at lower levels) are more similar to each other than clusters that merge later (at higher levels).

To analyze these relationships between the variables, we first calculated the pairwise Euclidean distances between the scaled observations, by applying an *R* function *dist*. Next, we performed hierarchical clustering using the average linkage method based on the distance matrix with the R Function *hclust* (R Core Team, 2023).

Multidimensional scaling is used to visualize similarities or dissimilarities in data by representing them in a two-dimensional space (Davison & Sireci, 2000). Variables or data points that are more similar in the original dataset are depicted as closer to each other in this space. Conversely, dissimilar variables or data points are positioned farther apart (Davison & Sireci, 2000). To analyze these relationships between the variables, we first calculated the pairwise Euclidean distances between the scaled observations, by applying an *R* function *dist*. Next, we performed multidimensional scaling with the R Function *cmdscale* (R Core Team, 2023).

2.6. Open Science Statement / Transparency and Openness

2.6.1. Open Data and Code. The data and the data analysis scripts for all experiments are available at https://osf.io/nys7q/ [doi:10.17605/OSF.IO/NYS7Q]. The study was not preregistered.

2.6.2. Study Materials. The stimuli used in the tasks are not openly shared, as they have been obtained from the authors of the original studies upon request.

2.6.3. Additional Questionnaires (Not Part of the Present Paper). All participants completed a set of questionnaires measuring traits and states in different domains of social, cognitive, and emotional functioning : (a) Behavioral Inhibition and Behavioral Activation System scale (BIS/BAS) (Carver & White, 1994), a scale measuring sensitivity to punishment (BAS) and sensitivity to reward and approach motivation (BAS); (b) Connectedness with the most closest person or community; (c) Positive and Negative Affect Scale (Watson et al., 1988), a scale measuring subjective experience of positive and negative affect; (d) Patient Health Questionnaire 9 (PHQ-9) scale, a diagnostic instrument for assessing depression severity (Kroenke et al., 2001); (e) Generalized Anxiety Disorder-7 (GAD-7) scale, a diagnostic instrument for assessing severity of anxiety (Spitzer et al., 2006); (f) Questionnaire of cognitive and affective empathy (QCAE) scale, an instrument for measuring trait empathy (Reniers et al., 2011); (g) Toronto Alexithymia Scale (TAS), an instrument for measuring difficulties in understanding, processing and describing emotions (Bagby et al., 1994); (h) UCLA loneliness Scale (UCLA-3), a self-report measure of loneliness (Russell, 1996). The results of these questionnaires are not part of the present study and will be reported elsewhere.

2.6.4. Tasks Validation. Prior to index calculation, we conducted task validation analysis. On the project's OSF page [https://osf.io/nys7q/], readers can find the task validation code [SOD5_TasksValidation-27-03-2024.html] and the final written report [SOD5_TasksValidation-27-03-2024.pdf]. In this written report and in the present manuscript, we are following Loenneker et al. (2024) to transparently document and justify our RT preprocessing decisions. Here, we omitted the task validation section to enhance the manuscript's conciseness, thereby improving readability and maintaining clarity for the readers.

Briefly, the results for all tasks replicated expected findings based on prior studies, with the notable exception of the AIT task. In the AIT task, we uncovered a new pattern of results in terms of a significant interaction between spatial and imitative congruencies as a function of the sample size. Notably, the AIT task developed by Sowden et al. (2015) was tested for the first time on a large sample and was specially designed to disentangle spatial from imitative congruencies.

2.6.5. Software. Data were analyzed using R, version 4.3.0 (R Core Team, 2023) and the R packages: *apaTables* (Stanley, 2021; Stanley & Spence, 2018), *dendextend* (Galili, 2015), *dplyr* (Wickham et al., 2023), *effectsize* (Ben-Shachar et al., 2020), *emmeans* (Lenth, 2024), *flextable* (Gohel & Skintzos, 2023), *ggplot2* (Wickham, 2016), *ggpubr* (Kassambara, 2023), *here* (Müller, 2020), *interactions* (Long, 2019), *jtools* (Long, 2022), *lmerTest* (Kuznetsova et al., 2017), *mergeutils* (Bloggs, 2014), *officer* (Gohel, 2023), *rio* (Chan et al., 2023), *Rmisc* (Hope, 2022), *sjPlot* (Lüdecke, 2023), *SSRTcalc* (Leontyev, 2021), *tibble* (Müller & Wickham, 2023), *tidyr* (Wickham et al., 2024), *tidyverse* (Wickham et al., 2019), and *writexl* (Ooms, 2024).

