WHAT IS SOCIAL AND EMBODIED ABOUT SITUATED EMBODIED SOCIAL COGNITION? CURRENT ISSUES AND PERSPECTIVES

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Embodied Dyadic Interaction Increases Complexity of Neural Dynamics: A Minimal Agent-Based Simulation Model

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The concept of social interaction is at the core of embodied and enactive approaches to social cognitive processes, yet scientifically it remains poorly understood. Traditionally, cognitive science had relegated all behavior to being the end result of internal neural activity. However, the role of feedback from the interactions between agent and their environment has become increasingly important to understanding behavior. We focus on the role that social interaction plays in the behavioral and neural activity of the individuals taking part in it. Is social interaction merely a source of complex inputs to the individual, or can social interaction increase the individuals' own complexity? Here we provide a proof of concept of the latter possibility by artificially evolving pairs of simulated mobile robots to increase their neural complexity, which consistently gave rise to strategies that take advantage of their capacity for interaction. We found that during social interaction, the neural controllers exhibited dynamics of higher-dimensionality than were possible in social isolation. Moreover, by testing evolved strategies against unresponsive ghost partners, we demonstrated that under some conditions this effect was dependent on mutually responsive co-regulation, rather than on the mere presence of another agent's behavior as such. Our findings provide an illustration of how social interaction can augment the internal degrees of freedom of individuals who are actively engaged in participation.

Keywords: social interaction, agent-based models, artificial neural networks, evolutionary robotics, embodied cognition

1. INTRODUCTION

Social interaction has become a hot topic in cognitive science. Not too long ago a radical individualism about collective phenomena was the only game in town, leading respected philosophers to conclude that ultimately the basis of our mental life does not depend on others at all, such that it would make no difference if others were just a hallucination of a "brain in a vat" (Searle, 1990). Nowadays there is a growing consensus that this pessimistic view is inadequate, and that social interaction can make a difference to the mental and behavioral activity of individuals (Froese, 2018). For instance, evidence from neuroimaging, psychophysiological studies, and related fields has revealed that the mechanisms of social cognition are different when we are in real-time interaction with others compared to when we are passive spectators (Schilbach et al., 2013).

Nevertheless, the extent and nature of the influence of social interaction on an individual is still contentious. Most researchers adopt a moderate individualism in which interaction with others can make a difference but only externally so, for example by serving as a source of additional information, by having a causal influence, or by providing an opportunity for adopting a more socially oriented mode of cognition (Gallotti and Frith, 2013). Other researchers adopt an enactive approach that questions the validity of this restriction, proposing instead that the interaction in itself can play a role in realizing an individual cognition, thereby transforming and augmenting the individual capacities (De Jaegher et al., 2010). On this latter view, social interaction could allow an individual to overcome the limitations of their individual capacities by incorporating the complex dynamics of the interaction process into the basis of their internal activity.

Agent-based modeling offers a suitable framework with which to start investigating this possibility in a systematic manner. In particular, by simulating pairs of mobile agents in highly simplified scenarios it becomes possible to systematically assess the relationship between individual complexity and social interaction (Froese et al., 2013b). For instance, in previous work one of us provided a proof of concept that evolving two agents to locate each other in an open-ended arena via acoustic coupling can result in activity in their neural controllers, which in principle would have been too complex for them to generate in isolation (Froese et al., 2013a). Here, we show that this is not an isolated finding: directly evolving pairs of agents to increase the complexity of their neural activity consistently results in behavioral strategies involving mutually coordinated interaction between them. Moreover, we show that there is a crucial difference between forms of interaction in which the agents behaviors are interdependent compared to independent from each other: neural complexity achieved during mutually coordinated interaction tends to be even higher than what can be achieved during one-way coordinated interaction.

2. MATERIALS AND METHODS

Experiments were conducted on pairs of simulated agents that interacted with one another in an empty 2-dimensional environment. Each agent emitted an acoustic signal, which could be sensed by the other via two sensors positioned at the perimeter of their circular bodies (Di Paolo, 2000). The strength of the emitted signal faded linearly with distance, and sensors were positioned to be 90° apart from one another (**Figure 1**). Thus, agents can gather information about their relative distance and orientation to one another. Neural controllers were modeled as dynamical recurrent neural networks (Beer, 1995). Sensory input filtered through sensory neurons into an inner layer of two interconnected neurons, whose activity modulated the power of the emitted acoustic signal and controlled motor neurons that propelled the agent around its environment.

Parameters of the neural controllers, such as weights and signs of the connections, biases, and time-constants, were optimized using an evolutionary algorithm. Each evolutionary run was initialized with a random population of 96 solutions, that was evolved over 500 generations. Hundred such runs were executed and the best solution in the population from each run was collected to be analyzed. In order to evaluate the fitness of the individuals, we computed the entropy of the time series of neural activity taken from simulated trials. This measure allowed us to operationalize the complexity of internal neural dynamics exhibited by each agent in various interaction conditions. In particular, neural entropy was measured for each agent in trials where they were evolved and interacted in pairs (*interaction entropy*), as well as control conditions where agents were placed in the environment by themselves (*isolation entropy*). Our decision to use neural entropy as an index of internal complexity was motivated by its interpretability and computational tractability, as well as a range of previous studies that have associated elevated levels of neural entropy with improved cognitive performance, including therapeutic benefits (Carhart-Harris et al., 2014), increased levels of consciousness (Schartner et al., 2017), and improved generalization in motor learning tasks (Dotov and Froese, 2018). Please refer to the **Supplementary Material** for more details on the parameters of the evolutionary optimization methodology adopted.

3. RESULTS

3.1. Interaction Enhances Internal Complexity Beyond What Is Possible Alone

First, in order to study the effect of interaction on internal complexity, we artificially evolved pairs of agents to maximize their interaction entropy, without explicitly specifying any desired behavior. The resulting movement and neural traces from one trial of one of the best evolved pairs of agents from 100 runs is shown in **Figure 2**. During interactions, agents exhibited normalized neural entropies of 0.7568 and 0.8763. Although behavioral interactions were not selected for, evolved agents exhibited a complex pattern of moving toward and away from each other in a coordinated manner (**Figure 2B**, **Supplementary Figure 5**). Qualitatively similar behaviors were observed in the rest of the evolutionary runs (**Supplementary Material**).

We expected that agents would evolve to make use of social interaction to enhance their internal complexity, if there was an opportunity to do so. In order to verify this prediction, we performed another set of experiments where we evolved isolated agents using the same fitness function. Comparing the neural entropy achieved by agents in 100 independent evolutionary runs in each condition revealed that internal complexity was significantly higher when agents had the ability to interact as

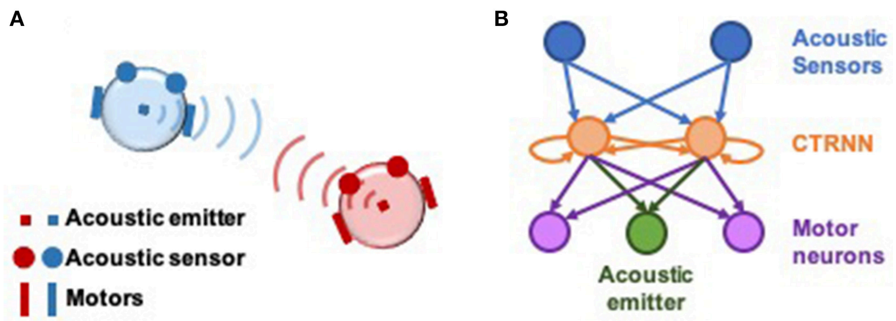

FIGURE 1 | Setup of computational model and neural network architecture. **(A)** Illustration of socially interacting agents. Two agents, each consisting of an acoustic emitter that they are able to modulate, a pair of acoustic sensors to sense the other agent, and two motors to move in a 2-dimensional environment. The ability to modulate their own signal combined with their ability to listen to their counterpart, enables interaction in this model. Agents cannot sense themselves. **(B)** Neural architecture of the agents. The two acoustic sensors feed into a 2-neuron fully-connected continuous-time recurrent neural network (CTRNN) circuit which in turn feed into the two motors and the acoustic emitter. The movement of the agent is result of the net activation of the left and right motor neurons.

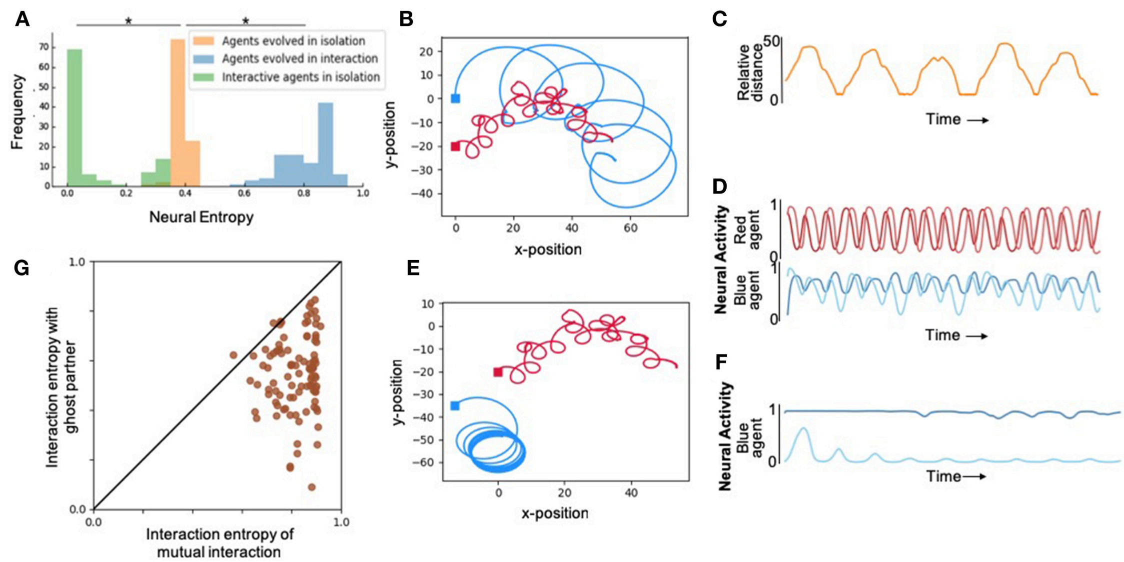

FIGURE 2 | Results depicting effect of social interaction on neural complexity. **(A)** Fitness distributions of best agent in the population from 100 runs for each of the different levels of social interaction. Agents evolved with interaction (blue) showed highest neural complexity, however, when the same agents were evaluated in isolation (green) showed significantly lower neural complexity even compared to agents evolved in isolation (orange). *Denotes statistically significant difference with $p < 0.005$ (see **Supplementary Material** for details). **(B)** An illustration of the 2-dimensional behavioral pattern of two agents evolved to interact demonstrating aperiodic oscillatory patterns that cannot be achieved by the 2-neuron systems of each agent in isolation. **(C)** Relative distance over time of the two agents shown in **(B)**, also demonstrating interesting complex patterns that cannot be achieved by passive 2-neuron CTRNNs. **(D)** The neural activity of the 2 interneurons of red and blue agents shown in **(B)**, demonstrating chaotic aperiodic activity that cannot be generated by 2-dimensional CTRNNs in isolation in the absence of interaction. **(E)** The same agents as in **(B)**, but in this case the red agent plays back the recorded behavior from the trial shown in **(B)**, while the blue agent is allowed to interact with it. Significantly reduced behavioral complexity is observed under this "ghost" condition where agents are unable to mutually interact with each other. **(F)** Neural activity in interneurons of blue agent under the ghost condition, showing significantly lower complexity compared to the same agent's neural activity in the interactive mode shown in **(D)**. **(G)** Neural entropy and behavior in the presence of an active partner vs. ghost partner. All agents exhibit high values along the horizontal axis demonstrating high internal complexity in the presence of responding partners. However, as it can be seen from the spread along the vertical axis, below the diagonal, these agents lose internal complexity when their partner is a ghost. This loss tends to be more pronounced for higher levels of interaction entropy, which suggests that these higher levels are more readily achieved by interdependent rather than independent interaction.

opposed to when they existed in isolation (**Figure 2A**). In other words, the interaction entropy of agents evolved in social contexts is consistently larger than the isolation entropy of agents evolved in isolation.

3.2. Complex Interactive Behavior Does Not Require High Isolation Entropy

From the previous results, it does not directly follow that agents that show high interaction entropy would also exhibit high isolation entropy. This is an empirical question regarding the emergence of complex interactive behaviors from simple systems. In order to test this, we disabled the sensors in agents that were optimized in interactive environments and measured their neural entropy in isolation. These agents consistently showed lower levels of entropy than what they exhibited during interaction (**Figure 2A**). Importantly, all of these agents also showed significantly lower levels of entropy than what was typically achieved by agents evolved in isolation to maximize isolation entropy (**Figure 2A**). In other words, although these agents were more complex during interaction, they are not intrinsically more complex. This has implications for developmental psychology, since these results suggest that complex interactive behaviors do not require high intrinsic internal complexity, as long as infants have the capacity to take advantage of the complexity provided by interaction.

3.3. Agents Exhibit Higher-Dimensional Dynamics During Interaction

From a dynamical systems perspective, in isolation, these simulated mobile robot systems are two-dimensional autonomous systems (2 neuronal states) that can at most have fixed-point or limit-cycle attractors (Beer, 1995). During the course of interaction with another agent, these dynamical systems show aperiodic dynamics more complex than limit-cycles and that in principle require at least 3 dimensions (**Figure 2D**). In the presence of another agent, the coupled system is of higher dimensionality involving both agents and their relative environmental states. In this case, measuring the neural entropy in one agent neural activity is akin to measuring the entropy of the two-dimensional projection of a higher dimensional system. This explains the enhanced levels of internal complexity in agents that are in the presence of others through their interaction the two embodied agents can become integrated into a larger, dynamically extended system (Froese and Fuchs, 2012).

This dependence on interaction with their partner to enhance neural complexity, and hence behavioral complexity, could be from two categorically different underlying interactive modes.

1. The partner could be a source of complex stimuli that drives the agent in question to perform behaviors through complexification of neural dynamics. In this case, the other agent becomes a passive component of a complex environment that the agent in question uses to realize complex neural dynamics. We refer to this mode as *independent interaction*.
2. The two agents could be engaged in mutually interdependent interactive behaviors, thereby bootstrapping neural complexity in each other through continuous interaction via acoustic modulation and spatial navigation. In this case, the other agent is no longer passive but is an active responsive component that continuously influences and is influenced by the neural dynamics of the agent in question. This mode of interaction is henceforth referred to as *interdependent interaction*, which is a generic form of coordination.

3.4. Internal Complexity Is Enhanced More by Interdependent Interaction

In order to disambiguate the aforementioned two modes of independent and interdependent interaction, we measured interactive entropy in the presence of "ghost" partners. "Ghosts" were agents that were merely playing back their movements from a previous trial, without being responsive to the "live" agent whose neural entropy is being measured. The "ghost" condition preserves complexity of the signal that the "live" agent experiences, nevertheless, it does not present any opportunity for interdependent interaction or coordination. Under the ghost condition, live agents suffered a loss in internal complexity in most cases. This demonstrates that their neural complexities were enhanced by active interdependent interaction with the other agent, and not just because of the presence of complex driving signals (**Figure 2F**).

The same pair of agents described in **Figure 2B** were examined again in **Figure 2E**. This time, however, one of the agents was made into a "ghost" (same movement as before, but unresponsive to environmental feedback). As a result from this change, the live agent's behavior becomes starkly different and its entropy drops to 0.4712. This shows that the agents did not simply rely on the complex sensory stimuli from the behavior of the other agent. Instead, the two agents were mutually interacting: they were coordinating their movements and were thereby enhancing each other's neural and behavioral complexity in a complementary manner. More generally, we found a statistically significant correlation between increasing internal complexity and interdependent interaction, and that this form of interaction tended to be more ordered, as would be expected from social coordination (see **Supplementary Material** for details).

4. DISCUSSION

From a complex systems perspective we expected that placing embodied agents in an interactive context would transform their neural and behavioral dynamics, and that certain forms of interaction would lead to an increase in their complexity. Our modeling results confirmed this expectation by providing a proof of concept that the behavior of embodied agents in real-time dyadic interaction cannot be fully understood from studying their brains in isolation, nor even in the context of non-responsive social stimuli.

In our simulation model an agent's neural complexity could increase beyond its individual degrees of freedom when the agent is interacting with a complex environment, and especially so when it is coordinating its behavior with another responsive agent. Our analysis revealed that this increase is not just a matter of activating latent internal complexity: interaction allows an agent's neural activity to increase its complexity to such an extent that in principle it would be impossible for that activity to be generated in isolation. This finding suggests that the enactive approach to social cognition is on the right track:

the dynamical basis of an agent's behavior during real-time interaction with another agent becomes the whole brain-body-environment-body-brain system (Froese et al., 2013b), of which each agent brain is just one important component (Gallagher et al., 2013) whose neural activity becomes a projection of the overarching interaction process. Future modeling work could analyze in more detail how this interactive expansion of individual complexity is dynamically realized, for example by analyzing the transformation of the state space of the overarching brain-body-environment-body-brain system as it goes from an uncoupled to a coupled mode. It also remains to be seen to what extent this increase in individual complexity scales with the number of individuals that are interacting.

Another avenue for future investigation is to verify these modeling findings in the context of actual human social interaction. The so-called "second-person" approach to social cognitive neuroscience has already revealed that the brain is activated differently when participants are engaged in real-time social interaction when compared to passive observer scenarios (Schilbach et al., 2013). The complex systems perspective adopted by the enactive approach could help to provide an explanation for this observed difference. More specifically, it would be interesting to verify our finding that an agent's neural activity tends to be transformed more substantially in scenarios involving interdependent compared to independent forms of interaction between agents. Importantly, our results reveal that interpersonal behavioral synchrony in itself is not sufficient to distinguish between interdependent and independent forms of interaction. Accordingly, future experimental work could compare neural activity in a task requiring real-time coordination with neural activity in a non-responsive "playback" control condition, for instance by employing the human dynamic clamp paradigm (Dumas et al., 2014).

DATA AVAILABILITY

The datasets generated for this study are available on request to the corresponding author.

AUTHOR CONTRIBUTIONS

TF conceived of the presented idea. All authors designed the experiments. MC, MS, and EI developed the code. MC carried out the experiments and analysis of the data. All authors discussed the results. MC was the main contributor to the Methods and Results of the manuscript with input from all authors. TF was the main contributor to the Introduction and Discussion of the manuscript with input from all authors. All authors discussed and contributed to the writing of the final manuscript.

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HYPOTHESIS AND THEORY
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Sociality to Reach Objects and to Catch Meaning

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Sociality influences both concrete and abstract concepts acquisition and representation, but in different ways. Here we propose that sociality is crucial during the acquisition of abstract concepts but less for concrete concepts, that have a bounded perceptual referent and can be learned more autonomously. For the acquisition of abstract concepts, instead, the human relation would be pivotal in order to master complex meanings. Once acquired, concrete words can act as tools, able to modify our sensorimotor representation of the surrounding environment. Indeed, pronouncing a word the referent of which is distant from us we implicitly assume that, thanks to the contribution of others, the object becomes reachable; this would expand our perception of the near bodily space. Abstract concepts would modify our sensorimotor representation of the space only in the earlier phases of their acquisition, specifically when the child represents an interlocutor as a real, physical *"ready to help actor"* who can help her in forming categories and in explaining the meaning of words that do not possess a concrete referent. Once abstract concepts are acquired, they can work as social tools: the social metacognition mechanism (awareness of our concepts and of our need of the help of others) can evoke the presence of a *"ready to help actor"* in an implicit way, as a predisposition to ask information to fill the knowledge gaps.

Keywords: WAT theory, abstract concept, body, social tool, words as tools, bodily space, embodied cognition, grounded cognition

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INTRODUCTION

Sociality is pivotal for survival and for well-being of our species. It would be difficult to deny that sociality permeates a cognitive process like language, since when talking we need to have an interlocutor, i.e., a person that takes part to the conversation/dialogue with us. In contrast, the role of sociality for processes such as perceiving, categorizing and thinking, is not always sufficiently emphasized. Concepts are "bricks" to build an internal world; they serve to filter the surrounding world, to understand the incoming stimuli for acting and to create new systems of meanings. Here we will argue that sociality is relevant for the formation and representation of concrete and abstract concepts (e.g., "bottle," "fantasy"), but in different ways. We will first clarify what we intend with concrete and abstract concepts, then we will formulate our theoretical proposal, illustrate evidence supporting it and discuss some open issues.

Concrete and Abstract Concepts

Concepts have been defined as the "glue" that links our current with our past experience (Murphy, 2002). We intend them as distributed patterns of multimodal experiences, forms of re-enactment of past sensorimotor experiences with their referents (Barsalou, 1999; Borghi, 2005). Concepts play a predictive role (Gallese and Lakoff, 2005): re-enacting our past experiences we can prepare ourselves to interact with a given object or entity. Hence, our concept of computer links our current writing experience with previous ones; in addition, possessing a concept of computer helps us to form expectations and predictions on how to interact with a novel computer.

We will here focus on the distinction between abstract and concrete concepts (e.g., "table" vs. "justice"). We do not intend such a distinction as a dichotomy but we rather conceive it as blurred and not stable, for a number of reasons (Wiemer-Hastings et al., 2001; Barsalou, 2008; Crutch et al., 2013; Borghi et al., 2017). First of all, because concepts are variable and dynamic entities. Second, because each concept can include a mix of concrete and abstract aspects: for example, the concept "dog" can evoke patterns of interaction with the animal, but also more abstract feelings related to possessing a pet etc. Finally, studies performed in our and in other labs have recently shown that the dimension of abstractness and concreteness are typically highly correlated and difficult to disentangle from other dimensions, and that different kinds of abstract concepts exist (Ghio et al., 2013, 2018; Mellem et al., 2016; Borghi et al., 2018c; Desai et al., 2018; Villani et al., 2019; Villani et al., unpublished). Nevertheless, some concepts can be defined as mostly abstract, others as mostly concrete.

On the negative side, abstract concepts are typically less associated than concrete ones to sensorial and perceptual modalities (Barsalou, 2003; Connell and Lynott, 2012), they are typically less imageable (Paivio, 1990) and evoke less Body-Object interactions (BOI) (Siakaluk et al., 2008). On the positive side, abstract concepts are more complex and refer to relations rather than to single, perceptually bounded referents (Borghi and Binkofski, 2014), abstract words are generally acquired later (AoA) and more through linguistic explanations than through perception, i.e., indicating their physical referents (MoA) (Wauters et al., 2003; Della Rosa et al., 2010). Finally, abstract concepts evoke more than concrete ones "social metacognition" (Borghi et al., 2018b,c), i.e., the metacognitive feeling that our knowledge is not adequate (Shea, 2018) and that we need others – possibly authoritative others – to complement it (Prinz, 2012). The preparation to ask information to others seems to be expressed in the activation of the mouth effector. A number of studies, from our lab and other labs, provide evidence that abstract concepts processing involves the activation of the mouth motor system (Borghi et al., 2011; Ghio et al., 2013; Granito et al., 2015; Borghi and Zarcone, 2016; Barca et al., 2017; Mazzuca et al., 2018; see for a review Borghi et al., 2018a). For example, in a recent study, Zannino et al. (unpublished) have shown that articulatory suppression slows down processing of abstract but not of concrete concepts, confirming the importance of inner speech for abstract language processing. In addition to the social metacognition mechanism, other mechanisms might underlie abstract concepts processing: the social experience of word acquisition might be re-enacted, leading to a re-activation of the mouth motor system. Alternatively, the complexity of abstract words might require to re-explain their meaning to ourselves, through the mediation of inner speech.

In sum: in our view both concrete and abstract concepts are grounded in perception-action, in sociality and in linguistic experience, even though the weight of the sensorimotor experience is higher for concrete concepts, that for the social and linguistic experience higher for abstract concepts. In this paper we will focus on the role social experience plays in acquisition and representation of both kinds of concepts.

THE PROPOSAL: WORDS AS SOCIAL TOOLS AND SOCIALITY

The main thesis of this paper, that we will articulate and defend, is that acquisition, learning, and representation of both concrete and abstract concepts rely and are influenced by social experience. However, we will qualify this social experience and contend that different kinds of social relationships are involved during processing of concrete and abstract concepts.

Let us consider concrete concepts first. In our view the social dimension is less important for the acquisition of concrete concepts compared to that of abstract ones, since the referents of concrete concepts are perceptually similar and are clearly bounded objects. There is a clear and unique relation between the concept and the referent, that can be autonomously learned. For example, children can form the category of "entities that move on their own," even if learning the correspondent word, e.g., "animals," can contribute to refine and render more compact their category (Mirolli and Parisi, 2011). Hence, the linguistic and social input is obviously pivotal in order to learn concrete words, while it is important but not as crucial as it is for abstract concepts in order to form pre-linguistic categories. Once concrete concepts and words have been acquired, their implicit reference to sociality is so strong that it can influence and modify the representation of our bodily space. Indeed, once we have acquired concrete concepts, we can use corresponding words to implicitly ask others to collaborate. Concrete words can thus be used similarly to tools. For example, instead of reaching a far object with a physical instrument we can reach it thanks to a word: pronouncing a concrete word we might induce others to give us objects that we cannot reach. Hence the implicit reference of concrete words to the social dimension can modulate and change the perception of our bodily space, extending it. The impact of using concrete words on shaping our representation of the environment is in our view much more relevant than that of abstract words.

Taking into account abstract concepts (e.g., "fantasy," "freedom"), we argue, instead, that sociality is crucial for their acquisition. Since the referents of abstract concepts are not perceptually similar and are not clearly bounded objects, we need the others' linguistic and social input in order to form categories. Consistently, we will advance the new hypothesis that abstract concepts might include a sensorimotor representation that affects the perception of the environment. Because in the early phases of abstract concepts acquisition we might need the another person sufficiently close to us to explain the word meaning, this might impact our space representation. Indeed, we would implicitly assume the "real" presence of a social referent, at least in the earlier phases of conceptual acquisition. The presence of another person, his/her explanations, would be fundamental in order to allow us to form concepts composed by a variety of heterogeneous events and situations, as the members of abstract categories are. Once abstract concepts are acquired, we contend that they always refer to the social dimension, but in a more implicit way. Differently than for concrete words, we might not be able to use abstract words as physical instruments, e.g., to ask others for an object. However, at a metacognitive level we might be less satisfied of our knowledge related to abstract than to concrete concepts, and we might want the help of authoritative others to fill these gaps. Hence, we may continue to need others to complement the gaps of our knowledge (**Table 1**).

One important note: in distinguishing between concrete and abstract concepts we mentioned "their referents." Because we intend words as tools that modify our relationship with the surrounding world, it is worth of note that we do not intend referents as something static, that is simply out there in the world. Words are not only pointers to referents, they are rather tools that modify the environment and the space. In this perspective, in keeping with Weber and Varela (2002) and Di Paolo (2005), word meaning depends on the specific mode of coupling that each system realizes with its environment, hence on the specific relation between each language-user and the surrounding context. In the next sections we will sketch how conceptual acquisition might occur, highlighting the differences between acquisition of concrete and of abstract concepts, and how sociality is differently involved once abstract and concrete concepts and words have been acquired.

Developmental Course: From the "Instrumental Interaction" to the "Intellectual Interaction"

In the human being, the social self emerges quite early compared with the other mammals. At 3–6 months infants are already involved in complex interactions with the mother/caregiver (Kaye, 1982). Imitation, turn-taking games, shared attention, anxiety for the separation and use of the adult's emotional expression to interpret ambiguous events are examples of sophisticated social expressions (Scaife and Bruner, 1975; Walden and Ogan, 1988; Morales et al., 1998). Infants express their needs and desires through the gaze, the sounds and the gestures; these primitive instruments are called by Vygotsky (1978) "psychological tools." We can also refer to the "psychological tools" as pragmatic capabilities that would represent the precursor of the language acquisition. The early pragmatic achievements involve three type of communication: (1) negotiating an activity (requesting help, an object, or directing another action), (2) taking part to social routines (saying bye-bye), and (3) regulating mutual attention (vocalizing to attract the other's attention). Tomasello and Call (1997) introduced the above mentioned distinction. With negotiating an activity they meant to depict the scenario of a kid who, in order to reach for an object, vocalizes or looks at the caregiver, because she knows that the last one is the instrument to obtain the target. Taking part to a social routine is more complex compared with negotiating an activity, because the kid has to respect turn taking, to respond adequately to the other and to be part of a shared context, but still there is no "mentalization" of the other. Only when the kid starts to be interested in capturing the other's attention, she recognizes the other as an individual able to validate common meanings.

TABLE 1 | This table illustrates the social components of concrete and abstract concepts during and after their acquisition.

	Concrete Concept	Abstract Concept
Acquisition	Sociality−	Sociality +
Post-acquisition	The other as concrete instrumental referent	The other as intellectual referent
	Tools to re-arrange the space	Social tools to re-arrange our social relationships

Negotiation of activity is the less complex level among the pragmatic abilities, indeed it belongs also to non-human primates since it is based on the instrumental use of language (Tomasello and Call, 1997). At this level, in humans, the mother would be perceived as an acting body with the capacity to optimize the world features serving the infant's requests. The mother's body would be the physical bridge with the world. Such a phase is followed by the acquisition of the social participation capability, that still requires a less sophisticated level of intersubjectivity compared with the regulation of mutual attention (Ninio and Snow, 1999). This last ability emerges around one-year of age, when a sort of Copernican Revolution occurs in infants: The object/action, from fully capturing the infant's attentional focus becomes the instrument to catch the mother's attention. The mother/caregiver does not resemble anymore a *bodily tool* or a sort of *instrumental referent* to reach the object when it is outside the infant's reaching area. She rather starts to be considered also as an *intellectual referent,* somebody to draw knowledge from, who can help to build meanings, to acquire the vocabulary and to construe the concepts useful to interpret the daily life. This shift of the infant's interest opens to the connection between two minds with the beginning of the cultural development.

This is the phase in which language acquisition occurs. Smith et al. (2011) have beautifully illustrated this process in their studies on word learning with a head-mounted eye tracker (Smith et al., 2011; Yu and Smith, 2013) able to capture children's perspective and point of view. One-year old infants solve the problem of referential ambiguity (many objects in a scene to which the new word could refer) by focusing their attention on single objects; word learning occurs at best when naming events occur during the moments in which one single object is in their view. Furthermore, they learn new words coordinating their looking behavior with their parents looking together at the objects held by themselves or by the others. Hence, word learning is an embodied and social process, in which statistical learning of words is combined with dynamics of attention, and it is characterized by the presence of the other together with that of the word referent.

Differences in the Acquisition of Concrete and Abstract Concepts?

When the child acquires new concepts and new words, both concrete and abstract, he/she needs the presence of others. Which are, then, the differences in the acquisition of concrete and abstract concepts and words?

We contend that the presence of others is more crucial during the acquisition of abstract concepts, because their members are quite diverse and heterogeneous. Consider the difference between the concepts "table" and "freedom." Different tables share many similarities, and often they can be reconducted to a prototypical image; so the child can quite easily learn on her own to abstract from the more idiosyncratic features and to form the category of "table." This does not mean that children learn concepts on their own, solely on the basis of the perceptual inputs. The linguistic and social input is clearly determinant to refine and render more compact the categories they have formed (Mirolli and Parisi, 2006, 2011; Lupyan and Thompson-Schill, 2012), as well as to associate the label "table" with its referent. Even if important, however, the linguistic and social input it is not indispensable in order to form concrete concepts as it is for abstract concepts.

One further difference is that learning of concrete concepts and words typically occurs in presence of an object/entity, the conceptual referent. Abstract words like "freedom," instead, do not refer to an object with which the child can interact and that the adults/others can indicate. In order to learn concrete concepts a single label might be a sufficient input, while to learn abstract concepts more extended explanations of the word meaning are generally required in order to gather the multiple experiences abstract concepts assemble together. The guidance of the other/adult and of a rich linguistic input is therefore of paramount importance (for more details on this, Pexman et al., 2002; Recchia and Jones, 2012; Borghi and Binkofski, 2014; Borghi et al., 2018c). Recent findings of Bergelson and Swingley (2013) on 6–16 month-old infants are consistent with this idea. They showed videos to children and parents; parents named events in the video and they verified whether infants followed with their gaze the mentioned object. Results showed that parents tended to mention concrete words in presence of their referent; this occurred less frequently for abstract words. Furthermore, while infants seemed to comprehend concrete words already at 6 months (Bergelson and Swingley, 2012), very simple abstract words (e.g., all gone, more) were not learned before 10 months, and there was a sharp increase of learning abilities around 14 months. This increased acquisition ability can be connected to the development of important social competences, such as the capability to follow the gaze of others at around 10 months (Brooks and Meltzoff, 2005; Beier and Spelke, 2012), and with the development of mature forms of joint attention (Carpenter and Call, 2013). Later, the period in which children learn the majority of abstract words, from 3 years onward, is characterized by their increased capability to discriminate reliable sources: they learn to choose competent others to ask information, as literature on testimony clearly shows (Borghi et al., 2018c).

Even if we focused on conceptual acquisition in children, we do not intend to argue that the involvement of sociality during concepts acquisition is limited to young age. Adults also rely on others to learn new concepts, particularly when concepts are more difficult and more abstract. Compared to young children, adults might have better strategies in identifying competent others, and might be more able to benefit of multiple sources – beyond the interaction with others, they can recur to written sources such as books, Internet, repositories such as Wikipedia etc.

Once both concrete and abstract concepts are acquired, they are obviously updated in light of new experiences and information. For example, experiencing new chairs can lead us to restructure our previous concept of "chair"; the same updating mechanism characterizes both concrete and abstract concepts, even if these last remain more variable, not only between individuals but also for the same individual. The main difference is that concrete words are linked to specific and clearly bounded referents, and because of this once we have learned words we plausibly need others only to communicate with, not to further understand/renegotiate the word meaning.

Acquisition of Abstract Concepts and Representation of the Space

We have seen that for the acquisition of abstract concepts the presence of others is fundamental. Now the question is whether this can have an effect on the representation of the surrounding space. When the infant starts to learn new words and to explore the correspondence among the words and the reality, in order to master a new ability e.g., talking, she requires to have feedback provided by other people. Specifically, abstract concepts, i.e., the "units" of thinking, would be learned by asking meanings to an *intellectual referent*, usually the mother or a caregiver. Here the social dimension is particularly crucial, because the kid needs another person to acquire meanings and to frame these meanings inside categories in order to interpret the reality. The need of an *intellectual referent* in the acquisition of abstract concepts might induce the child to have an internal physical representation of a "*ready to help actor*" and such representation might weaken when the kid learns to master her question marks and thinking becomes a private act.

We propose that the peculiar modality of acquisition of abstract concepts and words might affect children's sensorimotor representation of the environment. Indeed, the thinking ability develops in a real human relation, between actors in flesh and bones. The idea is that abstract concept could shape the space perception when the child moves the first steps toward their acquisition, in other words when the physical presence of the *intellectual referent* is crucial. In this phase, when hearing an abstract word, the child would automatically represent/ask for the *"ready to help actor"* endowed with intellectual but also instrumental abilities. The bodily/instrumental potential of the *"ready to help actor"* might determine a re-configuration of the physical reality. In older children and adults, the automatic "instrumental" representation of *"ready to help actor"* would be less strong and the social component in the language acquisition would remain detectable in the sub-threshold mouth motor activation. Understanding abstract concepts would include a more internalized strategy and consequently the process would be a more private experience.

For these reasons it can be hypothesized that when a young kid pronounces or listens an abstract concept and immediately after she is asked to express a sensorimotor judgment, i.e., how much Near/Far is an object, this object would be perceptually filtered by the kid's body and also by the "ready to help actor's body." Later, such sensorimotor co-representation will be less pronounced, and listening/pronouncing abstract concepts would affect the sensorimotor representation to a lesser degree and depending on the abstract concepts meanings. For example, the words "freedom/oppression" might expand/shrink a physical space, or enlarge/reduce a hole, not because the kid imagines a real interlocutor endowed with bodily and knowledge resources, but because of the influence of semantic meaning on the perceptual processes.

THE WORD AS FORM OF ACTION

Both concrete and abstract concepts are grounded in the perception-action system (Caligiore et al., 2010), but for concrete concepts the sensorimotor component is more important than for abstract ones, which are more detached from sensorial modalities (Barsalou, 2003). A study by Connell and Lynott (2012) provides evidence of this different relevance of sensorimotor experience. They collected norms asking participants to determine to what extent they experienced words through each of the five senses. They demonstrated that the so-called concreteness effect, i.e., the advantage of concrete over abstract words, depends on perceptual strength; abstract words are typically less associated to the sensory modalities compared to concrete ones. This does not exclude that the sensorimotor component is important also for abstract concepts. This it is very clear if we consider abstract concepts such as "near/far," "some," "more," but it is true also for concepts like "freedom," that might re-enact sensorimotor experiences such as running, crossing a border, breaking chains etc.

It is known that the motor system is activated when producing and reading words and that this activation can even be specific to different word types (Pulvermüller et al., 2001; Hauk and Pulvermüller, 2004; Hauk et al., 2004; Shtyrov et al., 2004; see for reviews Barsalou, 2008; Fischer and Zwaan, 2008; Toni et al., 2008; Meteyard et al., 2012; Barsalou, 2016). Specifically, hearing a word seems to be associated with activation of its articulatory motor program, and understanding an action word seems to lead to the immediate and automatic thought of the action to which it refers (Pulvermüller, 2005). A word can vehicle a meaning mapped in a somatotopic manner: it is the case of action words, e.g., "to kick" vs. "to lick." Alternatively, words can have as referent an affordable object "a cup," still evoking a motor interaction that recruits a specific effector. Such sensorimotor component in the language is permeated of interpersonal motor resonance, meaning that the words, like the bodies, can scale our representation of the environment by taking into account our own and the other's action potential. Evidence like this indicates that words are grounded in action (Gallese, 2008; Glenberg and Gallese, 2012).

However, this is not the whole story. Words are not only grounded in action, they can be considered also as a form of action themselves (see Borghi et al., 2013, for extensive discussion on this; Clark, 1998; Dove, 2018). With words we can orient and potentiate our thoughts, modify the opinions and attitudes of others and more generally change the state of the world. We propose that both concrete and abstract words can be used as tools.

More specifically, concrete words can be used as physical tools, i.e., to reach for objects. When using a concrete word, the visual representation of the object might just not demand a motor behavior to the self if the object is located outside our own acting area, but it could also trigger the sensorimotor representation of another actor able to act upon it. In this section we will describe how this representation of concrete words, that explains their nature of "tools," has an effect on space representation. We will also explain how abstract concepts/words can be instead intended as social tools, that do not impact our spatial representation to the same extent as concrete words but that we use to rely and evoke others.

Concrete Words as Tools and Their Influence on Space Categorization

Influence of Physical Tools and of the Presence of Others on Space Categorization

We propose that words can be intended as physical tools, that extend our spatial representation. Since seminal work by Wittgenstein (1961) and Vygotsky (1978), other authors have claimed that words can be considered as kinds of tools (e.g., Clark, 1998; Tylén et al., 2010). The novelty of our point of view, illustrated in previous work, is to claim that this characteristics of words leads to an expansion of the near space (Borghi and Cimatti, 2010; Borghi et al., 2013; Scorolli et al., 2016). Here we will delimit this claim, arguing that an expansion of the near space occurs only for concrete and not for abstract words. To present our argument, it is important to briefly review studies on tool use and space categorization.

The body is our bridge with the world, it allows us to enact goal directed behavior. Another body, able to act like us is processed with intrinsic action potentialities tailored in response to the space context. Evidence pointed out that we represent the body of others as endowed with our same action potentialities: an object may namely afford a suitable motor act not only when it is close to our own hand but also, crucially, to the hand of an avatar or of another person (Coello and Delevoye-Turrell, 2007; Costantini et al., 2011a; Cardellicchio et al., 2012). In the peripersonal space it has been shown that the presence of others is able to modulate our predisposition to act toward a graspable object (Costantini et al., 2011b).

Studies on tool use revealed that the boundary between near and far space is a flexible one, and that using tools to reach for objects leads to an extension of our representation of peripersonal (near) space (Berlucchi and Aglioti, 1997; Berti and Frassinetti, 2000; Maravita and Iriki, 2004; Farnè et al., 2005; see also Arbib et al., 2009). This expansion of the peripersonal space does not occur only when we use tools, but also when we observe others using them. The simple observation of someone reaching an object with a tool, extends our perception of the peripersonal space (Costantini et al., 2011a; Bloesch et al., 2012). Recent evidence indicates that this flexibility of our spatial representation is not confined to the peripersonal, near space, but it is extended to the extrapersonal space. Fini et al. (2014) have shown that seeing a human body, potentially able to cover a distance in the extrapersonal space (outside the reaching space), can reduce our space categorization. These findings indicate that another human body is a relevant stimulus automatically processed as a like-us intentional agent. Since we are social animals, we likely assume the same agent to have a collaborative attitude toward us. In presence of "*another like-me body*" who is located close to us, we perceptually build a spatial layout that takes into account the impact of another person on our goal directed behavior. That is, the other is processed as a "social arm-tool" to pass a cup that we cannot reach, or as "a social-leg tool" to walk to the soccer ball if we are too tired to cover the distance.

Concrete Words as Ethereal Tools

If the body is our bridge with the world, the word is our bridge with the others. In general we communicate with other people through verbal language or gestures if we are too much distant to be heard, still we can scream. Either the words and the body serve to communicate meanings, but the words are able to convey more complex meanings and allow us to be more precise, for example to refer to a specific object among many. When an adult talks usually there is at least interlocutor to promote a dialogue.

Let us consider two different roles among the many that language can play. Words can help us to find a solution to reach concrete aims, e.g., "Can you pass me the pen?," or to create new knowledge e.g., "Do you think that this object/entity/event belongs to this category? What does this word mean?" In the first case, the sentence invokes the help of an *instrumental referent* who can give us the pen, making the pen closer to us and expanding our near space. In the second case, the sentence invokes the help of an *intellectual referent*, who help us to learn the meaning of new words. These two functions can be summarized as follows: (1) The word, like a physical tool or like the body of another agent, serves to reach distant objects that are outside our action domain; (2) The word is useful to understand the meaning of words, to create and build new conceptual networks. We propose that the first function of language concerns primarily concrete concepts, while the second function of words concerns both concrete and abstract concepts, but is particularly prominent for abstract ones.

Empirical evidence supports the idea that concrete words work as physical tools. Experimental results obtained by Scorolli et al. (2016) indicate that an object located on a table in the border space the participant's reaching area, can be perceived as closer not only when participants are grabbing a rake, or when they can press a button to make the object appear, but crucially also when participants simply pronounce the name of the object. When we pronounce a word, typically "another-like us" listens our speech. Assuming that he/she has a cooperative attitude, he/she becomes an instrument to reach for objects located far away from us. We propose that such social dimension would be automatically activated also when simply pronouncing a word. In other terms, the presence of the other can be implicit, i.e., language can re-evoke the presence of another person, even if there is no physical trace of this. While it has been shown that concrete words can affect our perception of the environment through the intrinsic social dimension that they have, so far there is no evidence on how the social dimension of abstract words can induce a similar effect.

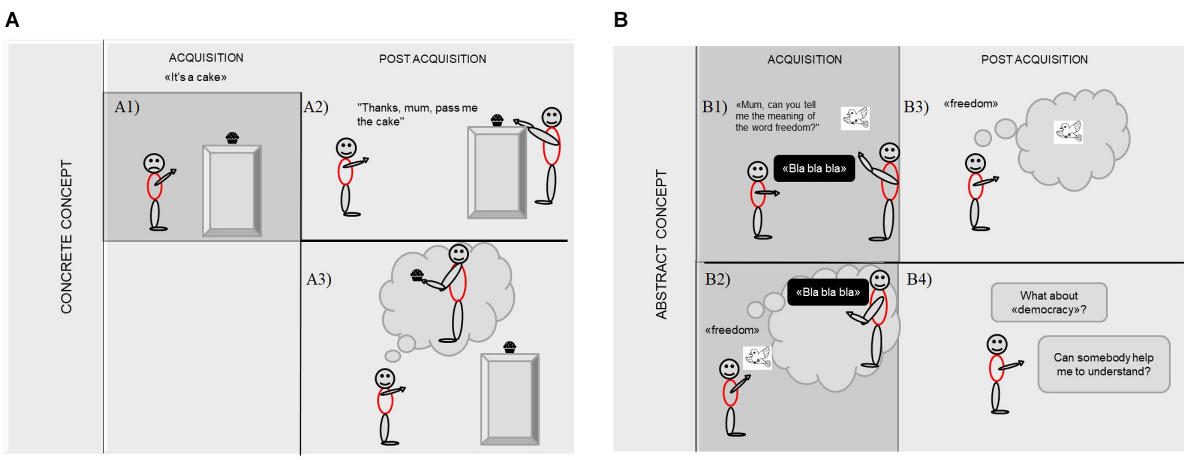

FIGURE 1 | (A) The mechanism underlying the acquisition of concrete concepts: **(A1)** The child has the perceptual experience of the concrete referent and acquires the correct word associated with it, **(A2)** The child asks help to the mother as an *instrumental referent*, to reach the concrete object that has been conceptually acquired, and **(A3)** The child associates with the concrete concept the sensorimotor simulation of the interaction of her/other's body, and this interpersonal motor resonance can re-shape the environmental representation. **(B)** The mechanism underlying the acquisition of abstract concepts: **(B1)** The child asks to the mother to explain the meaning of an abstract word and the mother tries to explain this meaning also by using concrete referents, **(B2)** The child when using and/or listening a new concept and/or observing a specific referent that refers to it, re-enacts the experience of the mother as intellectual referent. In these phase the intellectual referent might be implicitly perceived as real, inducing an interpersonal motor resonance that can re-shape the environmental representation, **(B3)** The child has acquired the conceptual knowledge, she masters the new meaning, and **(B4)** The child when learning new concepts, can ask for the presence of a *"ready to help actor"* in an implicit way, as a predisposition to ask information to fill the knowledge gaps (social metacognition).

ABSTRACT WORDS AS SOCIAL TOOLS: THE MECHANISM OF SOCIAL METACOGNITION

So far we have claimed that sociality is more crucial for abstract than for concrete concepts acquisition, and that, once concepts are acquired, we might use concrete words as tools. Concrete words namely implicitly evoke the presence of others who may help us in reaching objects, and this impacts our representation of the reachable space. While the representation of abstract words likely does not impact and modulate the borders of our bodily space, in our view sociality continues to influence abstract concept representation in different ways.

Once abstract concepts have been acquired, to what extent does their processing involve the presence of others? Can this presence be evoked only in an implicit way? Let us consider separately the three mechanisms that we briefly illustrated in section. We propose that these mechanisms, that are not mutually exclusive and can co-exist, underlie abstract concepts processing, and explain why the mouth motor system is activated (for details, Borghi et al., 2018b,c). These mechanisms are: (A) Re-enactment of the linguistic/social acquisition process. Because we would re-enact the past experience of acquiring the concept, it is unlikely that the use of such a mechanism is influenced by the real presence of others when we process concepts. The others are simply evoked re-acting situation in which their presence and contribution facilitated word acquisition. (B) Re-explanation of the meaning of the abstract words, possibly through the use of inner speech. This mechanism does not imply the physical presence of others, since it involves the use of speech for ourselves. (C) Social metacognition. Basically, we would tell to ourselves that our concepts are not adequate, and try to find solutions outside from ourselves. The mouth activation would be due to the motor preparation to ask information to others. It is certainly possible, and needs to be tested with appropriate experiments, that the presence of others is influential when such a social metacognition mechanism is active. The presence of others who might potentially fulfill our needs can render the activation of the mouth motor system more pronounced. However, in purely theoretical terms such a mechanism could work also in absence of real others.

In sum, sociality would be involved in all these mechanisms that we hypothesize to be at the basis of abstract concepts processing. In all cases the involvement of sociality would have a bodily impact, determining a selective activation of the mouth motor system. However, the involvement of sociality differs in extent across the three mechanisms. For the first two mechanisms not only language would become internalized, in Vygotskian terms (Vygotsky, 1986), but also the reference to a possible companion/other. Things differ for the social metacognition mechanism, for which we hypothesize that the presence of real, physical others, although not necessary, can determine a stronger activation of the mouth motor system. In presence of real others, we might namely prepare ourselves to ask them information more promptly than if we implicitly refer to possible others.

CONCLUSION

According to Words As social Tools proposal (WAT), concrete concepts like "glass" or "table" have a sensorial well-defined referent and their acquisition stems from the sensorimotor experience of the physical object/entity to which concepts refer. Abstract concepts are more detached from the sensorial experience, and evoke more social and linguistic experience than concrete ones (Borghi and Binkofski, 2014; Borghi et al., 2018b,c). Both the abstract and the concrete concepts are embodied. The embodied counterpart of the abstract concept is manifested in the mouth motor activation, trace of the inner language acquired through the social relation. The embodied counterpart of the concrete concept is manifested in the whole body.

The main thesis of this paper is that sociality influences both concrete and abstract concepts acquisition and representation, but in different ways. We revised developmental literature showing how the point of contact between the infant and the surrounding reality/environment is the mother/caregiver. Far from being considered just an *instrumental referent* to reach an object, she becomes an *intellectual referent* to catch meanings. The role of the other as intellectual referent is particularly crucial for the acquisition of abstract concepts: due to the heterogeneity of their members and to their detachment from sensory modalities they are more difficult to learn relying exclusively on the perceptual inputs.

Once concrete and abstract concepts have been acquired, sociality continues to be determinant for their representation. We briefly illustrated theoretical proposals and evidence showing how concrete words can act as tools (Borghi and Cimatti, 2010; Borghi et al., 2013; Scorolli et al., 2016): similarly to human bodies (Costantini et al., 2011b; Cardellicchio et al., 2012; Fini et al., 2015), they affect the sensorimotor representation of the surrounding environment leading to an extension of the near space.

Here, we propose that also abstract concepts, like concrete ones, might influence the perception of the environment but following two different modalities. In the earlier phases of abstract concepts acquisition, the child might represent an interlocutor as a real, physical *"ready to help actor*," with a consequent interpersonal bodily representation of the physical reality (sensorimotor modalities) until the moment in which the dialogue between the infant and the real interlocutor becomes internalized. When the infant masters a solipsistic inner language, three possible mechanisms underlie and explain the activation of the mouth motor system during abstract concepts processing. For the re-enactment and re-explanation mechanisms the reference to a possible companion/other would be implicitly evoked. The social metacognition mechanism can evoke the presence of a *"ready to help actor"* in an implicit way, but it can lead to a stronger activation of the mouth motor system in presence of real others, to whom to prepare to ask information and help (**Figure 1**).

New research is necessary to investigate how the social component of abstract concept evolves, from being external and more embodied, to be internal and more semantic and how this is reflected in a different perception of the world.

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All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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OPINION
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Socio-Cultural Influences on Situated Cognition in Nature

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INTRODUCTION

To what extent are cognitive processes rooted in "simple" body-environment interactions, and the situation in which they take place? And to what extent does the body-environment interaction depend on socio-cultural processes?

Questions like these are pertinent to the field of environmental psychology, especially attention restoration theory (ART) (Kaplan and Kaplan, 1989; Kaplan, 1995). Here, concrete nature experiences are believed to incur certain attentional and cognitive states in the individual. Proponents of ART argue that self-regulation (Kaplan and Berman, 2010) and executive functioning involved in advanced cognitive operations like working memory, cognitive flexibility and attentional control (Diamond, 2013) gains from exposure to green environments. Recent meta analyses have pointed more specifically to the restoration of the system supporting so-called directed attention (Ohly et al., 2016; Stevenson et al., 2018).

The assumption is that the particular materiality of nature, e.g., the sounds, colors, and diversity (Fuller et al., 2007; Ratcliffe et al., 2013; Ossola and Niemelä, 2018), taps into our effortless stimulus-dependent attention at the expense of the directed (e.g., voluntary, sustained) attention we need in goal-directed tasks (e.g., Schilhab et al., 2018).

Accordingly, resting in nature leads to enhanced perceptual activity in a state of so-called soft fascination (Kaplan and Berman, 2010), reducing the time spent on problem-based cognition that involves the mentally fatiguing executive functions (Bratman et al., 2012) and inhibitory mechanisms to prevent external distractions (Diamond, 2013). This leaves time for the directed attention network to replenish (Stevenson et al., 2019). In this interpretation, natural stimuli work bottom-up by exteroceptive activation (Berman et al., 2008; Chun et al., 2011), irrespective of socio-cultural practices. As such, natural stimuli in the environment automatically trigger the particular cognitive state of soft fascination in an all or none fashion (e.g., Lee et al., 2015).

Based on ART, trips to the forest or park have become interventions to stimulate physical and mental health in children (McCurdy et al., 2010; Swank and Shin, 2015) and to relieve stress in adults (e.g., Corazon et al., 2011). Further, recent literature reviews agree that exposure to nature is generally beneficial to cognitive processing in a broad sense (Ohly et al., 2016; Stevenson et al., 2018).

However, the rather simple relationship between natural environments and cognitive states in ART raises questions about factors involved in body-environment interactions and situated cognition. What are the broader mechanisms governing green environments' ability to cause particular cognitive states? Does the materiality of nature work regardless of the meaning-making practices that occur in such environments? Although studies on individuals' favorite places for resting and self-regulation (e.g., Korpela et al., 2001), as well as studies on connectedness to nature, show that intersubjective variations exist (Mayer et al., 2009; Capaldi et al., 2014), explanations in environmental psychology and ART seldom include social or cultural modifiers of the nature-induced cognitive state (e.g., Auburn and Barnes, 2006). The extent to which we *learn* in childhood to categorize particular environments as "feasible" favorite places and as aids in self-regulation, or how to identify and appreciate "nature connectedness," seems under-researched (however, see Adevi and Grahn, 2012).

Here, we point to and clarify a selection of possible sources that might influence situated cognition and thus explain deviations in, for instance, private preferences. Hence, we focus on possible areas of learning that may influence the "simple" body-environment interaction while resting in nature. The aim is to identify socio-cultural components and sources that are likely to moderate not only the relation of the natural environment with cognitive states in ART but situated cognition in general. Thus, we suggest that claims about the rooting of cognitive processes in bodily interaction with the environment would benefit from a consideration of the involvement of socio-cultural processes, similar to those we claim are pertinent to nature-induced cognitive states in ART.

LEVELS OF SOCIO-CULTURAL INFLUENCES

Following ART, when conditions are favorable, green environments elicit particular cognitive states in the individual[1].

Apparently, this effect occurs automatically and with necessity, which paves the way for evolutionary inspired suggestions that rate green environments as more adaptive than urban and human-made settings (for a critique, see Joye and Van den Berg, 2011). Largely, the contention is that nature-induced cognitive effects depend on our prehistoric adaptation for bonding with and inhabiting green environments (e.g., Joye and De Block, 2011; Beery et al., 2015).

However, socio-cultural factors like meaning-making in situated social practices (Lave and Wenger, 1991), cultural learning processes in situated practices (Hasse, 2012, 2016), and the continuous forming of self-understanding in the individual, including motivations and emotions in relation to the surrounding social spheres (Holland et al., 1998), may modify the environmental impact on cognitive states. The presence of such socio-cultural factors questions any unconditional bottom-up causality in cognition. We therefore conjecture that socio-cultural processes co-determine the cognitive processes when perceiving a green environment, as suggested by (Lentini and Decortis, 2010, see also Nova, 2005; Clark and Uzzell, 2006)(p. 408):

in terms of *people's experience, sense of place refers to the fact that people apprehend physical space not only through the perception of its spatial characteristics, but also through the awareness of the social cues related to it.*

[1]Please note, qualifying conditions such as "being away," "extent," "fascination," and "compatibility" must be met for natural environments to facilitate stimulus-dependent attention (Kaplan, 1995). "Being away" accentuates the distancing of oneself from the activities that lead to mental fatigue, whereas "extent" expresses the need of the putatively restorative site to be sufficiently materially "rich" to be perceived as a coherent structure. "Fascination" is the attraction of attention that does not require effort and no inhibition of competing stimuli, while "compatibility" denotes the co-occurrence of what the individual is trying to achieve and the affordances provided by the environment.

Overall, the socio-cultural approaches question the validity of claims about the impact of green environments on cognition in so far as these ignore the implicit or explicit connotations of green environments learned by the individual.

In the following, as a heuristic tool in order to exemplify, we divide the socio-cultural influences by how the individual learns about them[2]. For the sake of clarity, we distinguish between socialization through joint activities and talk when acting together in the moment, activities that often take the form of discursive and embodied learning (e.g., Auburn and Barnes, 2006), and socialization through socio-cultural imaginaries that seem more explicitly construed. Imaginaries can be viewed as "collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order" (Jasanoff, 2015, p. 4). However, both kinds of socio-cultural processes are likely to influence cognitive processes simultaneously.

EXAMPLES OF SOCIO-CULTURAL LEARNING

Simply put, a child's very first bodily exposure to a green environment entails a concomitant exposure to the attitudes held by parents and caregivers toward this particular environment (e.g., Schilhab, 2015, 2018). The attitudes appear in the discourse surrounding the experience of the green environment, what is articulated and explicitly pointed to, and in the practices on the spot (for a neural description of the cognitive processes, see Schilhab, 2011, 2015a, 2017a).

According to the Russian psychologist Vygotsky, cultural development occurs initially on a social level (interpsychological) and only afterwards on an individual level (intrapsychological) (Vygotsky and Cole, 1978, p. 57).

If, say, the hooting of an owl is consciously noted by caregivers, then the presence of owls and their significance to the experience of nature is also emphasized, and the owl as phenomenon is attributed value (Tylén et al., 2010). This may explain why the presence of certain birds such as magpies and crows is negatively correlated with a subject's sense of recreation in green environments, although bird song is generally valued (Cox and Gaston, 2015; Gunnarsson et al., 2017).

In that sense, any momentary interaction with green environments involves both the processing of the materiality (e.g., the sight, sounds, smells, tactility, the kinaesthetic, and interoceptive responses) and the processing of the social interpretations (Barrett, 2009). Hence, families that use walks in green areas for leisure and pleasure will often socialize younger members into this particular green area mind-set. In such cases, the experience of a relaxed atmosphere and the attentive presence of parents become associated with spacious green stretches, experiences of freedom, bird song, and the smell of pine or blooming flowers, for example. Similarly, avid bird watchers or botanically skilled adults emphasize particular occurrences and events in concrete ways. These ways may

[2]Making sense of places is far more nuanced than the picture adopted here. Please refer to Cross (2015) for a more systematic categorisation.

also include certain technologies such as binoculars, cameras, taxonomic encyclopedias, or smartphone supported apps, while physically or meditatively minded adults corroborate either the physiological presence or the tranquility of the natural environment in sync with their particular perception (for preferences for particular sites, see Schebella et al., 2017).

The social glossing over of how to perceive and embody green environments implicitly co-orchestrates the perceptual experiences of the child.

Such socio-cultural socialization is not limited to early childhood, however, as socialization processes continue during preschool. This is where practices in green areas may be defined both by formal didactics (e.g., Higgins, 2009) and the practices displayed in different families by classmates, as Carlone et al. (2015) shows.

CULTURAL ATTITUDES

However, socio-cultural processes also work on a far larger cultural scale (e.g., Buijs et al., 2009; Kloek et al., 2015). Obviously, in the modern discourse, nature is often articulated alongside concepts such as climate change, sustainability, and the Anthropocene, and in opposition to society, technology, and artificial intelligence (e.g., Steffen et al., 2007; Schilhab, 2015b, 2017b,c). Today, natural environments are considered to offer peace and quiet and especially time off from the stressful rat race that seems to dominate human life (e.g., Pearson and Craig, 2014). The natural environment replaces screen time with bodily activity and therefore ideally counteracts obesity and other welfare diseases (Maller et al., 2006).

Historically, nature has been attributed quite different qualities. In the industrial age, nature as a concept was perceived as a battlefield to be conquered and brought under the control of humanity (Steinberg, 1986; Moore, 2017).

The historical variability in the conception of nature also points to cultural aspects of how we conceive of nature. It is more than likely that in certain countries, both geographical and socio-economic parameters have hugely influenced the qualities attributed to nature (e.g., Skar et al., 2016).

For example, Denmark, where the authors live, is not at risk of largescale earthquakes, volcanic activity, or extreme weather conditions. There are no mountain creeks, avalanches, or underground caves, and only a few actual cliffs. Neither does the fauna contain large predators such as grizzly bears, Bengali tigers, or crocodiles, nor extreme herbivores like hippopotamuses, herds of wildebeests, or swarms of locusts. Along with ectoparasitic ticks, the sea may present the more imposing and dangerous part of nature in Denmark. This said, for a long time, nature has not posed any noteworthy risk to the lives of Danes. In such conditions, we conjecture, the understanding of nature as relaxing and accommodating is especially prone to develop (e.g., "dwelling habitus," Aner, 2016).

CONCLUDING REMARKS

Summing up, we conjecture that natural environments exert their influence on cognitive states via actual sensory interactions, the socio-cultural perception learned through embodied practices, and the large-scale imaginations held by society and culture. That the comprehension of green spaces is more closely connected with socio-cultural expectations than mere physical qualities has been pointed out convincingly in a recent study from New Zealand, showing how nature may become associated with crime (Fleming et al., 2016).

Obviously, the multiple sources founding the environmental impact on cognitive states do not invalidate the claims of ART. One way to explain the apparent instinctual automaticity often found relating natural environments with particular cognitive states is that socio-cultural factors tend to blend into the tacit knowledge of the individual. As part of the perceptual activity, they front the atmosphere and enrich the conditions for learning in particular interpretations. Eventually, at the level of the individual, these human-based conditions appear innate (Lin et al., 2014).

The question remains as to whether mono-causal relations between the physical environment and cognitive states are ever realized. In other words, can the processing of perceptually available components of the physical environment ever occur in isolation from socio-cultural processes, or is the physical environment undeniably nested within socio-cultural processes through learning (e.g., Lidskog, 1998)? The answer is in need of basic research on the extent to which perceptual processes are modified by learning and whether socio-cultural practices perfuse every part of life.

AUTHOR CONTRIBUTIONS

TS and GE conceived of the study. TS and GE contributed conception of the study. TS wrote the first draft of the manuscript. GE wrote sections of the manuscript. Both authors contributed to manuscript revision, read and approved the submitted version.

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"Science Manipulates the Things and Lives in Them": Reconsidering Approach-Avoidance Operationalization Through a Grounded Cognition Perspective

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Approach and avoidance orientations are key elements of adaptive regulation at the evaluation-behavior interface. On the one hand, continuous evaluations of the world fuel approach-avoidance reactions as a function of the individual's immediate environment. On the other hand, in turn these individual-environment adjustments influence evaluations. A grounded perspective of social cognition, placing the sensorimotor aspects of individual-environment interactions at the core of cognition, has much to offer for the understanding of evaluative processes. Despite the growing enthusiasm for a grounded view of cognition and action in the approach-avoidance literature, its core principles are seldom reflected at the operationalization level. In this paper, we relied on the insights of a grounded perspective to propose more encompassing operationalizations of approach-avoidance orientations and investigate their influence on evaluations. Across six studies, we varied the approach-avoidance operationalizations (upper-body incline, upper-body posture and walking steps) and incrementally considered the grounded assumptions. We failed to obtain the theorized positive effect of approach (as compared to avoidance) on evaluations. Interestingly, further exploratory analyses on two studies conducted in Virtual Reality suggested that the more participants felt being *present* in the situation, the more the approach-avoidance ecological actions activated the corresponding neuropsychological systems. We discuss these emergent findings in light of grounded cognition and the notion of feeling of presence.

Keywords: approach-avoidance, grounded cognition, evaluations, construct validity, virtual reality

INTRODUCTION

"Science manipulates things and gives up living in them" Merleau-Ponty (1964). Individuals' interactions with their social world are steered by two fundamental forces: approach and avoidance — i.e., the energization to move toward or away (Price and Harmon-Jones, 2016). The literature shows a flexible two-way influence between approach-avoidance and the way people evaluate their environment. Such an interplay enables individuals to tailor their behavior to the current challenges and constraints of the immediate situation. A grounded cognition perspective has much to say about approach-avoidance orientations, as it specifically addresses the dynamic interactions between the brain, the body, and the environment. However, we contend that up to now experimental implementations of approach-avoidance have not fully exploited the theoretical insights provided by a grounded view of cognition. In this paper, the major goal is to capitalize on the grounded cognition perspective, which offers a useful theoretical toolbox to conceive appropriate and warranted operationalizations of approach-avoidance orientations. In doing so, we aim to circumvent the limitations of previous research and to offer a more ecological investigation of the influence of approach and avoidance on social information processing.

Approach and avoidance represent the elemental energization and direction of behavior for a majority of living organisms (from unicellular ancestors to more complex ones). Humans, like every organism, are able to adapt to their dynamic environments by reducing the distance toward appetitive stimuli and increasing the distance vis-à-vis noxious stimuli in keeping with their survival (Schneirla, 1959; Elliot and Covington, 2001; McNaughton et al., 2016). Hence, individuals' survival strongly depends on their ability to spontaneously detect approachable and/or avoidable entities (objects, people, events, ideas). This detection is assumed to spontaneously trigger appropriate behaviors (Chen and Bargh, 1999; Alexopoulos and Ric, 2007; Rougier et al., 2018). On a majority of cases, entities that entail a positive value for the organism trigger approach while those entailing a negative value trigger avoidance. Concerning interpersonal situations, research shows that, during social interactions, people tend to approach others if they seem trustworthy (Slepian et al., 2012), are smiling (Stins et al., 2011) or belong to the same group (Paladino and Castelli, 2008); but tend to avoid them if they display anger (Stins et al., 2011) or represent members of stereotyped and prejudiced groups (Word et al., 1974; Neumann et al., 2004; Paladino and Castelli, 2008). At the same time, when individuals are engaged in approach or avoidance behaviors, their cognitive activity is tuned to meet the specific requirements for goal attainment. For instance, people evaluate more positively stimuli or people they approach as compared to those they avoid (Cacioppo et al., 1993; Kawakami et al., 2007; Wiers et al., 2011; Slepian et al., 2012; Woud et al., 2013b). As a result, approach and avoidance regulate individual-environment interactions through a cyclical loop: continuous evaluation guides behavior appropriately and, in turn, ongoing behavioral activity spurs compatible evaluative processes. This cyclical influence possesses a functional value as it allows individuals to effectively pursue their actions until goal attainment (Förster et al., 2007).

As humans are social organisms endowed with a high level of complexity, they tend to deploy their approach-avoidance repertoire flexibly (Schneirla, 1959). Thus, the interplay between evaluated stimuli and approach-avoidance actions is not hard-and-fast but flexible and context-sensitive. Among other examples, the presence/absence of affective evaluation goals as well as the action outcome moderate the influence of approach-avoidance actions on evaluations (Cacioppo et al., 1993; Mertens et al., 2018). Moreover, approach-avoidance orientations may support distal goals, meaning that evaluations can trigger incompatible behaviors (e.g., approaching a very critical researcher) if they ultimately lead to compatible effects (e.g., the exchange will benefit one's work; Krieglmeyer et al., 2011).

Obviously, approach-avoidance orientations represent the key elements of an adaptive process at the evaluation-behavior interface. Such a process implies a constant combination of sensorimotor interactions with the world involving the brain, the body and the situation. It appears thus compelling to conceptualize approach-avoidance orientations by capitalizing on a view of cognition that emphasizes the role of brain-body-environment interactions.

Historically, since the advent of the cognitivist revolution, cognition has been considered to involve a relatively independent brain system performing computations on abstract and amodal representations (i.e., involving the symbolic translation of perceptual, motor and introspective states). Within this computationalist tradition, approach and avoidance were considered as amodal action representations and the body was a mere vehicle executing those actions based, for instance, on their threshold activation (Bower, 1981; Carver and Scheier, 2000). It has been argued since, that such a view of cognition cannot be adaptive as it is far too rigid and detached from ongoing brain-body-environment interactions, and these objections set the stage for alternative views.

A grounded view of cognition offers a more encompassing account of the flexible two-way influence between approach-avoidance tendencies and evaluation than the computationalist view. From such a perspective, human cognition is *grounded*[1] in modality specific systems, in the body and actions, as well as in the physical and the social environment (Wilson, 2002; Niedenthal et al., 2005; Pecher and Zwaan, 2005; Barsalou, 2008, 2015). According to one common approach within this perspective, as individuals interact with their world, the brain captures and integrates traces of perceptual, motor and introspective states into multimodal and situated representations (situated conceptualizations, Damasio, 1989; Barsalou, 1999, 2008; Barsalou, 2003, 2015; Versace et al., 2014). A matching between actual experience and some previously captured traces can reactivate the (whole) patterns of traces of the corresponding past experiences. This multimodal simulation aligns the brain and the body with past experiential states (*re-enactment*) depending on what is relevant for the immediate situation (i.e., physical environment, potential for actions, motivational/emotional states, etc.). This process is adaptive because it enables individuals to both anticipate and adapt their interactions to the world based on their past sensorimotor interactions as well as their actual environment. From a grounded perspective, repeated approach-avoidance interactions with the world entail the accumulation of motor, perceptual and introspective states (including positive and

[1] In keeping with Barsalou (2008), we used the term *grounded* rather than *embodied* to address all forms of cognitive grounding: not only based on the body, but also on modalities, on situated actions and on physical as well as social environments.

negative ones). Thus approach-avoidance orientations can be defined as the re-enactment of these states which impels to move toward or away (Papies and Barsalou, 2015).

Such a grounded perspective dictates specific operationalizations at the empirical level. Indeed, an optimal approach-avoidance manipulation should enable a close matching between the ongoing experience and past approach-avoidance traces. This depends on the potential of the current setting or situation to activate: (1) *prototypical* (i.e., most representative in terms of memory traces), (2) *multimodal*, as well as, (3) *situated* traces of approach-avoidance experiences (Barsalou, 2003, 2005, 2015; Versace et al., 2014; Papies and Barsalou, 2015). Here, we argue that approach-avoidance operationalizations from previous research (even those which are anchored in a grounded perspective) do not entirely reflect their grounded essence, as they have not systematically and jointly integrated the three aforementioned aspects.

Trace Prototypicality

Past research frequently operationalized approach-avoidance through arm flexion-extension as people generally flex (vs. extend) their arm to approach (vs. avoid) positive (vs. negative) graspable objects. These operationalizations involved among others: pressing the palm below/above the surface of a table, pulling/pushing a joystick, pressing/releasing a button, etc. (Cacioppo et al., 1993; Wentura et al., 2000; Kawakami et al., 2007; Laham et al., 2014). Others relied on oral muscular contractions resembling deglutition of edible substances (approach) or expectoration of noxious ones (avoidance; Topolinski et al., 2014). However, these two motor-based operationalizations cover a relatively restricted number of approach-avoidance experiences: not all external stimuli can be grasped, nor do they concern oral consumption (Rougier et al., 2018). Instead, whole-body operationalizations are more likely to capture most past approach-avoidance experiences. Among these whole-body operationalizations, we find: upper-body posture/inclination (Galton, 1884; Mehrabian, 1968; Word et al., 1974; Riskind, 1984; Price and Harmon-Jones, 2010), walking steps (Worthington, 1974; Dotsch and Wigboldus, 2008; Koch et al., 2009; Fayant et al., 2011; Stins et al., 2011), and simulation of whole-body movements (from a third-person perspective[2], De Houwer et al., 2001; or from a first-person perspective, Rougier et al., 2018).

Trace Multimodality

Some scholars constrained operationalizations of approach-avoidance to a single modality (e.g., motor information, Cacioppo et al., 1993; Topolinski et al., 2014; visual information, De Houwer et al., 2001; Rougier et al., 2018). From a grounded perspective, it is indeed conceivable that information in one modality activates other modality-specific traces of approach-avoidance (Damasio, 1989; Barsalou, 1999; Versace et al., 2014). However, an efficient simulation of approach-avoidance states should involve as many different multimodal traces of past experiences as possible (Labeye and Versace, 2007). For instance, a (visual) zoom effect has been combined to the (motor) pulling/pushing joystick movements in order to enhance the operationalization of approach-avoidance orientations (Rinck and Becker, 2007; Krieglmeyer and Deutsch, 2010). Hence, approach-avoidance operationalizations that combine motor, visual and proprioceptive information are more likely to enable the re-enactment of the corresponding states. Among these multimodal operationalizations, we consider: upper-body postures (Price and Harmon-Jones, 2010) or walking steps (Fayant et al., 2011; Stins et al., 2011; Bouman and Stins, 2018). Indeed, these whole-body approach-avoidance behaviors inherently entail changes in information flow and visual perspective while concurrently engaging motor components.

Trace Situatedness

The majority of work relied on operationalizations of approach-avoidance experiences that scale down the situation to isolated and minimal encounters with stimuli (even when, paradoxically, they make use of prototypical and multimodal aspects, Fayant et al., 2011, Exp. 2; Rougier et al., 2018)[3]. Undoubtedly, this practice runs counter the assumption that the perceptual, motor and introspective traces of approach-avoidance states are not stored in isolation but together with traces of the situation settings in which these states occurred (e.g., elements of the environment, action possibilities, individuals' intentions, emotional states; Barsalou, 2003, Papies and Barsalou, 2015). Failures to take into account this situatedness may lead to unsatisfactory or ambiguous operationalizations (Markman and Brendl, 2005; Seibt et al., 2008; Van Dantzig et al., 2008; Beatty et al., 2016). Indeed, depending on the situation, the very same muscular contraction can either be considered as approach or avoidance: for example bringing a cake closer or withdrawing one's hand from a spider both involve arm flexion[4], and deglutition involves the swallowing of appetitive food stimuli but could also be involved in stress reactions (Ritz and Thöns, 2006). Moreover, as any situation, the experimental setting offers specific action possibilities (i.e., *affordances*) that may interfere with traces targeted by the operationalization of approach-avoidance orientation (Cesario et al., 2010). For instance, intrinsically social stimuli as faces generally evoke whole-body approach-avoidance behavioral actions which are relevant for social interactions. In front of such stimuli, arm flexion-extension operationalizations that activate traces of approach-avoidance experiences in

[2]Admittedly, the Manikin Task of De Houwer et al. (2001) does not involve whole-body movements *per se*. In this task, participants have to move a little figure representing the self toward or away from the stimuli. Even if the Manikin Task is not anchored in a grounded perspective, it is still conceivable that the perceived visual distance change could re-enact whole-body approach-avoidance experiences.

[3]These experiments involved for example approach-avoidance toward isolated words presented on a screen. Indeed, in everyday life words on posters or signs may sometimes appeal or repel people, but evidently this constitutes a fairly small subset of approach-avoidance experiences.

[4]The same contraction can also be interpreted differently across studies. Generally, scholars considered that flexion is involved in bringing something closer to the self (approach) while extension is involved in pushing something away (avoidance). However, some studies operationalized approach as extension and avoidance as flexion (Mertens et al., 2018).

response to graspable objects (Kawakami et al., 2007; Slepian et al., 2012, but see Streicher and Estes, 2016) seem unwarranted, to say the least. Therefore, an optimal manipulation of approach-avoidance should rely on contextualized and ecological whole-body approach-avoidance experiences which by virtue of their situatedness re-enact more fully the corresponding states. As appropriate examples of situated approach-avoidance operationalizations we can readily identify those that rely on real life settings and/or confederates (Word et al., 1974; Worthington, 1974)[5] and those that rely on Virtual Reality (Bailenson et al., 2003; Dotsch and Wigboldus, 2008; Ruggiero et al., 2017) although these works dealt more with proxemics than approach-avoidance behaviors *per se*.

From this literature review, it follows that operationalizations of approach-avoidance orientations relying on **multimodal interactive and contextualized whole-body movements** are the most suitable to reflect their grounded essence. So far, and despite some promising attempts, approach-avoidance operationalizations did not jointly consider the prototypicality, multimodality and situatedness requirements that emerge from an analysis of grounded cognition.

OVERVIEW OF THE STUDIES

In this paper, we argue that even if a grounded view of approach-avoidance orientations has gained in popularity over the past few years, somewhat ironically, its theoretical assumptions have not been systematically and jointly considered at the time of choice of operationalization. Bearing in mind that approach and avoidance orientations are grounded in sensorimotor interactions with the physical and social environment, we tentatively propose a prototypical, multimodal and situated operationalization. An appropriate and exhaustive operationalization of approach-avoidance orientations is crucial as this constitutes one of the major obstacles when connecting theory to data (Rakover, 1981). To assess the viability of this operationalization, we implemented it in the examination of the influence of approach-avoidance behaviors on interpersonal evaluations. In all studies, we manipulated approach-avoidance orientations through ecological whole-body approach-avoidance behaviors and measured evaluations in a self-reported way. As a general hypothesis, and in line with previous literature (Cacioppo et al., 1993; Slepian et al., 2012), we anticipated that, using highly ecological settings, approach behaviors would lead to more positive evaluations as compared to avoidance behaviors. We followed a two-stage process to test this hypothesis and incrementally consider the grounded assumptions. In a first stage, in order to provide continuity with past research, we relied on operationalizations that have been previously used in the literature (but not in the field of interpersonal evaluations) and that satisfied the prototypicality and the multimodality requirements: upper-body incline/posture. We set these behaviors in the context of social interactions as we deem them particularly relevant for this kind of situation and tested their effect on interpersonal evaluations in four pilot studies. In the second stage, and in a break with past research, we went further in the situatedness consideration and took seriously the grounded nature of approach-avoidance orientations. To this aim, we relied on upper-body incline and walking steps operationalizations in two main studies that we conducted through immersive virtual reality (VR). VR is increasingly viewed as a promising tool in the study of social interactions in that it allows considering the ongoing individual-environment interaction while maximizing experimental control (Blascovich et al., 2002; McCall, 2015; Pan and Hamilton, 2018). In all studies we planned to run at least 50 participants per condition as recommended by Simmons et al. (2013). Such a criterion enabled us to detect an effect size η^2 comprised between 0.05 and 0.15 (depending on the design) with a power of 80%. We collected and analyzed anonymously all data with written informed consent from participants in accordance with the American Psychological Association's ethical principles. However, we did not seek the explicit ethics approval as it was not required for the present studies as per Université de Paris's guidelines and applicable national regulations.

PILOT STUDIES

As an initial step in considering the grounded nature of approach-avoidance orientations in their operationalization we conducted four pilot studies. In these pilots, we aimed at replicating and extending the influence of approach-avoidance orientations on self-reported evaluations relying on prototypical and multimodal operationalizations by adapting existing inductions: upper-body incline/posture. We set these behaviors in the context of a social interaction (i.e., face stimuli). By doing so, we intended to maximize trace activation and expected more positive evaluations in the approach than in the avoidance condition. The procedure was comparable throughout the pilots: participants evaluated faces while performing an approach or avoidance behavior. At the end, they also indicated to what extent they found the task pleasant, difficult and tiring to control for any potential confounded variables. We present the main elements of the pilot studies below and provide details for these pilots in **Supplementary Material 1**.

In Pilot 1 (N_{Analyzed} = 50), participants were seated between two wooden boards perpendicular to which we affixed two computer mice and facing a computer screen (see **Supplementary Material 1**). Pretexting a study on ergonomic positions, we asked them to greet computerized faces (taken from Oosterhof and Todorov, 2008) while performing different movements. Depending on the block of a within-participants design, participants had to either lean their upper-body forward or backward in order to click the corresponding mouse button (behind vs. in front of the coronal plane). The mouse click triggered the appearance of a speech bubble saying "hello," indicating that participants effectively greeted the character. After this instrumental movement (i.e., greeting), participants returned

[5]Obviously, the use of real life settings or confederates implies a lot of methodological shortcomings (e.g., confederates enter an experimental social interaction with their own past experiences background and perfectly controlling one's behavior in such situation is nearly impossible to achieve; McCall, 2015).

to the body's "home" position (i.e., an upright position) and rated the pleasantness of the face (from 1: *very unpleasant* to 7: *very pleasant*).

In Pilot 2 ($N_{\text{Analyzed}} = 107$), we relied on a between-participants design. We further added contextual cues by connecting an upper body to each face and placing them in an office room background. These were projected real size on a wall. We also reduced the distance between the wooden boards to obtain a more ecological movement amplitude. Pretexting a study on impression formation during a job-interview, we asked participants to greet characters verbally while leaning their upper-body either forward or backward depending on condition. In order to circumvent the fact that both approach and avoidance movements were performed before evaluating characters (as this could have been potentially an issue in the case of the manipulation in Pilot 1) participants had to maintain the position while evaluating characters. Instead of asking participants to judge the faces, we asked them to provide their impression of them on a scale anchored at −3: *I do not like at all* and +3: *I like very much* (Chen et al., 2004).

In Pilot 3 ($N_{\text{Analyzed}} = 97$), we manipulated approach-avoidance orientations through corresponding postures and relied on the same stimuli as in Pilot 2. Participants were seated in front of a computer screen and were instructed to give their impression of characters verbally, while leaning forward or backward throughout the experimental procedure.

Pilot 4 ($N_{\text{Analyzed}} = 154$) followed the same procedure as Pilot 3 except two changes. To increase reliance on their affective feeling, we led participants to believe that they subliminally received pseudo-individualizing information about each presented target-person (Yzerbyt et al., 1998). To increase ecological validity, we also sampled pictures instead of computerized faces from a distinct database (i.e., the Chicago Face Database, see Ma et al., 2015).

Across the four pilots, we failed to show a positive effect of approach behaviors (as compared to avoidance) on interpersonal evaluations. A random effects mini meta-analysis (with the "metafor" R package) on the standardized regression coefficients (Kim, 2011) revealed a statistically non-significant effect of approach-avoidance behaviors on evaluations, $z = -0.75$, $p = 0.455$, $\beta_Z = -0.05$, 95% CI (−0.17, 0.07)[6].

Upper-body inclination/postures used in previous research are arguably prototypical and multimodal operationalizations of approach-avoidance orientations, which are also relevant in the context of face evaluation. However, such operationalizations only partially consider the grounded essence of approach-avoidance orientations as they are low in situatedness. The social interaction context and face stimuli may have not been sufficiently interactive to satisfy the situatedness requirement and allow for the re-enactment of approach-avoidance experiences. With an objective of bringing a possible solution with respect to this aspect, we used VR — an immersive and interactive tool — in the two following studies.

[6]For Pilot 1, we only considered the first block of trials in the meta-analysis. Even if this choice affected power, it was done for the sake of comparability with the other pilots that used a between-participants design and also because there was an interaction between movement and block order.

MAIN STUDIES: A VIRTUAL REALITY SETTING

In Study 1 and 2, we tested the effect of approach-avoidance behaviors on interpersonal evaluations relying on VR and using self-reported evaluations. We expected more positive evaluations in the approach than in the avoidance condition, with the control condition falling in between. Importantly, the inconclusive results of the four pilot studies may also be due to the failure of activating approach-avoidance tendencies. Thus, to directly address this issue in these studies we also included additional measures of approach-avoidance tendencies in order to assess the construct validity of the manipulation. We thus measured action tendencies (with the Visual Approach/Avoidance by the Self Task, VAAST; Rougier et al., 2018, for a similar procedure see Smith and Bargh, 2008) and the activation of approach-avoidance neuropsychological systems (Reinforcement Sensitivity Theory of Personality Questionnaire, RST-PQ; Corr and Cooper, 2016). We expected that our manipulation of approach-avoidance orientations would activate the corresponding action tendency and neuropsychological system. We also took care to measure the feeling of Presence and Cybersickness that could hinder the Virtual Reality experience (see Pan and Hamilton, 2018), as well as the judgment of pleasantness, tiredness and difficulty of the task to control for any potential confounded variables. All hypotheses, measures, instructions and statistical analyses were pre-registered[7,8].