The manuscript has been written in R Markdown, which is avaliable at the project's OSF page https://osf.io/nys7q/ [doi:10.17605/OSF.IO/NYS7Q].

3. Results

The descriptive results are reported in Table 1.

Table 1: Indexes Mean and Standard Deviations (prior Scaling)

№	Variable	Mean	SD	№	Variable	Mean	SD
1	AIT imitative sp bis	0.03	1.21	7	EEB altercentric	0.76	1.24

№	Variable	Mean	SD	№	Variable	Mean	SD
2	AIT inhibitionCosts sp bis	-0.02	1.14	8	EEB egocentric	1.17	1.73
3	AIT spatial bis	0.00	1.17	9	EEB conflict	0.96	1.19
4	VPT altercentric bis	-0.04	1.16	10	Stroop congruency bis	-0.12	1.21
5	VPT egocentric bis	0.05	1.35	11	Stroop inhibitionCosts bis	0.05	1.30
6	VPT conflict bis	0.00	0.92	12	SSRT	226.23	40.88

Note. *N* = 243. AIT = automatic imitation inhibition task, VPT = visual perspective-taking task, EEB = audio-visual emotional egocentricity bias task, SSRT = stop signal reaction time task. sp = indexes calculated on spatial congruent trials; BIS = indexes controlled for speed-accuracy trade-off.

3.1. Correlation Analyses

Table 2: Correlation Table. Altercentric bias

Variable	1	2	3	4	5
1. AIT imitative sp bis					
2. VPT altercentric bis	-.12 [-.24, .01]				
3. EEB altercentric	.08 [-.04, .21]	.01 [-.12, .14]			
4. Stroop congruency bis	.12 [-.01, .24]	-.00 [-.13, .12]	-.03 [-.15, .10]		
5. AIT spatial bis	.05	.12	-.00	.11	

Variable	1	2	3	4	5
	[-.08, .17]	[-.01, .24]	[-.13, .12]	[-.01, .24]	
6. SSRT	.01	.06	.05	-.03	-.04
	[-.12, .13]	[-.07, .18]	[-.07, .18]	[-.15, .10]	[-.16, .09]

Note. This table presents Pearson correlation coefficients with pairwise deletion calculated with the function *apa.cor.table* from the R Package *apaTables* (Stanley, 2021; Stanley & Spence, 2018). Values in square brackets indicate the 95% confidence interval for each correlation. *N* = 243. AIT = automatic imitation inhibition task, VPT = visual perspective-taking task, EEB = audio-visual emotional egocentricity bias task, SSRT = stop signal reaction time task. sp = indexes calculated on spatial congruent trials; BIS = indexes controlled for speed-accuracy trade-offs. * p<.05, ** p<.01

Correlation analysis revealed no significant between-tasks correlations in the altercentric group of indexes.

Table 3: Correlation Table. Egocentric bias

Variable	1	2	3
1. VPT egocentric bis			
2. EEB egocentric	-.05		
	[-.17, .08]		
3. AIT spatial bis	.06	.02	
	[-.07, .19]	[-.11, .14]	

Variable	1	2	3
4. SSRT	.01	-.04	-.04
	[-.12, .13]	[-.16, .09]	[-.16, .09]

Note. This table presents Pearson correlation coefficients with pairwise deletion calculated with the function *apa.cor.table* from the R Package *apaTables* (Stanley, 2021; Stanley & Spence, 2018). Values in square brackets indicate the 95% confidence interval for each correlation. *N* = 243. AIT = automatic imitation inhibition task, VPT = visual perspective-taking task, EEB = audio-visual emotional egocentricity bias task, SSRT = stop signal reaction time task. sp = indexes calculated on spatial congruent trials; BIS = indexes controlled for speed-accuracy trade-off. * $p<.05$, ** $p<.01$

In the egocentric group, neither were the SOD between-tasks correlations significant, nor were the correlations between SOD indexes and the domain-general indexes.