Study 1

Methods

Participants

In total, 211 French-speaking participants took part in the study in exchange of partial credit course or 15€. They were randomly assigned to the approach, avoidance, or control conditions in a between-participants design[9]. We excluded participants that: guessed the hypothesis (5), did not follow the instructions (e.g., using only the head instead of the upper body; 56) and reported having consumed substances (3). Finally, we excluded one participant with excessive missing data (46.67%) due to a

[7]osf.io/sqhvw

[8]After extensive consultation among all authors, we applied exclusion criteria deviating from the pre-registered ones. **(1)** Because of the absence of explicit approach-avoidance labels, we had a considerable amount of participants that did not understand and correctly perform the requested action. Including those participants would have excessively increased variance in the analyses. **(2)** We did not exclude participants who reported cognitive troubles as the item did not prove able to detect effective troubles and this exclusion did not change the pattern of obtained results. **(3)** We did not exclude participants according to their cybersickness score as there is no clear exclusion criterion for cybersickness in the literature and the Simulator Sickness Questionnaire (Kennedy et al., 1993) is not built for cybersickness *per se* and is very sensitive ("merely closing one's eyes for an extended period of time can affect the measurement," Rebenitsch and Owen, 2016). Moreover, we exposed participants to VR for approximately 15 min which induces generally low levels of cybersickness (Stanney et al., 2002; Pan and Hamilton, 2018). Again, excluding those extreme participants (which were outliers on studentized residuals, that is above four, when running a simple regression analysis on cybersickness scores alone; Judd et al., 2011) did not change the pattern of results.

[9]As experimenters have to insert manually the script in the file read by the application, they were not blind to conditions.

technical problem with the VR equipment. We thus analyzed the data of the remaining 162 participants.

Material

Twelve first names per gender, half of them containing the sound /o/ (e.g., Margaux, Jerome) and the other half containing the sound /i/ (e.g., Emeline, Remy) served as stimuli for the VAAST. We controlled them for frequency based on the national database (Institut National de la Statistique et des Etudes Economiques [INSEE], 2015).

Procedure

Virtual reality task. Upon their arrival, participants received instructions about the VR task on a computer screen. The task was presented as a study on impression formation and administered through a VR headset (HTC Vive©). Participants were seated at a table in a neutral virtual room and had to maintain an upright position. Each virtual character sat in front of them and greeted them by saying "hello." Depending on the condition, participants had to reply back "hello" and perform a 10-degree forward-lean (approach condition), a 10-degree backward-lean (avoidance condition) or no movement (control condition). A Likert-type scale appeared in the virtual environment 2000 ms after participants performed the correct action. While maintaining their position, participants used the HTC controllers to provide their impression of the character anchored at 1 (negative) and 7 (positive). Once the response was recorded, the virtual character walked away and participants in the approach and avoidance conditions were instructed to go back to the central position. Then, participants waited for the appearance of the next virtual character to repeat the sequence. After five training trials with a test character, participants encountered 30 characters (15 men and 15 women). In line with previous research, we expected more positive evaluations in the approach than in the avoidance condition.

Based on our theoretical rationale, we refrained from explicitly mentioning approach or avoidance labels in the instructions in order to limit potential demand characteristics and the direct influence of these labels on evaluations (Van Dessel et al., 2015). Thus, in order to assist participants in reaching the correct orientation without an explicit mention of the terms "approach" or "avoidance," we presented them a position bar displaying the onset position (the white mark on **Figure 1**), the requested final position (the gray mark on **Figure 1**) and their tracked position (the black circle on **Figure 1**) on the right side of the screen. Using this position bar, their task was to align their upper-body to the requested position. If participants deviated too much from the requested position, they received an auditory feedback.

Action tendencies

After the VR task, participants performed the VAAST (Rougier et al., 2018) to check if our manipulation of approach-avoidance orientations activated the corresponding action tendency. They had to categorize first names depending on the sound they contained (i.e., the /o/ vs. /i/ sound) by pressing a "move forward" key (approach response) or a "move backward" key (avoidance response). In one block, participants had to approach first names containing the sound /o/ and avoid those containing the sound /i/. In the other block, this was reversed. Each trial began with a white circle displayed in the center of the screen prompting participants to press a "start" button. Then, a fixation cross was displayed (with a random duration of 800–2000 ms) and participants had to keep their finger pressed until a first name appeared. When the target name appeared, participants had to categorize it by pressing the "move forward" or "move backward" key four times, as quickly and as accurately as possible. Depending on keypress, the background image and the target first name was zoomed in (i.e., "move forward" button, approach) or zoomed out (i.e., "move backward" button, avoidance) by 10% after each button press. In each block, participants performed 8 training trials followed by 48 experimental trials. We recorded reaction time (RT) at the onset of the name until the first keypress. At the outcome, participants indicated their age, gender, laterality and if they were fluent in French (in case they were not, they indicated their skills on a scale from 1 = *very low level* to 7 = *very high level*). We expected participants to approach stimuli faster in the approach than in the avoidance condition but to avoid stimuli faster in the avoidance than in the approach condition, or to put it short an interaction between movement and response type.

FIGURE 1 | Image captures from the Virtual Reality task in Study 1 (left) and Study 2 (right).

Neuropsychological systems

Then, participants completed the French version of the RST-PQ (Corr and Cooper, 2016; L.-C. Vannier, personal communication, December 4, 2017) to check if our manipulation of approach-avoidance orientations activated the corresponding system. Based on the revised reinforcement sensitivity theory (Corr and McNaughton, 2012), this questionnaire measures the Behavioral Approach System (BAS, related to approach behaviors and appetitive stimuli; 29 items), the Fight-Flight-Freeze System (FFFS, related to active avoidance behaviors and aversive stimuli; 10 items) and the Behavioral Inhibition System (BIS, related to passive avoidance behaviors and conflictual stimuli; 15 items). The RST-PQ has the advantage of taking into account the multidimensionality of the BAS and distinguishing the FFFS from the BIS. We expected higher BAS scores in the approach than in the avoidance condition and higher FFFS scores in the avoidance than in the approach condition.

Complementary measures

Subsequently, participants completed the French versions of the Presence Questionnaire (PQ; Witmer and Singer, 1998; Robillard et al., 2002) and the Simulator Sickness Questionnaire (SSQ; Kennedy et al., 1993; Bouchard et al., 2007). They also indicated to what extent they found the VR task pleasant, difficult and tiring (on a scale from 1 = *not at all* to 7 = *extremely*). All these complementary measures were included to control for any potential confound. Finally, they reported any trouble or substance intake which could have impaired their performance. They were probed for suspicion, debriefed and compensated for their participation.

Results

We ran several General Linear Model analyses. In order to test the linear effect of movement, we created two contrast codes. In the first, we opposed the approach (+1) to the avoidance condition (−1), ignoring the control condition (0). In the second, we opposed the control condition (+2) to both the approach (−1) and avoidance conditions (−1). As participants judged the task more tiring in the avoidance than in the approach condition ($M_{\text{Approach}} = 2.60$, $SE_{\text{Approach}} = 0.23$; $M_{\text{Avoidance}} = 3.45$, $SE_{\text{Avoidance}} = 0.21$; $F(1, 155) = 7.47$, $p = 0.007$, $\beta_Z = -0.26$, 95% IC [−0.45, −0.07]), we included the tiredness judgment in the analysis to control for this potential confound[10]. All reported descriptive statistics were those estimated by the models and the 95% confidence intervals reported hereafter are based on the standardized differences between the tested means.

Evaluations

We deleted trials where participants performed a wrong movement (1.30%), deviated from the position they had to maintain (6.32%) and/or did not directly reach the correct position (5.13%). On the remaining trials, we estimated a linear mixed-effects model with the linear codes of contrast, tiredness judgment and their interactions terms as fixed factors as well as participants and stimuli as random factors (with the "lmer" R package). Contrary to the tested hypothesis, the first contrast revealed that evaluations did not significantly differ between the approach ($M = 4.26$, $SE = 0.17$) and the avoidance conditions ($M = 4.34$, $SE = 0.16$), $F(1, 153.09) = 0.39$, $p = 0.534$, $\beta_Z = -0.03$, 95% IC [−0.12, 0.06]. No other effect was significant, Fs < 1.39, all ps > 0.239.

Action tendencies

Concerning the VAAST, we examined RTs for experimental trials only and removed incorrect trials (3.29 %). In order to correct a positively skewed distribution, we deleted RTs faster than 200 ms or above 2000 ms (1.06%) and applied a log-transformation on raw RTs. We estimated a linear mixed-effects model with the linear codes of contrast, response type (approach, avoidance), tiredness judgment and their interaction terms as fixed factors, as well as participants and stimuli as random factors (with the "lmer" R package). The analysis first revealed a significant main effect of response type, $F(1, 14360) = 62.81$, $p < 0.001$, $\beta_Z = -0.11$, 95% IC [−0.14, −0.08]. Participants were faster to approach ($M = 719.10$ ms[11], 95% IC [699.24, 739.52]) than to avoid ($M = 741.74$ ms, 95% IC [721.26, 762.80]) the first names. However, we did not obtain the expected interaction between the first contrast and response type, $F(1, 14360) = 0.06$, $p = 0.806$, $\beta_Z = 0.00$, 95% IC [−0.03, 0.04]: participants were not faster to approach (vs. avoid) first names in the approach than in the avoidance condition (see **Table 1**). The analysis also revealed a marginal interaction between response type and tiredness judgment indicating that the more participants judged the task as tiring, the quicker they were to approach than to avoid, $F(1, 14360) = 3.24$, $p = 0.02$, $\beta_Z = -0.02$, 95% IC [−0.03, 0.00].

Neuropsychological systems

For RST-PQ scores, we estimated a linear regression model with the two contrast codes, tiredness judgment and their interaction terms as predictors. Contrary to what we expected, we did not obtain higher BAS scores in the approach than in the avoidance condition, $F(1, 151) = 0.46$, $p = 0.499$, $\beta_Z = -0.06$, 95% IC [−0.25, 0.12]. The results are even in the opposite direction with higher BAS scores in the avoidance ($M_{\text{BAS}} = 2.89$, $SE_{\text{BAS}} = 0.05$) than in the approach condition ($M_{\text{BAS}} = 2.84$, $SE_{\text{BAS}} = 0.05$). Neither we obtained higher FFFS scores in the avoidance ($M_{\text{FFFS}} = 2.12$, $SE_{\text{FFFS}} = 0.08$) than in the approach condition ($M_{\text{FFFS}} = 2.07$, $SE_{\text{FFFS}} = 0.08$), $F(1, 151) = 0.21$, $p = 0.649$, $\beta_Z = -0.04$, 95% IC [−0.23, 0.14] although the pattern was in the expected direction. There was no other significant effect, nor for the BAS, neither for the FFFS, Fs < 2.68, ps > 0.104.

Discussion

In Study 1, we took advantage of the immersive and interactive nature of VR to implement a grounded operationalization of approach-avoidance orientations and to test their effect on interpersonal evaluations. However, we failed to show the expected positive influence of approach on evaluations. We also did not obtain any indication of an activation of the corresponding action tendencies or neuropsychological systems. Nevertheless, as a relatively substantial part of the sample did not correctly perform the instructed action, it appears that upper-body incline was not very intuitive to participants within this setting. This may have rendered the operationalization of approach-avoidance orientations ambiguous. In Study 2, we pursued the examination and relied on an experimental variation of the foregoing grounded operationalization.

Study 2

Methods

Participants

Two-hundred and four participants took part in the study in exchange of partial credit course or 15€. They were randomly assigned to the approach, avoidance, or control conditions in a between-participants design. We excluded participants that:

[10]With four observations deleted due to missing values on task judgment. As pleasantness judgment, difficulty judgment, simulator sickness and presence did not differ between approach and avoidance conditions in both studies, we did not include them in the models. Moreover, unlike the four pilots, the difficulty, pleasantness and tiredness judgment of the task in this study were confounded with judgments of the VR due to item wording problems.

[11]For the sake of clarity, we reported the antilog of log-transformed means.

TABLE 1 | Estimated means and standard errors (or confidence intervals) for evaluations, neuropsychological systems and action tendencies.

	Avoidance		Control		Approach	
Variable	***M***	***SE (or 95 % CI)***	***M***	***SE (or 95 % CI)***	***M***	***SE (or 95 % CI)***
Evaluations						
Pilot 1[a]	3.54	0.15	/	/	3.78	0.16
Bloc 1	3.7	0.21	/	/	3.44	0.36
All data	3.54	0.15	/	/	3.78	0.16
Pilot 2[b]	0.35	0.12	/	/	0.11	0.12
Pilot 3[b]	0.13	0.2	/	/	0.23	0.19
Pilot 4[b]	0.45	0.13	0.4	0.13	0.56	0.14
Experiment 1[a]	4.34	0.16	4.31	0.16	4.26	0.17
Experiment 2[a]	4.46	0.17	4.41	0.17	4.34	0.17
Neuropsychological Systems						
BAS						
Experiment 1	2.89	0.05	2.92	0.05	2.84	0.05
Experiment 2	2.93	0.05	2.97	0.05	2.96	0.04
FFFS						
Experiment 1	2.12	0.08	2.01	0.07	2.07	0.08
Experiment 2	2.17	0.08	2.18	0.08	2.16	0.07
Action Tendencies						
Approach RT						
Experiment 1	720.54	[689.52, 753.70]	732.89	[702.11, 765.10]	704.16	[672.50, 736.57]
Experiment 2	731.43	[701.35, 762.04]	750.7	[719.82, 782.11]	739.52	[710.52, 769.70]
Avoidance RT						
Experiment 1	744.71	[711.94, 778.99]	755.21	[723.43, 787.61]	725.6	[692.98, 759,76]
Experiment 2	752.95	[722.70, 785.25]	782.9	[750.70, 815.66]	762.04	[732.16, 793.14]

M, estimated mean; SE, estimated standard error; CI, confidence interval; BAS, behavioral approach system; FFFS, fight, flight and freeze system; RT, reaction times. [a]*Scale from 1 to 7.* [b]*Scale from −3 to +3.*

guessed the tested hypothesis (2), did not follow the instructions (e.g., steps incompletely done; 7), reported substance intake (4) and declared low French skills (i.e., below 5 on the 1 to 7 scale; 1). Due to an experimenter error, one participant received opposite behavioral instructions from the behavior he had to perform in VR. We excluded this participant and analyzed the data of the remaining 189 participants.

Procedure

We followed exactly the same procedure as in Study 1, except the approach-avoidance orientations operationalization. This time, participants stood at a bus stop in a virtual street and had to maintain an upright position (**Figure 1**). Virtual characters came across to them and greeted them by saying "hello." Depending on the condition, participants had to reply back "hello" making one step (approx. 20 cm wide) forward (approach condition), backward (avoidance condition) or standing in place (control condition).

Results

Again, we ran several General Linear Models to test our predictions. We created the same two contrast codes as in Study 1 in order to test the linear effect of movement. In the first, we opposed the approach (+1) to the avoidance condition (−1), ignoring the control condition (0). In the second, we opposed the control condition (+2) to both the approach (−1) and avoidance conditions (−1).

Evaluations

We deleted trials where participants performed a wrong movement (0.20%), deviated from the position they had to maintain (1.85%) and/or did not directly reach the correct position (2.4%). On the remaining trials, we estimated a linear mixed-effects model with the same linear codes of contrast as fixed factors as well as participants and stimuli as random factors (with the "lmer" R package). Again, the analysis revealed that evaluations did not significantly differ between the approach ($M = 4.34$, $SE = 0.17$) and the avoidance condition ($M = 4.46$, $SE = 0.17$), $F(1, 186.43) = 1.03$, $p = 0.310$, $\beta_Z = -0.04$, 95% IC [−0.13, 0.04]. The second contrast also was not significant, $F < 1$, $p = 0.922$.

Action tendencies

Concerning the VAAST, we examined RTs for experimental trials only and removed incorrect trials (3.72 %). In order to correct a positively skewed distribution, we deleted RTs faster than 200 ms or above 2000 ms (1.06%) and applied a log-transformation to raw RTs. We estimated a linear mixed-effects model with the linear contrast, response type (approach, avoidance) and their interaction terms as fixed factors as well as participants and stimuli as random factors (with the "lmer" R package). As in

Study 1, participants were faster to approach (M = 740.26 ms, 95% IC [721.26, 759.76]) than to avoid (M = 765.86 ms, 95% IC [746.20, 786.03]) the first names, $F(1, 17050) = 93.24$, $p < 0.001$, $\beta_Z = -0.12$, 95% IC [−0.15, −0.10]. We did not obtain the expected interaction between the first contrast and response type, $F(1, 17050) < 0.01$, $p = 0.962$, $\beta_Z = -0.00$, 95% IC [−0.03, 0.03] (see **Table 1**).

Neuropsychological systems

For RST-PQ scores, we estimated a linear regression model with the two contrast codes as predictors. The analysis revealed no effect of the approach-avoidance orientations manipulation on BAS scores ($M_{\text{Approach}} = 2.96$, $SE_{\text{Approach}} = 0.04$; $M_{\text{Avoidance}} = 2.93$, $SE_{\text{Avoidance}} = 0.05$, $F(1,182) = 0.14$, $p = 0.705$, $\beta_Z = 0.03$, 95% IC [−0.14, 0.21]) neither on FFFS scores ($M_{\text{Approach}} = 2.16$, $SE_{\text{Approach}} = 0.07$; $M_{\text{Avoidance}} = 2.17$, $SE_{\text{Avoidance}} = 0.08$, $F(1, 182) < 0.01$, $p = 0.962$, $\beta_Z = -0.00$, 95% IC [−0.18, 0.17]).

Discussion

In Study 2, although we increased the ecological character and situatedness of the operationalization of approach-avoidance orientations, we again failed to confirm the theorized prediction. Approach-avoidance behaviors did not influence evaluations as well as the activation of corresponding action tendencies or neuropsychological systems.

Complementary Analyses

Although VR is a promising tool to operationalize approach-avoidance as grounded in individual-world experiences, it nevertheless remains a technology-mediated experience. Thus, virtual approach-avoidance interactions might enable to re-enact internal states only when individuals did not consciously perceive such a mediation (Parsons and Rizzo, 2008). That is, in the case the virtual environment successfully supports approach-avoidance interactions while offering the same sensorimotor information as in non-virtual settings and providing individuals the feeling of “being there.” This subjective experience of being in one environment, even when one is physically situated in another, is coined the “feeling of *presence*” (Witmer and Singer, 1998). Some scholars consider the feeling of presence as reflecting the full integration of every relevant aspect of the situation pertaining to the “here and now” including: movement and perception, actions, representation of the self in the overall situation, possibilities for action, etc. (Carassa et al., 2005; Riva, 2009; Mennecke et al., 2011; Riva and Waterworth, 2014; Willans et al., 2015). In this sense, the notion of presence may gauge the extent to which cognition is grounded in the virtual environment, and may be a necessary condition to re-enact approach-avoidance states through VR.

The overall feeling of presence in the current studies ($M_{\text{Exp1}} = 95.52$, $SE_{Exp1} = 1.07$; $M_{Exp2} = 92.75$, $SE_{Exp2} = 1.05$) was lower than the French speaking norm (M = 104.39, SE = 1.89; from the Cyberpsychology Lab at University of Quebec in Outaouais, 2013). This moderately low feeling of presence could explain that we failed to obtain the positive effect of approach on evaluations. For this reason, we added the feeling of presence as a fixed factor in the models previously estimated. For the sake of clarity, we only report results that we deemed relevant for the goal of this paper (the interested reader can refer to **Supplementary Material 2**).

Complementary Analyses of Study1

Although not significant, the patterns showed that the more participants felt being present in the situation the more the approach manipulation activated the BAS as compared to the avoidance condition, $F(1, 144) = 0.36$, $p = 0.549$, $\beta_Z = 0.00$, 95% IC [−0.01, 0.02][12]. However, the patterns also showed that the more participants felt being present the less the avoidance manipulation activated the FFFS as compared to the approach condition, $F(1, 144) = 1.11$, $p = 0.295$, $\beta_Z = 0.01$, 95% IC [−0.01, 0.02].

A closer inspection of evaluative ratings suggested that the more participants felt being present in the situation, the more they evaluated positively the characters in the avoidance as compared to the approach condition, although this effect was not significant, $F(1, 146.3) = 0.04$, $p = 0.847$, $\beta_Z = -0.00$, 95% IC [0.00, 0.01].

Complementary Analyses of Study 2

The patterns reveal that the more participants felt being present in the situation the more the approach manipulation activated the BAS compared to the avoidance condition, $F(1, 179) = 3.95$, $p = 0.048$, $\beta_Z = 0.01$, 95% IC [0.00, 0.02]. Correspondingly, the more participants felt being present in the situation the more the avoidance manipulation activated the FFFS compared to the approach condition, $F(1, 179) = 1.49$, $p = 0.224$, $\beta_Z = -0.01$, 95% IC [−0.02, 0.00], although the latter results were not significant.

Interestingly, including presence in the analysis of evaluative ratings revealed that the more participants felt being present in the situation, the less they evaluated positively the characters in the avoidance as compared to the approach condition, $F(1, 180.9) = 0.20$, $p = 0.66$, $\beta_Z = -0.00$, 95% IC [−0.00, 0.01].

Discussion of Complementary Analyses

These exploratory analyses suggest that the approach-avoidance manipulation is contingent on the way participants experience the immersive virtual situation. At least in Study 2, the analyses revealed patterns of interaction between the manipulation of approach-avoidance orientations and the feeling of presence on the activation of the neuropsychological systems. Indeed, the corresponding motivational states seem to be activated by the manipulation when individuals felt being present (in a non-mediated interaction with the environment). Although non-anticipated, we deem these results important as they emphasize the role of ongoing individual-environment interaction in social cognition and arguably fit well with a grounded view of cognition putting subjective sensorimotor experiences at the core of knowledge. However, the results of Study 1 are less clear with patterns of interaction in the opposite direction. As previously mentioned, a large proportion of participants had not correctly performed the requested

[12]We excluded one participant due to missing data on the Presence Questionnaire.

action in Study 1, while this was not the case in Study 2. This may suggest that upper-body incline was a more ambiguous operationalization of approach-avoidance experiences than walking and may explain the mitigated pattern.

GENERAL DISCUSSION

In this paper, our aim was to capitalize on a grounded view of cognition to develop a thorough and appropriate operational definition of approach and avoidance. According to this view, an optimal operationalization should enable a close matching between ongoing experience and past approach-avoidance traces. To this aim, we relied on prototypical whole-body movements, involving multi-sensory information, in relevant interpersonal contexts. We implemented these operationalizations in the study of the influence of approach and avoidance on interpersonal evaluations. In six studies, we relied on prototypical and multimodal operationalizations previously used in approach-avoidance studies (e.g., evaluative-assimilation, Fayant et al., 2011; cognitive categorization, Price and Harmon-Jones, 2010). In the last two studies, we went a step further and relied on immersive VR in order to fully consider the grounded aspect of approach-avoidance orientations. Doing so, we also satisfied a third (and frequently overlooked) requirement for an optimal grounded operationalization of approach-avoidance: its situatedness. Despite this, the present studies failed to show more positive evaluations in the approach than in the avoidance condition. Including all standardized regression coefficients from VR studies and pilots in a random effects meta-analysis revealed a statistically non-significant effect of approach-avoidance behaviors on evaluations, $z = -1.06$, $p = 0.2887$, $\beta_Z = -0.03$, 95% CI $(-0.07, 0.02)$[13]. This estimated effect is even in the opposite direction with more negative evaluations in the approach than in the avoidance condition. Thus, in the present studies, it seems as if approach and avoidance do not influence interpersonal evaluations. This non-finding is puzzling and opposes a wealth of studies that obtained reliable effects of approach-avoidance actions on evaluations (Cacioppo et al., 1993; Slepian et al., 2012; Woud et al., 2013b).

With all cautions taken, the fact that the influence of approach-avoidance on evaluations did not emerge with the use of more ecological behavioral operationalizations raises some questions. First, it may be the case that previous effects were only the fact of unimodal and decontextualized operationalizations of approach-avoidance experiences that activated a very specific and limited pattern of traces. However, social psychologists have the ultimate goal of studying how human social cognition unfolds in daily individual-environment interactions, rather than in (overly) simplistic approximations of those situations (e.g., being seated in front of pictures or words presented on a computer screen in an experimental box). In isolated and simplistic situations, a very narrow and specific pattern of traces may be activated. However, when common sensory surroundings stimulate the individuals' body and brain, the same pattern may interact with others and become highly context-dependent. In line with this, Varela et al. (1991, p. 94) observed that "the brain is a highly cooperative system: the dense interconnections among its components entail that eventually everything going on will be a function of what all the components are doing." Moreover, the effects of approach-avoidance tendencies on evaluations are often studied for intervention purposes (e.g., addiction treatment, Wiers et al., 2011; prejudice reduction, Kawakami et al., 2007; phobia reduction, Jones et al., 2013). Nevertheless, the effectiveness of interventions would be very limited if daily life experiences differ from the traces involved in these specific intervention phases.

Second, the present studies differed in some aspects from previous work. For instance, we asked participants to evaluate individuals after each encounter while many research involved evaluations only after the presentation of the stimulus set. While the former may be considered as a "priming paradigm," the latter resembles more a learning paradigm (Gast et al., 2012; Laham et al., 2014). Moreover, in previous literature participants are often required to repeatedly approach and avoid specific stimuli/categories, unlike the procedure we relied on in this paper. Thus, extensive behavioral repetition may be necessary to obtain effects of ecological approach-avoidance behaviors on evaluation. It may also be necessary to perform both approach and avoidance behaviors contingent upon specific stimuli/categories. Indeed, according to a grounded perspective, these contingencies could foster the integration of multimodal traces of ongoing experiences (Barsalou, 1999) and/or predictive inferences based on these multimodal representations (Van Dessel et al., 2018b). These observations call for further work along these lines while pursuing the use of ecological operationalizations of approach-avoidance orientations.

Third, in our studies we relied on neutral faces as the effect of approach-avoidance behaviors on evaluations was often studied with neutral stimuli (e.g., neutral ideograms, non-words, fictitious social groups, neutral faces; Cacioppo et al., 1993; Slepian et al., 2012; Van Dessel et al., 2018a). However, the use of such stimuli may have been problematic for two reasons. First, it is possible that neutral expressive faces are not very prototypical of interpersonal approach-avoidance experiences and may thus require more expressive ones. Second, some scholars suggested that approach-avoidance behaviors influence evaluations depending on their motivational compatibility with stimuli: yielding more positive evaluations in the case of compatibility (i.e., approached-positive and avoided-negative), but more negative evaluations in the case of incompatibility (i.e., approached-negative and avoided-positive, Centerbar and Clore, 2006; Krishna and Eder, 2019). This possibility may explain the absence of effects and deserves further investigation. For example, we could add an emotional expression on individuals faces (Dru and Cretenet, 2008; but see Woud et al., 2013a). Current research developments in our lab are specifically dedicated to this issue.

Fourth, as we globally failed to activate approach-avoidance action tendencies and neuropsychological systems, we may have faced a construct validity issue. One or more elements in the situation may have impeded the reactivation of past

[13] Again we considered only data of the first bloc for Pilot 1.

approach-avoidance traces. For instance, if cognition is grounded in multimodal processes relevant for the immediate situation, the pattern of captured traces would differ depending on the task at stake (Barsalou, 1999). We asked participants to perform ecological interpersonal actions without explicitly labeling them as approach-avoidance. This was done in order to avoid potential demand characteristics and the direct influence of these labels on evaluations. In turn, participants may have been overly focused on understanding and correctly performing the requested action rather than on merely interacting with the characters (as reflected by the large proportion of participants in Study 1 that did not perform the action correctly). This may have led to a different pattern of traces than the one associated with usual interpersonal approach-avoidance experiences.

Finally, in two studies we relied on immersive VR to satisfy the requirements of a grounded perspective in the operationalization of approach-avoidance orientations. However, the use of VR is not without challenges and any asynchrony between the visual (virtual) environment and proprioceptive or motor information may impede individuals' experience of having a body in the environment as well as their experience of interacting with elements of it (Pan and Hamilton, 2018). If it is indeed the case, traces of previous approach-avoidance experiences may have not been appropriately activated by the ongoing VR experience. Importantly, the exploratory results of the studies suggested the importance of taking into account the quality of the VR experience in the ecological operationalization of approach-avoidance. Indeed, the more individuals felt present in the virtual environment and the more the ecological approach-avoidance behaviors activated the corresponding neuropsychological systems (at least in Study 2). Thus, following others (Pan and Hamilton, 2018), we agree that increasing the feeling of presence is thus the necessary next step (and challenge) in the avenue of research on the ecological operationalization of approach-avoidance orientations through VR.

Beyond these VR issues, the obtained exploratory results may be of theoretical interest. The feeling of presence is not confined to VR but consists in a more general psychological state – similar to a basic state of consciousness (Loomis, 1992) – accompanying all interactions with the physical and social environment, be it real or virtual (i.e., inner presence, Riva et al., 2004; Carassa et al., 2005; Riva, 2009; Willans et al., 2015). Some consider presence as emerging from the match between simulated sensory predictions (i.e., relevant past experiences traces) and the ongoing sensory consequence of an action (i.e., traces captured from the ongoing interaction, Riva et al., 2011). Others regard presence as a dynamical self-organizing system that emerges from a constant interaction between an organism and its environment and can further combine with emotional dynamical systems (Willans et al., 2015). Due to these potential links between presence, action, emotion, intentionality and embodiment, we deem important to further investigate the role of presence in the operationalization of approach-avoidance orientations and their downstream consequences. For instance, future work could test if the feeling of presence is an experiential phenomenon that is either necessary and/or sufficient to manipulate approach-avoidance.

CONCLUSION

We believe that the present findings and non-findings are interesting for the topic of this Special Issue as they suggest that approach and avoidance are much more complex phenomena than basic whole-body movements toward or away from a person (or object). Just as other actions, approach and avoidance are rooted in the subjective experience of the ongoing individual-environment interaction (James, 1904). Hence, we view the present work as a first step and a basis for further discussion and research on proper operationalizations of approach-avoidance experiences considered within the realm of a grounded view of cognition. We also believe that this work stimulates new fundamental questions about the influence of approach-avoidance behaviors on evaluations.

DATA AVAILABILITY

The datasets analyzed and the corresponding R scripts for the pilots can be found in Open Science Framework (https://osf.io/quk3j/?view_only=acca3acd55284968a935b97debf55828). The datasets analyzed and the corresponding R scripts for the two studies can be found in Open Science Framework (https://osf.io/sqhvw/?view_only=9624d0c0d73345029d48a67ea4892e9f).

ETHICS STATEMENT

We collected and analyzed anonymously all data in accordance with the American Psychological Association's ethical principles. However, we did not seek the explicit approbation of an ethics committee for the present studies as there is no law concerning non-interventional research in France.

AUTHOR CONTRIBUTIONS

All authors contributed to the study concept and design. Data collection was organized by IN. She performed the data analysis and was supported by TA and M-PF in the interpretation of the results. All authors drafted the manuscript and approved the final version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2019.01418/full#supplementary-material

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Optimizing Performative Skills in Social Interaction: Insights From Embodied Cognition, Music Education, and Sport Psychology

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Embodied approaches to cognition conceive of mental life as emerging from the ongoing relationship between neural and extra-neural resources. The latter include, first and foremost, our entire body, but also the activity patterns enacted within a contingent milieu, cultural norms, social factors, and the features of the environment that can be used to enhance our cognitive capacities (e.g., tools, devices, etc.). Recent work in music education and sport psychology has applied general principles of embodiment to a number of social contexts relevant to their respective fields. In particular, both disciplines have contributed fascinating perspectives to our understanding of how skills are acquired and developed in groups; how musicians, athletes, teachers, and coaches experience their interactions; and how empathy and social action participate in shaping effective performance. In this paper, we aim to provide additional grounding for this research by comparing and further developing original themes emerging from this cross-disciplinary literature and empirical works on how performative skills are acquired and optimized. In doing so, our discussion will focus on: (1) the feeling of being together, as meaningfully enacted in collective musical and sport events; (2) the capacity to skillfully adapt to the contextual demands arising from the social environment; and (3) the development of distributed forms of bodily memory. These categories will be discussed from the perspective of embodied cognitive science and with regard to their relevance for music education and sport psychology. It is argued that because they play a key role in the acquisition and development of relevant skills, they can offer important tools to help teachers and coaches develop novel strategies to enhance learning and foster new conceptual and practical research in the domains of music and sport.

Keywords: embodied cognition, interaction, skill acquisition, music education, sport psychology

INTRODUCTION

Expert musicians and skilled athletes often display the stunning ability to adapt to, and coherently engage with, the shifting demands of their contingent milieu. A sudden change in the tempo of a music performance or the emergence of a particular spatial configuration of players in team sports requires the immediate generation of appropriate novel actions to keep the music "alive" or the sport performance possible. Traditionally, this process is described as a largely automatic mechanism, where little or no attention is dedicated to the generation and enactment of the new actions (see Dreyfus and Dreyfus, 1986; Schmidt and Wrisberg, 2008). These forms of *skillful coping* are fluidly integrated within one's repertoire of action, such that no explicit thought is necessary for them to be implemented (see Dreyfus, 2002). Indeed, according to this standpoint, there is no need for reflection at this stage because our cognitive systems can detect and select the most adequate behavioral outcomes in response to the unfolding contingencies of a given context. It has been argued that the *automaticity* of such mechanisms develops through a progressive shift from an initial phase where skills are acquired to a final performative stage where the task (e.g., repeating and elaborating an "error" to make it sound intentional in improvised music or dribbling the opponent in ball games) can be achieved without any explicit "cognitive" involvement (c.f., Papineau, 2013). By this view, musicians and athletes do not follow pre-defined rules as they become experts; it is only at the beginning of the process, when skills are acquired and developed, that these schemas need to be examined and discussed. Therefore, a novice singer will explicitly consider whether her\his posture and breathing technique are consistent with what she\he has learnt from her\his teacher before starting a performance, just as the beginner basketball player will be paying attention just before taking the shot to whether her\his shooting style aligns with her\his coach's guidelines. But when expertise has been acquired and one is fully "absorbed" in the dynamics of the event, so the story goes, there is no time for inferential mediations – i.e., an awareness of the kinematics of a given action is arguably no longer necessary (e.g., Araújo and Davids, 2011). A soccer player does not have to think about his or her movements when dribbling an opponent, just like the expert rock guitarist does not have to explicitly recall each position of the fingers during a solo performance (see Menin and Schiavio, 2012). "Conceptualizations" and "explicit reflections" are part of the process only "when the agent's absorption fades away or is not yet ready. In this perspective, [conscious] representation comes either before skill acquisition or after skilful performance, i.e., it is either a temporary scaffold necessary to automatize a routine (as during training), or a conceptual expedient to rationalize its defining principles a-posteriori" (Cappuccio, 2015, p. 219).

Positions based on similar insights have contributed an important perspective to the understanding of expertise and performance. However, they also entail some necessary limitations, particularly when the entire process of acquiring and optimizing skills is considered to be a march toward thoughtless automaticity. First, the strict dichotomy between *conscious processes* and *mindless behavior* may appear too static to capture the complexity of the phenomenon. As Sutton and colleagues comment:

> "because practitioners in many skilled movement domains know that self-conscious thought can disrupt well-practised actions, they like to entrust grooved action sequences to the body, to the habitual routines of kinaesthetic memory. But because they also know that open-ended, flexible performance is context-sensitive and, in the ideal, exquisitely responsive to subtle changes in a situation, they also want to be able to bring all of their experience to bear in the moment, to bring memory and movement together, with thought and action cooperating instead of competing" (Sutton et al., 2011, p. 80).

Second, the entire process of skill acquisition is often conceived of as an individual achievement.

Many of the contributions reported in **Table 1**, for example, appear to remain neutral on whether individual skills should be regarded as inherently social and on the role that social aspects may play in their acquisition and development. However, if we look at the concrete settings where skills are acquired, we find that researchers, educators, and coaches are increasingly considering the importance of participation and reciprocal interaction[1].

Recent approaches in music education, sport psychology, and motor control place a strong emphasis on the inherently *social contingencies* of performative activity in sports and the arts (see e.g., Borgo, 2005; Davids et al., 2007; Hauw, 2018; Schiavio et al., 2018a,b). Here the conscious process of "explicit rule-following" leading to tacit knowledge has been traded for more nuanced, fluid, and flexible understandings of how optimal skills are developed (Bril, 2002; Araújo and Davids, 2011). This move is particularly useful for reconsidering the role of internal models based on mental representations. In musical contexts, for example, mental representations of desired performative outcomes are traditionally thought to offer an excellent scaffolding to assist the students' learning trajectory (Lehmann, 1997; Gruhn, 2006; Hallam and Bautista, 2018). Such representations are arguably developed through hours of "studying the score and playing the music" (Lehmann and Jørgensen, 2018, p. 134), being shaped by a rich variety of self-monitoring and evaluation strategies (e.g., McPhail, 2013). In other words, this model portrays musical learning as an input–output process mediated by the internal cognitive laws of the individual. This way, the mismatch between the predicted outcome (understood in terms of a mental representation) and the actual performance becomes the main focus of the training, with its minimization being the general goal of learning.

[1]Because of their performative dimensions, sport and music are two ideal domains to explore the social, embodied, and creative dynamics involved in skill acquisition. While they both display different traditions, contexts, and specific objectives, one point of continuity between these areas precisely involves the monitoring of one's skills, as well as their development and optimization.

TABLE 1 | Examples of previous research on skill acquisition.

Author(s)	Major findings/claims
Miller, 1956; Gobet et al., 2001	Skill acquisition is moving from processing and executing component task units at the bottom level toward Gestalt processing at the top level: grouping information into chunks
Fitts and Posner, 1967	Skill acquisition involves three stages: cognitive, associative, and autonomous
Cundey, 1978	Skill is any competent, rapid and accurate performance, including a wide range of mental activities
Newell and Rosenbloom, 1981	The effect of practice time on performance for cognitive and perceptual-motor skills
Adams, 1987	Skill forms a wide domain of possible behaviors; skill must be learned; skills are defined by motor performance in attainment of a task-specific goal
Holding, 1989	All human skills involve the coordination of perception and action
Schmidt, 1993	Skill acquisition is based on information processing and selection of adequate motor programs
Dreyfus, 1996	Skill acquisition transforms our relation to the world
VanLehn, 1996	Different kinds of skills involve cognitive or intellectual ability: from explicit, slow, detached processing to implicit, automatic, and engaged performance
Ericsson and Lehmann, 1996	Expertise is maximal adaptation of the performer to the task-environment
Hurley, 1998	Expert performance carries out actions or processes that are intentional but not consciously intended
Ingold, 2001	Combined anthropological and ecological approach to skill
Rosenbaum et al., 2001	Skill is the ability to achieve goals within some domain with the increased likelihood as a result of practice
Ericsson, 2006, 2008	Expert performance is related to active engagement in deliberate practice. Major role of immediate feedback, problem-solving, and evaluation, and opportunities for repeated performance

In more recent years, young musicians and performers are increasingly encouraged to freely explore their musical potential and the best way to express themselves in interaction with others, avoiding the constant self-monitoring of their actions (see Bowman, 2004; Borgo, 2007; Schiavio and van der Schyff, 2018). Similarly, recent accounts in sport psychology have emphasized the adaptive nature of athlete-environment interactions during practice and performance (e.g., Hristovski et al., 2012; Seifert et al., 2014). With regard to this point, it has been shown that participants in team sports can collaboratively modify their offensive and defensive strategies to co-adapt to changing environmental constraints (e.g., the opposite team) (see Duarte et al., 2012). Such adaptability has been described in music and sport at both *behavioral* and *phenomenological*[2] levels (e.g., Schiavio and Høffding, 2015; Hauw, 2018; Rochat et al., in press), with demonstrations of how self and other, behavior and experience, are in fact intrinsically interdependent at various levels and timescales. Jacobs and Michaels (2006), in a similar vein, considered expert performance as a dynamical system comprising performer, tools, the environment, and other individuals. Rodger (2010, unpublished) also argues that skill acquisition involves the development of tight action-perception couplings, leading to the recruitment of both bodily and environmental resources.

In this article, we aim to provide additional grounding for this line of research by comparing and further developing original themes concerning how performative skills are acquired and optimized by novices in the context of music and sport. In particular, we will draw on recent research in *embodied cognitive science* (ECS) with the aim of developing a more integrated view of how action and thought shape each other dynamically. Scholars inspired by ECS emphasize the deep continuity between perception, action, biological organization, reflection, and intersubjectivity (Di Paolo et al., 2017). By this view, talking about the physical location of the mind becomes meaningless. Instead, "mind" is here conceived as an emerging property of the interplay between a brain–body system and the contingent (social, cultural, physical) environment in which the organism is situated (Thompson, 2007). Drawing from these insights, we argue that because musicians and athletes often learn in groups and share experiences, actions, cultures, and "histories of structural couplings[3]" with their surrounding world (Varela et al., 1991), ECS offers important conceptual resources to capture the rich web of contextual contingencies that music and sport entail. Our claim is that embodied and phenomenological insights can help reconcile thought and action, as well as individuality and collectivity – which are often conceived of as separate when looking at skill acquisition.

The paper is structured as follows: in the next section, we introduce the main tenets of ECS, focusing on its phenomenological and interactive groundings. In line with recent work by Gallagher (2017), Chemero (2009), and Fuchs (2017), it is argued that explanations of the mental cannot be limited to the individual's brain–body system (e.g., his or her internal biological norms), nor should they entail a separation between high-level and low-level cognitive processes. Instead, we maintain that mind depends on the dynamical interplay of brains, bodies, and the social, cultural, and physical features of the environment (Clark, 1997, 2006; Donald, 2001; Malafouris, 2013). Focussing on the role of intersubjectivity, we then consider how social contingencies and reciprocal interactions can offer novel possibilities to acquire, develop, and optimize performative skills. In doing so, we examine (1) the feeling of being together, (2) the capacity to skillfully adapt to the contextual demands of the social environment, and (3) the development of distributed forms of bodily memory. In conclusion, we discuss how these categories are relevant to future research, theory, and the practical issues related to how

[2]Phenomenology is a philosophical tradition that explores the structures of experience and consciousness, associated with authors like Husserl, Merleau-Ponty, and Heidegger.

[3]Oversimplifying, this term refers to the developmental and evolutionary patterns of exchanges between living systems and their environment.

music teachers and sport coaches can develop novel strategies to enhance and optimize skill acquisition.

RECONCILING DICHOTOMIES

An Open Mind

ECS offers a non-reductive view of mental life – one that brings together insights from disciplines such as theoretical biology, linguistics, phenomenology, aesthetics, constructivism, ecological psychology, and complex systems theory, among others (see e.g., Shusterman, 2009; Stewart et al., 2010; Colombetti, 2014). In its broadest sense, the central idea of ECS is that physical resources from the entire body of a living system and its environment participate in driving cognitive processes. Therefore, our capacity to think, feel, reason, and interact with others depends directly on the ongoing patterns of interaction between a brain–body system and its niche (Johnson, 2007; Clark, 2008). Because factors external to the brain are said to co-constitute the mind, this approach offers a useful alternative to more traditional accounts of mentality, which are often based on an individualist and internalist perspective.

To illustrate the point, we might consider the following two approaches: *functionalism* and what we define as *internalist embodiment*. While different on many levels, both approaches share a common assumption – namely, that cognition is a property of the individual. Functionalist psychologists identify cognition with information-processing operating in the individual's head, metaphorically equating minds with computer devices (see Fodor, 1983). To understand a psychological state, according to this framework one should not focus on its physical make-up; what really matters, instead, is the functional role it plays for the cognitive economy of the system. This move, it is argued, allows researchers to better explore the complexity of mental phenomena and create specifications general enough to capture a wide variability in physical implementation[4]. However, the kinds of generalizations necessary to explain cognitive life do not go beyond the system where the psychological state is individuated. Psychology, so to speak, remains intrinsic to the system that displays the causal properties required to instantiate the mental state being studied.

As an example of "internalist embodiment" instead, let us now briefly consider the work on body-formatted (or B-formatted) representations (see Goldman and de Vignemont, 2009). The central idea here, as explained by Gallagher (2017), pp. 4–5, is that the brain can develop internal representations with a specific bodily related content, without them being propositional – or conceptual – in format. Because the content of these representations may involve interoceptive states (e.g., physiological states, visceral sensations, etc.), motor goals (e.g., the control and monitoring of behavioral outcomes), and social contingencies (e.g., the understanding of the intentions of another person, realized by the perceiver's mirror-like activity[5]), they are thought to play a good explanatory role in ECS. However, some argue that the appeal to internal models based on representations still fails to capture the unity of action and perception, thought and action, and subjectivity and intersubjectivity. In fact, on this view "social cognition […] is embodied only to the extent that B-formatted representations involved in perceptual mirroring are used to represent the actions or mental states of others" (Gallagher, 2017, pp. 4–5). In both functionalism and internalist embodiment, the mind is thus described in terms of the living system's *internal* factors. Functionalists look for the causal role each mental state plays for the system's operational functioning, while defenders of the other account would consider the integration of bodily and neural states of the agent as constitutive of mentality. For both, however, the external world remains, in a sense, *detached* from the internal processes that truly instantiate mental activity. Internal and external resources are *discontinuous* with each other – they are part of separate domains.

More recent scholarship inspired by ECS and phenomenological philosophy offers a different view. If we are to consider the body as a constitutive tool for cognition, we cannot but examine the body in its dynamical interplay with its environment. The body, in other words, does not operate in a vacuum (Chemero, 2009). Because of this, ECS emphasizes the necessarily full involvement of body and world for the realization of mental life. This involves patterns of behavioral, emotional, and social adaptivity that are enacted within a contingent milieu, giving rise to a complex *brain–body-environment system*, where aspects inherent to each of them are mutually relevant for its maintenance and development (Varela et al., 1991). Such a view resonates with earlier insights on the notion of "functional system" discussed by Luria (1966), who defined *flexibility* as the set of constant and coherent goals implemented by the responses emerging from the environment. However, ECS does not conceive of the relationship between the living system and environment as captured by a stimulus-response schema. Instead, ECS scholars often argue that there is a mutual adaptation between niches and living systems that constantly shifts the trajectories of inner and outer constraints, making the recourse to inputs and outputs superfluous. These scholars therefore increasingly draw from the resources offered by *dynamical systems theory*–a mathematical tool adopted to explore how complex systems develop in time through the convergence and divergence of its elements (Strogatz, 1994; Kelso, 1995). Work inspired by such insights trades the adoption of stimulus and response for sets of "differential equations that express the magnitude of variability between pairs of (non-linearly) coupled components" (van der Schyff et al., 2018), applying it to a vast range of domains, including music (Large et al., 2016; see also

[4]Consider the extreme case of a creature with a totally different biochemical organization than ours (i.e., an alien). Because it is quite easy to imagine this living system having the same psychological disposition to feel pain as we do (for example), it is argued that psychology should deal with abstract generalizations rather than neural or physical substrates.

[5]This refers to the functional properties of "mirror neurons" – a set of sensorimotor neurons that fire when performing an action and when observing the same action performed by another individual (di Pellegrino et al., 1992; Gallese et al., 1996; Rizzolatti et al., 1996). Their activation, as Rizzolatti and Sinigaglia (2010) suggest, can transform the sensory representations of the others' motor activity into a motor representation (a B-formatted representation) of the same action in the brain of the observer.

Schiavio et al., 2017a; van der Schyff and Schiavio, 2017a,b; Walton et al., 2014).

Because this unfolding network of interactivities defines an open horizon of viable opportunities for action, ECS can help us describe the flexible processes whereby skills are acquired and developed (Schiavio et al., 2017b). In particular, as ECS gives equal importance to structures and processes internal and external to the living system, an approach to skill acquisition informed by such a view assumes strong *continuity* between the intrinsic biological organization of living systems, their phenomenology, and their capacity to generate and maintain stable relationships with the environment[6] (Weber and Varela, 2002).

Collective Dynamics and the Emergence of Optimal Skills

Consider two young amateur musicians improvising music together, or two non-professional athletes participating in a pick-up basketball game. As they perform together, expertise and social understandings are developed collaboratively, requiring mental and behavioral resources to be fluidly integrated. While it is easy to see how existing skills can be improved through participation in such practices, it is more complicated to explain how novel skills might emerge. Indeed, here knowledge is not transmitted between the two (it is assumed that the participants have similar expertise), nor can it be detected in the environment (no instructions are given by a teacher or coach).

A first solution might involve what is usually defined as "folk psychology"–each agent interprets what the other is doing in terms of his or her own mental states (e.g., intentions, desires, drives, etc.). By systematically analyzing and predicting each other's minds, novel behavioral configurations can emerge as adaptations to what the other is (about to be) doing. According to this interpretation, it could be stated that interactors constantly monitor and modulate their existing motor patterns in light of what others might do, giving rise to modifications in their actions, which then give rise to novel skills. At a closer look, however, this view implies that the achievement of a given goal (e.g., playing a vibrato at the right time during an improvisation, finding the open player during a fast-break in basketball) still remains based on the stored sensorimotor repertoire that is available to the individual agent (see Proctor and Vu, 2006). Indeed, following the classic description of James (1890), action plans are selected by a cognizer in terms of their immediate consequences. This, however, entails a possible paradox. How can performance in joint situations become effective if the motor possibilities relevant for the immediate contextual contingencies are limited by the vocabulary of actions accessible to the singular individual? Consider how a classical violinist might respond to an unexpected crescendo by the pianist with whom she\he is playing. Are already existing *internal* resources manipulated and transformed in light of the specific contextual demands? Or does the generation of new valuable behavioral strategies require the living system to negotiate in real time between both *internal* and *external* resources?

To answer these questions, it may be helpful to discuss examples of improvised and collective music-making activities (Borgo, 2007; Heble and Laver, 2016) and private practices and deliberate play sequences in sports (Côté et al., 2007; Laurin-Landry, 2018; Uehara et al., 2018).

Children and adolescents often spend their recreation time at school in activities such as backyard versions of soccer or street-style basketball. In these situations, they are free to experiment with various movements and interactions and explore their physical possibilities. Because the rules of these pick-up games[7] are flexible and often apposite to the context, they can both adapt to these rules and make the rules adapt to them. Such "deliberate play" therefore provides relevant opportunities to improvise, explore, learn, and negotiate contextually novel behavioral solutions. For instance, in order to take part in a street soccer game with older – and more skilled – opponents, a child must develop novel repertoires of action (e.g., technical and tactical skills) that are consistent with the kinds of possibilities that can be explored and that will equip him or her to keep participating in the unfolding dynamics of the match. Reading the opponent's mind is not enough. Adaptation has to be fast, fluid, dynamic, and contextually meaningful. Similarly, when improvising with an expert jazz musician, one might discover that differences in expertise are bigger than expected. However, novel solutions to optimize the performance might emerge through moment-to-moment interactions: both musicians can adapt to each other – e.g., a solo can be intentionally repetitive to enable the other to explore novel harmonic possibilities and progressions. In the context of music education, it has recently been argued that settings where performance and collaboration are prioritized may foster important benefits in terms of negotiating differences and stimulating trust and social understandings (Higgins and Mantie, 2013), leading researchers to focus on informal learning practices (Green, 2001, 2008). In these contexts, (musical) meanings are recursively and collaboratively transformed, giving rise to creative outcomes that do not involve prescriptive rules to be followed or mind-reading mechanisms (see van der Schyff et al., 2016). Similarly, Ryan and Schiavio (2019), among others, advanced the hypothesis that music-making is inherently *extended*, suggesting how cultural, social, and physical resources (internal and external to the agent) are fluidly integrated and constitutive of the performance outcome. By this view, even categories like "agency" can become distributed across individuals, giving rise to a complex network of collective experiences that can contribute to individual practice.

In sport psychology, recent research has offered similar insights. Adopting qualitative methodologies based on interviews

[6]Such insights have been systematically explored by scholars who defend a more radical view on ECS – 'Enaction' (see Di Paolo et al., 2017; Gallagher, 2017) – which puts major emphasis on how an organism's cognitive complexity is recursively determined by (1) its own metabolic laws and (2) the (meta-metabolic) structures inherent to its niche (Maturana and Varela, 1980). For the present paper, however, we will mostly focus on the phenomenological roots of ECS.

[7]Pick-up games are traditionally defined as games that are spontaneously started by their participants.

that enable athletes to re-enact their previous experiences, several studies have focused on the collaborative dynamics in various sport settings. Examples include a match in table tennis (Sève et al., 2002), a competitive exercise in acrobatic sports (Hauw and Durand, 2004), and the attempt to finish an ultra-trail running race (Rochat et al., 2017, 2018). These studies emphasize the strong recursive interplay between bodies-in-action, internal states, and extrabodily resources[8]. It might therefore be argued that athletes' actions are properties emerging from the fluid integration of internal and external components (see also Semin and Cacioppo, 2008; Hwang et al., 2018; van Opstal et al., 2018). Importantly, such elements can only be exploited through action, giving rise to continuous loops where athletes shape and are shaped by the various contextual contingencies associated with (the goals of) each performance. Here the structural unity between behavioral and phenomenological processes has been addressed in cases where agents are able to monitor and supervise "from within" the dynamics of their own performance[9].

The wide range of examples provided here shows how new possibilities for action can be developed and negotiated in real time as a performance unfolds. Unidirectional forms of learning are then traded for more dynamical "explorations" of the different possibilities for action emerging from the interactions and from the affordances of the environment (see Schiavio and Cummins, 2015; Schiavio, 2016). Here, it appears that "forms of flexible and adaptive actions which are clearly not the product of deliberation or explicit reflection can nonetheless be best understood as involving certain sorts of (dynamic, embodied) intelligence" (Sutton et al., 2011, p. 78). The experience of performing with one or more other individuals cannot be reduced to a simple "mindless" response to an external perturbation. It emerges from, and sustains, the ongoing interactive coupling; it brings together emotional, bodily, and cultural aspects that may not be present in individual contexts; it is continuous with a wide range of unique metabolic and neural processes; and gives multiple agents shared responsibilities (e.g., the maintenance of the interaction) among others. As the joint activity unfolds, different behavioral trajectories are developed, with a shared horizon of meaningful possibilities for novel (inter)actions being co-created. This embodied dynamicity helps eschew the dichotomy between behavioral and reflective domains and, at the same time, shifts the unit of analysis from the individual to the group. Here, what is meaningful becomes what is *shared*. On this view, skills are "relational" in the sense that they are shared and negotiated by a community of practice, and developed and experienced contextually. The move can be particularly useful to differentiate intersubjective experiences from cases where living systems engage with the physical tools of the environment (e.g., a musical instrument, a ball, etc.). While both dimensions are important for the acquisition of optimal skills, each has its own phenomenology and core principles – as such, they might be best described autonomously. In what follows, we focus on social, embodied, experience. In doing so, we first individuate three categories that can arguably only emerge in such context and then explore their role in the participatory foundations of skill acquisition.

SKILLS BEYOND THE INDIVIDUAL

Many individual skills in music and sport are often optimized and developed collaboratively, through an (inter)active effort based on reciprocal adaptation and phenomenological awareness (see Montero, 2010). In many cases, performance and learning largely overlap, integrating self and other, action and perception, and doing and knowing in the contextual dynamics of action. To better understand how this could be so, this section examines three main dimensions of skill acquisition: (1) the feeling of being together, as meaningfully enacted in collective musical and sport events; (2) the capacity to skillfully adapt to the contextual demands from the social environment; and (3) the development of distributed forms of bodily memory.

The Feeling of Being Together

The patterns of coordinated behavior occurring between sport teammates or members of a music ensemble are not fully preestablished; instead, they are constantly being shaped by the environmental contingencies that agents learn to master and exploit during performance (Fuchs and De Jaegher, 2009; Di Paolo et al., 2010; Araújo and Bourbousson, 2016; Schiavio and van der Schyff, 2016). Gesbert and Durny (2017), for example, highlighted how the objectives pursued by soccer players in competition (i.e., trying to score a goal while maintaining the team's defensive balance) are constantly open to interpretative processes that emerge from their interactions with the environment. Depending on the musical score, the feedback from the audience, the moment in the match, the teammate with the ball, the positioning of opponents, the area where the ball is situated, and so on, each musician or player can constantly reinterpret the unfolding situation in ways that are meaningful for the whole ensemble or team. The pursued objectives of individual players, in a way, are thus never fully "individual" – they are developed, transformed, and manipulated in light of specific collective constraints, opening a new horizon of possibilities for joint action. Along these lines, other studies have shown how a specific sensitivity to environmental information enabled co-performers and team members to grasp the state of the group's coordination through the feeling of being together – or not being together – with others (see Lund et al., 2012, 2014). A significant part of these experiences corresponds to the immediate feelings of being affected by others (Colombetti and Torrance, 2009; He and Ravn, 2017). According to Himberg et al. (2018), the feeling of acting with

[8]Consider how bodily based signals emerging from on-line action (e.g., the feeling of running too fast) can be associated with environmental affordances (e.g., the particular shape of the race track), and the ways in which they can inform the outcome of a given situation (e.g., a "wrong" feeling of take-off in a jumping the hurdle results in the athlete being more careful for landing). Because of the interplay of internal and external resources, they cannot be considered as B-formatted representations.

[9]For example, trampolinists in acrobatic sports reported a clear conscious awareness of what goes on in certain moments (e.g., Hauw and Durand, 2007).

others is an essential part of collective performance: because in certain situations, the activity of individuals depends on reciprocal interaction with others, one is required to actively take part in participatory processes of skillful co-adaptation. This involves shared forms of emotionality, intelligence, and coordination – action and perception of co-performers coexist in a continuous coupling where individual experience is constituted in part by what constitutes the other's experience (Froese and Di Paolo, 2011; Tanaka, 2017).

A similar scenario was discussed in a recent study by Schiavio et al. (2018a); see also Gande and Kruse-Weber, 2017. Here, a program for informal pedagogy was examined by means of qualitative interviews collected with "facilitators" – expert musicians who guided the sessions and enabled the participants to discover musical possibilities through collective improvisation and coordinated music-making. The novices who participated in the program were asked to reciprocally interact and adapt to the specific demands of each session (e.g., drums, choir, etc.). The study shows how the categories of collaboration, non-verbal communication, and sense of togetherness were continuous with more general cognitive processes related to meaning-making, and fostered a shared sense of community through musical (inter)action. The feeling of being together, particularly, allowed the novices to generate music organically – as a whole. The program, from the perspective of the "facilitators", brought out a sense of being a group, which allowed the attendees to help each other and actively seek musical configurations that were appropriate for their cultural backgrounds and their ongoing experience.

In the context of sports, Lund et al. (2012) described how rowers gradually learned and developed the experience of a joint rhythm by becoming increasingly attuned to their mutual interaction. The tension felt between their movements during performance allowed them to mutually adjust their activity, suggesting that co-performance is realized through an on-line integration of internal and external resources, where awareness and meanings are developed through interactive forms of action (see also Schaffert et al., 2011, for a focus on how auditory feedback can facilitate the adjustments of performance in rowing). In the same vein, Gesbert et al. (2017) described how soccer teammates during no-possession phases of the ball were attuned to the recognition of their expected defensive configuration before shifting to the collective work of ball recovery. The perception of such expected configuration – and of the associated feeling of being together – was crucial for each player for starting this collective work. Here, the movements of only one player, because of his position or speed of replacement, could simultaneously prevent the recognition of this collective configuration and the perception of being together. As coordination is constantly re-played by the dynamics of individual activities, the feeling of being together is constantly under threat. Mutual sensitivity to these fluctuations in experience is therefore considered as one of the main characteristics of collective expertise (see e.g., Saury et al., 2010). Gesbert and Durny (2017), moreover, described how two players sharing the same objective during a soccer counterattack (quickly attacking the opposing goal) were able to develop highly specific expectations on how to attack the opponent goal. As they drew closer to the opposing goal, one of them (Phil) became sensitive to the quick decrease in the distance that separated his ball-carrying teammate (Andrew) from the opponent (situated in front of him), understood that he did not have the same expectations as Andrew, and sought to adjust his behavior. While this example clearly showed how the experience of soccer players is distributed across different layers of individual and collective awareness, it should also be noted that individuals display various degrees of sensitivity to such an experience. Indeed, in the same case, Andrew was focused on other environmental information and did not perceive the tenuousness of this feeling of being together. He was not sensitive to the slowing down of Phil's ball call and did not adapt his activity to this information.

Skillful Adaptation

While being attuned to the feeling of being together, teammates often make use of and (re)interpret environmental information to skillfully adapt to the needs of collective behavior (Walton et al., 2015; Bourbousson and Fortes-Bourbousson, 2016). This helps co-performers engage with a vast range of contingencies in meaningful ways, developing patterns of action and perception that are constitutively dependent on their mutually adaptive behavior (see Fuchs and De Jaegher, 2009). With regard to this point, one can consider three adaptation modalities that have recently been observed *via* inductive analysis in soccer-specific situations: these are called "local," "global," and "mixed" (Gesbert and Hauw, 2017).

The "local" mode describes an adaptation of the player's activity to his proximal social environment, such as the behavior of a nearby opponent or a teammate ball-carrier and one's direct opponent (e.g., moving away from the direct opponent to offer a pass solution to the partner carrying the ball). The "global" mode describes the adjustment of an activity to the collective organization of a part of the team. The "mixed" mode, finally, accounts for adaptations to the activity of a nearby opponent or partner and those of more distant agents. A recent study (Gesbert et al., 2017) focused on these modalities by studying how soccer team players mutually adapt to each other during competition. As team coordination emerged, many players achieved good sensitivity to it by constantly shifting between these modalities. Similarly, work in progress in synchronized swimming (Gesbert and Hauw, in preparation) aims to characterize the interaction modalities that these swimmers use in order to predict how they will interact as they cope with different environmental perturbations. Adopting a phenomenologically inspired method based on qualitative interviews, the authors describe how two swimmers (Monica and Isabella) managed to organize their behaviors and adapt to each other despite substantial difficulties in maintaining optimal distance[10]. During a training session, their coach prompted them to actively seek each other, stimulating a reorganization of existing patterns of behavior on the basis of their capacity to adapt to each other. The coach did not ask

[10]It emerged from the interviews that monitoring and control of the distance between swimmers are indeed their main concern.

them to manipulate their existing motor knowledge; instead, he modified the task constraints (e.g., their distance) to promote a novel set of actions that required a sensitive *reconfiguration* of their consolidated motor knowledge, which then led to the acquisition of novel skills and expertise. Again, resources that emerge when agents meaningfully interact are seen to play a constitutive role in developing individual skills (Reed and Bril, 1996; Hutto et al., 2015). This aligns with data from a recent qualitative study comparing musical learning experiences in individual and collective settings (Schiavio et al., 2019). Here it was found that while students often rely on their teacher to optimize their performative skills, they can also benefit from an active interaction with their peers: by exchanging musical ideas, providing feedback to each other, improvising together, and sharing their personal experiences, novices find new possibilities to transform and develop their technical, expressive, and communicative, musical skills. The benefits of joint learning are also recognized by music teachers, when they purposely "step back" to leave their students with more freedom and responsibilities for their own learning (Schiavio et al., 2018a). This suggests that the capacity to skillfully adapt to the contextual demands of the social environment is not only present in experts, but can also be found in novices – albeit in a more learning-oriented sense.

In expert athletes, finally, Lund et al. (2014) observed improved synchronization of professional trampolinists' movements when the athletes remained engaged in the process of jumping together[11]. Here the authors describe how the athletes became progressively sensitive to their partners' jumps through the sound produced by the two trampolines during training[12]. In other words, adjustment modalities can be developed and enhanced through a different, cross-modal, interaction process – athletes directly feel and shape the other's performance, and learning opportunities are continuously renegotiated by synchronizing with others. Put simply, it seems that without interaction, new behavioral solutions appropriate for this context might not emerge.

Distributed Bodily Memory

According to Fuchs (2017), p. 341, distributed bodily memory involves "an ensemble of behavioral and interactive dispositions characterizing the members of a social group that have developed in the course of earlier shared experiences and now prefigure similar interactions of the group". Consider the classic work by Sudnow (1978), where a detailed phenomenological description of the learning trajectory necessary to develop adequate improvisatory skills on the piano is put forward. While the main focus of Sudnow remains the author's own body and his subjective experience, the role of the *other bodies* is not dismissed. In fact, in an oft-cited passage of the book, Sudnow describes the intense feeling of watching his mentor Jimmy Rowles performing on stage as follows:

> "I watched him night after night, watched him move from chord to chord with a broadly swaying participation of his shoulders and entire torso, watched him delineate waves of movement, some broadly encircling, others subdividing the broadly undulating strokes with finer rotational movements, so that as his arm reached out to get from one chord to another it was as if some spot on his back, for example, circumscribed a small circle at the same time, as if at the very slow tempos this was a way a steadiness to the beat was sustained" (Sudnow, 1978, p. 82).

Such occurrence, Sudnow admits, played an important role in helping him develop the ability to improvise and produce similar musical phrases on the piano. Through the body of his mentor, he gained access to new motor possibilities and configurations that he then explored autonomously. In this case, individual behaviors were forged by a shared experience, and developed after the event to be further elaborated in other situations. In other cases, however, co-actors might have no time to wait, and must reciprocally interact and share their skills as the performance unfolds. Consider the following example reported in an ongoing study with a team of eight synchronized swimmers (Gesbert and Hauw, in preparation). During choreography, one of the swimmers (Barbara) managed to lead the other swimmers without having the opportunity to perceive them visually. How was she able to do this? She explains:

> "At this moment, I know that the swimmers are a little too far apart after the last movement, so I'm doing a breaststroke of a certain length, I'm sensitive to the amount of movement in the water so they can follow me and we're all at the right distance."

Interestingly, when Barbara was outside the pool, she was unable to describe where she had to stop. She only verbalized her experience when she was able to move into the pool. Her movements affected what she sensed, allowing her to gain access to "mental landscapes," words, and experiences that were not present before. When she felt she had reached the *right length*, she decided to stop. While this decision emerged intuitively from her embodied activity in the pool, her behavior was clearly under the influence of all the past situations, which constrained it (see Sutton, 2007; Fuchs, 2012, 2016; Sutton and Williamson, 2014). Said differently, the enaction of this *specific feeling about length* was linked to the breaststroke patterns that she had built from earlier experiences through multiple interactions with other swimmers in this specific configuration. In a sense, therefore, the patterns of action sedimented in Barbara's bodily memory do not really belong to her, nor are they to be considered a property of her individual activity. They can be actualized through her lived body, but they have been developed through the embodied interaction with other swimmers (see Hauw and Bilard, 2017).

[11]Trampoline jumping is characterized by a continuous act of compensation. As such, the main concern for jumpers is to agree on the degree of compensation required to help them maintain their timing.

[12]This aligns with recent work in sport science that emphasizes the role of auditory feedback in optimizing performance (e.g., using sounds to detect an opponent's intention) (see Allerdissen et al., 2017; Camponogara et al., 2017; Sors et al., 2017, 2018).

In this view, Barbara, her teammates, the pool, the coach, and their patterns of interactivity have all become a constitutive part of her learning trajectory, with different dynamical configurations individually enacted as part of a collective process. Barbara's swimming style, in other words, can be understood as a continuous adaptation to the patterns of reciprocal interaction involving people and things. To better capture this idea, we may refer here to the notion of "degeneracy" (Bernstein, 1967; Mason, 2010; Kelso, 2012; Komar et al., 2015). Degeneracy is a term to describe how the same outcome can be achieved in many ways using different components. For instance, it has been shown that expert basketball players may use lower and upper body joints (and limb segments) differently to shoot successfully while coping with various task constraints, including the distance to the basket or the position of the nearest defenders (Davids et al., 2013). In other words, degeneracy accounts for the various possibilities in which athletes adapt their behaviors to the interacting social or physical constraints of the performative environment they are embedded in.

In a recent paper, Gesbert and Durny (2017) described how soccer players can regain ball possession by exploiting specific and independent goals. According to their position on the pitch (forward, axial midfielder, side-offensive midfielder, etc.), they each developed a specific and compatible mutual understanding of what was going on. Even though they were attuned to common environmental information (such as their own defensive style and/or the opponent's offensive configuration to recognize a potential situation of regaining ball possession), they were no longer deliberately sensitive to the activity of their teammates. After regaining ball possession, the players directly foresaw what would happen both individually and collectively. They "saw" things before they happened through their capacity to re-enact their previous contextual experience and project it against the new contextual demands. The rehearsal of these realistic situations in training brought about fundamental changes in the way the players perceived their environment. In fact, the development of this bodily memory enabled them to unburden their attentional resources, facilitating that performance. At that moment, all the interactive dispositions that the soccer players had developed through repeated interactions in past competition and/or training were intuitively re-enacted. Through collective bodily memory, each player's movements were correctly understood and put into context by his teammates just before regaining ball possession, improving their capacity to predict and adapt their behavior (e.g., "we are not in position … Wilson is a bit too far from his opponent…So I do not engage in pressing"). Last, as noted earlier, Lund et al. (2012) described how two rowers (one was a novice) learnt to coordinate rhythm. Their results highlighted how the experience of mutual synchronization mediated by coupled ergometers enabled them to develop a kinaesthetic, implicit memory of poor rhythm and gave them the possibility of monitoring their own performance (Sutton and Williamson, 2014). The rowers' interlaced movements sometimes involved divergent experiential qualities described by the novice rower as a "tjuk-tjuk" – or the feeling of *not being together* (see section "The Feeling of Being Together"). For instance, as she sometimes had the tendency to slide in the seat, she noted how this movement was linked to the experience of a poor rhythm characterized as movements that work against each other. This feeling of "tjuk-tjuk" became an immediate kinaesthetic reminder for the rowers during performance, helping them re-establish the correct rhythm.

CONCLUSION

Because skills are often understood as properties of single agents, their acquisition is conceived of as an individual process based on internal dispositions, talent, and individual practice. However, frameworks based on solitary achievements may lead to the assumption of a strong discontinuity between inner psychological states and external behavior. A focus on automatic responses (i.e., "mindless" action) may not resolve this dichotomy. Indeed, positing strict automaticity in response to a given environmental perturbation in order to explain music-making or sport performance would keep high-level and low-level processes separate. As Sutton et al. (2011), p. 89, insist, "theorists tend to evacuate psychology entirely from action, running the risk of thus neglecting the complex interplay between embodied dynamical factors and cognitive factors". As we have seen, however, ECS offers a way forward: by shifting the unit of analysis from individual behavior to the collective dynamics, we can better comprehend how collaboration contributes to learning skills, how adaptations to the performative event are often enacted in socially meaningful environments, and how habits and repertoires of actions are distributed within the relevant community of practice.

These insights might call for an important reconceptualization of learning settings. Tools to understand and develop skills inspired by ECS may help teachers and coaches find novel ways to enhance the learning process. For example, numerous studies in music and sport have shown how learners use *preferential behaviors* (e.g., Lund et al., 2012; Laroche and Kaddouch, 2015) – that is, they spontaneously re-enact particular configurations that previously led to an optimal performance. Coaches and teachers can thus help learners explore areas of practice that fall outside their spontaneous achievement zone in various collective situations. This process requires a familiarization with the interaction dynamics involving (1) new opportunities based on the feeling of being together, (2) constant adaptation to the environmental resources being explored, and (3) an awareness of the distributed forms of bodily memory to help performers take decisions together and act as one when needed. There should be points of continuity across areas, and exploration might be developed in autonomy or under constant supervision. In both ways, each learner can flourish and push herself to reach novel achievements from a well-known starting point and by reciprocally relying on the interactor. By exploring novel opportunities together, learners can be "in-the-moment" together, with the possibility to also share thoughts and impressions on their practice.

A promising way to take this dimension into account in learning settings involves the explicit use of "re-enactment" techniques. In the sport context, for example, videos are extensively used to provide post-performance feedback and help the athletes to (re)connect the feelings and outcomes of their activity (e.g., Hauw, 2018). However, the feedback is very often associated with normative remarks on the outcomes or behavior (i.e., "you should do it like this!"). For this reason, it has been argued that a stronger effect might be obtained by integrating videos with a form of reflective practice (e.g., Hauw, 2009). Here, the aim is not to compare a performance to a model of expected or ideal behavior, but instead to generate a re-enactment – or a form of artificial re-living of the experience – with the support of the video, which can then be linked to a normative example in order to work on it. Hauw (2018) described how the use of such re-enactments was able to solve problems or resolve disruptions in motor behavior, to modify a counterproductive involvement in competition, and to supervise athletes' long-term development. In these cases, athletes are asked to relive the feelings (including body sensations) that they have experienced in various situations. This involves an effort to "disconnect" from the present moment and project oneself into a previous situation. The athletes are able to describe how they managed their interactions with the environment and how they created their own situations (Hauw and Durand, 2007; Villemain and Hauw, 2014; Mohamed et al., 2015; Antonini Philippe et al., 2016; Gesbert et al., 2017; Gesbert and Durny, 2017; Rochat et al., 2018). Videos or other traces of past activity are thus very useful for maintaining the markers that preserve the dynamics of an activity. And indeed, it should be noted that re-enactment techniques are not limited to visual information only, but can also involve auditory signals (Pizzera et al., 2017; see also Sors et al., 2015, and Schaffert et al., 2019 for reviews). In general, these interventions can help learners to again "feel" the dynamics of action without any overt movement. *Prima facie*, it seems that the kind of exploratory behaviors associated with the three categories described above are here lost. Instead, there are ways to stimulate a sort of mental exploration: athletes can be offered the opportunity to analyze their own activity by assessing the relevance of their actions for the context or they can be prompted to consider new possibilities by provoking a shift in the way they experience their activity. For example, are there other more efficient ways to reach high performances? How can collective activities between team members be promoted and developed in future interactions? Athletes can also be simultaneously prompted to evaluate their performance with regard to their individual and collective adaptive possibilities (e.g., MacNamara and Collins, 2011; Gesbert et al., 2018). In this last case, discussions and shared reflection would still provide the feeling of being together and thus potentially elicit possibilities for adaptation that are developed collectively. Similar practices can thus help capture the non-dichotomous nature of thought and action, providing important methodological insights that can be useful for understanding the main properties of skill acquisition and future developments in education and pedagogy. In music education, a similar account might involve the adoption of so-called "conscious strategies" and the recourse to metacognitive competence (see Concina, 2019). As reported by Nielsen (1999), Jorgensen (1995) argues that with problems about learning goals, the contents of the piece, the available learning media, time allocation, and methods needing to be explicitly considered and addressed. A possible extension of such practices might include the "mental exploration" (Høffding and Schiavio, 2019) of collective situations, where individual agents are asked to explicitly account for interactions and joint situations. While there is no agreement on how to coherently implement similar practices across different contexts, the adoption of such strategies may be an apt counterpoint to improvisational music pedagogies and less formalized forms of sport and play.

DATA AVAILABILITY

All datasets analyzed for this study are included in the manuscript and the supplementary files.

AUTHOR CONTRIBUTIONS

AS made major contributions to content in all areas of the paper. VG and DH made substantial contributions to sections "Skills Beyond the Individual" and "Conclusion." MR and RP provided comments and suggestions throughout the development of the paper that were implemented in the final draft. All authors approved the final version of the paper.

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Self-knowledge as a Result of the Embodied and Social Cognition

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The claim that a cognizer needs to act with the environment to gain knowledge about the world is trivial. No more does the claim sound trivial than when it is said that the cognizer[1] also needs to interact with the environment to know himself, i.e., to gain self-knowledge (SK), defined generally as the subject's knowledge of his mental states, such as feeling, beliefs, or desires (cf. Peacocke, 1999). But why should the cognizer interact with the external world to know the content of his states if they are given to him directly by introspection? In this paper, I support the thesis that to meet the requirements put on SK as knowledge (i.e., as justified, true belief), it must be both embodied and social. Otherwise, the subject has no tool to correct his false beliefs about himself since he is simply unaware that they are false. The vision of such a self-blind subject seems not quite optimistic; hence, in this article, I would like to investigate certain solutions which could help in the argumentation against such vision.

The traditional account of SK separated the cognizer from the influence of other subjects by giving him the first-person-authority grounded on his privileged access to his internal psychological states. On such account, a society consisted of individual minds, interacting however with one another, but with no access to others' minds. On the early stage of computationalism, the already classic paradigm in cognitive science, an intuitive approach to SK was the one according to which a cognizer knew his own mental states by virtue of their appearance in mind (Haugeland, 1987; Guttenplan, 1994; Dretske, 1995). SK was then characterized by the propositional form of "I believe that I believe that *p*." An explanation could easily be formulated with the nomenclature of computationalism by saying that to know himself, a subject needs to present two abilities (or in terms of functionalism: dispositions): to have a concept of I/Me to ascribe the attitude to oneself as to the subject of the experienced state, and to have a concept of an attitude such as BELIEF or DESIRE in order to identify the mental state in which he is (cf. Peacocke, 1992). If the concepts were understood as representations falling under computational operations (Fodor, 1998, 2000), then the SK also had a representational form composed of two basic representations: the one of I and the other of an experienced phenomenal state such as pain or belief (Newen and Vosgerau, 2007). The computability of SK, also called information processing, was determined by algorithmic processes on representations (Dretske, 1981; Fodor, 1987, 1991; Leake, 1995; David et al., 2004; Miłkowki, 2017).

On such computational account of SK, a subject was closed in the internal loop of self-representational mind, which needed no non-neural body to gain the knowledge about itself. One of the newest examples of such an internalistic model of SK is the Epistemic Agent Model (EAM,) formed on the level of conscious processing and representing its owner as an individual capable of keeping autonomous epistemic self-control, i.e., monitoring and voluntary modification of his own mental states (Metzinger, 2017, p. 8). The components of EAM are two smaller models: a model of an entity exerting control (the self) as well as a model of the satisfaction conditions of the specific mental action and the asymmetric dynamic relation connecting these two models, the one which can be interpreted simply as an intentional attitude toward a content of the mental state such as belief (cf. Metzinger, 2017). All the components are internal and based only on the neural information processing.

[1]The terms "cognizer" and "subject" are used interchangeably.

The subject (self) aiming at some action in the world first needs to be aware of the belief according to which he acts. To know this belief, he needs to be equipped with the model of himself as the subject having that belief. Therefore I interpret the EAM as a model of SK. Although this model does not include external elements (which are needed in the conception of the social and embodied SK) it points to a very important constituent of SK, namely the minimal phenomenal selfhood—the subjective experience of being a self. The processes responsible for physical self-specification are neuronal and hence internal. Basically, these are both homeostatic regulation as well as proprioception, which is understood as sensorimotor integration (Christoff et al., 2011, p. 104). They underlie higher level processes giving rise to self-experience. This self-experience is a fundament of EAM and, hence, SK. The constitution of SK as relying on the constitution of the self is crucial here. On the one hand, the development of self-experience constitutes a necessary element of SK, but on the other hand, it is the source of errors in self-cognition.

The errors in self-cognition are reported in many empirical studies: Rubber Hand Illusion (RHI), Full Body Illusion (FBI), or Body Swap Illusion (BSI) have shown that the perception of self-location and first-person perspective can be experimentally influenced and changed (Lenggenhager et al., 2007; Blanke and Metzinger, 2009; Ionta et al., 2011; Aspell et al., 2012), and that certain dimensions of minimal phenomenal selfhood can be manipulated (cf. Limanowski, 2014, p.1). The cases of experiencing a phantom (*de facto* missing) limb as still belonging to the body (Ramachandran and Blakeslee, 1998; Ramachandran and Altschuler, 2009; Case et al., 2010; Ramachandran et al., 2011) well exemplify lack of resistance to an error in self-cognition. The examples involving self-illusions explicitly show that we can artificially induce the experience of self-location and ownership from the outside to evoke a false self-identification, and hence, to create a false content of SK. The newest empirical findings show the connection between impairment of the self in Schizophrenia (SZ) and Autism Spectrum Disorders (ASD) accompanied by disturbances during interaction of those affected by the abovementioned mental condition with the social environment. In these cases, a subject possesses either a sharper self-others boundary which extends beyond the norm (ASD) or has weaker distinction (SZ) (Noel et al., 2017). The experiments with FBI involving ASD patients showed that the patients do not experience FBI as intensively as the healthy subjects do (Mul et al., 2019). The conclusion therefore drawn was that the multisensory integration, which constitutes the base for the minimal phenomenal selfhood formation, may be related to deficits in social functioning.

The abovementioned cases indicate the connection between the internal subjective sphere with the external sphere of the social, without giving up the role of the body in the constitution of the self. The question of SK is the question of how the body (something private and individual) interacts with the world (public and social). According to this issue called *body-social problem* (Kyselo, 2015), the social interaction relies on the tension between what is objective and what is subjective in cognition expressed in terms of distinction and participation (Kyselo, 2015). Self-cognition can be formed from the bottom up, as the basic representation of the subject as an individual distinct from other entities, but also it is shaped top-down through a subject's participation in joint actions. Both, distinction and participation lead to the development of the cognizer's beliefs as belonging to him as an individual entity with privileged access to his own states and first-person authority. They both are complementary components of the process of the cognizer's constitution as an autonomous individual in the process of continuous balancing between what is his own and what is social (cf. Kyselo, 2015).

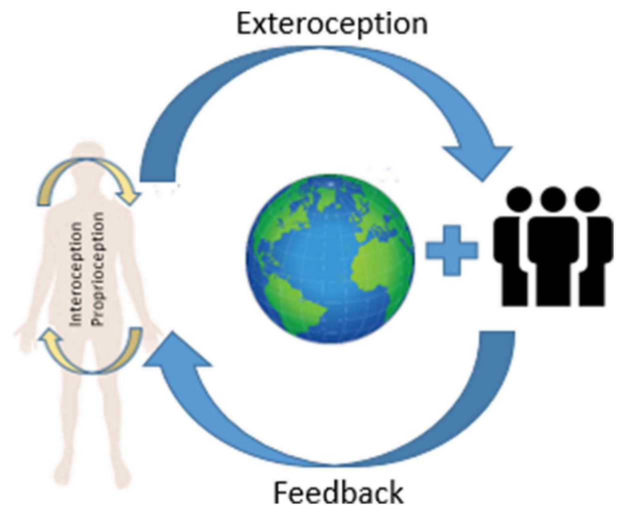

FIGURE 1 | Factors influencing SK.

The uniqueness of human cognition is characterized by the ability to participate with others in collaborative activities with shared goals and intentions. This ability is the so-called shared intentionality defined as an ability to share the mental states (e.g., beliefs) of others owing to the ability to represent these states. The shared intentionality can be interpreted as a reasonable conscious participation (in opposition to unreflective imitation) in social practices (Tomasello and Rakoczy, 2003; Tomasello et al., 2005). It helps to develop one's own self exemplified in the set of beliefs constituting SK. Two-year-old children are ready to understand others as intentional agents, but by age four, show the ability to read others' minds skillfully enough to be able to look from others' perspectives and understand that others can have beliefs different from their own (Baron-Cohen et al., 1985; Tomasello and Rakoczy, 2003; Tomasello et al., 2005). The ability to take the perspective of others—to think like others—to understand that others can have different beliefs is the symptom that a child has developed the theory of mind, i.e., accepts that others have their own individual minds distinctive from that of a child. This is one of the milestones in the development of SK.