Table 4: Correlation Table. Inhibition costs

Variable	1	2	3	4	5
1. AIT inhibitionCosts sp bis					
2. VPT conflict bis	.07				
	[-.05, .20]				
3. EEB conflict	.04	.01			
	[-.09, .16]	[-.12, .13]			

Variable	1	2	3	4	5
4. Stroop inhibitionCosts bis	-.03	.04	-.02		
	[-.15, .10]	[-.09, .17]	[-.15, .10]		
5. AIT spatial bis	.54**	.12	.01	.02	
	[.44, .62]	[-.01, .24]	[-.11, .14]	[-.11, .14]	
6. SSRT	-.00	.04	-.00	.04	-.04
	[-.13, .12]	[-.08, .17]	[-.13, .12]	[-.09, .17]	[-.16, .09]

Note. This table presents Pearson correlation coefficients with pairwise deletion calculated with the function *apa.cor.table* from the R Package *apaTables* (Stanley, 2021; Stanley & Spence, 2018). Values in square brackets indicate the 95% confidence interval for each correlation. N = 243. AIT = automatic imitation inhibition task, VPT = visual perspective-taking task, EEB = audio-visual emotional egocentricity bias task, SSRT = stop signal reaction time task. sp = indexes calculated on spatial congruent trials; BIS = indexes controlled for speed-accuracy trade-off. * p<.05, ** p<.01

Correlation analysis revealed no significant between-tasks correlations in the SOD inhibition costs group of indexes. AIT inhibition costs on spatial congruent trials controlled for speed-accuracy trade-off correlated with AIT spatial index ($r = 0.54$, $p < 0.001$).