Due to the conception of embodied and social SK self-cognition is the result of the body interactions with the world (**Figure 1**). Mind is not only "in the head" but also "in the body." This general idea was presented by Seth (2015) and is based on empirical research on how self-experience emerges, or how the phenomenal selfhood is constructed. For the body-world interaction to be effective, the organism must present adequate abilities to control the body. These include, among others, the sense of ownership and self-identification (Seth, 2015, p. 11). The integration of bodily information in the form of bodily awareness is required because in this manner the brain creates the body model as a whole (Seth, 2015, p. 11). The self is thus an effect of interoceptive, exteroceptive, and proprioceptive sensory stimuli (Seth, 2015, p. 12). The interaction between interoceptive and exteroceptive signals is significant here (Seth, 2015, p.13), which means that, as an essential component, the self-model must also contain an external element, whose presence allows the constitution of this model. In such an externalist model of the self, an action will be a tester of SK and it will be a verifier of the beliefs concerning the subject's own states, showing that the subject in specific cases such as RHI can be wrong about the perceived object as belonging to his body, although the first information is about its integration within the body. Worth emphasizing is the fact that the presented internal and external models are based on the mechanism of predictive coding, showing that the same mechanism can underlie different models. Predictions running in the brain allow to "properly read" the current states of the world on the basis of a sensory input for the purpose of performing an appropriate action (Friston et al., 2009). I think, however, that it works properly only in the external model of SK, owing to the probability which increases after the interaction of the subject with the environment. The interaction with the world (action performing) serves as a tester of sensory input (Seth, 2015).

As it has already been said, the empirical evidence shows that the cognizer may be wrong about his experienced states. If an error arises on the basic level of information processing, for instance, an error in proprioception where the minimal phenomenal self is constituted, it is inherited by consequent levels (i.e., from sub-personal neuronal level via phenomenal up to the level of propositional mental content) until the false information appears in self-consciousness, giving the subject a wrong representation about his state. The social element constituting SK is the answer to this problem.

The social constitution of SK allows us to step out from the first-person perspective and take the third-person perspective by judging the reliability of the beliefs about the subject's own mental states. This ability opens the mind to the possibility that the cognizer can be wrong about the content of the experienced state. Although bottom up processes determine the inheritance of errors in self-experience, SK prepares us for being mistaken about our own mental states.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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Economic Reasoning and Interaction in Socially Extended Market Institutions

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An important part of what it means for agents to be situated in the everyday world of human affairs includes their engagement with economic practices. In this paper, we employ the concept of cognitive institutions in order to provide an enactive and interactive interpretation of market and economic reasoning. We challenge traditional views that understand markets in terms of market structures or as processors of distributed information. The alternative conception builds upon the notion of the market as a "scaffolding institution." Introducing the concept of market as a "socially extended" cognitive institution we go beyond the notion of scaffolding to provide an enactive view of economic reasoning that understands the market participant in terms of social interactive processes and relational autonomy. Markets are more than inert devices for information processing; they can be viewed as "highly scaffolded," where strong constraints and incentives predictably direct agents' behavior. Building on this idea we argue that markets emerge from (a) the economic interaction of both supply and demand sides, in continual and mutual interplay, and (b) more basic social interactions. Consumer behavior in the marketplace is complex, not only contributing to determine the market price, but also extending the consumer's cognitive processes to reliably attain a correct evaluation of the good. Moreover, this economic reasoning is socially situated and not something done in isolation from other consumers. From a socially situated, interactive point of view buying or not buying a good is something that enacts the market. This shifts the status of markets from external institutions that merely causally affect participants' cognitive processes to social institutions that constitutively extend these cognitive processes. On this view the constraints imposed by social interactions, as well as the possibilities enabled by such interactions, are such that economic reasoning is never just an individual process carried out by an autonomous individual, classically understood. In this regard, understanding the concept of relational autonomy allows us to see how economic reasoning is always embodied, embedded in, and scaffolded by intersubjective interactions, and how such interactions make the market what it is.

Keywords: market structure, economic reasoning, socially extended mind, autonomy, functional integration, task dependency

INTRODUCTION

Theories of situated cognition typically ignore an important set of situated practices that are pervasive in our everyday lives – our participation in markets and economic activities. Such activities involve the exercise of a common form of reasoning embedded in significant social interactions and/or socially and normatively defined contexts. The lack of attention to these practices, however, is for the most part one-sided. Although there is a diverse set of economists who discuss situated and institutional approaches to economic reasoning (e.g., North, 1990; Kirman, 1999; Smith, 2007; Hodgson, 2009), philosophers, psychologists and cognitive scientists who venture into the study of situated cognition or social cognitive processes rarely discuss economic reasoning or economic behavior. Moreover, when philosophers, psychologists and cognitive scientists more generally discuss economic reasoning or economic behavior it is, with few exceptions, without regard for situational or intersubjective factors. In particular, they typically frame them in terms of traditional notions of rational choice and abstract decision-making or, more recently, in terms of behavioral and cognitive biases. In addition we note that, even those who count as exceptions emphasize the idea that economic institutions, such as markets, operate primarily as external constraints on individual cognitive processes. Thereby they adopt a relatively conservative and narrow conception of situated cognition.

In contrast, we propose an enactivist interpretation of the notion of market that emphasizes the role of social interactions. On this view, markets are socially extended cognitive institutions (Gallagher, 2013). This means that market forces, rather than external constraints or inert substructures, constitute an economic order enacted in the dynamical interplay of embodied, situated, and materially engaged agents who maintain relational autonomy in a world that is both physical and social. Understanding the nature of such markets, we argue, throws light on an important dimension of everyday situated behavior.

In working out this enactive conception of market we challenge some traditional views that understand markets in terms of market structures or as processors of distributed information. To develop an alternative conception we take as a starting point the notion of the market as a 'scaffolding institution' understood in terms of the extended mind (Clark, 1997a,b, Chapter 9; Clark and Chalmers, 1998). Markets can be understood through the lens of *scaffolded choice* in which, rather than internal mental states – such as "beliefs, desires, or other psychological features of individuals involved" – what counts for economic reasoning are the engagements with external structures that constrain and enable agents' behaviors and interactions (Clark, 1997a, p. 272; see also Denzau and North, 1994). In this paper we push this idea in a more enactive direction and toward a socially interactive interpretation of economic reasoning, by employing the concept of *mental* or *cognitive institution* understood in terms of the "socially extended mind" (Gallagher and Crisafi, 2009; Gallagher, 2013; Slaby and Gallagher, 2015).

We begin by reviewing some basic concepts of the market and economic reasoning, especially as understood in the neoclassical tradition and its recent developments. We do this both for purposes of later contrast, and because these neoclassical concepts influenced Andy Clark's ideas about markets as "extended institutions," which he proposed some 20 years ago (Clark, 1997a,b) when neoclassical models were still relatively unchallenged by behavioral economics. We then discuss Clark's model of the market as scaffolding and constraining economic reasoning, and some deficiencies that we find in it. We next introduce the model of the socially extended mind and the concept of cognitive institution as a way to understand how markets are enacted in social interactions. This perspective allows us to see that economic reasoning is a more socially interactive process than an individual deliberation, and that in specific conditions it can veer toward purely instrumental calculation, or under different conditions promote autonomy in its relational form.

THE TRADITIONAL VIEW OF MARKETS: STRUCTURE, INFORMATION PROCESSING AND MENTAL MODELS

Theoretical speculations about markets as exchange and allocation mechanisms go back at least to the classic idea of the 'invisible hand' proposed by Adam Smith (Smith, 1776). According to this view, markets are seen as mechanisms allowing parties to exchange goods and services, thus increasing individual and social welfare. However, more recently, economists have looked at markets more generally as coordination mechanisms: whenever transaction costs – i.e., the costs of using the *price mechanism* – are low, markets are considered to solve a number of coordination problems better than alternative coordination mechanisms (see Williamson, 1981a). A "paradox" (Hodgson, 2008) in the research on markets is that economists have been nearly obsessed with market prices and market efficiency but relatively inattentive to markets as "places" in which people interact, build relationships, learn, and take care of an increasing part of their life interests. This suggests that much is still to be understood about markets. The ubiquity of the textbook definition stating that a market is a "mechanism through which buyers and sellers interact to determine prices and exchange goods, services, and assets" (Samuelson and Nordhaus, 2010, p. 26) just reinforces the sense of taken-for-grantedness surrounding this notion.

Although Samuelson and Nordhaus's definition aptly focuses on the fundamental requirement that buyers and sellers *interact* in the market, economics has mostly refrained from studying the process of interaction itself, focusing more on the *structure* of markets and how information is processed either by market structure or by individual traders. Market structure is defined by a few key features (also called "basic conditions," Scherer, 1980): the number, size, and distribution of buyers and sellers, market share, possibility of free entry, and product differentiation. Any particular combination of these variables is said to determine the behavior and economic decisions of market participants, and eventually market price. Ideal-typical market structures are perfect competition, monopolistic competition, oligopoly, duopoly, monopoly, monopsony, and oligopsony.

More concretely, the notion of 'market micro-structure' aims to study the specificities of different negotiation, trading, and exchange mechanisms (O'Hara, 1995).

The work of Friedrich A. Hayek has given a fundamental epistemological twist to the study of markets by focusing on the role of market information (this has been called the "information revolution" in economics; see Mirowski and Nik-Khah, 2017). According to Hayek, information is so fragmentary and dispersed across a large number of individuals in society that it cannot be effectively collected and processed by any centralized agency (Hayek, 1948). It is the market interaction and economic reasoning of individuals guided by their own beliefs and preferences that render market prices "signals" of the underlying beliefs and preferences. In other words, the market mechanism would process dispersed information and convey it in the form of market prices. In this view, markets are conceptualized as *information processors* (Hayek, 1945). From the work of Hayek onward, information has acquired a central status among the basic conditions of market structure.

Various benchmarks can be used to assess markets. Traditionally, the four main market benchmarks are static and dynamic efficiency, equity (a particularly relevant benchmark in fields like law and economics), and macroeconomic stability (Scherer, 1980). Efficiency can be further specified depending on the scale (at the firm or at the industry level) and on the focus (technical, economic, productive, and allocative efficiency) (see Tremblay and Tremblay, 2012). Informational efficiency is the market's property of reflecting in the prices all available information: to put it normatively, a market is informationally efficient to the extent that the market price is able to reflect all available information (Fama, 1965). In this framework, "asymmetry of information" between buyers and sellers is considered one of the main causes of market failure, i.e., when the price system does not reliably work as signal mechanism (Akerlof, 1970). Furthermore, searching for information in markets is costly (Stigler, 1961), so that the search process may considerably affect the convenience of using the market mechanism. The cost of information is one of the determinants of so-called "transaction costs," i.e., those costs associated with the use of the market mechanism (Williamson, 1981a). The fact that transaction costs affect the convenience of the market mechanism leads buyers (individuals or firms) to look for other, possibly more convenient, coordination mechanisms. One main alternative to markets is the "make" option, i.e., buyers/firms decide to make a product or service on their own instead of buying it on the market (Coase, 1937).

Hierarchies may be preferable to the market mechanism when transaction costs are high. The existence of hierarchies – such as large-scale business enterprises – can be explained by structural features of complex and advanced economies in which transaction costs play a fundamental role (Williamson, 1981b). Chandler's (1977) provocative notion of the 'visible hand' emphasizes the role of managerial activity for coordinating the allocation of economic resources as an alternative to market mechanism. Such a view deliberately contrasts with the classical view of market as an efficient and self-organizing device. But hierarchies are not the sole alternative to the market form of coordination. For instance, 'clans' are alternative forms to hierarchies and markets as they characterize situations in which obligations among transacting agents are not coordinated by an authority (as it happens in hierarchies) and cannot be extinguished 'just in time' (as it is possible in some forms of market) (see Ouchi, 1980; Adler, 2001).

Buyers and sellers, whether single individuals or firms, are said to act according to their beliefs, preferences and, most importantly, convenience. This is a basic assumption of neo-classical economics. In the last decades, the new field of 'behavioral economics' has tried to introduce more realistic assumptions on how agents behave in economic contexts (such as markets), by investigating the behavioral and cognitive determinants of economic actions. Nowadays, behavioral economics has become a standard framework in economics, by abandoning the aprioristic form of theorizing typical of neoclassical economics, and embracing experimental methods borrowed from the behavioral and cognitive sciences (Mullainathan and Thaler, 2000; Camerer and Loewenstein, 2004). The new partnership between economics and behavioral and cognitive psychology has rendered a more realistic image of market participants as ridden by behavioral and cognitive biases, which prevent them from reliably and consistently processing (even their own) information. For instance, the "endowment effect," which is the difference between the price a seller assigns to her own product and the price that seller would be willing to pay, had she to buy that product on the market (Kahneman et al., 1991), arguably affects the reliability of the market mechanism (Kahneman et al., 1990). By taking this behavioral route, economic models of markets now typically include agents that are both rational (i.e., utility maximizers; see Blume and Easley, 2008) and irrational (i.e., non-utility maximizers) (Akerlof and Yellen, 1985; Russell and Thaler, 1985), or agents who are "psychologically enhanced," i.e., provided with behavioral features (e.g., Bénabou and Tirole, 2016). Some 'pragmatic' interpreters of behavioral economics (e.g., Chetty, 2015) maintain that the true aim of behavioral economics should be that of discerning the contexts in which the assumptions of neoclassical economics work from those in which they should be replaced. Behavioral finance is a field that makes large use of cognitive and behavioral insights to study financial decisions beyond the neoclassical view (Barberis and Thaler, 2003). As far as markets are concerned, behavioral finance suggests that behavioral and cognitive biases would ultimately explain why prices in financial markets follow "irrational" patterns (Shiller, 2015). This does not mean, however, that behavioral economics as such supports an anti-market position (Sugden, 2018).

By taking a different route with respect to behavioral economics, also in the kind of experimental methods employed (Hertwig and Ortmann, 2001), the field of so-called 'experimental economics' studies how monetary incentives and rule-based coordination mechanisms are able to cancel out individuals' cognitive biases either in single transactions or in the aggregate (Smith, 2007). The development of new game-theoretic tools has allowed economists to study how various market arrangements differ in terms of information efficiency, not just with the aim of assessing extant markets' efficiency but also with the aim of designing from scratch new markets with customized informational properties. The possibility of designing entirely new markets stems from the development of information technologies (ITs) allowing the construction of virtual marketplaces and from the development of new branches of economics able to provide a more complex and sophisticated picture of market phenomena (Shapiro and Varian, 1998). The development of new fields in economics such as "mechanism design" (e.g., Hurwicz and Reiter, 2006), and more specifically "market design" (Vulkan et al., 2013), testifies to the fundamental need to address new forms of market, a need invariably satisfied by focusing and intervening on markets' informational properties (Mirowski and Nik-Khah, 2017). Typically, market designers aim to off-load much of the market participants' cognitive burden onto the rules of the market: market rules as strict, unambiguous, and as easy-to-follow as possible would lead to more effectively attain the desired level of efficiency. Analytical results that demonstrate that market efficiency can be attainable also by "zero-intelligence" traders (Gode and Shyam, 1993) support this market design's constructivist view.

The rise of market design approaches also stems from economists' awareness that markets are better conceptualized as "institutions" that order interpersonal relations.[1] This view is best represented by the work of Douglass North (e.g., North, 1990). Institutions, according to North, would stem from individuals' "shared mental models" (Denzau and North, 1994), and institutional change would take place only when these mental models change (North, 2005).[2] The lack of perfect knowledge or information, i.e., uncertainty, would be at the root of this process of mental model sharing:

> Under conditions of uncertainty, individuals' interpretation of their environment will reflect their learning. Individuals with common cultural backgrounds and experiences will share reasonably convergent mental models, ideologies, and institutions; and individuals with different learning experiences (both cultural and environmental) will have different theories (models, ideologies) to interpret their environment (Denzau and North, 1994, pp. 3–4).

North's emphasis on mental models testifies to the fact that this strand of research on "markets as institutions" is part of the information-processing paradigm within economics, as these mental models are mainly constituted by beliefs, preferences, expectations that populate people's mental representations of the institutions they act in.

We can agree with Denzau and North that something is "shared" in markets conceived as institutions. We pursue this suggestion in the following sections: what is shared are the cultural practices, the external cognitive artifacts and technologies that contribute to making the market an institution, rather than internal mental variables. The notion of zero-intelligence traders is an abstraction; but there is something real that can be specified about market intelligence. One attempt to build on this kind of externalism can be found in the notion of the extended mind.

MARKET AS EXTENDED MIND

Social and economic environments are more than passive products of human agency; they actively contribute to the reproduction of the stable organizations and practices that enable and constrain human behaviors (see Giddens, 1984). Accordingly, markets are more than inert structures for information processing devoted to solving allocation and coordination problems involving collectivity. Borrowing significantly from Denzau and North, Clark (1997a) conceives of markets as structures that provide epistemic scaffolding, involving strong constraints and incentives that predictably direct agents' behavior. Such structures are able to produce a "cognitive economy" as they steer individuals' decisions and actions: they reduce in a significant manner the cognitive effort for information processing by externalizing a number of processes. The idea that economic decision-making takes place in such highly scaffolded environments would explain why neoclassical economics works, "(insofar as it works at all)" (Clark, 1997b, p. 271).

Clark understands scaffolded cognition as an instance of the extended mind (Clark and Chalmers, 1998). The idea of the extended mind is based on the general hypothesis that cognitive processes are not limited to what happens in the head but may occur by allowing the external world to do some of the work. Factors external to brain and body may be functionally integrated in the overall cognitive system. On this account, cognition consists of a specific kind of action that manipulates an external tool or instrument, for example, using pencil and paper to do math. Such extension occurs in cases in which the manipulation of the external world can be considered functionally equivalent to internal processes (Clark and Chalmers, 1998). What allows something to be part of a cognitive system or "a proper part of a genuinely cognitive process" (Clark, 2010, p. 85) is tied to its function.[3] According to the extended mind hypothesis, this is expressed as the "parity principle" and is stated as follows.

> If, as we confront some task, a part of the world functions as a process which, were it done in the head, we would have no hesitation in recognizing as part of the cognitive process, then that part of the world is (so we claim) part of the cognitive process (Clark and Chalmers, 1998, p. 8).

Doing math in one's head counts as a cognitive process; likewise, doing it with paper and pencil should count as a cognitive process where paper and pencil function as a mechanism or vehicle of cognition, functionally similar to internal (e.g., neural) mechanisms. Just as in our heads we

[1] On the basis of North (1990), Denzau and North (1994, p. 4) define institutions as "the rules of the game of a society [consisting] of formal and informal constraints constructed to order interpersonal relationships."

[2] "The mental models are the internal representations that individual cognitive systems create to interpret the environment; the institutions are the external (to the mind) mechanisms individuals create to structure and order the environment" (Denzau and North, 1994, p. 4).

[3] The details of the relationship between functionalism and the extended mind have been a focus of a number of important papers – see Sprevak (2009), Miyazono (2017), and Wadham (2016).

may manipulate a mental model to solve the problem, we manipulate paper and pencil to accomplish the same task (Clark, 1997b, p. 297).

If in some cases there is a functional similarity between inner and outer processes, there are also many cases that involve significant differences. This motivates an emphasis on complementarity or functional integration, which includes the idea that "different components of the overall (enduring or temporary) system can play quite different roles and have different properties while coupling in collective and complementary contributions to flexible thinking and acting" (Sutton, 2010, p. 194; see Menary, 2013). Functional integration is indexed by differences in individual cognizers, and differences in particular environments. Individual agents may have different proclivities to use external props and instruments versus internal processes like memorization, and this balance might be modulated by changes or structures in the environment or what one particular environment in contrast to another affords.

> The argument for the extended mind thus turns primarily on the way disparate inner and outer components may co-operate so as to yield integrated larger systems capable of supporting various (often quite advanced) forms of adaptive success (Clark, 1997b, p. 99).

The ideas of parity and complementarity signal, respectively, different ways in which internal processes (beliefs, desires, mental models and other representational states) play a role together with the external vehicles or mechanisms that scaffold cognition. The extended mind involves a hybrid of internal and external processes where, in some cases, the cognitive processes are carried primarily by external factors, and in others, by internal factors.

Building on the work of Denzau and North (1994) and Satz and Ferejohn (1994), Clark recognizes that the larger system supporting cognition can include institutions. "Institutions, firms, and organizations seem to me to share many of the key properties of pen, paper, and arithmetical practice in this example" (Clark, 1997b, p. 279). At the same time, such institutions impose structural limitations on individual choice. "[W]hat is doing the work, in such cases, is not (so much) the individual's cogitations as the larger social and institutional structures in which she is embedded" (Clark, 1997b, p. 272).

In terms of economics, Clark's argument continues, market mechanisms understood as institutional rules and practices, promote actions that maximize returns relative to a fixed set of goals. Thus, "firms and organizations provide an external resource in which individuals behave in ways dictated by norms, policies, and practices; norms, policies, and practices that may even become internalized as mental models" (Clark, 1997b, p. 279). In many cases, rather than basing economic choices solely on a set of beliefs, desires, or other psychological states within the individual, larger scale market structures that rule firm-level strategies impose strong constraints on individual choice.

> In the embrace of such powerful scaffolding, the particular theories and worldviews of individuals may at times make little impact on overall firm-level behavior. Where the external scaffolding of policies, infrastructure, and customs is strong and (importantly) is a result of competitive selection, the individual members are, in effect, interchangeable cogs in a larger machine. The larger machine extends way outside the individual and incorporates large-scale social, physical and even geopolitical structures (Clark, 1997b, p. 272).

Individuals may play interchangeable functional roles [at the extreme as zero-intelligence traders (Gode and Shyam, 1993)] in the larger institutional processes. Such processes may be underdetermined and open to varying dynamics of positive feedback (the result of, for example, small early perturbations in the overall economic system) (Arthur, 1990), but these effects may still involve external factors rather than individual psychological determinants. Accordingly, "the explanatory burden is borne by overall system dynamics in which the microdynamics of individual psychology is relatively unimportant" (Clark, 1997b, p. 276). This, according to Clark, but also according to the thought of well-known neoclassical economists (e.g., Becker, 1962), would ultimately explain why neoclassical economic theory works:

> In cases where the overall structuring environment acts so as to select in favor of actions which are restricted so as to conform to a specific model of preferences, neoclassical theory works. And it works because individual psychology no longer matters: the "preferences" are imposed by the wider situation and need not be echoed in individual psychology (Clark, 1997a, p. 183)

This does not mean that there is no role for individual psychology in the economic system. Clark brings us back to the notion of the extended mind where individual cognizers are coupled to various external factors and institutional practices. Specifically, there is interplay between individual internal mental processes and a set of larger mechanisms that accounts for innovation, the possibility of learning and expanding intellectual horizons. Clark suggests that these may depend on individual idiosyncrasies and positive feedback effects (Clark, 1997a, pp. 186–192). We think there is more to say on this issue. At any point beyond zero-intelligence, the larger mechanisms can support and motivate different practices leading to unpredictable innovation outcomes. One type of behavior allowed but not strictly dictated by the market mechanism is, for instance, strategic behavior.

It would be useful for purposes of explicating Clark's views further, to see how both sides of the markets, suppliers and consumers, can use the market mechanisms in seemingly 'unorthodox' ways. In general, consistent with Clark's framework, price can be re-conceptualized as an *offloading* device, i.e., a *cognitive artifact* (see Risko and Gilbert, 2016), able to reduce cognitive demands. Consistent with Clark (2005)'s emphasis on the external vehicles of cognition, prices can be considered external artifacts able to compensate for the lack of information about allocation possibilities, which can be considered part of economic agents' bounded rationality (e.g., Simon, 1982; see also Arnau et al., 2014).[4] Clark, however, suggests that the market mechanism differentially affects market participants.

[4] As Clark suggests: "Simon saw, very clearly, that portions of the external world often functioned as a non-biological kind of memory. He thus saw the deep parity (parity, not identity) that can obtain between external and internal resources" (Clark, 2001, p. 139).

On the supply side, he emphasizes that "[s]trong constraints imposed by the larger scale market structure result in *firm-level strategies and policies* that maximize profits" (Clark, 1997a, p. 272, emphasis added). In other words, suppliers would be highly scaffolded, to the point of being induced to maximize profits (or, more generally, utility), as dictated by neoclassical economics.

Even if evidence on bounded rationality largely shows that firms do not systematically maximize profits (Simon, 1979), we suggest there is an even more important point to consider, namely, that imposing constraints is not the only direction in which a market scaffolds suppliers. For example, suppliers can use the price mechanism strategically. Such strategic use of the market can be visible, for instance, in the implementation of price strategy – to defend market positions or conquer new segments, for example – as prices can be considered signaling and explorative tools (Spiegler, 2011; Tremblay et al., 2018). This does not imply that strategy is the only way in which the market enables suppliers. A variety of suppliers' behaviors are enabled by the market mechanism that are not necessarily compatible with the immediate purpose of maximizing profits. This is to say that scaffolding works in two directions and not only in the constraining way (see also Cardinale, 2018). There are degrees of freedom in the scaffolding mechanism, and the very same market mechanism can enable novelty. In this view the same notion of market efficiency, discussed above, is challenged by the consideration that the economic environment continuously invites new uses of existing economic resources, allowing the emergence of innovations (Felin et al., 2016).

On the demand side, Clark claims that "the theory of consumer behavior is weak [. . .] and the external scaffolding is commensurably weaker" (Clark, 1997a, p. 183), thus implying that consumers would be less bounded by the market mechanisms than suppliers. In our understanding, however, this postulated asymmetry between supply and demand can be misleading. We know that consumers, by definition, go to the market in order to solve their problems to procure their means of subsistence compatibly with their budget constraints. Even this simple neoclassical characterization of the consumer problem would suffice to make clear that consumers are, in principle, as equally scaffolded as suppliers by the market mechanism. Even if we are less surprised that consumers often behave more irrationally than suppliers do (but, not to forget, also suppliers can be irrational, see Kahneman et al., 1991), again this may not be the full story. The other part of the story is the central and active role played by consumers in the market mechanism, which goes beyond the simplistic view that markets pragmatically provide goods and epistemically provide information. Leibenstein (1950) emphasized that there are various motives behind consumers' actions in the market (such as functional, speculative, social, and irrational motives). We may add that there exists a further motive, in so far as by acting in the market the consumer behaves so as to solve a real epistemic problem. Not only does the consumer's behavior ("to buy" or "not to buy" at a certain price) contribute to determining the market price; in addition the market process serves to extend the consumer's cognitive process in order to solve the consumer's problem, which involves reliably attaining a correct evaluation of the good.[5]

We are led to the following ideas: markets (a) emerge from the interaction of both sides (supply and demand), in their continual and mutual interplay, and (b) involve more basic social interactions that shape both sides. In both cases – supply and demand – actions involved in price negotiations (in terms of bid and ask prices) can be considered from an epistemic point of view, not just pragmatically. Kirsh and Maglio (1994 p. 513) distinguish between pragmatic and epistemic actions: pragmatic actions are "performed to bring one physically closer to a goal" whereas epistemic actions are "performed to uncover information that is hidden or hard to compute mentally." In these terms, price setting can be considered not just as a pragmatic action that puts market parties a step closer to the exchange moment, but as an action in which prices as artifacts are manipulated for epistemic reasons, that is to say, to uncover, or even create new knowledge. For example, on the supply side a firm could change prices to evaluate how their competitors will react to different price levels, and in general to try to discover their strategic intent. On the demand side, a consumer could negotiate the price not only to save money but to create a stable and credible contact with the seller. To some extent, negotiating could be a way to disclose intentions, and establish trust and reciprocity between parties.

MARKET AS COGNITIVE INSTITUTION

In this and the next section, we build upon the notion of the market as a "scaffolding institution" understood in terms of the extended mind. We pursue an enactivist interpretation that emphasizes social interaction. Thus, we propose to understand a market as a socially extended cognitive institution and to develop a picture of economic interactions among agents framed in terms of relational autonomy, in an economic order enacted by those very same economic agents. That markets are cognitive institutions enabling and constraining economic reasoning also leads to the possibility of specific types of economic reasoning processes.

A market is not just a mechanism, a structure, or a narrowly-conceived institution; it's a social institution, and it emerges as such because it involves intersubjective interactions embedded in social and cultural practices. In an extended-mind model of scaffolded choice, at least in some cases, rather than "beliefs, desires, or other psychological features of individuals involved," what counts are the external structures that constrain and enable economic agents' behavior (Clark, 1997b, p. 272; see also Denzau and North, 1994). Taking this one step further, on the model of a *socially* extended mind (Gallagher, 2013) the constraints imposed by social interactions, as well as the possibilities enabled by such interactions, are such that *economic reasoning* is never just an individual process carried out by an autonomous individual, classically understood. Such considerations change

[5]For a different sort of epistemic problem solved by markets consider the case of so-called "prediction market," i.e., market used to reliably predict future events (e.g., Wolfers and Zitzewitz, 2004).

the theoretical notion of market from a mere economic mechanism able to solve allocation and coordination problems of collectivity (in specific circumstances, better than alternative mechanisms) to an enactive cognitive institution. Considering the perspective of the agents involved, the market as *cognitive institution* is like Clark's extended mind notion of scaffolded cognition insofar as it (i) extends the participants' cognitive processes of economic reasoning, and (ii) both constrains and enables the actions and interactions of embodied and embedded agents in the economy. The enactive notion of cognitive institution involves something more, however.

To see this, consider Slors' (2019) recent clarification of the difference between an extended-mind conception of institution as a causal-functional unit, and the enactive model of socially extended cognition, i.e., the idea of a mental or cognitive institution. Slors defines cognitive institutions, following Gallagher (2013, p. 6): "not only as institutions with which we accomplish certain cognitive processes, but also... without [which] such cognitive processes would no longer exist." Socially extended cognition is constituted in a specific form of dynamical engagement with the world, one that involves reciprocal causality.[6] Simply put, an institution is formed by cognitive (e.g., problem solving) practices that involve multiple interacting agents pursuing multiple interrelated tasks, and reciprocally, such interactions are shaped by instituted (normative) practices that extend our cognitive processes when we engage with them (that is, when we interact with, or are enactively coupled to them in the right way).

This includes, as an example, the legal system, which "enables an array of thoughts and actions that are unintelligible without the concepts and procedural social routines associated with the law" (Slors, 2019, p. 5). The practice of law is constituted by just such cognitive and communicative processes carried out in the cooperative activities of many agents relying on conventional cognitive schemas and rules of evidence provided by the legal institution itself. Reasoned judgments made in such contexts, specified as *legal* judgments precisely because they are made in such contexts, are forms of cognition that depend on the large and complex system without which they could not happen. For example, in the case of a highly trained attorney who may be engaged in a process of legal reasoning, what makes this kind of cognition what it is depends not only on the fact that she was trained within a related institutional system (i.e., in the specific practices of law school), but also on the continued workings of the legal system. Indeed, some tasks would never even arise if it were not for the legal system.

Slors contrasts the extended-mind conception of institution, which, as we saw in the previous section, is based on the idea of functional integration, with what he calls a "symbiotic" arrangement. He argues that in contrast to Clark's concept of institution (derived from Denzau and North, 1994) – understood as an external mechanism that structures and orders the individual's environment so as to scaffold cognition – the symbiotic cognition model is a better way to think about socially extended cognitive institutions. A cognitive institution is different, in principle, from the pencil and paper that I might use to solve a math problem. Specifically, Slors defines the notion of symbiotic cognition in terms of "task dependency."

> "Task dependency" is the extent to which the intelligibility of a task depends on a larger whole of coordinated tasks. Task dependency is a notion that is connected with coordination and planning. It is a normative notion in the sense that high task dependency means that tasks play specific roles in the overall organization of a cognitive system or a cultural cognitive ecosystem; roles that can be played properly or improperly (Slors, 2019, p. 18).

For example, the legal system is characterized by high task dependency since judge, prosecutor, defense attorney, clerk, and other officials are inter-defined in a holistic way, such that what an attorney does is understandable only by referring to what judges and prosecutors do. As Slors suggests, this means that there is a division of labor in a symbiotic system.

> Division of labor involves a specific type of offloading, one which is typical for symbiotic cognition but not for extended [mind]. Every participant in a symbiotic system profits from whatever the system as a whole offers (education, justice, social coordination) while contributing only a small part. The tasks, jobs and roles of others in the system co-define and enable one's own task, but one does *not* have to perform them or even think about them, while nevertheless benefiting from the overall outcome of the system (Slors, 2019, p. 30).

In regard to the concept of market, we suggest that on a symbiotic model one would have to think about market dynamics in more complex terms than simply supply side and demand side.[7] On the symbiotic view, the market is a "marketplace" (as Callon, 1998 specifically defines it) – that is, a real set of human interrelationships embedded in a workspace of different tasks – government regulator or planner, corporation, manufacturing unit, information (or other service) provider, marketer, wholesaler, retail agent, purchaser, consumer (household), and any number of economic roles in between these categories. Each task category may be defined not simply by economic principles, but by non-economic norms and practices, and by less formal and imperfect social interactions that may involve a variety of biases. Different task-players are dynamically related in a gestalt arrangement such that an intervention (above a certain threshold) on one node or element in the system will lead to modulations in other nodes or elements, or in the whole (Gallagher, 2018b).

The concept of symbiotic arrangements clearly characterizes some forms of cognitive institutions, but we note that, as Slors acknowledges, the contrast between functional integration and task dependency is a matter of degree. He suggests that the

[6] The notion of constitution at stake in this concept of socially extended cognition is not simply, as Slors suggests, the notion of a synchronic compositional constitution, as one finds in the new mechanist literature (e.g., Craver, 2007), but also involves a diachronic dynamical constitution understood to involve reciprocal causal relations. Acknowledging the concept of dynamical constitution is a way to avoid one of the major objections to the extended mind idea – the idea that extended and enactive models commit a causal/coupling-constitution fallacy (Adams and Aizawa, 2008; Aizawa, 2010, Aizawa, 2014, and Gallagher, 2018b).

[7] This is what economic sociologists typically do (e.g., Burt, 1992; Fligstein, 2001).

legal system is characterized by high task dependency and low functional integration, and he then (perhaps too quickly) generalizes this to apply to all cognitive institutions in contrast to extended mind models (high functional integration; low task dependency), and models of distributed cognition (high functional integration; high task dependency). We think the issue is more complex and that the distinction between "low" and "high" functional integration and task dependency is probably too coarse-grained; rather, cognitive institutions vary in degree between task dependency and functional integration depending on where one is looking in the system, or from what perspective one examines the system.[8] For example, in the legal system, from a systems perspective one sees high task dependency, whereas from the perspective of the individual agent who engages with the system, one finds a significant degree of functional integration. An attorney, for example, has to make the system work by doing certain things that require material engagement with papers, law books, courtrooms, and many other people. What she does may be defined in terms of specific tasks, but those tasks are accomplished only by engaging with instruments and people, and often in flexible and creative ways. Contracts and written (official) documents are instrumentally functional and, at the same time, they are "pieces" of the legal structure that in some cases predefine or scaffold the roles of individuals. That is, at the same time, they are, from the individual's perspective, functionally instrumental for extending legal reasoning and, from the systems perspective, constitutive parts of the legal structure.[9]

We propose that more generally a cognitive institution always involves varying degrees of task dependency and functional integration. A market system is a good example of a cognitive institution in this regard. A market is symbiotic, not in Slors' sense, where the level of functional integration is low, but in the sense that there is always a co-dependency between the actions and social interactions of individual agents and the market institution. Buying or not buying a good in the market is, from an interactive point of view, something that enacts the market. In this respect, the level of functional integration is high. Engaging in "epistemic actions" (biding or selling items on the market) enacts the market such that the market would not be there without these actions. At the same time, the market, as a cognitive institution is not only an institution that supports or scaffolds specific acts of economic reasoning; it is also such that without it "such cognitive processes would no longer exist" (Gallagher, 2013, p. 3). From this perspective, markets and price mechanisms are more than extended processes that scaffold economic reasoning about the scarcity of goods. They are institutions for *enacting* economic, task-dependent relations, as social interactions, which themselves become the object (or subject-matter) of economic reasoning, *which would not exist – as we know it – without markets*.

Specifically, we contend, there are reciprocal relations, symbiotic interactions involved in the cognitive institution, characterized by degrees of both functional integration and task dependency. The judge not only extends his cognitive processes by engaging with the legal system through, or facilitated by, a set of intersubjective interactions; in addition, it's precisely by the judge's engagement (and many other such engagements) that the legal system is enacted. Just so, the individual economic agent extends his reasoning by engaging with the market through, or facilitated by,[10] a set of intersubjective interactions, thereby epistemically benefiting from the market process; and reciprocally it is precisely by that engagement (and many other such engagements) that the market is enacted.

The efficiencies and inefficiencies, as well as degrees of trust and mistrust (to make room for what Clark (1997a, p. 276) calls "individual psychological profiles," without putting them entirely back in the head) present in the market are anchored in the specific types of social interactions that a market makes possible. It's true, as Denzau and North (1994) point out, that gains from trade and productive coordination in a market economy are based on the existence of some degree of trust: "The morality of a business person is a crucial intangible asset of a market economy, and its non-existence substantially raises transaction costs" (Denzau and North, 1994, p. 20). Trust, however, to whatever degree, is not the product of shared mental models, as they suggest; it's a product of and varies with different types of intersubjective interactions; it gets cashed out in the meaning that emerges from and transcends any individual's actions or thoughts as it gets instituted (De Jaegher et al., 2010).

The trust that is characteristic, for instance, of impersonal (typically electronic) forms of financial markets is not equivalent to forms of intersubjective trust that may characterize hierarchical or clan societies. In impersonal (e.g., anonymous) markets, economic reasoning, and appropriate degrees of trust, are enabled by the fact that individual decisions may sometimes be "cold" and calculative since an interaction with other economic agents may be "living" only in the immediate transaction, through which a mutual benefit is reached and after which all obligations are extinguished. Price mechanisms allow an efficient allocation so that before and after the transaction all

[8] We take the distinction between task-dependency and functional integration to reflect different kinds of coupling. Task-dependency involves structural coupling (an agent engages with the system by performing a certain type of task or occupying a certain place in the system); functional integration is causal (or dynamical, reciprocally causal) coupling. One can characterize different cognitive systems (or institutions) as involving different combinations of these kinds of coupling.

[9] Slors further points out that in a symbiotic system the interaction that constitutes a cognitive institution "is facilitated by a physical infrastructure and specific physical artifacts." Although this is clearly an aspect that fits with conceptions of extended minds and markets, we note that material engagement theory (Malafouris, 2013) leads to a stronger claim based on enactivist principles: markets are constituted by material engagements which in turn, and over time, shape the rationality and agency of market participants and create meanings that go beyond economic significance. This involves not only engagement with commodities – goods or services that depend on production or exchange facilities, infrastructure, transport and communication equipment, as well as advanced technology processes – but also a range of embodied or virtual intersubjective interactions that characterize any institution. There is much more to say on this point, but to pursue it would lead beyond the scope of this paper.

[10] That the engagement is "facilitated by" a set of intersubjective interactions is a way of expressing the idea that even in cases of anonymous activity where there is no occurrent intersubjective interactions (as, e.g., in regulated financial markets or in computer-run algorithmic trading) the anonymous processes are ultimately grounded in previous intersubjective interactions.

information is exploited and balance is immediate. Of course, we are not arguing that this is the case of any market (many real-world markets require the building of long-term relationships, see Ben-Ner and Van Hoomissen, 1991), but that some markets are specifically appreciated for their frugality and impersonality. In other forms of institution (such as hierarchies or clans) the obligations between parties typically persist in the long-term. Accordingly, the single transaction in itself is not necessarily fair. In the case of a clan, the relational dynamics involved are something like "I do something for you today, and you will do something for me in the future;" in the case of hierarchies: "you work hard now but in the future you will be promoted to manager." Balance is postponed. Economic reasoning varies across these different institutions precisely because interactions and trust relations vary.

CRITICAL IMPLICATIONS: THE REIFICATION OF RELATIONAL POTENTIAL

Adam Smith's works *The Theory of Moral Sentiments* (Smith, 1759) and *The Wealth of Nations* (Smith, 1776) represent two significant contributions to understanding the origins of markets and their institutionalization. While in the first work Smith emphasizes the importance of "sympathetic" interaction for the development of morality, in the second he emphasizes the importance of self-interest and the calculative attitude as requisite features for a proper functioning of market economies. The intrinsic unity of the two contributions has hardly been acknowledged by neoclassical economics (see Bruni and Zamagni, 2007, Chapter 5), so much so that it has usually been easier to postulate the existence of two different Smiths (Smith, 1998). What results as problematic from the partial reading of Smith's opera is a notion of autonomy, understood in terms of self-sufficiency, self-legislation, or self-determination, which has colonized economics in general (Nelson, 2006), and the economics of market in particular (Zak, 2008; Sandel, 2013), through the notion of *homo oeconomicus.* This situation does not particularly change if we add more modern readings of Smith's work, which for instance identify Smith as a father of behavioral economics (Ashraf et al., 2005).

An alternative concept of *relational autonomy* is based on the idea that autonomy is actualized in social interactions that involve varying and imperfect degrees of mutual recognition (Mackenzie and Stoljar, 2000; Honneth, 2008; Gallagher, 2017). On an enactivist view of social interaction there is always a balanced and partial trade-off between the autonomy of the individual embodied agent and the autonomy of the process of social interaction itself (De Jaegher et al., 2010). Interaction requires the preservation of some degree of individual autonomy, but that makes one's autonomy relative to other agents and to the nature of specific interactions. Autonomous actions are thus embodied and situated in a world that is physical and social. This interpretation correlates with a more enactive view of economic reasoning that understands the market participant in terms of social interactive processes, and an autonomy that is by degree and that exists for the individual agent only because she is socially situated. Economic reasoning, understood in terms of relational autonomy, is always (to varying degrees) embodied,[11] embedded in material engagements, and scaffolded by intersubjective interactions. By contrast, the relational dimension is so much absent in neoclassical economics that, in economic modeling, it is often sufficient to assume the existence of a "representative agent" to stand in for the collectivity (Kirman, 1992).