3.2. Hierarchical Clustering and Multidimensional Scaling

Figure 4

Results of the Hierarchical Cluster Analysis

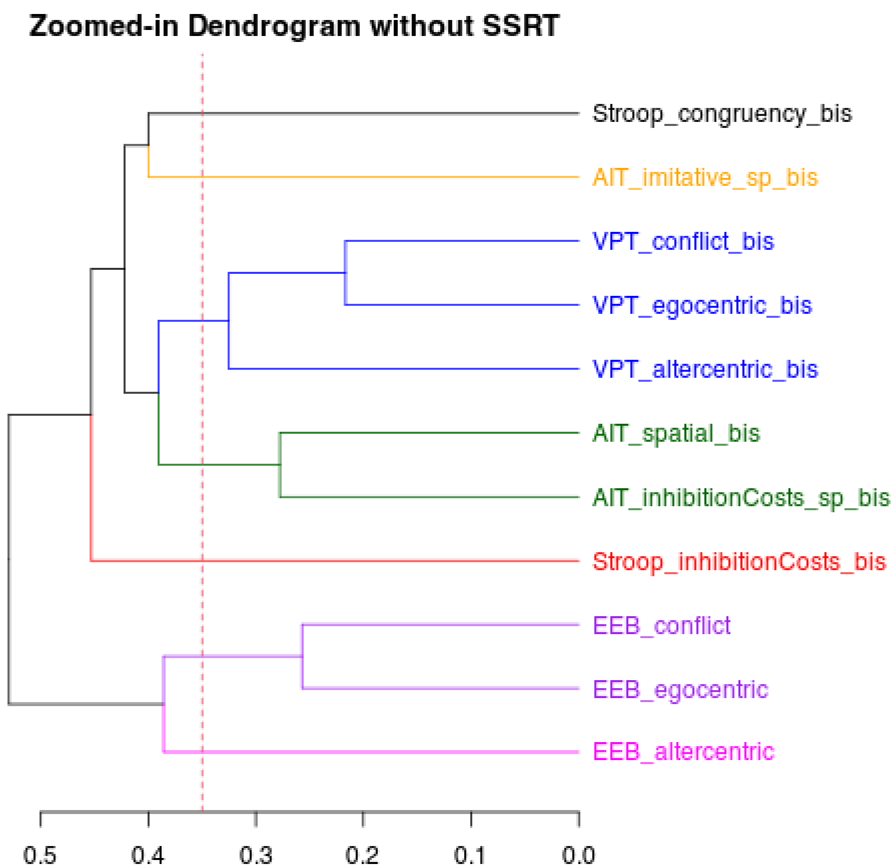

Figure 4: Note. The SSRT variable is not displayed on this graph due to its significant distance from other variables. Its exclusion is intentional to enhance graph clarity. In the provided dendrogram, a horizontal line is drawn at a height of 0.35. This cut-off was selected based on the largest vertical gaps between merges, indicating significant separations between clusters. By examining the dendrogram, it is evident that cutting at this height allows for the identification of distinct groups within the data.

The results of the hierarchical cluster analysis visualize the similarities and dissimilarities between the variables. The SSRT variable, being the most distant from all others, has been removed from the dendrogram to improve graph clarity.

Upon **visually** examining the dendrogram (Figure 4), it becomes evident that all three SODs (motor, cognitive, and affective) form **at first** distinct clusters. This is despite the performed preprocessing steps aimed at minimizing measurement-related “noise,” such as addressing speed-accuracy trade-offs in tasks like AIT and VPT, or additionally reducing spatial interference in the AIT indexes.

Notably, the VPT and EEB tasks exhibit a similar grouping pattern: the conflict index and egocentric bias are initially grouped together, followed by the altercentric tendencies. This implies that despite the conflict index representing the mean of egocentric and altercentric tendencies, it predominantly captures processing akin to egocentric tendencies.

Regarding domain-general processes, the Stroop congruency index was more closely related to the AIT imitative index, whereas spatial processes formed a separate cluster with the AIT inhibition costs. In a subsequent step, the Stroop inhibition costs index merged with the motor-cognitive cluster, entailing domain-general processes. And the EEB indexes were, if anything, minimally associated with the domain-general processes. Finally, in the very last step, all clusters were merged with the SSRT index (not shown in the figure).

Figure 5

Results of the Multidimensional Scaling

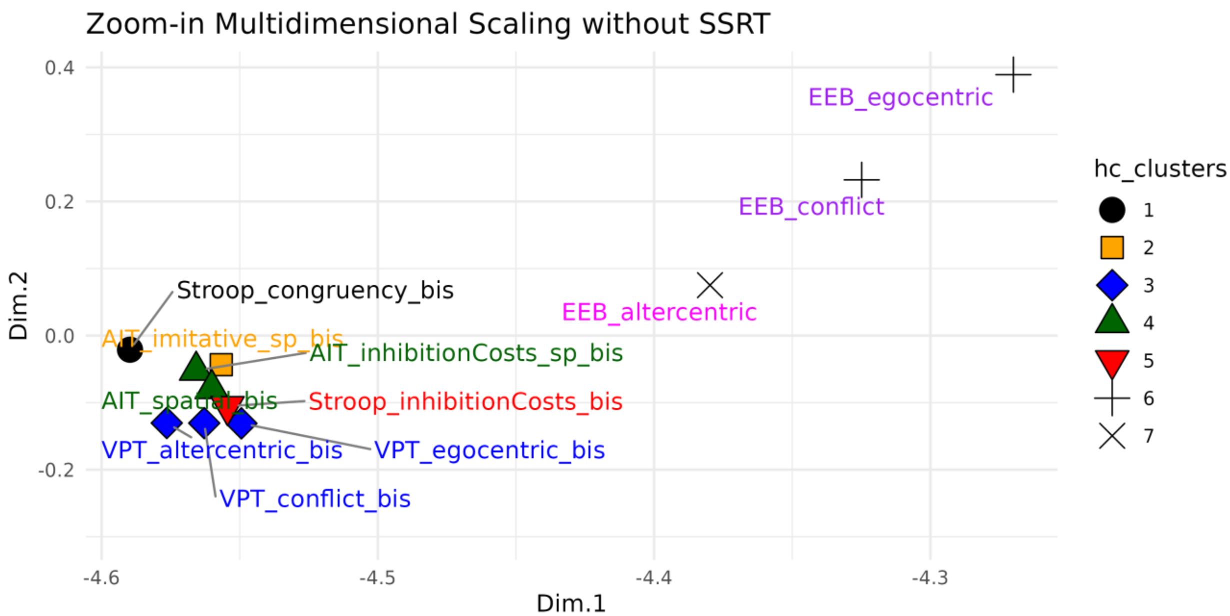

Figure 5: Note. The SSRT score is not displayed on this graph due to its significant distance from other scores. Its exclusion is intentional to enhance graph clarity. hc_clusters = Clusters identified through hierarchical clustering analysis.