But markets can be a double-edged sword. A market operating as a cognitive institution – enabling and constraining economic reasoning – can easily reflect an ideology. Market ideology is probably a byproduct of markets as cognitive institutions. There are reasons to think that markets – and in particular electronic financial markets, which can be viewed as market forms engineered to facilitate impersonal coordination – in some cases undermine recognition and relational autonomy, by imposing a form of "avatar recognition," a reification in which one's self and others are reduced to merely rational/calculative agents. Reification "means a forgetting of the primal recognition that two humans accord each other in a fundamental process of intersubjective interactions" (Jay, 2008, p. 8; see Honneth, 2008). In other words, reification is the opposite of autonomy.

Reification and the denial of autonomy, are real phenomena at the political level of nations and subnational groups, but they can be just as real in our everyday lives, in our relations with others, as well as in the externally imposed bureaucratic, administrative, and institutional pathologies that Honneth points to as involving "cold" and "calculating compliance" (Honneth, 2008, p. 17). Reified and pre-packaged ways of interacting lack dynamic spontaneity, impose a mechanistic order, and can undermine the autonomous processes implicit in genuine forms of interaction. It is important to note, in this regard, how reification can be even counterproductive with respect to economic principles themselves. Bowles (2016) makes a compelling case that market design and incentive-based policies are not the "substitute of good citizens." As Adam Smith acknowledged, non-strictly-economic values are needed to make a market really function (see also Zak, 2008). When the neoclassical notion of economic rationality is detached from more basic social interactions, it becomes a self-fulfilling prophecy (see Denzau and North, 1994; Ferraro et al., 2005), in so far as markets can be engineered in view of programmatically fostering and selecting that sort of rationality. In other words, markets can be said to be "performed" by economic theory, which would shape markets in its own image by imprinting in them its own notion of rationality (Callon, 1998; MacKenzie, 2006).[12] Markets are ways in which we can reasonably understand and predict others' behaviors within our human interactions; at the same time, the fact that we can do this

[11]For economic reasoning as a form of embodied rationality see Mastrogiorgio and Petracca (2016); also Gallagher (2018a); for traditional forms of rationality in economics see, e.g., Blume and Easley (2008).

[12]Similar criticism has been made about the large (and often reductionist) claims about human nature sometimes made by neuroscience, and especially popular media coverage of neuroscientific discoveries, namely that we all start to think of ourselves in those reductionist terms. See, e.g., Choudhury and Slaby (2012) and Slaby (2010).

means that often the relational potential is sometimes reified to calculative purposefulness.

Honneth (2008, p. 24) describes a change of perspective from empathic/sympathetic engagement to detached observation. The latter tends toward a reification of others and can be found in attitudes that commodify relationships and interaction (e.g., Summerville and Chartier, 2013). Reification and commodification can even become, as it has been observed in particular by Marxist theorists with special reference to the large mechanisms of capitalism, a social practice strategically relevant to social struggle (Postone, 1993). Honneth (2008, p. 28) however, suggests that the detached, observational relation may in fact be a necessary strategic stance required in developed societies to deal with some aspects of the business of everyday life. This kind of detached stance may have a "perfectly legitimate place" in some situations. How legitimate market detachment is also crucially depends on the object of the transaction [think of markets for organs from living donors (e.g., Rippon, 2014), which could be viewed as a patent example of reification (see Satz, 2010)]. Still, we can ask to what extent a market structure, intended as the set of market features that enable/constrain market participants, contributes to such detached attitudes and reductions in relational autonomy. That is, in studying the way that markets work, we can recognize the variability of market institutions in terms of how they affect intersubjective recognition and autonomy, thereby giving us a way to ask critical questions about how they might be adjusted or transformed with a view to reducing reification, increasing autonomy, and addressing institutionally generated distortions in intersubjective interactions.

CONCLUSION

An important part of what it means for agents to be situated in the everyday world of human affairs includes their engagement with economic practices. Traditional economic theory views the market as a set of mechanisms for exchange and allocation or coordination. Such conceptions focus more on the *structure* of markets and how information is processed by market structure in ways that may facilitate the deployment of a set of mental models and behaviors by the individual participant. This leads to the specific idea of market institution as external mechanism that orders or structures rational decisions and human relations. These ideas are taken up by Clark and framed in terms of the extended mind hypothesis. In this case, the market is understood as scaffolding economic reasoning *via* strong constraints that direct agents' behaviors in predictable ways. Markets produce a "cognitive economy" by reducing individual cognitive effort thereby steering individuals' decisions and actions.

We've argued that a market understood as an institution is not just a mechanism, or an external structure narrowly conceived; rather, it's a social institution that emerges as such from intersubjective interactions in social and cultural practices. On this view, it not only extends the participant's economic reasoning processes, constraining and enabling the actions and interactions of embodied and situated agents in the economy, but as a cognitive institution it is enacted in just these processes and is characterized by varying degrees of both task dependency and functional integration.

An enactive perspective on the market as a socially extended cognitive institution offers a picture of the economic interactions of individuals framed in terms of relational autonomy, in an economic order enacted by those very same economic agents. That markets are cognitive institutions enabling and constraining economic reasoning also leads to the possibility of specific types of economic reasoning processes, characterized in some cases by calculative purposefulness. Speculatively, this latter form of economic reasoning can be considered a "materialization" of Weber's ideal-type of "*Zweckrationalität*" or instrumental rationality. In the extreme it can lead to distorted social interactions. This is clearly recognized by critical theorists when they inquire about how institutions shape both our cognitive processes and our interpersonal interactions (Honneth, 2012; Gallagher, in press). An understanding of real-world markets as socially extended cognitive institutions helps us to see that designing and performing markets in ways that might counter distorting modes of rationality are not simply about changing external structures, but can have an effect on the individual (relational) autonomy involved in everyday situated practices.

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Language, Gesture, and Emotional Communication: An Embodied View of Social Interaction

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Spoken language is an innate ability of the human being and represents the most widespread mode of social communication. The ability to share concepts, intentions and feelings, and also to respond to what others are feeling/saying is crucial during social interactions. A growing body of evidence suggests that language evolved from manual gestures, gradually incorporating motor acts with vocal elements. In this evolutionary context, the human mirror mechanism (MM) would permit the passage from "doing something" to "communicating it to someone else." In this perspective, the MM would mediate semantic processes being involved in both the execution and in the understanding of messages expressed by words or gestures. Thus, the recognition of action related words would activate somatosensory regions, reflecting the semantic grounding of these symbols in action information. Here, the role of the sensorimotor cortex and in general of the human MM on both language perception and understanding is addressed, focusing on recent studies on the integration between symbolic gestures and speech. We conclude documenting some evidence about MM in coding also the emotional aspects conveyed by manual, facial and body signals during communication, and how they act in concert with language to modulate other's message comprehension and behavior, in line with an "embodied" and integrated view of social interaction.

Keywords: gesture, language, embodied cognition, mirror neurons, emotional communication, abstract concepts, motor resonance, social interaction

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INTRODUCTION

In the last years, the hypothesis of language as "embodied" in sensory and motor experience has been widely discussed in the field cognitive neuroscience.

In this review, we will firstly discuss recent behavioral and neurophysiological studies confirming the essential role of sensorimotor brain areas in language processing, facing the controversial issues and reviewing recent results that suggest an extended view of embodied theories.

We will discuss this hypothesis, providing evidences about the gestural origin of language, focusing on studies investigating the functional relation between manual gesture and speech and the neural circuits involved in their processing and production.

Finally, we will report evidences about the functional role of manual and facial gestures as communicative signals that, in concert with language, express emotional messages in the extended context of social interaction.

All these points provide evidences in favor of an integrated body/verbal communication system mediated by the mirror mechanism (MM).

WHAT IS EMBODIED ABOUT COMMUNICATION? THE INVOLVEMENT OF MIRROR MECHANISM IN LANGUAGE PROCESSING

It is well known that our thoughts are verbally expressed by symbols that have little or no physical relationship with objects, actions and feelings to which they refer. Knowing how linguistic symbols may have been associated with aspects of the real world represents one of the thorniest issues about the study of language and its evolution. In cognitive psychology, a classic debate has concerned how language is stored and recovered in the human brain.

According to the classical "amodal approach," the concepts are expressed in a symbolic format (Fodor, 1998; Mahon and Caramazza, 2009). The core assumption is that meanings of words are like a formal language, composed of arbitrary symbols, which represent aspects of the word (Chomsky, 1980; Kintsch, 1998; Fodor, 2000); to understand a sentence, words are led back symbols that represent their meaning. In other terms, there would be an arbitrary relationship between the word and its referent (Fodor, 1975, 2000; Pinker, 1994; Burgess and Lund, 1997; Kintsch, 1998). Neuropsychological studies provide interesting evidence for the amodal nature of concept. In Semantic Dementia, for example, a brain damage in the temporal and adjacent areas results in an impairment of conceptual processing (Patterson et al., 2007). A characteristic of this form of dementia is the degeneration of the anterior temporal lobe (ATL) that several imaging studies have highlighted to have a critical role in amodal conceptual representations (for a meta-analysis, see Visser et al., 2010).

In contrast, the embodied approaches to language propose that conceptual knowledge is grounded in body experience and in the sensorimotor systems (Gallese and Lakoff, 2005; Barsalou, 2008; Casile, 2012) that are involved in forming and retrieving semantic knowledge (Kiefer and Pulvermüller, 2012). These theories are supported by the discovery of mirror neurons (MNs), identified in the ventral pre-motor area (F5) of the macaque (Gallese et al., 1996; Rizzolatti et al., 2014). MNs would be at the basis of both action comprehension and language understanding, constituting the neural substrate from which more sophisticated forms of communication evolved (Rizzolatti and Arbib, 1998; Corballis, 2010). The MM is based on the process of motor resonance, which mediates action comprehension: when we observe someone performing an action, the visual input of the observed motor act reaches and activates the same fronto-parietal networks recruited during the execution of the same action (Nelissen et al., 2011), permitting a direct access to the own motor representation. This mechanism was hypothesized to be extended to language comprehension, namely when we listen a word or a sentence related to an action (e.g., "grasping an apple"), allowing an automatic access to action/word semantics (Glenberg and Kaschak, 2002; Pulvermüller, 2005; Fischer and Zwaan, 2008; Innocenti et al., 2014; Vukovic et al., 2017; Courson et al., 2018; Dalla Volta et al., 2018). This means that we comprehend words referring to concrete objects or actions directly accessing to their meaning through our sensorimotor experience (Barsalou, 2008).

The sensorimotor activation in response to language processing was demonstrated by a large amount of neurophysiological studies. Functional magnetic resonance imaging (fMRI) studies demonstrated that seeing action verbs activated similar motor and premotor areas as when the participants actually move the effector associated with these verbs (Buccino et al., 2001; Hauk et al., 2004). This "somatotopy" is one of the major argument supporting the idea that concrete concepts are grounded in action–perception systems of the brain (Pulvermüller, 2005; Barsalou, 2008). Transcranial magnetic stimulation (TMS) results confirmed the somatotopy in human primary motor cortex (M1) demonstrating that the stimulation of the arms or legs M1 regions facilitated the recognition of action verbs involving movement of the respective extremities (Pulvermüller, 2005; Innocenti et al., 2014).

However, one of the major criticism to the embodied theory is the idea that motor system plays an epiphenomenal role during language processing (Mahon and Caramazza, 2008). In this view, the activations of motor system are not necessary to language understanding but they are the result of a cascade of spreading activations caused by the amodal semantic representation, or a consequence of explicit perceptual or motor imagery induced by the semantic tasks.

To address this point, further neurophysiological studies using time-resolved techniques such as high-density electro-encephalography (EEG) or magnetoencefalography (MEG) indicated that the motor system is involved in an early time window corresponding to lexical-semantic access (Pulvermüller, 2005; Hauk et al., 2008; Dalla Volta et al., 2014; Mollo et al., 2016), supporting a causal relationship between motor cortex activation and action verb comprehension. Interestingly, recent evidences (Dalla Volta et al., 2018; García et al., 2019) has dissociated the contribution of motor system during early semantic access from the activation of lateral temporal-occipital areas in deeper semantic processing (e.g., categorization tasks) and multimodal reactivation.

Another outstanding question is raised by the controversial data about the processing of non-action language (i.e., "abstract" concepts). According to the Dual Coding Theory (Paivio, 1991), concrete words are represented in both linguistic and sensorimotor-based systems, while abstract words would be represented only in the linguistic one. Neuroimaging studies support this idea showing that the processing of abstract words is associated with higher activations in the left IFG and the superior temporal cortex (Binder et al., 2005, 2009; Wang et al., 2010), areas commonly involved in linguistic processing. The Context Availability Hypothesis instead argues that abstract concepts have increased contextual ambiguity compared to concrete concepts (Schwanenflugel et al., 1988). While concrete words would have direct relations with the objects or actions they refer to, abstract words can present multiple meanings and they needed more time to be understood (Dalla Volta et al., 2014, 2018; Buccino et al., 2019). This assumes that, they can be disambiguated if inserted in a "concrete context" which provides elements to narrow their meanings (Glenberg et al., 2008; Boulenger et al., 2009; Scorolli et al., 2011, 2012; Sakreida et al., 2013). Researches on action metaphors (e.g., "grasp an idea") that are involved in both action and thinking, found an engagement of sensory-motor systems even when action language is figurative (Boulenger et al., 2009, 2012; Cuccio et al., 2014). Nevertheless, some studies observe motor activation only for literal, but not idiomatic sentences (Aziz-Zadeh et al., 2006; Raposo et al., 2009).

In a recent TMS study, De Marco et al. (2018) tested the effect of context in modulating motor cortex excitability during abstract words semantic processing. The presentation of a congruent manual symbolic gesture as prime stimulus increased hand M1 excitability in the earlier phase of semantic processing and speeded word comprehension. These results confirmed that the semantic access to abstract concepts may be mediated by sensorimotor areas when the latter are grounded in a familiar motor context.

GESTURES: A BRIDGE BETWEEN LANGUAGE AND ACTION

One of the major contribution in support of embodied cognition theory derived from the hypothesis of the motor origin of spoken language. Comparative neuroanatomical and neurophysiological studies sustain that F5 area in macaques is cytoarchitectonically comparable to Brodmann area 44 in the human brain (IFG), which is part of Broca's area (Petrides et al., 2005, 2012). This area would be active not only in human action observation but also in language understanding (Fadiga et al., 1995, 2005; Pulvermüller et al., 2003), transforming heard phonemes in the corresponding motor representations of the same sound (Fadiga et al., 2002; Gentilucci et al., 2006). In this way, similarly to what happen during action comprehension, the MM would directly link the sender and the receiver of a message (manual or vocal) in a communicative context. For this reason, it was hypothesized to be the ancestor system favoring the evolution of language (Rizzolatti and Arbib, 1998).

Gentilucci and Corballis (2006) showed numerous empirical evidence that support the importance of the motor system in the origin of language. Specifically, the execution/observation of a grasp with the hand would activate a command to grasp with the mouth and vice-versa (Gentilucci et al., 2001, 2004, 2012; Gentilucci, 2003; De Stefani et al., 2013a). On the basis of these results the authors proposed that language evolved from arm postures that were progressively integrated with mouth articulation postures by mean of a double hand–mouth command system (Gentilucci and Corballis, 2006). At some point of the evolutionary development the simple vocalizations and gestures inherited from our primate ancestors gave origin to a sophisticated system of language for interacting with others conspecifics (Rizzolatti and Arbib, 1998; Arbib, 2003, 2005; Gentilucci and Corballis, 2006; Armstrong and Wilcox, 2007; Fogassi and Ferrari, 2007; Corballis, 2010), where manual postures became associated to sounds.

Nowadays, during a face-to-face conversation, spoken language and communicative motor acts operate together in a synchronized way. The majority of gestures are produced in association with speech: in this way the message assumes a specific meaning. Nevertheless, a particular type of gesture, the symbolic gesture (i.e., OK or STOP), can be delivered in utter silence because it replaces the formalized, linguistic component of the expression present in speech (Kendon, 1982, 1988, 2004). A process of conventionalization (Burling, 1999) is responsible for transforming meaningless hand movements that accompany verbal communication (i.e., gesticulations, McNeill, 1992) into symbolic gestures, as well as string of letters may be transformed into a meaningful word. Symbolic gestures therefore represent the conjunction point between manual actions and spoken language (Andric and Small, 2012; Andric et al., 2013). This leads to a great interest around the study of the interaction between symbolic gestures and speech, with the aim to shed light to the complex question about the role of the sensory-motor system in language comprehension.

A large amount of researches have claimed that, during language production and comprehension, gesture and spoken language are tightly connected (Gunter and Bach, 2004; Bernardis and Gentilucci, 2006; Gentilucci et al., 2006; Gentilucci and Dalla Volta, 2008; Campione et al., 2014; De Marco et al., 2015, 2018), suggesting that the neural systems for language understanding and action production are closely interactive (Andric et al., 2013).

In line with the embodiment view of language, *the theory of integrated communication systems* (McNeill, 1992, 2000; Kita, 2000) is centered on the idea that gestures and spoken language comprehension and production are managed by a unique control system. Thus, gestures and spoken language are both represented in the motor domain and they necessarily interact with each other during their processing and production.

At the opposite, the *theory of independent communication systems* (Krauss and Hadar, 1999; Barrett et al., 2005) claims that gestures and speech can work separately and are not necessarily integrated each other. Communication with gestures is described as an auxiliary system, evolved in parallel to language, that can be used when the primary system (language) is difficult to use or not intact. In this view, gesture-speech interplay is regarded as a semantic integration of amodal representations, taking place only after processing of the verbal and gestural messages have occurred separately. This hypothesis is primary supported by neuropsychological cases which reported that abnormal skilled learned purposive movements (limb apraxia) and language disorders (aphasia) are anatomically and functionally dissociable (Kertesz et al., 1984; Papagno et al., 1993; Heilman and Rothi, 2003). However, limb apraxia often co-occuring with Broca's Aphasia (Albert et al., 2013) and difficulty in gesture-speech semantic integration was reported in aphasic patients (Cocks et al., 2009, 2018). Alongside clinical data, disrupting the activity in both left IFG and middle temporal gyrus (MTG) is found to impair gesture-speech integration (Zhao et al., 2018).

Evidence in favor of the integrated system theory came from a series of behavioral and neurophysiological studies that have investigated the functional relationship between gestures and spoken language. The first evidence of the reciprocal influence of gestures and words during their production came from the study by Bernardis and Gentilucci (2006), who showed how the vocal spectra measured during the pronunciation of one word (i.e., “hello”) was modified by the simultaneous production of the corresponding in meaning gesture (and vice-versa, the kinematics resulted inhibited). This interaction was found depending on the semantic relationship conveyed by the two stimuli (Barbieri et al., 2009), and was replicated even when gestures and words were simply observed or presented in succession (Vainiger et al., 2014; De Marco et al., 2015).

Neurophysiological studies showed controversial evidences about the core brain areas involved in gestures and words integration, that include different neural substrates as M1 (De Marco et al., 2015, 2018) IFG, MTG and superior temporal gyrus/sulcus (STG/S) (Willems and Hagoort, 2007; Straube et al., 2012; Dick et al., 2014; Özyürek, 2014; Fabbri-Destro et al., 2015). However, IFG virtual lesion showed to disrupt gesture-speech integration effect (Gentilucci et al., 2006), in accordance with the idea of human Broca’s area (and so the mirror circuit) as the core neural substrate of action, gesture and language processing and interplay (Arbib, 2005). Partially in contrast, investigation of temporal dynamics of the integration processing by mean of combined EEG/fMRI techniques confirmed the activation of a left fronto-posterior-temporal network, but revealed a primary involvement of temporal areas (He et al., 2018).

Finally, further results in favor of motor origin of language came from genetic research, since it was suggested that FOXP2 gene was involved both in verbal language production and upper limb movements coordination (Teramitsu et al., 2004) opening the question about a possible molecular substrate linking speech with gesture (see Vicario, 2013).

In conclusion, a good amount of results evidenced a reciprocal influence between gesture and speech during their comprehension and production, showing overlapping activation of the MM neural systems (IFG) involved in action, gesture and language processing and interplay (see **Table 1**). Further studies should consider potential integration of neuroscience research with promising fields investigating the issue at molecular level.

TABLE 1 | Summary of main concepts, neural evidence, and future challenges about the theories explaining language semantic processing and evolution.

	Semantic processing	
	Embodied theory	**Amodal/Symbolic theory**
Main concepts	Conceptual knowledge is grounded in body experience and in the sensorimotor systems	Semantic concepts are stored and processed as formal symbols
Neural systems	Primary motor and sensory systems, Fronto-Parietal Mirror Circuit	Temporal cortex (Anterior Temporal Lobe, Middle Temporal Gyrus)
Main references	Gallese and Lakoff, 2005; Barsalou, 2008; Casile, 2012; Kiefer and Pulvermüller, 2012	Fodor, 1998; Patterson et al., 2007; Mahon and Caramazza, 2009; Visser et al., 2010
Challenges	No shared model about the dynamic and interplay between sensorimotor and temporal brain areas at different stages of semantic comprehension Necessity to further support the essential contribute of sensorimotor system in abstract language processing	
	Language evolution	
	Gestural origin of Language	**Independent evolution of gestures and language**
Main concepts	Speech evolved from arm postures that were progressively integrated with mouth gestures and vocalization by mean of a double hand–mouth command system. Gesture and speech necessarily interact during their processing and production	Gestures and speech evolved independently. They are functionally dissociated and processed separately, or eventually integrated as amodal concepts). Communication with gestures is described as an auxiliary system
Neural systems	Inferior Frontal Gyrus	Sensorimotor systems for gestures, temporal cortex for language
Main references	McNeill, 1992; Rizzolatti and Arbib, 1998; Gentilucci and Corballis, 2006; Gentilucci et al., 2006	Krauss and Hadar, 1999; Barrett et al., 2005
Challenges	Overlapping activation of areas belonging to mirror circuit (IFG) and linguistic areas (MTG) during gesture and speech processing Limited evidence about neural dynamic of gesture and speech interplay Potential fields of research (i.e., FOXP2 genes variations and communication behavior)	

MOTOR SIGNS IN EMOTIONAL COMMUNICATION

The majority of studies that investigated the neural mechanism of hand gesture processing focused on the overlapping activations of words and gestures during their semantic comprehension and integration. However, it was shown that, gestural stimuli can convey more than semantic information, since they can also express emotional message. A first example came from the study of Shaver et al. (1987) which tried to identify behavioral prototype related to emotions (e.g., fist clenching is involved in the anger prototype). More recently, Givens (2008) showed that uplifted palms postures suggest a vulnerable or non-aggressive pose toward a conspecific.

However, beyond hand gestures investigations, emerging research about the role of motor system in emotion perception dealt with the study of mechanisms underlying body postures and facial gestures perception (De Gelder, 2006; Niedenthal, 2007; Halberstadt et al., 2009; Calbi et al., 2017). Of note, specific connections with limbic circuit were found for mouth MNs (Ferrari et al., 2017), evidencing the existence of a distinct pathway linked to the mouth/face motor control and communication/emotions encoding system. These neural evidences are in favor of a role of MM in the evolution and processing of emotional communication through the mouth/facial postures. As actions, gestures and language become messages that are understood by an observer without any cognitive mediation, the observation of a facial expression (such as disgust) would be immediately understood because it evokes the same representation in the insula of the individual observing it (Wicker et al., 2003).

We propose that MM guides every-day interactions in recognizing emotional states in others, decoding body and non-verbal signals together with language, influencing and integrating the communicative content in the complexity of a social interaction.

Indeed, the exposure to congruent facial expressions was found to affect the recognition of hand gestures (Vicario and Newman, 2013), as the observation of facial gesture interferes with the production of a mouth posture involving the same muscles (Tramacere et al., 2018).

Moreover, emotional speech (prosody), facial expressions and hand postures were found to directly influence motor behavior during social interactions (Innocenti et al., 2012; De Stefani et al., 2013b, 2016; Di Cesare et al., 2017).

CONCLUSION AND FUTURE DIRECTIONS

Numerous behavioral and neurophysiological evidences are in favor of a crucial role of MM in language origin, as in decoding semantic and emotional aspects of communication.

However, some aspects need to be further investigated, and controversial results were found about the neural systems involved in semantics processing (especially for abstract language).

Nevertheless, a limitation emerges about experimental protocols which studied language in isolation, without considering the complexity of social communication. In other words, language should be considered always in relation to some backgrounds of a person mood, emotions, actions and events from which the things we are saying derive their meanings. Future studies should adopt a more ecological approach implementing research protocols that study language in association to congruent or incongruent non-verbal signals.

This will shed further light onto the differential roles that brain areas play and their domain specificity in understanding language and non-verbal signals as multiple channels of communication.

Furthermore, future research should consider to integrate behavioral and combined neurophysiological technique extending the sampling from typical to psychiatric population.

Indeed, new results will have also important implications for the comprehension of mental illness that were characterized by communication disorders and MM dysfunction as Autism Spectrum Disorder (Oberman et al., 2008; Gizzonio et al., 2015), schizophrenia (Sestito et al., 2013), and mood disorders (Yuan and Hoff, 2008).

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The Role of Social Power in Neural Responses to Others' Pain

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Recent evidence has demonstrated that empathic responses are modulated by social power. However, there is little consensus regarding how an observer's social power can shape empathic responses. The present study used event-related potentials (ERPs) to explore the role of social power in empathic responses. Specifically, to induce the sense of power, we asked participants to recall a past situation in which they were in a position of power (high power prime) or a situation in which they were lacking power (low power prime). Afterward, we used ERPs to record the responses when participants were viewing pictures depicting other people in painful or non-painful situations. The results revealed that larger amplitudes in the earlier P2 and the later P3 components in response to painful stimuli than to non-painful stimuli. Besides, participants primed with high power only showed larger P1 amplitudes than participants primed with low power. The present study extended previous studies by showing that social power tends to enhance the early sensory processing of both painful and non-painful stimuli, instead of directly decreasing the level of empathic responses to others' pain.

Keywords: social power, empathy, P1, ERP, pain

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INTRODUCTION

Empathy refers to the ability to share and understand the emotional states of others (Decety and Jackson, 2004). This ability is crucial for people's successful social interaction with others. According to the "shared representations" account of empathy (De Vignemont and Singer, 2006), observing another person in a particular emotional state generates a similar emotional state in oneself. Consistent with this view, brain imaging studies have demonstrated that merely observing pain in others can activate brain regions mediating affective and somatosensory pain in the observer (Decety and Jackson, 2004; Jackson et al., 2005). This phenomenon is presently explained by assuming that empathic responses to others' pain may occur automatically (Dimberg and Thunberg, 1998; Chartrand and Bargh, 1999; Dimberg et al., 2000; Han et al., 2008; Kramer et al., 2010).

However, recent several theories of emotions (Barrett, 2012; Mesquita and Boiger, 2014) proposed that emotions emerge from specific social interaction contexts. According to this view, each instance of any emotion is constructed by social interactions in which it takes place. For example, angry expressions are judged as a stronger signal of threat when they are shown by high-status people compared to low-status people (Ratcliff et al., 2012). It has to be pointed out that these theories do not deny that emotions are embodied, they just stress that emotions are situated in specific social contexts.

Consistent with this view, there are increasing evidence that empathic responses to others' pain were also modulated by social factors, such as interpersonal relations (Singer et al., 2006; Beeney et al., 2011; Cui et al., 2015), the social status (Boksem et al., 2009; Guo et al., 2012; Varnum et al., 2015; Feng et al., 2016). The present study aims to examine the role of the observer's social power in empathic responses to others' pain.

Social power is a fundamental concept of social life and impacts a wide range of important and beneficial individual outcomes (Podolny, 2005). Power may constitute and change the social context in which emotions occur. In the psychological literature, social power refers to an individual's relative ability to influence his or her partner's outcomes by controlling resources and punishments (Keltner et al., 2003). Social power has been measured by assessing generalized sense of power as a personal disposition (e.g., Anderson and Galinsky, 2006; Anderson et al., 2012). In most past research, power was activated by asking participants to imagine themselves in or simulate the role of a manager or a subordinate (e.g., Guinote et al., 2002; Guinote, 2008) or via a mindset priming method, which asked participants to recall either a situation in which they possessed power over someone else or a situation in which someone else possessed power over them (Galinsky et al., 2003). Among those techniques, relative to other power manipulations, such as word search task, the recall priming task by Galinsky et al. (2003) has been shown to have far-reaching effects on a variety of behavioral outcomes, including ability to recognize facial emotional expressions (Galinsky et al., 2006) and to ignore peripheral information and focus on task-relevant details (Guinote, 2007a,b).

Major power theories assumed that social power leads to reduced processing of others' emotions (Keltner et al., 2003; Russell and Fiske, 2010; Magee and Smith, 2013). Specifically, high-power individuals, because they control resources, tend not to attend to others' emotions. Thus, high-power people show low empathic accuracy compared to low-power people (Keltner et al., 2003; Van Kleef et al., 2008). In line with this view, numerous studies have shown that people with high power are less accurate in recognizing others' emotional expressions (Galinsky et al., 2006) or prosody (Uskul et al., 2016), and show lower levels of motor resonance than individuals with low power (Carr et al., 2014; Hogeveen et al., 2014).

In contrast, there is also conflicting evidence that individuals with a higher sense of power are associated with better facial emotion recognition or increased empathic accuracy (Schmid Mast et al., 2009; Côté et al., 2011). A recent meta-analysis (Hall et al., 2015) revealed the weak effect of power on emotion (averaged correlation = 0.07). One possible explanation for this is that the different power measurements or manipulations might require and affect different cognitive processing (Smith and Magee, 2015), thereby leading to different impacts on emotion. For example, the different aspects of power (feeling respect from others or the sense of controlling others) might modulate the power – empathy link. Recently, Magee and Galinsky (2008) argued that power is considered to be different from status, which refers to the relative level of respect and admiration one is conferred by others (Magee and Galinsky, 2008). Unfortunately, most of the previous researchers did not distinguish status from power when they assessed the impact of power on emotion. According to the widely accepted definition and manipulation method of power (Keltner et al., 2003), we argued that the controlling dimension of power is its core character. Thus, in the present study, we manipulated the social power by asking participants to recall and describe a particular incident in which they had power over another individual (high power prime) or someone else had power over them (low power prime).

Another limitation of previous studies is that empathic accuracy (the difference between the perceiver's perception and the partner's reported emotion) is usually used to test the effect of power on empathy. However, this behavioral method cannot assess the different stages of empathic responses to others' emotions. In the present study, we used event-related potential (ERP), because of its excellent temporal resolution. The ERP technique is well-suited to assess the temporal dynamics of this study. ERPs can differentiate specific cognitive processes by linking them with neural components, depending on their activation time course and topography in brain areas. Also, ERP can provide critical temporal information for precise analysis of the timing of empathy.

Previous ERP studies have shown that earlier (N1 and P2) and later (P3) components were revealed when observing other people in painful or non-painful situations. The earlier components reflect the affective response of empathy for pain, while the later components involve the cognitive processing of empathy for pain (e.g., Pratto and John, 1991; Han et al., 2008; Ibáñez et al., 2011; Meng et al., 2012, 2013; Lyu et al., 2014). Specifically, previous studies have suggested that the N1 component is an expression of the early effects of the pain scene response, an automatic processing in the process of pain empathy, and an early automatic activation and sharing process of emotion. Previous studies have found that P2 is sensitive to negative stimuli, which reflects that negative stimuli receive more attention (Dowman, 2007; Chen et al., 2008; Yang et al., 2010; Fields and Kuperberg, 2012). Studies on pain empathy have consistently found that P2 is modulated by stimuli, being of larger amplitude to the painful than non-painful stimuli (Fan and Han, 2008). P3 reflects the evaluation and judgment process of the stimulus. Compared with N1, P3 illustrates the evaluation and control processing of pain empathy, which is a conscious evaluation of stimulus after automatic processing of perception and emotional cues. P3 is the top-down attention to pain cues in stimuli (Polich, 2007; Dufey et al., 2011).

In the present study, we used ERP to test whether individual power affects neural responses when viewing other people in painful or non-painful situations. Before participants received painful or non-painful pictures, we manipulated the social power by asking them to recall and describe a particular incident in which they had power over another individual (high power prime) or someone else had power over them (low power prime). In short, we hypothesized that power would modulate neural empathic responses to painful stimuli. Specific to the ERP component, we predicted that the empathy-related N1, P1, and P2 responses would be negatively correlated with power, such that those high power should show reduced neural empathic responses, but in P3, power would increase empathic responses.

MATERIALS AND METHODS

Participants

A sample size of 40 undergraduate students participated in this study from Henan University and received financial compensation for their attendance in the study. The participants were alternately assigned to high power or low power condition. Besides, we discarded the data from two participants due to intensive head movements during EEG recording. Finally, 38 participants' data were included (M_{age} = 21.4, SD_{age} = 1.23, 19 males). There were nineteen participants in each group. Based on self-report, no participant had a current or past history of neurological or psychiatric illness and all had normal or corrected-to-normal vision. This study was approved by the local Ethics Committee of Henan University, and all participants signed informed consent before the experiment.

Apparatus and Stimuli

Electroencephalogram (EEG) was recorded from 32 scalp sites using tin electrodes mounted in an elastic cap (Brain Products, Brain Products GmbH, Gilching, Germany), arranged according to the International 10–20 System, with the reference on the right mastoid. EEG data were analyzed with the software Brain Vision Analyzer (Version 1.05; Brain Products, Munich, Germany).

The stimuli used in the experiment were pictures showing a person's hands/feet in painful or non-painful situations (**Figure 1**), which have been used in previous ERP studies (Meng et al., 2012, 2013). All situations depicted familiar events that occasionally happen in everyday life. Image size 9 cm × 6.76 cm (width × height), definition, and luminance level of pictures were matched across priming conditions between painful and non-painful pictures (Meng et al., 2012, 2013). We opened the picture in Photoshop, select image – adjust – luminance level, and set the luminance level to 0. All pictures were presented on a black background (4.5°× 3.15°visual angle), with 100 pixels/in.

Procedure

When the participants came to the laboratory, they first completed the agreeableness scale and the Interpersonal Reactivity Index. We used the 10-item agreeableness scale from the International Personality Item Pool (Goldberg, 1999). A sample item is "I make people feel at ease." Responses were made using 5-point Likert scales (1 = very inaccurate, 5 = very accurate) (α = 0.75). Then we administered the 22-item interpersonal reactivity index (IRI) (Davis, 1983), including four dimensions, perspective taking, fantasy, empathy, and personal distress, we found no statistically significant difference in agreeableness and empathy between the high- and low-power participants (**Table 1**). Then primed with high or low power. Participants assigned to the high power condition were instructed to recall and write about an experience which they had power over another individual. Participants assigned to the low-power group were instructed to write about an experience in which another individual had power over them (Galinsky et al., 2003).

After completing power priming, participants were asked to take part in a sensory test in which they had observed painful or non-painful pictures. The experiment consisted of four formal experimental blocks of 60 trials each. The experiment started with 20 practice trials to familiarize participants with the task. As illustrated in **Figure 1**. In each trial, a fixation cross or point was presented on a black screen during a random duration between 400 and 600 ms. Subsequently, a blank screen was presented between 350 and 450 ms, then the painful or the non-painful pictures were displayed for 1500 ms, followed by a random duration between 400 and 600 ms followed by a blank screen, after which a 9-point pain intensity scale (1, no sensation; 4, pain threshold; 9, unbearable pain) appeared. Participants were asked to provide a rating by a button press with the right index or middle finger as quickly and accurately as possible. The scale remained onscreen until a response had been made, or for a 4 s maximum. The order of block conditions was counterbalanced across participants. The order of pictures was randomized within each block.

After the completion of the empathy test (the agreeableness scale and the IRI), participants were asked to respond to a 2-item power manipulation check (Kraus et al., 2011), indicating how much they agreed with each statement. The two items were "Now I feel I have a great sense of power" and "Now I feel my wishes don't matter" (reverse scoring). Responses were made using 7-point Likert scales (1, "strongly disagree"; 7, "strongly agree") (r = 0.89). The manipulation check confirmed that participants in the high power condition (M = 4.74, SD = 0.98) rated themselves as more powerful than those in the low power condition (M = 4.03, SD = 0.94), t (38) = −2.29, p = 0.028. Moreover, Following past research (Galinsky et al., 2003; Anderson and Galinsky, 2006), the effectiveness of the power manipulation was determined by having two condition-blind coders rate participants' essays on content expressing high-power and low-power feelings (1, not at all; 7, very much) (r = 0.85), and therefore we combined the ratings of two coders to get a composite variable by averaging the ratings. As expected, participants in the high-power essays were rated as more powerful (M = 5.7, SD = 1.07) than participants in the low-power essays (M = 2.8, SD = 0.82), $t(36) = -9.519$, $p < 0.001$, d = 3.04. In addition, we calculated the correlation coefficient between our two manipulation checks (self-rating and coder's rating), no significant correlation was found, r = 0.08, p = 0.687. We will discuss this point later in the discussion.

After the experiment, we asked participants whether they were aware of the link between the sensory test and

TABLE 1 | Descriptive statistical values and differences between the scores of high and low power individuals.

	High power		Low power			
Dimension	***M***	***SD***	***M***	***SD***	***t***	***p***
Perspective taking	2.65	0.55	2.77	0.53	0.66	0.51
Fantasy	2.87	0.42	2.58	0.87	−1.30	0.20
Empathy	2.87	0.41	2.72	0.87	−0.91	0.37
Personal distress	1.74	0.50	1.99	0.69	1.24	0.17
Agreeableness	3.95	0.42	3.92	0.37	0.18	0.86

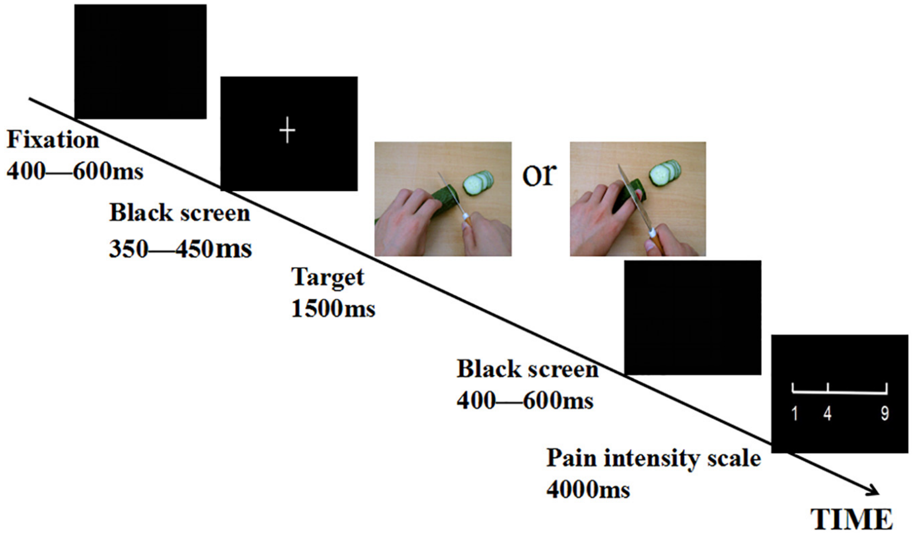

FIGURE 1 | Illustration of the procedure.

the power induction, such as "Did you feel that there is something special about the experimental procedure?" "Did you know the purpose of the experiment?", which confirmed that all participants were naive about the purpose of the study.

EEG Recording and Analysis

To monitor eye movements and blinks, the vertical electrooculogram (VEOG) was recorded from electrodes placed on the supraorbital and infraorbital ridges of the right eye. EEG and EOG activity was amplified with a 0.01–100 Hz band-pass, and continuously sampled at 500 Hz. Impedance was below 5 kΩ for all recordings. Trials contaminated by blinks, eye movements, and excessive muscle activity were rejected offline (voltage exceeding ± 75 μV in any channel) before averaging. In sum, 10% of the trials were discarded from analysis.

The data were then re-referenced to the common average, after which the signal passed through a 0.01–30 Hz band-pass filter. Time windows of 200 ms before and 800 ms after the onset of the picture were segmented from EEG. Before seeing the data, we planned to deal with the data in terms of mean amplitude (see section "Results" in **Supplementary Materials**). After seeing the data, analyses were conducted over the peak amplitude of the N1 and P1 components and the mean amplitudes of the P2 and P3 component. Based on the topographical distribution of grand-averaged ERP activity and previous studies, different sets of electrodes for each component were chosen. The following 5 electrode sites F_z, F3, F4, FC1, and FC2 were selected for the analysis of the N1 (110–160 ms); P3, P4, and Pz were selected for the analysis of the P1 (100–160 ms); F_z, F3, F4, FC1, FC2, C3, C4, and C_z were selected for the analysis of the P2 (160–240 ms), P3, P4, Pz, CP1, CP2, O1, and O2 were selected for the analysis of the P3 (400–800 ms).

RESULTS

We used PP graph and histogram to check the normality. The results suggested that our data conformed to the normal distribution. We used the Levene test to check homoscedasticity, the results suggested that our data conformed to the homoscedasticity. Also, we used a discarding rule of ± 3 standard deviations for outliers. A mixed-model analysis of variance with Power condition (High/Low) as a between-subjects factor and Pain (Painful/Non-Painful) as a within-subject factor was performed for all selected electrodes sites for each component. To compensate violations of the sphericity assumption, we used Greenhouse-Geisser correction to correct the *P*-values. Bonferroni correction was used for multiple comparisons.