The results of multidimensional scaling (Figure 5) **mostly** coincide with those of hierarchical clustering. Note, to enhance clarity, the SSRT score, the most distant index, has been excluded from both graphs but not from the respective analyses.

Consistent with the results of the hierarchical clustering, the SSRT (not shown in the figure) is positioned the farthest from all other indexes. The EEB indexes are notably distant, and the Stroop congruency index is somewhat closer to the motor-cognitive cluster. The motor-cognitive cluster itself includes the VPT and AIT indexes, along with the domain-general indexes of spatial processes and the Stroop inhibition costs index.

Overall, the MDS analysis indicates a similarity between **the Stroop**, VPT and AIT indexes compared to the EEB indexes.

4. Discussion

The present study addressed two main questions: (1) whether **the same processes** underpin **the** self-other distinction for motor, cognitive, and affective representations and (2) whether **the** self-other distinction can be explained by domain-general processes related to cognitive control and thus may not be specific to social cognition. For these purposes, we employed online versions of **the** three self-other distinction tasks pervasively used in the literature (motor SOD: (Sowden & Catmur, 2015); cognitive SOD: (Samson & Apperly, 2010); affective SOD: Von Mohr et al. (2020) and two domain-general cognitive control tasks (Stroop task, (Stroop, 1935); SSRT, (Logan & Cowan, 1984; Verbruggen et al., 2019). First, we discuss how our findings answer each question and then what additional insights our results convey regarding understanding of socio-cognitive processes.

Research question 1: Regardless of the number or nature of the processes underpinning SOD, are these the same processes for cognitive, affective, and motor mental representations? The correlation analysis showed no significant between-tasks associations. Similarly, separate task clusters emerged during the hierarchical clustering. However, the multidimensional scaling placed the AIT and VPT indexes closer together compared to the EEB indexes. These results provide correlational evidence that **the** self-other distinction **may not involve similar mechanisms uniformly applied across motor, cognitive, and affective mental representations**. The MDS two-dimensionality aligns with neuroimaging studies, which have shown that **the** motor-cognitive self-other distinction activates the same brain area (rTPJ), whereas **the** self-other distinction for affective representations engages a neighboring but distinct brain structure (Steinbeis, 2016).

Research question 2: To what extent domain-general processes confound SOD(s)? To investigate the extent to which the self-other distinction is specific to the domain of social cognition, we additionally included indexes considered as measures of domain-general processes. **First, our correlation analyses revealed that stimulus laterality (AIT spatial congruency) correlated with one of the AIT indexes, specifically the AIT inhibition costs. The results from multidimensional scaling and hierarchical clustering showed that AIT spatial congruency and the Stroop indexes were close to the motor-cognitive cluster, which comprised the AIT and VPT indexes.** While these confounding effects have already been extensively discussed in the motor-cognitive domains (Cooper et al., 2013; Martin et al., 2019; May & Wendt, 2013), **our study is among the few to specifically address the role of domain-general processes in the affective self-other distinction. The results of the present study provide no correlational support for the involvement of these domain-general processes in affective self-other distinction.**

Finally, SSRT inhibition of prepotent responses has shown no relationship with either the SOD tasks or Stroop indexes, indirectly supporting previous findings that the Stroop task and SSRT involve different cognitive processes (Khng & Lee, 2014).

In summary, our **correlative** findings align with some previous literature favoring the involvement of domain-general processes in **motor-cognitive** SOD (for review, Heyes (2014); Ramsey (2018)). **Yet, the lack of significant correlations between the SOD indexes and the domain-general indexes, combined with their relative distance in the dendrogram and**

multidimensional graph, suggests that SOD cannot be considered equivalent to a domain-general mechanism related to inhibitory control.

Fundamentally, with our findings, we highlighted a very complex structure of SOD (cf., (Qureshi et al., 2020).

4.1. Study Strength

As discussed in the *introduction*, previous inconsistent findings raised at least three possible scenarios:

1. researchers compare**d** many underpowered studies,
2. the measurement tools of **the** self-other distinction **were** built so that they **fail to capture the underlying shared processes**,
3. the self-other distinction processes for motor, cognitive, and affective mental representations **may appear functionally similar but are not underpinned by the same shared processes**.

Firstly, related to the first scenario, the strength of the present study is a relatively large sample size, which is sufficient for correlation analysis to provide an effect close to the true effect, given (or assuming) low task reliability (Hedge et al., 2017; Schönbrodt & Perugini, 2013).

Related to the second scenario, it is possible that similarities or dissimilarities of the measurement tools could at least partially confound the results. For example, almost all tasks, except for the audio-visual EEB task, are reaction time task paradigms. Additionally, both the VPT and AIT tasks involve spatial compatibility and rely on mental rotation of body positions. To rule out **this** scenario, we implemented several strategies to cancel out measurement noise, such as accounting for both reaction time and accuracy (BIS scores; (Draheim et al., 2019; Hedge et al., 2017)), introducing an alternative index of SOD ("conflict index") to achieve a more accurate representation of the construct, and canceling out the dominant spatial incongruence in the automatic imitation task. If the theoretical assumptions underlying data preprocessing hold true, then the resulting indexes are not confounded by measurement differences and should represent true underlying processes. Therefore, our results are consistent with the third scenario: the self-other distinction processes for motor-cognitive and affective mental representations **may appear functionally similar but are not underpinned by the same shared processes**.

4.2. Limitations

An alternative explanation of our results might be that the failure to find associations across tasks might still be of a methodological and not conceptual nature, relating to, **firstly**, how reliably these tasks can capture individual differences (Hedge et al., 2017). The VPT task shows modest to good test-retest reliability (Vestner et al., 2022) and has proven useful for detecting individual differences (Bukowski et al., 2020; Bukowski & Samson, 2017; Qureshi et al., 2020; Samuel et al., 2023; Shaw et al., 2020). The automatic imitation task shows high split-half reliability (Genschow et al., 2017), but to our knowledge, there has been no formal assessment of test-retest reliability. However, the AIT task robustly detects individual differences (meta-analysis: (Cracco et al., 2018), including the specific task version used in our study (Sowden et al., 2016). Less is known for the only recently introduced audio-visual EEB task; in its first use, a relationship was shown between interindividual differences in interoceptive accuracy and the EEB (Von Mohr et al., 2021). In another study, low test-retest reliability was suggested (Goregliad Fjaellingsdal et al., 2023). Note that this study introduced modifications to the task that render the results non-informative for the present study.

Secondly, the lack of association between the EEB task and the other SOD indexes or domain-general indexes can be attributed to the **response** differences (RT vs. Ratings) and not to differences in the underlying mechanisms, despite our attempts to reduce measurement noise. **Furthermore, for both the AIT and VPT tasks, the focus is on the external self, specifically body position in relation to the environment and other people. This is very different from the EEB task, which requires affect-relevant (internal state) judgments for the self and others. Finally, both the VPT and AIT tasks involve spatial compatibility and rely on mental rotation of body positions. While we are convinced that our data preprocessing cancels out differences in the self-focus and movements, isolating the handling of interference in its pure form, it is essential to recognize that current behavioral SOD tasks require improvement or replacement to advance the field. Although we utilized the most advanced tools available to capture self-other distinction (SOD), further developments in behavioral SOD tasks are necessary.**

A significant limitation of research on self-other distinction mechanisms, including the study presented here, is the lack of a single task that addresses multiple self-other distinctions separately while controlling for confounding variables. An example of such a task from a higher-order social domain is EmpaToM, which assesses empathy and theory of mind (Kanske et al., 2015). Similarly, there is no dedicated self-other distinction questionnaire, unlike the numerous questionnaires available for measuring e.g., empathy (Reniers et al., 2011). Furthermore, a recent EMA study on empathy found that different components of empathy often co-occur in daily life (Depow et al., 2021), making it challenging to investigate each facet, such as affective self-other distinction, in isolation.