Behavioral Performance

Reaction times (RT) and pain intensity ratings were calculated for each participant in each condition. The data were entered into a 2 (Power) × 2 (Pain) mixed model ANOVA with Power condition (High/Low) as a between-subjects factor and Pain (Painful picture/Non-Painful picture) as a within-subject factor. The analysis of RTs revealed a significant main effect of Picture, $F(1,36) = 4.40$, $P < 0.005$, $\eta_p^2 = 0.11$, Non-painful pictures ($M = 596$ ms, $SD = 26$) were recognized faster than painful pictures ($M = 629$ ms, $SD = 31$), the interaction of Power × Pain [$F(1,36) = 0.437$, $p = 0.513$, $\eta_p^2 = 0.012$] was not significant, the main effect of Power [$F(1,36) = 0.222$, $p = 0.64$, $\eta_p^2 = 0.006$] was not significant (see **Table 2**).

The ANOVA for pain intensity showed a significant main effect of Picture, $F(1,36) = 530.61$, $p < 0.0001$, $\eta_p^2 = 0.936$, indicating that painful pictures ($M = 5.77$, $SD = 0.19$) were rated as significantly more painful than non-painful pictures ($M = 1.298$, $SD = 0.103$), interaction of Power × Pain intensity [$F(1,36) = 0.043$, $p = 0.838$, $\eta_p^2 = 0.001$] was not significant, the

TABLE 2 | Mean RTs and Pain intensity scale for each group.

Power	Pain	RT (ms)		Pain intensity scale	
		M	*SD*	*M*	*SD*
High power	Painful picture	637	175	5.94	1.19
	Non-painful picture	614	149	1.43	0.88
Low power	Painful picture	621	209	5.60	1.14
	Non-painful picture	577	175	1.17	0.18

main effect of Power [$F(1,36) = 1.645$, $p = 0.208$, $\eta_p^2 = 0.044$] was not significant (see **Table 2**).

ERP Results

N1

ANOVA on N1 revealed, the main effect of Power [$F(1,36) = 0.328$, $p = 0.570$, $\eta_p^2 = 0.009$], main effect of Pain [$F(1,36) = 0.931$, $p = 0.341$, $\eta_p^2 = 0.025$], and the interaction of Power × Pain [$F(1,36) = 0.114$, $p = 0.738$, $\eta_p^2 = 0.003$] were not significant. Meanwhile, a significant main effect of electrode site was observed, $F(2,36) = 12.997$, $p < 0.0001$, $\eta_p^2 = 0.265$, suggesting that largest amplitudes were elicited at the F4 (−3.69 μV) electrode sites.

P1

ANOVA on P1 revealed, a marginal significant main effect of Power was observed [$F(1,36) = 3.772$, $p = 0.06$, $\eta_p^2 = 0.095$], indicating that participants in high power condition ($M = 4.07$ μV, $SE = 0.53$), elicited more positive P3 amplitudes than participants in low power condition ($M = 2.61$ μV, $SE = 0.53$). The main effect of Pain [$F(1,36) = 0.947$, $p = 0.337$, $\eta_p^2 = 0.026$], the interaction of Power × Pain [$F(1,36) = 0.201$, $p = 0.657$, $\eta_p^2 = 0.006$] were not significant. The main effect of electrode site was significant, $F(2,36) = 18.429$, $p < 0.0001$, $\eta_p^2 = 0.339$. Further analyses showed that largest amplitudes were elicited at the P3 (4.50 μV) electrode sites (see **Figure 2**).

P2

ANOVA on P2 revealed, the main effect of Power [$F(1,36) = 1.453$, $p = 0.236$, $\eta_p^2 = 0.039$] was not significant, we found that low-power participants ($M = -0.791$ μV, $SE = 0.318$) showed more positive amplitudes than high-power participants ($M = -1.333$ μV, $SE = 0.318$). We observed a significant main effect of Pain [$F(1,36) = 5.725$, $p = 0.022$, $\eta_p^2 = 0.137$]. Painful picture elicited a more negative P2 ($M = -0.99$ μV, $SE = 0.23$) than non-painful pictures ($M = -1.13$ μV, $SE = 0.23$). The interaction of Power × Pain [$F(1,36) = 1.564$, $p = 0.219$, $\eta_p^2 = 0.042$] did not reach significance. A significant main effect of electrode site was observed, $F(3,36) = 11.112$, $p < 0.0001$, $\eta_p^2 = 0.236$, suggesting that largest amplitudes were elicited at the F_z (−1.639 μV) electrode sites.

P3

ANOVA on P3 revealed, the main effect of Power [$F(1,36) = 0.313$, $p = 0.579$, $\eta_p^2 = 0.009$] and the interaction of Power × Pain [$F(1,36) = 2.057$, $p = 0.16$, $\eta_p^2 = 0.054$] were not significant, we found that high-power participants ($M = 1.741$ μV, $SE = 0.46$) showed more positive amplitudes than low-power participants ($M = 1.38$ μV, $SE = 0.46$). We found a significant main effect of Pain [$F(1,36) = 7.308$, $p = 0.01$, $\eta_p^2 = 0.169$], painful pictures elicited a significantly larger amplitude ($M = 1.75$ μV, $SE = 0.30$) than non-painful pictures ($M = 1.37$ μV, $SE = 0.39$). P3 amplitudes showed significant main effect at electrode size, $F(2,36) = 20.951$, $p < 0.0001$, $\eta_p^2 = 0.236$. Largest amplitudes were elicited at the CP2 (3.03 μV) electrode sites. None of the two-way, three-way, or four-way interaction reached significance (all p-values > 0.05).

To evaluate the strength of the empirical evidence, we also conducted a Bayesian analysis (Wagenmakers et al., 2017a,b). Bayesian analysis tests the strength of evidence between two theories (a null hypothesis theory and the proposed effect in the data), and its value ranges from 0 to infinity, with an increase in value indicating stronger support to reject the null hypothesis. The conventional cut-offs for Bayes factor sensitivity are 1/3 and 3, which means that any value outside of this range (less than 1/3 or greater than 3) provides strong evidence in support of the null hypothesis or the proposed effect in the data, respectively. Values between 1/3 and 3 are considered weak or "anecdotal" evidence. We found a Bayes factor of 1.417, which suggests that there is a difference between low-power and high-power individuals in RT. And a Bayes factor of 7.057e + 31 strongly supports the difference between low-power and high-power individuals in pain intensity. Consider the ERP results, a Bayes factor of 1.415 supports the difference between low-power and high-power individuals in pain intensity in P1, but there is anecdotal evidence for an effect of power on P1.

DISCUSSION

In some past studies, social power increased individuals' empathic accuracy (e.g., Schmid Mast et al., 2009), in contrast, other studies have shown that social power decreased individuals' empathic accuracy (e.g., Galinsky et al., 2006). In our study, we measured the ERP components of participants when they were viewing pictures depicting other people in painful or non-painful situations. The results revealed that larger amplitudes in the earlier P2 and the later P3 components in response to painful stimuli than to non-painful stimuli, suggesting that painful stimuli led to robust neural responses. In addition, participants primed with high power showed larger P1 amplitudes than participants primed with low power did. We will later discuss the implication of this finding.

Consistent with previous ERP studies about empathy for pain, the present study found that larger amplitudes in the earlier P2 and the later P3 components in response to painful stimuli than to non-painful stimuli (Han et al., 2008; Ibáñez et al., 2011; Meng et al., 2012; Lyu et al., 2014). The difference between painful and non-painful conditions was considered to be the participants' P2 and P3 empathy effect. However, Power × Pain interaction absent in the P2 and P3 components, indicating that the social power of participants might not modulate empathic responses to others' pain. The interaction

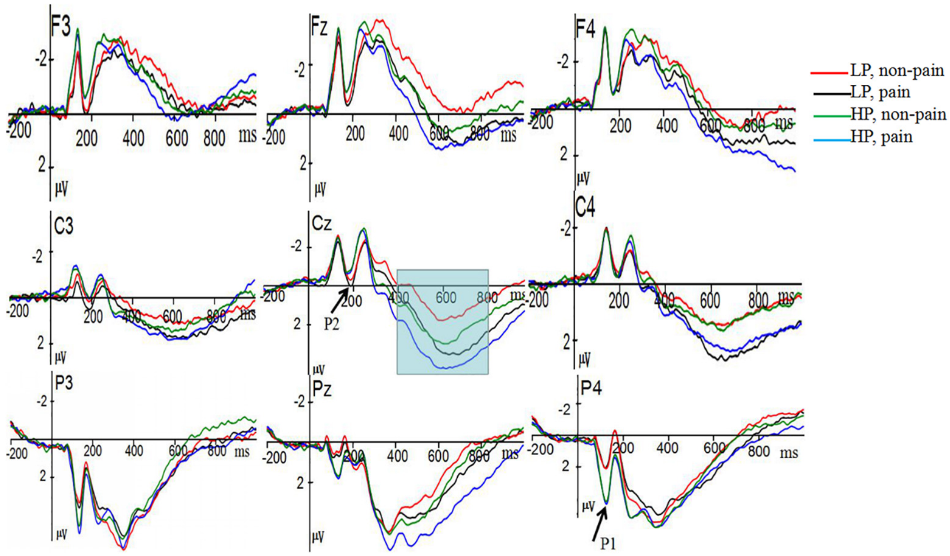

FIGURE 2 | Grand average event-related potentials (ERP) elicited at electrodes F3, F_Z, F4, C3, C_Z, C4, P3, Pz, and P4 in response to painful and non-painful stimuli for high-power (HP) and low power (LP) participants.

of Power × Pain was statistically non-significant, which was not consistent with the result of Paulmann and Uskul (2017). In their study, the same power priming procedure was used to induce the sense of high or low power, and, then participants were asked to judge six different emotional voice. The authors found Emotion × Power interactions in P2 (200–250 ms) and P3 (450–850) components. To test our results, we used the Excel spreadsheet (Lakens, 2013) to compute the omega squared as well as 90% CI for eta-squared. For our Power × Pain interaction effect on P2, $\eta_p^2 = 0.04$, 90%CI for η_p^2 = 0,0.18, omega^{2}p = 0.01. For Paulman & Uskul's Emotion x Power interaction effect on P2, $\eta_p^2 = 0.08$, 90%CI for η_p^2 = 0.02, 0.12, omega^{2}p = 0.06. However, as our research design was different from that of Paulmann and Uskul (2017), it is impossible to compare your partial eta^2 with theirs. Yet, the results mentioned above would help researchers to get better understanding of these studies. In addition, the possible explanation for our non-significant interaction is that different emphatic test might require different cognitive processing, general emotional stimuli were used in a previous study, whereas the physical painful stimuli were used in our study. Because pain stimuli might be very salient or vital for all participants, regardless of whether they have high or low-power sense, these stimuli could not distinguish low-power participants from high-power participants. However, it has to be noted that our results are not mutually exclusive with the previous study. In contrast, future studies should focus on the effect of power on empathy in empathic tests about various emotions.

In addition, the most important result of this study was that participants primed with high power tended to show larger amplitudes than participants primed with low power did in the earlier P1 stage. However, the main effect of Pain and the Power × Pain interactions were not statistically significant in the P1 stage. The null effect of Pain in P1 suggested that P1 could not distinguish painful from non-painful events, and empathy effect did not occur in the P1 stage. The P1 component in visual areas has been related to the early sensory encoding of emotional stimuli. Some ERP studies have shown evidence for an enhanced P1 component for negative relative to neutral stimuli (for review see Vuilleumier, 2005). This finding suggested that in the initial stage of all the stimuli processing high-power participants are more sensitive to the stimuli than lower-power participants. In the late stages, both high and low-power participants show the same level-responses to pain stimuli, as these stimuli are too salient. In other words, social power enhanced individuals' attention to the target goal. Our view is in line with the results of Côté et al. (2011), who argued that elevated power just enhanced goal focus rather than directly elevating or diminishing empathic accuracy. Recently, there was a work showing greater attunement of powerholders to their sensory states, for example, motor fluency (Woltin and Guinote, 2015; see also Guinote, 2017). Thus, together with work by Guinote (2017), our study at least demonstrated social power affected individuals' sensory stage.

In line with this view, there is increasing evidence that social situations modulate emotional processing (e.g., Hogeveen et al., 2014; Uskul et al., 2016). However, it is unclear how the social situation affects emotional processing. In most previous studies, emphatic accuracy (EA) is usually used to test the effect of power on the emphatic response, and the correspondence between observer's emotional judgment and target's self-report is computed as the indicator of emphatic accuracy. In the present study, the effect of power on pain empathy was examined by using ERP, because of its excellent temporal resolution. The results have shown that participants primed with high power only showed larger P1 amplitudes than participants primed with low power did. In other words, there is a trend that social power as an important social situation enhanced individuals' sensory processing.

According to situated emotions theories (Barrett, 2012; Mesquita and Boiger, 2014), social power affects emotional responses. These theories emphasize that emotions are situated in social contexts, rather than relative isolation. That is, emotions are closely tied to the interpersonal contexts in which they occur. This view has challenged the previous view of basic emotions proposed by Ekman (1992). The view of basic emotion assumes that at least some basic emotions are intrinsic and biological phenomena, which are linked with underlying physiological states and external facial expressions. According to this view, emotions take place at the interpersonal level, and are independent of the interpersonal contexts in which they take place. However, there is converging evidence that the processing of emotions can be modulated by social contexts in which they occur, such as the social status or power of the observer or the target (Guo et al., 2012; Varnum et al., 2015; Feng et al., 2016). These findings suggest that there are close links between social contexts and emotions, and social context should be taken into account in future emotional studies.

Moreover, the difference between the self and the blind coder's rating in manipulation check would be considered in future studies. As initial manipulation check, participants were asked to indicate which they felt powerful, we found an unstandardized mean difference of 0.71 unit of our power manipulation with a 95% CI for unstandardized μ (0.10, 1.32), Cohen's $d \approx 0.71$. However, using the same blind-coder-based manipulation check as in previous studies, we observed an unstandardized mean difference of 2.8 units of the 7-point Lickert scale, 95% CI for the unstandardized μ(2.28,3.33). In addition, using ESCI (Cumming, 2012) to conduct a small-scale meta-analysis of the effect of the autobiographical power manipulation on the coder's ratings including six studies (Anderson and Galinsky, 2006, Studies 2 and 4; Galinsky et al., 2003, Studies 2 and 3; Galinsky et al., 2006, Study 1; Yang et al., 2015, Study 1), it has been found an average unstandardized mean difference of 3.3 units of the 7-point Lickert scale, 95% CI for the unstandardized μ(2.93,3.67). Thus, although the meta-analysis was limited because of its small scale, the effect size of our manipulation on the manipulation check is not significantly different than those of the meta-analysis. In addition, there was no significant correlation between two manipulation checks. One possible explanation was that self-rating by participants might be affected by both participants' internal feelings and subjective standards, whereas the coder's rating might control participants' subjective standards. However, this explanation should be taken with caution, further studies would be needed to exam this difference.

Lastly, our current study did not find Power $\times$ Pain interactions, several potential limitations must be noted. First, the lack of a power-control condition is our limitation, adding a power-control condition would be considered in our future study. Secondly, alternate assignment of each participant in experimental conditions could affect our results. Finally, our effect was not statistically significant presumably because of an underpowered research design.

CONCLUSION

Taken together, the present results showed that power tends to enhance sensory processing of both painful and non-painful stimuli, instead of decreasing the level of empathic responses to others' pain.

ETHICS STATEMENT

This study was approved by the local Ethics Committee of Henan University, and informed written consent was signed from all participants before the experiment.

AUTHOR CONTRIBUTIONS

EZ and XM designed the study and drafted the manuscript. XM and KW performed the study. EZ, KW, and XM analyzed the data. EZ reviewed the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2019.02320/full#supplementary-material

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What "Tears" Remind Us of: An Investigation of Embodied Cognition and Schizotypal Personality Trait Using Pencil and Teardrop Glasses

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Facial expressions influence our experience and perception of emotions—they not only tell other people what we are feeling but also might tell us what to feel *via* sensory feedback. We conducted three experiments to investigate the interaction between facial feedback phenomena and different environmental stimuli, by asking participants to remember emotional autobiographical memories. Moreover, we examined how people with schizotypal traits would be affected by their experience of emotional facial simulations. We found that using a directed approach (gripping a pencil with teeth/lips) while remembering a specific autobiographical memory could successfully evoke participants' positive (e.g., happy and excited)/negative (e.g., angry and sad) emotions (i.e., Experiment 1). When using indirective environmental stimuli (e.g., teardrop glasses), the results of our experiments (i.e., Experiments 2 and 3) investigating facial feedback and the effect of teardrop glasses showed that participants who scored low in schizotypy reported little effect from wearing teardrop glasses, while those with high schizotypy reported a much greater effect in both between- and within-subject conditions. The results are discussed from the perspective of sense of ownership, which people with schizophrenia are believed to have deficits in.

Keywords: embodied cognition, facial feedback, congruence hypothesis, schizotypal personality trait, schizotypy, sense of agency/ownership, teardrop glasses

INTRODUCTION

Understanding the relationship between physiological changes and emotion has enticed scientists for a very long time. In writing his theory of evolution, Darwin and Prodger (1998) proposed the foremost statement about the physical body and emotion, stating that facial expressions developed because they were serviceable habits or gestures that solved a problem in our evolutionary past (Darwin and Prodger, 1998; Hess and Thibault, 2009; Niedenthal and Ric, 2017). William James was quite clear in his emotion theory that expressive behavior like crying and facial expressions like furrowed brows contributed to the experience of various emotions (James, 1884; Laird and Lacasse, 2014). James proposed that emotions take place when we perceive particular facets of our environment that generate a collection of physical changes, and that "our feeling of the same changes as they occur is the emotion" (Prinz, 2004). At the same time, Lange proposed that all emotions are developed from, and can be reduced to, physiological reactions to a given stimulus. Taking their work together – referred to as the James-Lange theory (Cannon, 1927) – emotions can be defined as feelings resulting from the physiological changes that arise in response to a stimulus.

Many studies have investigated the relationship between emotions and subsequent physical changes. In particular, many scientists have come to believe that our emotions are affected by our facial expressions. Emotion theorists (Tomkins, 1962; Izard, 2013) later developed the idea that facial behavior can activate or regulate the expression of emotion. The facial feedback hypothesis states that skeletal muscle feedback from facial expressions causes the regulation of emotional experiences and behavior. This is an important part of several contemporary theories of emotion (Buck, 1980).

In an early study of this phenomenon, participants were told that the purpose was to measure the electromyographic changes of facial muscles that accompanied perceptual tasks (Laird and Crosby, 1974). To this end, electrodes were attached to their faces, and they were asked to contract or relax the muscles while wearing different electrodes, which led them to form different facial expressions. In interviews about their understanding of the experiment, they tended to report feelings consistent with their expressions. In a study where participants were asked to either conceal or exaggerate facial displays associated with the anticipation and reception of painful shocks in intensity, results showed that the suppression of expressive responses decreased the magnitude of phasic skin conductance changes and subjective reports of painfulness when contrasted with free expression or exaggeration of pain-related expressive responses (Lanzetta et al., 1976). Primary research on the facial feedback hypothesis focused on the enhancing or suppressing effect of facial changes and emotional feedback. For the most part, the purpose of these studies was obvious until Strack et al. (1988) tested the theory with a solely physical facial change, using only certain facial muscles. Strack found that physical changes in facial expression (e.g., gripping a pencil with one's teeth) could unconsciously induce emotional arousal (e.g., feelings of happiness). Additionally, Zajonc et al. (1989) conducted research that found that participants' reactions that resulted from facial actions (namely, phonetic utterance) resembling but unrelated to emotional efference differed in hedonic qualities and produced correlated changes in forehead temperatures. Similarly, Soussignan (2002) examined the muscles involved in facial expressions and obtained results congruent with the facial feedback hypothesis; namely, facial feedback occurred when the facial structure formed a valid analog of a basic emotional expression.

Another experiment offering support for the facial feedback mechanism was provided using the toxin botulinum. The results of Lewis and Bowler (2009) suggested that botulinum could be used as a treatment for depression. Furthermore, Hennenlotter et al. (2008) studied facial feedback effects on limbic brain responses during the intentional imitation of facial expressions, applying botulinum toxin (BTX)-induced denervation of the muscles involved in frowning, combined with functional magnetic resonance imaging that was used as a reversible lesion model, to minimize afferent muscular and cutaneous input. Results showed that, during the imitation of angry facial expressions, feedback reduced by BTX treatment attenuated the activation of the left amygdala and its functional coupling with brain stem regions that were indicated to be involved in autonomic manifestations of emotional states. A later study on how facial feedback relates to emotion comprehension was performed by Neal and Chartrand (2011) and reached a similar conclusion.

On the contrary, opinions that disagreed with the facial feedback hypothesis, as well as doubts about it, arose in 2016 when a series of replications of the original 1988 experiment conducted in 17 labs did not find support for the hypothesis (Wagenmakers et al., 2016). While in the recent study, facial feedback theory was fairly supported when asking participants gripping pencil in their mouths and facial feedback effects were particularly greater in the presence of certain stimulus types (e.g., imagined scenarios, which were also adopted in the designing of the procedure of the present research) than others (e.g., pictures) (Strack, 2016). Marmolejo-Ramos and Dunn (2013) conducted a study that closely investigated the stimulus types that would likely drive facial feedback, finding that participants' sensorimotor systems were active when they were asked to judge emotional sentences. Even though that dual activation is not necessary for perceptual and motor systems, it was assumed that the perceptual system mainly drives this cognitive processing. Similarly, in another study, it was found that facial feedback has a stronger effect on emotional experience than do emotionally evocative stimuli (e.g., cartoons) and has a stronger effect when participants were also presented with emotionally evocative stimuli such as emotional sentences (Coles et al., 2019). Additionally, Noah et al. (2018) replicated the facial feedback experiment in two conditions: one with a video camera and one without it. The results revealed a significant facial feedback effect in the absence of a camera, which was eliminated in the camera's presence. Therefore, to achieve our aim of identifying the relationship between facial feedback phenomena and external stimuli, we adopted the pencil and teardrop glasses as stimuli. Participants were prompted to remember an emotional autobiographical scene to evoke emotional feedback, with no camera present in the environment.

We arranged the first experiment to start discovering the interaction between facial feedback phenomena and stimuli in the environment, on the assumption that there is a connection, determine how they interact with each other. In the first experiment, participants were asked to remember an impressive event while we had them simulate a positive/negative facial expression (i.e., holding a pen between the teeth induces a smile; holding it between the lips induces a pout) in order to evoke a consistent emotion (e.g., a happy feeling) with the external environmental stimuli (e.g., holding a pencil to forming smile facial expression).

Interestingly, researchers studying facial feedback found that the effects of positive and negative facial expressions might differ. Alam et al. (2008) examined the injection of botulinum toxin (BTX) in the upper face and its relation to positive and negative emotional states. They believed the injection of BTX might induce positive feelings as it reduces the ability to generate negative facial expressions, and postulated that the injection of BTX reduced negative facial expressions more than it reduced positive expressions. Another study showed that dysphoric individuals reacted less to positive stimuli, while they showed more responsiveness to negative stimuli such as frowning facial expressions (Sloan et al., 2002). The controversy around facial feedback theory and personality traits in the literature inspired us to launch further investigation, and we wonder if personality traits are the key to various reactions to facial feedback.

We postulated that the schizotypy personality trait would offer a reasonable correlation to investigate, as individuals with high schizotypy are sensitive to social emotional feedback, such as criticism, considered to be negative, and praise, considered positive (Premkumar et al., 2019). Moreover, schizotypy is generally considered to be related to a sense of ownership/agency. Early in 1966, a study called the false heartbeat study was conducted by Valins (1966), where participants were shown a series of seminude female photos; those who heard a false heart rate tended to rate the female in the photo as significantly more attractive. Ehrsson et al. (2004) performed studies on the "rubber hand illusion," which is regarded as a measure of sense of ownership. Subjects with normal brain function were placed with their left hand out of sight. In front of them, a life-like rubber left hand had been placed. Both the hidden left hand and the visible rubber hand were then caressed with a paintbrush. When the two hands were stroked in the same direction simultaneously, subjects began to feel that the rubber hand was theirs. However, if the real and rubber hands were caressed in different directions or non-synchronously, this did not occur.

Therefore, in the second experiment, participants were asked to remember an impressive event while wearing not a pencil, but a tool with indirective emotional reaction – "tears." We selected teardrop glasses (i.e., water drops coming out of the glasses to induce negative emotion; no water drops coming out of the glasses for a control condition) to observe the relationship between the emotion evoked by the teardrop glasses and participants' retrieved autobiographical memory. The teardrop glasses, first introduced by Yoshida (2015) from The University of Tokyo, are shaped like a pair of glasses dispensing a tear-like liquid (i.e., heavier than water) near the lacrimal gland when worn on the face. Yoshida examined emotional feedback while wearing these teardrop glasses and found that participants tended to evaluate a neutral scene as sad when wearing them. Even though the tear-like liquid was issued from the glasses – a physical object in the environment – and not from the user's physical body, it was perceived as a stimulus that aroused a related emotion. More importantly, participants with schizotypal traits were of particular focus here.

While everyone probably experiences a sense of agency at one time or another, as we mentioned before, patients with schizophrenia experience this illusion more than others do. Mirucka (2016) conducted a series of experiments to investigate how often patients with schizophrenia experienced the rubber hand illusion and found that they experience disruptions in the sense of body ownership much more intensively compared to healthy controls. They thought that potential reasons for this result were two characteristic symptoms of schizophrenia: disturbed perception of authorship and feeling of limited control over one's own body.

The concept of schizotypy was developed by renowned psychologists including Eysenck (1992) and Claridge et al. (1996) who wanted to understand unusual thoughts and behaviors within the framework of personality theory. Schizotypy refers to a continuum of personality characteristics and experiences that range from normal dissociative, imaginative states to extreme states related to schizophrenia. Moreover, schizotypy is also considered to be related to the sense of ownership/agency frequently shown in many psychological studies (Asai et al., 2011; Kallai et al., 2015).

As patients with full-blown schizophrenia experience illusions related to the sense of ownership/agency more than others do, individuals high in schizotypy also experience more illusions related to the sense of ownership/agency than people low in schizotypy. Therefore, wearing the teardrop glasses might make people high in schizotypy feel that the "tears" being dispensed are their own or that they are crying. In the present experiments, we adopted these teardrop glasses, and particularly the tear-like liquid they issue, as stimuli for inducing negative emotion. If negative emotion was indeed facilitated, it would support the congruence hypothesis.

Finally, in Experiment 3, we compared the variety and content of the retrieved memories among participants in the simulated smile and crying conditions, again with a particular focus on participants with schizotypal personality traits.

To summarize, in the present study, we conducted three experiments to determine the interaction between facial feedback phenomena and a directive environmental stimulus (in Experiment 1) and indirective environmental stimuli (in Experiments 2 and 3) by prompting the recall of a specific emotional autobiographical memory. We supposed there to be a connection, determined by how they interact with each other. We further investigated individual differences (Experiments 2 and 3), especially in individuals with schizotypal personality traits, in the influence of facial feedback phenomena when controlling the environment. Finally, we designed our experiments to determine whether there are different reactions or tendencies among individuals.

MATERIALS AND METHODS

Pencil in Experiments 1 and 3

We followed the procedure of Strack et al. (1988) in which a pencil was used to induce the appropriate facial responses. Subjects were instructed to hold a pencil with their teeth only or with their lips only. In order to facilitate a smiling face, participants were told to hold a pencil with the teeth only; this would mainly contract the zygomaticus major or the risorius muscles, which are part of the smiling response (Ekman and Friesen, 1982). In order to inhibit the smiling face and facilitate a pouting face, participants were told to hold a pencil with the lips only, which would contract the orbicularis oris muscle, making it impossible to contract the zygomaticus major or the risorius muscles that are used in smiling.

Teardrop Glasses in Experiments 2 and 3

The frames of the teardrop glasses used in the experiments were created *via* a 3D printer (see **Figure 1**). They weighed about 72 g and were 175 mm × 150 mm × 40 mm in size. Two adjustable pipes were installed beside each spectacle frame to allow dispensation of the tear-like liquid. Since tears drop from the corners of the eyes and often run along the nose, we ensured that the tear-like liquid was dispensed from the inner side of the frames to better emulate the experience of actual crying. The teardrop glasses are installed with a special module that utilizes an infrared communicator and changes in the brightness of the module signals when the tear-like liquid should be dispensed. More specifically, when the module turns black, no liquid is dispensed, but when it turns white, the liquid is immediately dispensed. To avoid distracting participants, we set the module to change color every 2.5 s automatically in our experiments. In order to induce a negative emotion, the switch of the teardrop glasses was turned on while the switch of the teardrop glasses was turned off as a control.

Measures

Participants rated the intensity of two general kinds of emotions, namely positive and negative emotions. More specifically, considering cultural differences in facial cognition between Asian and western populations (Ekman et al., 1987), four basic emotions (Ekman, 1999) – happy, excited, sad, and angry – were adopted. The feelings of happy and excited were selected to represent positive emotions, since they are commonly evoked by a smiling facial expression (Freitas-Magalhães, 2007). Sad and angry were selected to represent negative emotions, as they commonly related to the behavior of crying, especially in a negative sense (Kottler, 1996; Scheirs and Sijtsma, 2001). The emotional scales of the recalled positive emotional (i.e., happy or excited) and negative emotional (i.e., sad or angry) memories were rated using a five-point Likert scale (Likert, 1932) (e.g., for happiness: not happy at all; not happy; neutral; happy; and very happy).

The Schizotypy Traits Questionnaire (STA; Claridge and Broks, 1984; Gregory et al., 2003) was adopted to measure participants' schizotypal traits. The STA is a questionnaire comprised of 37 true-false, self-report items, based on the DSM-III diagnostic criteria for schizotypal personality disorder. It has a particular focus on perceptual aberrations, which are analogous to the positive symptoms of schizophrenia (e.g., auditory hallucinations, thought insertion, and delusions of control).

Recruitment, Ethics Approval, and Informed Consent

Participants were all recruited at the Tokorozawa campus of Waseda University, where all the experiments were conducted. Participants were chosen from volunteers who saw a poster advertising the experiment or who attended a class of one of the researchers, under the conditions that they had no history of mental illness, were mentally and physically healthy, and that their native language was Japanese.

All participants were paid for their participation. The Graduate School of Human Sciences Committee of Waseda University approved the protocol. Informed consent was obtained from all participants, who stated that the experiment was conducted by their own free will, all data regarding the behavioral experiments and results were kept separate from their personal information, their privacy was protected, and they could cease participation and withdraw their data any time they felt uncomfortable, during or after the research. After the experiment, they were debriefed, asked whether they had any questions, provided a copy of the consent form, and given a final opportunity to withdraw their data.

According to the *Ethical Guidelines for Medical and Health Research Involving Human Subjects* of Waseda University, we believe that ethical approval was not required for the study, and written informed consent was obtained from all participants.

EXPERIMENT 1

Participants

Forty undergraduate students from Waseda University (16 males; 24 females; mean age = 19.85 years; SD = 0.82; range: 19–21 years)

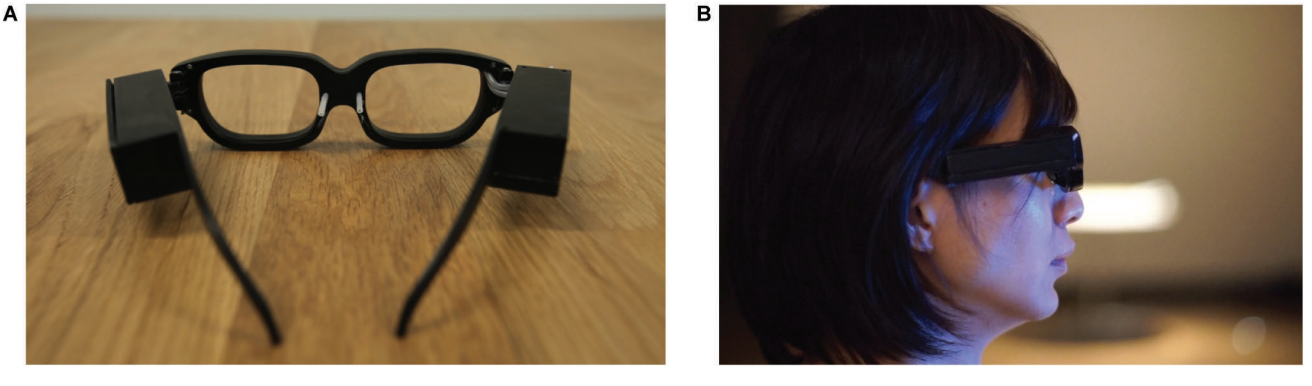

FIGURE 1 | Teardrop glasses, by Yoshida (2015), http://www.shigeodayo.com/tear_drop_glasses.html.

were randomly allocated into two conditions: 20 were placed in a "smile" condition and 20 in a "pout" condition. Participants were tested individually.

Procedure

In line with the experiment conducted by Strack et al. (1988), participants were randomly divided into two conditions according to the way they held the pencil. Participants in the smile condition were directed to grip the pencil with their teeth to create a smile-like facial expression, while participants in the pout condition were directed to hold the pencil with their lips without letting their teeth touch it, thus creating a pout face-like facial expression.

Before the experiment, all participants were told they would take part in an experiment intended to study facial muscles so they would not know the true purpose of the study. The instructions were as follows:

This is a study for psychomotoric coordination. Sometimes, physically impaired people use their mouths to write words, draw pictures, or perform basic tasks, which normally people would not do with their mouths. Knowing the potential to do several tasks with their mouths is important for their future lives. This experiment is just a part of the larger project, and our interest in the experiment is how tired people get when they keep opening their mouths. We would like you not to pay attention to your mouth but rather focus on the task we are going to give you.

Assistants used photographs (a man who is gripping a pencil with his teeth, or a man who is holding a pencil with his lips) to indicate to the participant how to grip the pencil properly. When participants under both conditions were holding the pencils, they were asked to recall an impressive experience that occurred at some point in their lives in 3 min without doing anything, and they were expected to recall this memory as vividly as possible, especially focusing on the emotions they were experiencing while holding the pencil. The instructions were as follows:

Here is your task. From now, you will have 3 min. During the 3 min, we would like you to recall your autobiographical memory—that is, any episodes recollected from your life. When an individual episode comes up in your mind, please think about more details, what happened, and how you felt at that time.

Subsequently, participants were asked to write that experience down on paper including as detailed as possible a description of what had happened and, more importantly, how they felt at that time. Upon finishing it, the intensities of four emotions, "happy," "excited," "sad," and "angry" on their memory were rated *via* the Likert scale questionnaire.

The emotional valence (e.g., happy or sad) of the participant's written memory was carefully compared with their reported emotional state score (e.g., happy or sad), to ensure they were reasonably consistent with each other. For memories that were not clearly described, their reported emotion states scores were selected to represent their current emotional states. By doing so, we were able to analyze the emotional valence of their emotional states while holding a pencil in the lab.

Results

Analyses were conducted with ANOVA 4.0 online (Kiriki, 2002). **Figure 2** shows the self-reported scores of happy, excited, angry, and sad emotional states of participants for both the smile and pout conditions. A mixed analysis of variance (ANOVA) with the environmental stimuli condition factor (i.e., smile vs. pout) as a between-subjects variable and the self-reported scores of emotional states of the participants (i.e., happy, excited, angry, and sad) as the within-subjects variable was conducted. There was a significant interaction [$F(3, 114) = 5.14$, MSE = 1.99, $\eta^2 = 0.14$, $p = 0.0023$] between the environmental stimuli condition factor (i.e., smile vs. pout) [$F(1, 38) = 0.04$, MSE = 0.056, $\eta^2 = 0.00$, $p = 0.8392$] and the self-reported scores of emotional states of the participants (i.e., happy, excited, angry, and sad) [$F(3, 114) = 27.60$, MSE = 54.86, $\eta^2 = 0.73$, $p < 0.001$]. Analysis of main effect showed that the scores of happy emotional states in the smile condition ($M = 4.55$, SD = 0.97) were significantly higher than in the pout condition ($M = 3.60$, SD = 1.74) [$F(1,152) = 4.9$, $p = 0.0277$]. The scores for excited emotional states in the smile condition ($M = 4.20$, SD = 1.17) were not significantly different from those in the pout condition ($M = 3.55$, SD = 1.69) [$F(1,152) = 2.31$, $p = 0.1304$]. Negative emotions, such as the scores of angry emotional states in the smile condition ($M = 1.85$, SD = 1.10), were not significantly different from those in the pout condition ($M = 1.90$, SD = 1.00) [$F(1,152) = 1.66$, $p = 0.2002$], while the scores of sad emotional states in the smile condition ($M = 1.85$, SD = 1.11) were also significantly lower than in the pout condition ($M = 3.05$, SD = 1.63) [$F(1,152) = 7.88$, $p = 0.0057$]. Additionally, positive emotional states, such as happy and excited, were reported higher in the smile condition reported with more positive emotional autobiographical memories, while negative emotions, such as sad and angry, were reported lower, and less negative emotional-related memories were wrote. These results suggest that people who simulated a smiling face not only felt more positive emotions but also tended to recall positive memories, specifically memories that evoked positive emotions; the same pattern was not found for negative memories.

Discussion

The result of Experiment 1 fairly proved that participants were affected by the facial expressions created by the pencil, consistent with facial feedback theory. Participants reported experiencing emotion consistent with the facial expression created by gripping the pencil with their teeth, especially in the smile condition. Moreover, they reported a congruent emotion (e.g., happy and excited) while recalling the autobiographical memory with their self-reported emotion when the embodied cognition experience occurred (e.g., a smiling facial expression). This may be caused by mood congruency effects.

Previous studies showed that emotional memories tend to be clear and detailed, regardless of whether they focus on good or bad events (Bradley et al., 1992; Christianson, 1992; Hamann, 2001; Buchanan and Adolphs, 2002). Mood congruency effects suggest that emotional memories are also better recalled

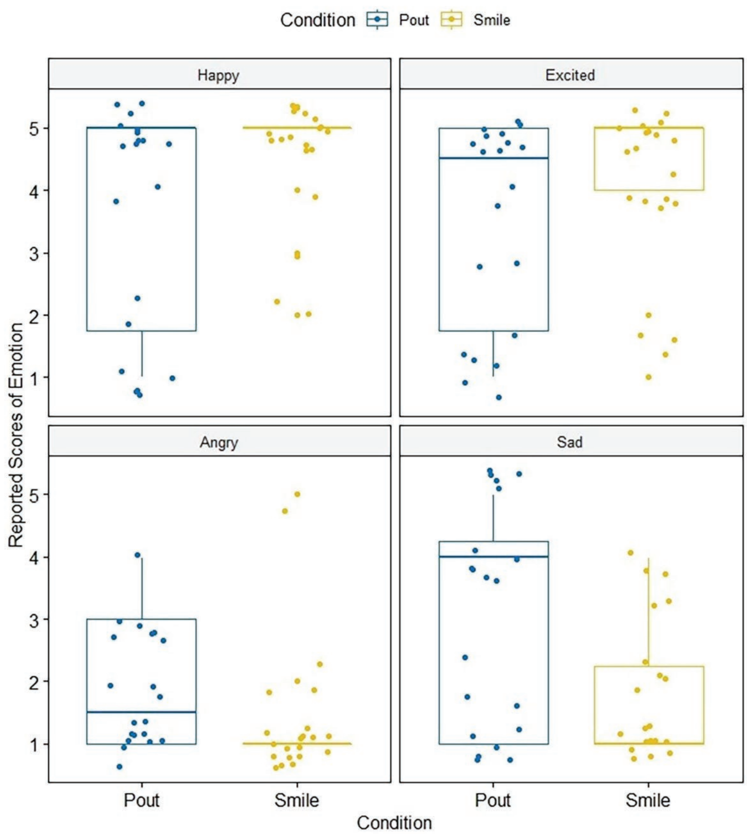

FIGURE 2 | Self-reported score of emotional states (happy, excited, angry, and sad) in the smile and pout conditions of Experiment 1.

when the participant is in a similar mood to that of the recalled memory (Bower, 1981). This is a type of memory bias called emotion-congruent retrieval, which specifically refers to how people remember past events or the features of past events, not as they happened but with the same emotional tone as their current state (Bower, 1981; Kensinger, 2004). Riskind (1983) similarly suggested that people tend to recall experiences where they were experiencing emotions comparable to their current mood state. The simulation view of autobiographical memory is that modality-specific states of perception, action, and introspection activated during the original experience of an event are reactivated when the experience is later represented (Niedenthal et al., 2005, 2014). This view was supported by a study where participants retrieved autobiographical memories in body-congruent and body-incongruent positions, relative to that of the original experience (Dijkstra et al., 2007). Participants were not only faster at retrieving the memory in a body-congruent position, but also retained the memory better (Dijkstra and Post, 2015). In a study by Drače et al. (2015), participants were asked to recall one personal memory after being subjected to negative and neutral mood inductions. Results showed that after being exposed to the same semantic material, the recalled memories of participants in the strong negative mood condition were more negative than those in the moderate negative mood condition.

As discussed previously, negative facial expressions seemingly work differently to positive facial expressions (Alam et al., 2008). The difference in self-reported scores of positive and negative emotional states in the pout condition was not as distinct as in the smile condition. We postulate that this was related to culturally specific negative emotional expression styles, since Japanese people tend to inhibit their negative feelings to adapt to the social expectation of harmony (Matsumoto, 1991; Winton et al., 1995; Jack et al., 2012). Another explanation might be found in individual differences in regard of negative emotion and its expression. In the next phase, the self-reported scores of positive and negative emotional states when using the teardrop glasses were compared to examine if the situation would be different in an indirective emotion-evoked circumstance and, more importantly, to investigate whether individuals with schizotypal traits would be more strongly affected in indirective environmental simulated conditions, such as teardrop glasses.