That said, SOD can be operationalized in various ways beyond the approach presented in this paper. For instance, cognitive SOD can be measured by assessing the ability to differentiate self and other-related beliefs or desires, rather than focusing solely on visual perspectives. Affective SOD can be assessed by evaluating automatic emotional disentanglement or by involving allocation of specific emotions (within a wide range e.g., happy, angry, bored etc.) to the self vs. other. Exploring new ways of operationalizing SOD, along with addressing other limitations, represents promising avenues for future research. Yet, until a single task for the three domains or a self-other distinction questionnaire is developed, the scientific community will need to continue relying on converging evidence from different empirical studies or from studies utilizing various experimental paradigms within a single sample.

Lastly, the absence of correlations between Stroop and SSRT indexes may question the effectiveness of our analysis strategy in identifying a domain-general cognitive control process. Yet, our study intentionally aimed to cover distinct facets of cognitive control, avoiding an overly narrow focus on just one aspect. **Additional questions might arise whether the control tasks used have been an appropriate choice. Our results indicate that the Stroop task is closely related to the AIT and VPT tasks, suggesting that they share some similarities, making our choice appropriate. However, the SSRT task has been less informative and should be replaced in future replications by tasks related to change detection or set-shifting. Future research may benefit from exploring these additional paradigms.**

4.2.1 Constraints on Generality. **Following Simons et al. (2017), our**

Constraints on Generality statement will help other researchers evaluate the scope and generalizability of our claims. We believe that the results of our study can be generalized to individuals with similar demographic characteristics in terms of age, gender, and education.

Our convenience sample comprised 310 participants who performed at least one task. Only 243 of those completed all five tasks and were included in the final analysis. Given our focus on examining the effects across the five tasks, we implemented strict exclusion criteria, which meant only considering the data from those who completed every task with fewer than 20% errors, experienced no technical difficulties, or explicitly stated that they performed the task according to instructions (self-reported). This was used as indirect evidence of understanding the instructions.

While this approach ensures that our analysis is based on a consistent and complete dataset, it introduces potential bias. Excluding participants who did not complete all tasks may inadvertently exclude individuals with certain traits relevant to social cognition, such as motivation, attention span, or internet access stability, which might systematically differ between those who completed all tasks and those who did not. Additionally, excluding participants with more than 20% errors is common practice in RT research, but this practice ignores the fact that a large number of errors can represent a true underlying effect. Consequently, our findings might not fully represent the broader population, as the excluded participants could have provided valuable insights that are now missing from the analysis.

Importantly, our data collection took place during the acute phase of the COVID-19 pandemic, including social distancing and lockdowns. It remains unclear how this time of uncertainty influenced the participants' underlying **the** self-other distinction ability and, as a consequence, their task performance.

Furthermore, we tested social cognition and cognitive control with simple experimental paradigms. While these methods are well-suited to study underlying processes, it is yet to be determined how these findings translate to the outside real world.

4.3. Future Directions

Our correlational study, although informative, cannot definitively eliminate the alternative explanation that the results are driven by the differences in the measurement tools utilized to assess **the** self-other distinction. To further advance scientific understanding of SOD underlying processes, progress in measuring SOD is needed, such as a development of a single task with alternating motor, cognitive, and affective representational contents or via alternative SOD measures capturing individuals' everyday social life, using an ecological momentary approach.

Next, in contrast to correlation studies as the present study, interventional and neurostimulation studies are needed to provide causal evidence of the processes involved in SOD. However, targeting these specific processes presents methodological challenges both at the behavioral (Bukowski et al., 2021) and the brain (Bukowski et al., 2020) levels.

Further, one could argue that the results of our analyses depend upon many parameters chosen by the researcher (see multiverse debate (Olsson-Collentine et al., 2023; Steegen et al., 2016), which questions the replicability of the findings. **We are convinced that the methodological choices made in our study will set a new standard for future research. For example, unlike past research, we have excluded spatially incongruent trials in the AIT task, the *bees* trials in the EEB task, and transformed the RT indexes into BIS scores**

(Liesefeld & Janczyk, 2019). The version of the AIT task we used (Sowden & Catmur, 2015) is relatively new, and not much work has been done on it. We believe (and our data shows) that, contrary to what the creators of the task expected, the interaction between spatial and imitative compatibilities will be an issue when the sample size is large. Therefore, we foresee that future studies will follow our approach to remove spatially incongruent data. Furthermore, using BIS scores (Liesefeld & Janczyk, 2019) is a common procedure to control for speed-accuracy trade-offs. Similar to the AIT task, the audio-visual version of the EEB task (Von Mohr et al., 2020) is new and would benefit from a larger stimulus pool. Since our goal was to keep the present manuscript concise, we advise readers to refer to our *Task Validation* report and online data (https://osf.io/nys7q/), which provide necessary information to put our results in the context of past research.

Overall, in the present study, we adopted a combined approach of confirmatory and exploratory investigation (Höfler et al., 2022). While our intention was to confirm **SOD** one-dimensionality, we achieved this by transparently employing diverse exploratory methods, contributing to a broader and more extensive understanding of the cognitive processes involved. Validating the observed result pattern with new data (Höfler et al., 2023) and integrating it with past and future research is crucial to ascertain the robustness and generalizability of the findings.

In light this, it becomes imperative to consider the necessity for investigations within clinical populations to further elucidate the underlying mechanisms. Overall, our results represent an essential intermediate phase in the progression from basic to clinical research. **For instance, Eddy (2018) discussed the differences and similarities between schizophrenia and Tourette syndrome regarding social functioning. Both clinical populations showed increased internal simulations of others' actions and emotions but reduced mentalizing (Eddy, 2018).**

However, some of the deficits might have been confounded by general cognitive impairment (Eddy, 2018). Given the heterogeneity of symptoms, specifically in schizophrenia, it is not surprising that the empirical results are often mixed. For example, Simonsen et al. (2019) reported intact top-down modulation of imitation in patients with schizophrenia, whereas Rudolph et al. (2022) found the opposite.

Our study can encourage psychiatric research to investigate SOD across at least three domains (motor, cognitive, and affective) and to include measures of general cognitive abilities. If we assume domain independence, based on the results of the current correlation study, we might expect different disorders to exhibit disorder-specific impairments in one of the domains, alongside overall nonspecific impairments in general cognitive mechanisms. Therefore, clinical work could be particularly informative by identifying specific SOD impairments that contribute to symptoms in various psychiatric conditions. Another prediction is that impairments in one domain might be associated with enhanced SOD in another domain as a compensatory mechanism for disorder-specific deficits, potentially uncovering markers of resilience. Given the impairement of SOD in several psychiatric conditions, such as borderline personality disorder (De Meulemeester et al., 2021), SOD is viewed as a transdiagnostic mechanism (Eddy, 2022) and, therefore, a strategic target for interventions.

4.4. Conclusion

In the present study, we addressed two highly debated questions: 1) whether **the same processes underpin the** self-other distinction for motor, cognitive, and affective representations and (2) whether or to what extent **the** self-other distinction involves domain-general processes related to cognitive control. For these purposes, we employed online versions of the three well-established self-other distinction tasks and the two domain-general cognitive control tasks on a large sample (*N* = 243).

Our study not only provides an extensive investigation of SOD on multiple levels but also highlights the complex structure of SOD and reveals novel association patterns when considering conflict SOD index, controlling for spatial compatibility, and accounting for speed-accuracy trade-offs. The converging results suggest a **potential** two-dimensionality between motor-cognitive and affective representational contents. **Crucially, the general ability to inhibit prepotent response tendencies measured by the Stroop task and the interference from stimulus laterality seem to play a role in the motor-cognitive SOD.**

Consent to publish

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Conflicts of Interests

The authors have no relevant financial or non-financial interests to disclose.

Author contributions

E.P.: Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing H.B.: Formal analysis, Methodology, Supervision, Validation, Writing – review & editing, C.L.: Conceptualization, Funding acquisition, Methodology, Resources, Supervision, Validation, Writing – review & editing, All authors approved the final version of the paper for submission.

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