EXPERIMENT 2

Participants

Seventy undergraduate students from Waseda University (37 males; 33 females; mean age = 19.76 years; SD = 0.86; range: 19–21 years) participated in this experiment. First, they were randomly allocated into two conditions: the "crying" condition (35 participants) and "no-crying" condition (35 participants). Participants were tested individually. All participants answered the STA questionnaire after the experiment.

Procedure

All participants were equipped with teardrop glasses during the experiment, after which they were allocated to the crying and no-crying conditions. In the former condition, participants wore teardrop glasses that dispensed liquid every 2.5 s, while participants in the latter condition wore teardrop glasses that did not dispense liquid.

Participants were told how the teardrop glasses worked. To prevent participants from becoming suspicious of the study purpose, they were given the following explanations. In the crying condition, participants were told, "These are a pair of glasses frames in development. Liquid is dispensed from the glasses. People who wear these teardrop glasses will look like they are crying from the viewpoint of others who are looking at them. In the future, the glasses will be used to study empathy—specifically, how people feel when they see others crying. This experiment is just a pilot study to know how comfortable the glasses are while people wear them and focus on thinking about another thing." In the no-crying condition, participants were told, "These are a pair of glasses frames in development. Liquid is dispensed from the glasses. People who wear these teardrop glasses will look like they are crying from the viewpoint of others who are looking at them. In the future, the glasses will be used to study empathy—specifically, how people feel when they see others crying. This experiment is just a pilot study to know whether the frame is light enough to feel comfortable when people wear them. That is, liquid will not come out in this experiment. We want to know how comfortable they are while people wear them and focus on thinking about another thing."

While wearing the glasses, participants in both conditions were asked to perform the recall task as in Experiment 1 (recalling their autobiographical memory). Subsequently, participants were asked to write that experience down on paper including as detailed as possible a description of what had happened and how they felt at that time. Upon finishing it, the intensities of four emotions, "happy," "excited," "sad," and "angry" on their emotional states were rated *via* the Likert scale questionnaire. After filling out the STA, they were dismissed.

The emotion states of the written-down memory and reported content were carefully compared, as in study 1.

Results

The self-reported scores of emotional states, rather than the written-down autobiographical memories, were analyzed to avoid ambiguous emotional descriptions. Analyses were conducted with ANOVA 4.0 online (Kiriki, 2002). Positive crying (e.g., tearing up when feeling happy) was not reported in this experiment. **Figure 3** shows the self-reported scores of happy, excited, angry, and sad emotional states of participants for in the crying and no-crying conditions. Again, a mixed ANOVA was conducted with the condition (crying vs. no-crying) as a between-subjects variable and the self-reported scores of emotional states (happy, excited, angry, and sad) as a within-subjects variable. There was no significant main effect for the crying and no crying conditions [$F(1, 68) = 0.67$, $\eta^2 = 0.00$, $p = 0.42$] or the self-reported scores of emotional states (happy, excited, angry, and sad) [$F(3, 68) = 12.39$, $\eta^2 = 0.18$, $p = 0.42$], nor was there significant interaction [$F(3, 204) = 0.72$, $\eta^2 = 0.01$, $p = 0.0.54$]. The scores for the four emotional states, happy (crying condition: $M = 3.63$, SD = 1.76; no-crying condition: $M = 3.37$, SD = 1.59), excited (crying condition: $M = 3.57$, SD = 1.83; no-crying condition: $M = 3.23$, SD = 1.61), angry (crying condition: $M = 1.94$, SD = 1.45; no-crying condition: $M = 1.71$, SD = 1.34), and sad (crying condition: $M = 2.63$, SD = 1.84; no-crying condition: $M = 3.09$, SD = 1.50), were not significantly different between the crying and no-crying conditions. This means that when comparing the crying and no-crying conditions, people whose teardrop glasses dispensed tears did not experience stronger negative emotions (i.e., angry and sad), than did people whose glasses did not dispense tears.

Subsequently, Pearson's correlation analyses were also conducted to measure the degree of the relationship between participants' scores in schizotypy (STA) and the self-reported scores of emotional states in both the crying and the no-crying conditions (**Figures 4, 5**). In the no-crying condition, the Pearson's correlations between STA score and the rates of positive emotional scales and between STA score and the rates of negative emotional scales for recalled action statements were not significant (happy: $r = -0.06$, p = n.s.; excited: $r = 0.05$, p = n.s.; angry: $r = 0.17$, p = n.s.; sad: $r = 0.05$, p = n.s.); meanwhile, those in the crying condition were significant (happy: $r = -0.47$, $p < 0.001$; excited: $r = -0.48$, $p < 0.001$; angry: $r = 0.40$, $p < 0.01$; sad: $r = 0.42$, $p < 0.42$). This analysis shows that in crying condition, participants with high scores in STA reported more negative emotion (i.e., angry and sad) than positive emotion (i.e., happy and excited).

Additionally, a percentage bend correlation (Mair and Wilcox, 2019) was also conducted with the free software R 3.6.1 to double check the analysis. The result was similar to that of the Pearson's correlation. Percentage bend correlations between the STA score and the rates of positive emotional scales and between the STA score and the rates of negative emotional scales for recalled action statements were not significant (happy: $r = -0.1214$, $p = 0.6663$; excited: $r = -0.112$, $p = 0.6910$; angry: $r = 0.2776$, $p = 0.3164$; sad: $r = 0.0996$, $p = 0.7241$); however, those in the crying condition were significant (happy: $r = -0.4809$, $p = 0.0035$; excited: $r = -0.501$, $p = 0.0022$; angry: $r = 0.4611$, $p = 0.0053$; sad: $r = 0.4173$, $p = 0.0126$).

Discussion

These results show that the higher the STA score, the more participants tended to report negative emotions, such angry and sad, to recall more negative events under the condition where tear-like liquid was dispensed from the glasses. The results suggest that participants high in schizotypy were more influenced by the teardrop glasses than those low in schizotypy,

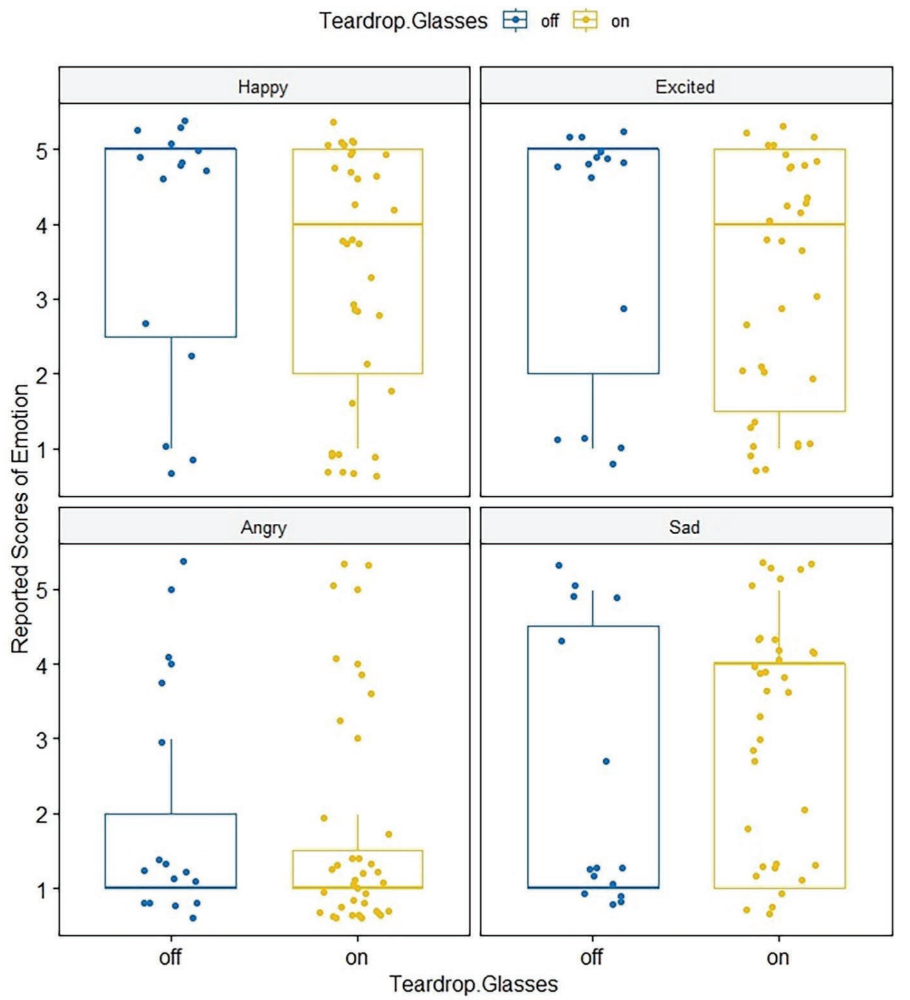

FIGURE 3 | Self-reported score of emotional states (happy, excited, angry, and sad) in the crying and no-crying conditions of Experiment 2.

suggesting that individuals' personality traits affected the result. The sense of ownership/agency, which is "the subjective awareness of initiating, executing, and controlling one's own volitional actions in the world," also refers to the ability to recognize oneself as the agent of a behavior, and the way the self establishes itself as an entity independent from the external world (Jeannerod, 2002)," was considered to be related to the results. There is some evidence for a similar relation between schizotypy and an individual's sense of agency/ownership. Kallai et al. (2015) found that people with high schizotypy, including feelings of depersonalization when the rubber hand illusion was induced, tended to have higher interpersonal sensitivity and vulnerability scores. Asai et al. (2011) examined the relationship between individual differences in the rubber hand illusion and empathic and schizotypal personality traits, as the existing literature suggested that schizophrenic patients would be more susceptible to the illusion. The results showed that people who experience a stronger rubber hand illusion may have both stronger empathic and schizotypal personality traits. This finding might also be related to empathic functioning, which is what allows us to simulate behavior observed in others.

In the next phase, an experiment within participants was conducted, expected to provide more support for why some participants were not affected by the teardrop glasses and whether or not schizotypal personality traits could provide a satisfactory explanation.

EXPERIMENT 3

Participants

Sixty-one undergraduate students from Waseda University (30 males; 31 females; mean age = 19.49 years; SD = 1.49; range: 18–21 years) participated in this experiment. Thirty-one of them were allocated randomly to a "smile-crying" condition and the other 30 to a "crying-smile" condition. Participants were tested individually. All participants answered the STA questionnaire after participating in the experiment.

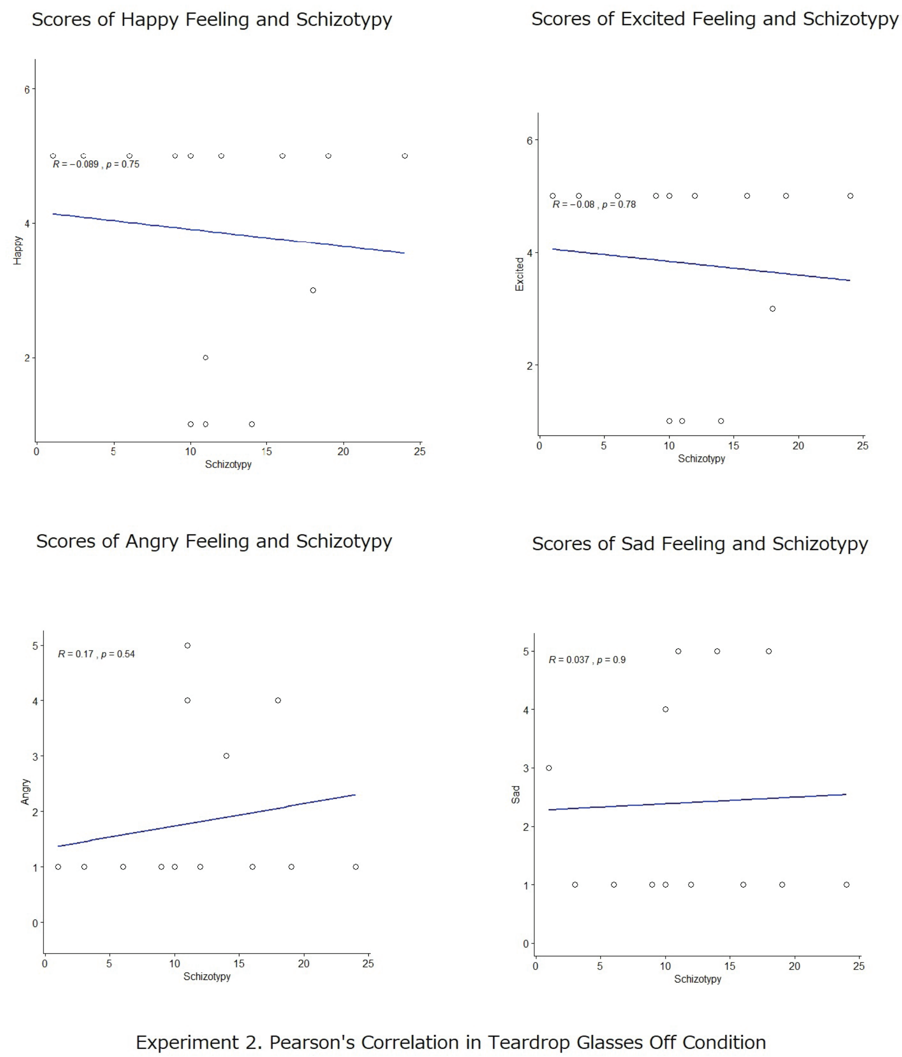

FIGURE 4 | Pearson's correlation analyses between participants' scores in schizotypy (STA) and the self-reported scores of emotional states (happy, excited, angry, and sad) in the no-crying conditions.

Procedure

All participants were asked to visit the experimental setting twice, separated by a one-week interval (Day 1 and Day 2). On Day 1, participants in the smile-crying condition were told to hold a pencil between their teeth to create a smile-like facial expression and recall their autobiographical memory under the same instructions with those in the smile condition in Experiment 1. After a week, they returned to continue the experiment on Day 2. At this session, they completed the entire procedure of the crying condition in Experiment 2. Participants in the crying-smile condition completed the same procedures but in reverse order (i.e., the crying condition first on Day 1, followed by the smiling condition on Day 2). They completed the four emotional scales (i.e., happy, excited, angry, and sad) *via* a Likert scale at the end of each task.

Results

Figure 6 shows the self-reported scores of four types of emotional states – happy, excited, angry, and sad – in the smiling and crying conditions. A two-way ANOVA, conducted with ANOVA 4.0 online, was conducted with condition (smile vs. crying) and the scores of emotional states (happy, excited, angry, and sad) as within-subjects' factors. We observed a significant interaction [$F(3, 180) = 18.86$, MSE = 32.23, $\eta^2 = 0.31$, $p < 0.001$] between the smile and crying conditions [$F(1,60) = 0.02$, MSE = 0.008, $\eta^2 = 0.00$, $p = 0.9029$] and the self-reported emotional state (i.e., happy, excited, angry, and sad) [$F(3, 180) = 13.31$, MSE = 45.69, $\eta^2 = 0.45$, $p = <0.001$]. Analysis of main effects showed that the scores of happy emotional states in the smile condition ($M = 3.72$, SD = 1.45) were significantly higher than in the crying condition ($M = 2.89$, SD = 1.66) [$F(1, 240) = 15.03$, $p = 0.0001$]. The scores for

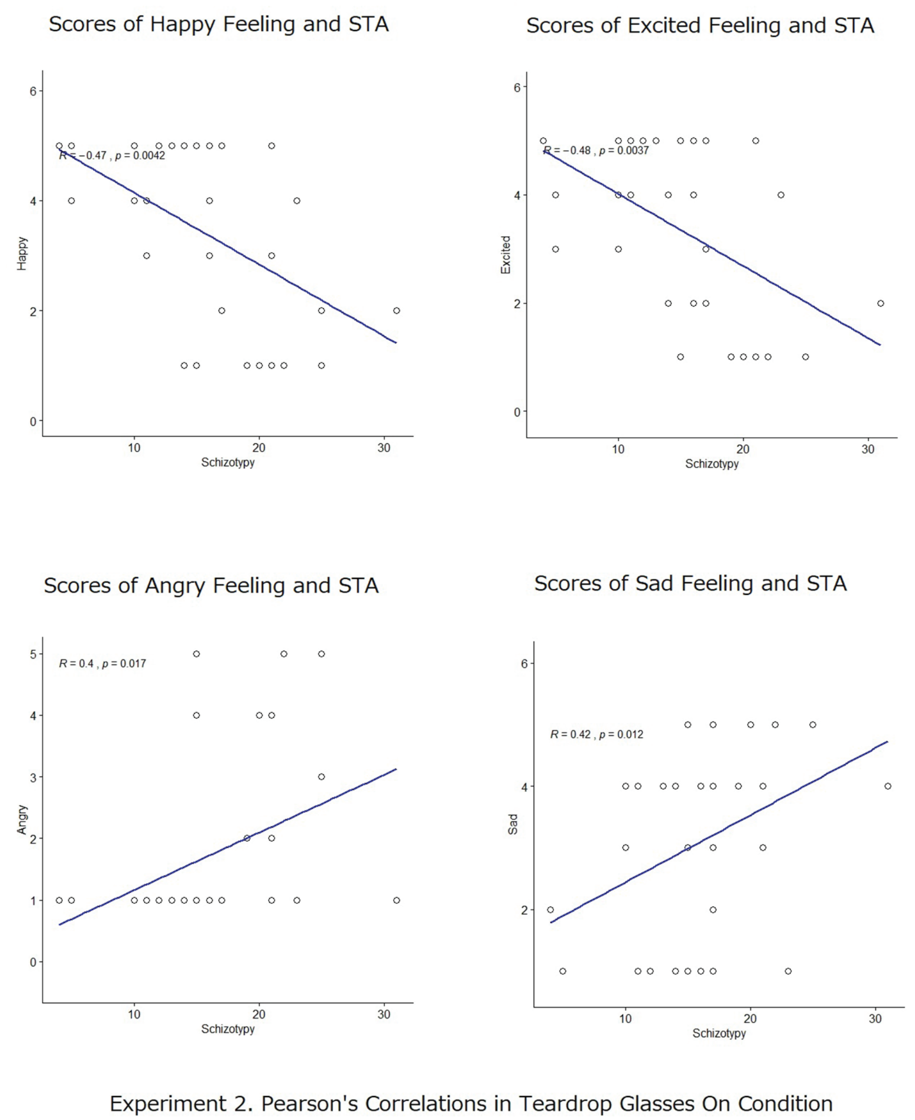

FIGURE 5 | Pearson's correlation analyses between participants' scores in schizotypy (STA) and the self-reported scores of emotional states (happy, excited, angry, and sad) in the crying conditions.

excited emotional states in smile condition (M = 3.66, SD = 1.49) were also significantly higher than in the crying condition (M = 2.75, SD = 1.55) [$F(1,240) = 17.49$, $p < 0.001$]. Negative emotions, such as angry emotional states, in the smile condition (M = 1.62, SD = 1.12) were significantly lower than in the crying condition (M = 2.30, SD = 1.38) [$F(1, 240) = 9.72$, $p = 0.0020$]. The scores for sad emotional states in the smile condition (M = 3.65, SD = 1.50) were also significantly lower than in the crying condition (M = 2.75, SD = 1.55) [$F(1, 240) = 25.95$, $p < 0.001$]. Additionally, the order of the smile and crying conditions was analyzed; we found no significant interaction related to the order [$F(1, 59) = 1.95$, MSE = 1.91, $p = 0.1677$].

Pearson's correlation analyses were also conducted to measure the degree of the relationship between participants' scores in schizotypy (STA) and the rates of positive and negative emotional scales for recalled action statements both in the smiling and in the crying conditions. The results are shown in **Figures 7**, **8**. In the smiling condition, there was no significant correlation between STA scores and the scores of positive emotional states (happy: $r = -0.004$, p = n.s.; excited: $r = 0.14$, p = n.s.); nor between STA scores and the scores of negative emotional states (angry: $r = 0.22$, p = n.s.; sad: $r = 0.08$, p = n.s.). Meanwhile, in the crying condition, there were significant correlations according to the Pearson's correlation coefficient between STA scores and the scores of the excited emotional states ($r = -0.35$, $p < 0.001$), indicating strong negative correlations between the variables as well as the scores of sad emotion states ($r = 0.40$, $p < 0.001$), indicating strong positive correlations between the variables. While no significant correlations were found in this

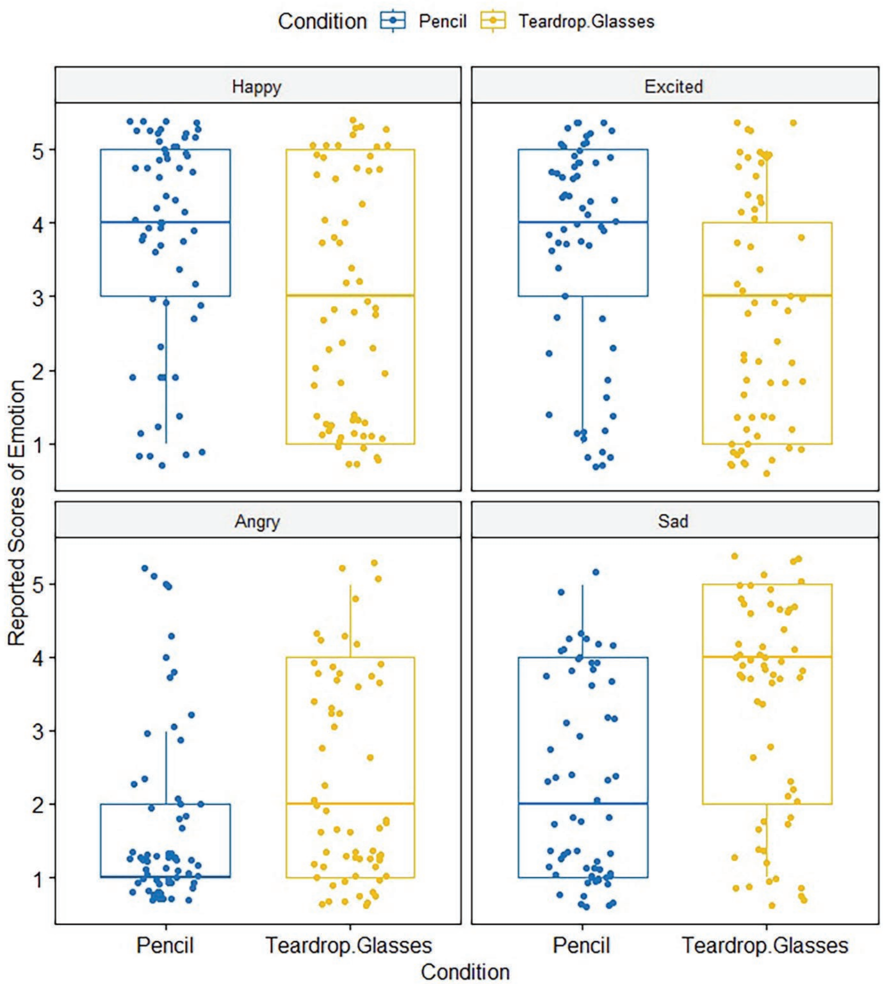

FIGURE 6 | Self-reported score of emotional states (happy, excited, angry, and sad) in the smile (pencil) and crying (teardrop glasses) conditions of Experiment 3.

analysis for STA scores and the scores of happy emotional states ($r = -0.06$, p = n.s.) and STA scores and the scores of angry emotional states ($r = 0.14$, p = n.s.).

Again, percentage bend correlation (Mair and Wilcox, 2019) was conducted to check the results. It was found that in the crying condition, there were significant correlations between STA scores and the scores of the excited emotional states ($r = -0.3501$, $p = 0.0057$), indicating strong negative correlations between the variables, as well as the scores of sad emotion states ($r = 0.4161$, $p = 0.0009$), indicating strong positive correlations between the variables. No significant correlations were found in this analysis for STA scores and the scores of happy emotional states ($r = -0.0678$, $p = 0.6035$) and STA scores and the scores of angry emotional states ($r = 0.1302$, $p = 0.3172$).

Discussion

These findings successfully replicated Experiments 1 and 2 within participants, further suggesting that participants high in schizotypy were more affected by wearing the teardrop glasses – that is, they tended to recall memories related to that negative emotion – while there was no relationship between the emotional scales and schizotypy when holding a pencil between their teeth. Moreover, participants with low schizotypy, indicated through low scores on the STA questionnaire, showed a different trend in the smile and crying conditions than those with high schizotypy. In the crying condition, they scored higher in the negative emotional state of the recalled autobiographical memory, which might suggest that they remembered more negative emotion-related memories consistent with the "teardrop" condition.

GENERAL DISCUSSION

"Emotions are complex perceptions created in the mind of a perceiver when people make meaning of basic visceral feelings in a given context (James, 1884)." James argued that people instead experienced various elemental biological and psychological states, from which they constructed a personal emotional experience for themselves (Lindquist, 2013). Meanwhile, emotion theorists have proposed that producing

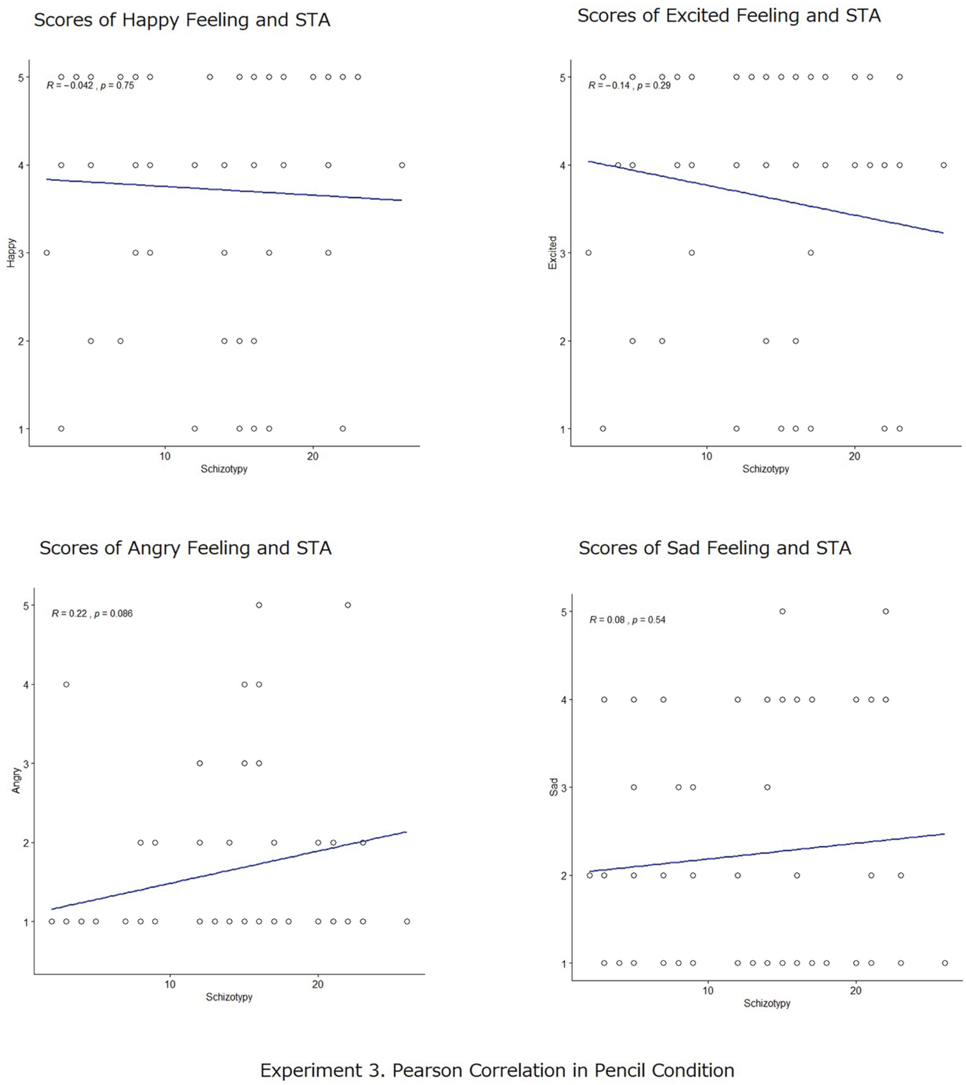

FIGURE 7 | Pearson's correlation analyses between participants' scores in schizotypy (STA) and the self-reported scores of emotional states (happy, excited, angry, and sad) in the smile conditions.

facial expressions and receiving sensory feedback from the face modulates the intensity of—or, in the strong formulation of the hypothesis, creates—emotional experience. According to the facial feedback hypothesis, congruent facial expressions enhance corresponding feelings, whereas the inhibition of these expressions or the display of expressions incongruent with the felt emotion attenuates those feelings (Niedenthal, 2007). Several experiments have found support for this hypothesis; for example, inhibition of facial expressions attenuated self-reported pleasantness ratings, whereas amplification of these expressions increased pleasantness ratings (Lewis and Bowler, 2009; Hyniewska and Sato, 2015). Furthermore, people instructed to imitate angry facial expressions had greater pupillary dilation and skin conductance than did participants who were simply viewing angry expressions (Lee et al., 2013). We are interested in how stronger facial feedback would affect people's mood, or whether it would only affect their current emotion. We noticed that there were few studies exploring how facial feedback theory works in directive and indirective stimuli, thus we decided to further investigate the facial feedback effect and different environmental stimuli. Our study's findings confirmed that facial feedback effect occurs more strongly under some conditions and emotional experience influences facial feedback more strongly than do other types of experiences, similar to what Coles et al. (2019) found in their research.

Considering that the paradigms we adopted in these studies are controversial, as we mentioned in the "Introduction" section, we designed our experiments based on the facial feedback hypothesis in a carefully controlled situation. We asked participants to imagine rather than watch subjects, and we did not monitor them with a camera. We also focused on the different emotional experiences caused by personality

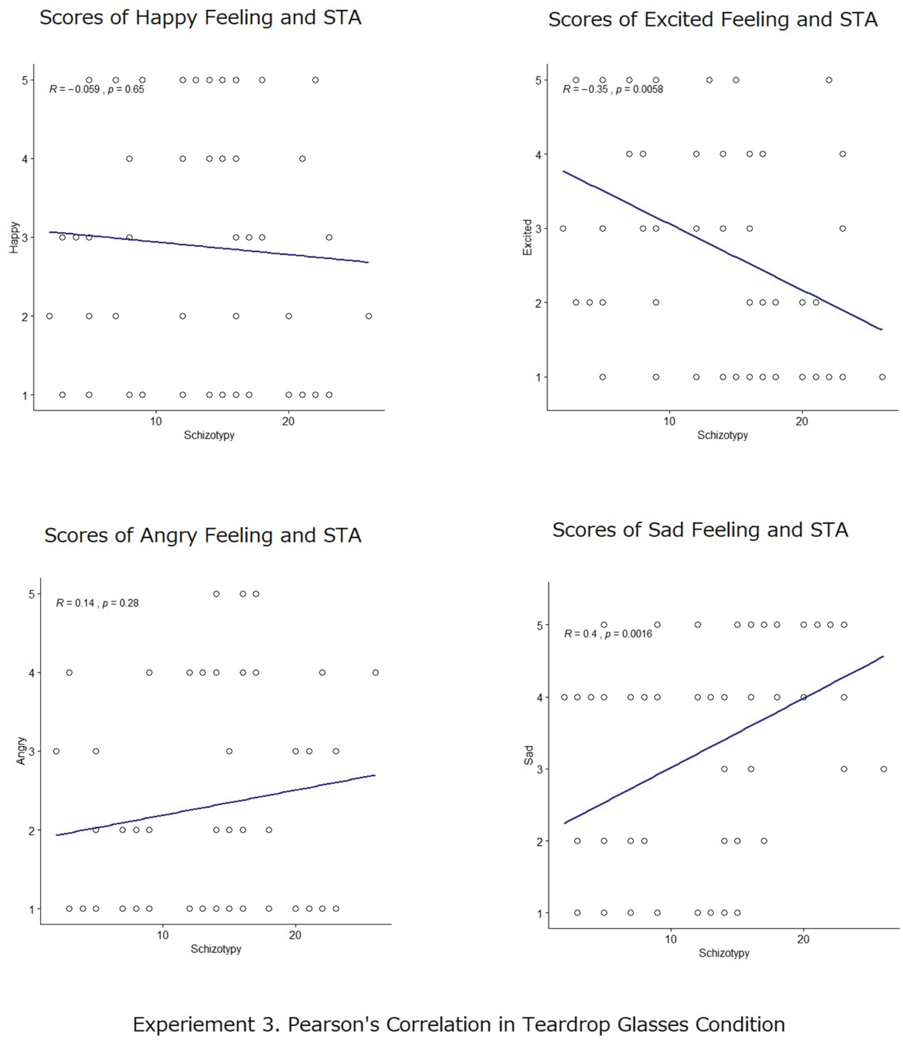

FIGURE 8 | Pearson's correlation analyses between participants' scores in schizotypy (STA) and the self-reported scores of emotional states (happy, excited, angry, and sad) in the crying conditions.

traits in the phenomenon of facial feedback and how they relate to the participants' autobiographical memories. We also employed a newly created tool, teardrop glasses to simulate negative emotion, as well as a traditional method of using a pencil to stimulate positive (smile) and negative (pout) emotions, in the investigation of embodied cognition and environmental stimuli.

We found that using a directed approach (gripping a pencil with teeth/lips) while recalling emotional biographical memory could possibly evoke participants' positive (e.g., happy and excited)/negative (e.g., angry and sad) emotions associated with that emotion. We believe that it also provides evidence for facial feedback theory and implies that the congruency hypothesis (Riskind, 1983) not only applies to intentionally stimulated emotions but also to emotions evoked by external forces. The results are consistent with a similar study conducted by Baumeister et al. (2015), who concluded that a mask blocking facial expressions influenced participants' performance during both encoding and retrieval of emotional items from memory. Embodied cognition has been linked to specific behavior such as facial mimicry and eye gaze (Niedenthal et al., 2010).

The evidence concerning the teardrop glasses is more complicated. Compared to participants gripping a pencil ("the smiling face is my own smile"), participants wearing teardrop glasses do not physically interact with the tool (no facial muscle was adopted), which means you have to have a sense of ownership for the tears on your cheeks ("the tears on my cheeks are our own tears"). Therefore, it is harder to have a sense of ownership over the "tears." Linked to the result of Experiment 1, where no significant differences in positive and negative rates were found in the pout condition, a possible explanation could be that the lower effect depended on the valence of the induced emotion in relation to its congruence. The results of our experiment investigating the effect of the teardrop glasses on memory (Experiments 2 and 3) were robust, showing that while participants who scored low in schizotypy reported little effect from wearing the teardrop glasses, participants with high schizotypy reported a much greater effect. People with schizophrenia compared to healthy people (Mirucka, 2016), or people with high schizotypy compared to those with low schizotypy (Asai et al., 2011), are more likely to experience the rubber hand illusion. As those previous studies, results we obtained in this research can be attributed to schizophrenia's or high-schizotypy's disruptions in the sense of body ownership. Nishio et al. (2018) investigated the relationship between body ownership and facial feedback phenomena. In that study, when participants felt ownership of a robot, they were likely to interpret the facial expression of the robot as their own emotional situation (Nishio et al., 2018), suggesting that having ownership of your facial expression ("The smiling face is my own") makes you reason that the facial expression comes from your emotional situation. Another explanation could be the affective traits and variate emotion recognition of schizotypy (Edwards et al., 2002). Horan and Blanchard (2003) stated that schizophrenic patients might experience stress related to negative affectivity, with similar decreases in positive mood in a controlled group during a role-play test of social encounters, requiring assertive or affiliative social skills.

These experiments conducted in this study provided evidence for facial feedback theory, revealing that the mechanism of the effect of facial feedback might be complicated. The effect could be influenced by the environmental setting, such as the presence or absence of a camera, the process of stimulating emotion, such as remembering an emotional autobiographic memory, and individual differences, such as schizotypal personality traits. A recent study exploring embodied experience in a virtual environment with a similar conclusion stated that how strongly a participant became immersed in a VR was related to their personal traits, especially the way they view and accept the given story in VR (Shin, 2018). Tschacher et al. (2017) discussed the implications of embodiment and schizophrenia, explicitly saying they believed that understanding people with schizophrenia is particularly pertinent in embodiment studies because most of the symptoms and signs of schizophrenia could be driven by false perceptions and beliefs about the cause of sensations, which is consistent with previous studies of sense of agency/ownership. We believe that this study could offer some recommendations for body psychotherapy, such as how to improve the construction of therapeutic environments (Röhricht et al., 2014), and the psychotherapy of schizophrenia patients (Gallese and Ferri, 2015).

Our study adds to the literature on the relationship between simulated emotion and emotion of recalled autobiographical memory, suggesting that external equipment, such as teardrop glasses, could affect the recall of individuals' emotional autobiographical memory. In a previous study, patients suffering from major depressive disorder showed reduced symptom severity after receiving Botox injections to the muscles involved in eyebrow furrowing, a movement associated with negative emotions (Finzi and Rosenthal, 2016). Accordingly, our results might be applied to the clinical field to help people suffering from emotional problems or people with schizophrenia (Helt and Fein, 2016).

The results of these experiments provide novel insight into embodied cognition and its association with emotional autobiographical memory. However, the cognitive processes that arise when someone is wearing teardrop glasses (an indirect process) might not be the same as what happens when gripping a pencil in one's teeth (a direct process). Future research should therefore employ similar processes, such as incendiary reflection (Yoshida, 2013) and teardrop glasses, to make comparisons more objective.

DATA AVAILABILITY STATEMENT

All datasets generated for this study are included in the article/supplementary material.

ETHICS STATEMENT

Ethics approval was not required for this study as per the Waseda University's Ethical Guidelines for Medical and Health Research Involving Human Subjects and applicable national regulations. Written informed consent was obtained from all participants.

AUTHOR CONTRIBUTIONS

YL conceived and designed the analysis, collected the data, performed the analysis, and wrote the manuscript. KS conceived and designed the analysis, collected the data, and performed the analysis. SY invented the teardrop glasses, made instructions how to use them, and fixed them when they didn't work. SY also checked the section "Methods and Discussion." ES conceived and designed the analysis, contributed to data and analysis tool, revised the first version of the manuscript, and performed the final check of the manuscript.

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REVIEW
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Cognitive Processes Unfold in a Social Context: A Review and Extension of Social Baseline Theory

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Psychologists often assume that social and cognitive processes operate independently, an assumption that prompts research into how social context *influences* cognitive processes. We propose that social and cognitive processes are not necessarily separate, and that social context is innate to resource dependent cognitive processes. We review the research supporting social baseline theory, which argues that our default state in physiological, cognitive, and neural processing is to incorporate the relative costs and benefits of acting in our social environment. The review extends social baseline theory by applying social baseline theory to basic cognitive processes such as vision, memory, and attention, incorporating individual differences into the theory, reviewing environmental influences on social baselines, and exploring the dynamic effects of social interactions. The theoretical and methodological implications of social baseline theory are discussed, and future research endeavors into social cognition should consider that cognitive processes are situated *within* our social environments.

Keywords: social baseline theory, Bayesian theory, economy of action, attachment theory, dyadic interactions

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INTRODUCTION

With the start of the cognitive revolution in the mid-20th century came a renewed interest in applying the scientific method to studying the mind. Simultaneous advances in technology and computer processing strongly influenced psychologists' approach to their endeavors. Scientists of the time applied the current technological terminology and definitions to the mind. The mind was comprised of cognitive *processes* that operated on *representations*, and often in *serial* manner. A particularly tricky aspect of this approach was isolating mental processes. To do so, the researcher must tightly control for any and all confounding variables, isolating individuals, and specifying appropriate control conditions, to ensure they were, in fact, measuring the variable of interest. The ingenuity and creativity of early cognitive scientists are impressive, and there is no doubt their efforts resulted in psychological advances too numerous to quantify.

Recently, researchers have embarked on studies in embodied and social cognition, whose primary area of interest is to move beyond isolated cognitive process and study instead how our physiological and social environments interact with our cognitions, respectively. Still, these endeavors in social cognition often still function from an isolationist perspective. For embodied cognitive psychologists, the focus still revolves around how the *individual*'s physiology affects cognition. For social cognitive psychologists, the predominant assumptions are that social effects on cognition are either the results of an individual's top-down processes or involve separate cognitive processed devoted specifically to social situations.

Conversely, researchers have proposed social baseline theory, which suggests that the default in cognitive processes is to assume the availability of social resources (Beckes and Coan, 2011; Coan and Maresh, 2014; Coan and Sbarra, 2015). If social baseline theory is correct, then it is not a question of which cognitive processes are involved in social situations. Rather, it is more appropriate to state that our physiological, neural, and cognitive processes are almost always situated within social situations. However, the effect of social environments is more complicated than simply a net positive/negative effect. Indeed, there are individual and environmental differences as well as group dynamics that must be taken into account. In the current paper, we will review the empirical evidence supporting social baseline theory, extend the theory to basic cognitive processes, highlighting research on individual differences, environment effects, and dyadic interactions, and offer suggestions for future research to move the field forward in studying the interaction between cognitive processes and social environments.

REVIEW OF SOCIAL BASELINE THEORY: WHAT IS A BASELINE

Social baseline theory first rests on the assumption that individuals operate under an economy of action. That is, all organisms must take in more energy than they expend (Proffitt, 2006; Beckes and Coan, 2011). This requires that individuals maintain homeostasis around a baseline. We outline two physiological examples of a baseline, blood glucose, and thermoregulation, as we will later summarize published research supporting social baseline theory involving these physiological processes.

Glucose is a necessary component of human functioning that operates via a feedback system. When sugar is consumed, the body keeps a baseline level of glucose in the bloodstream, ready for use. If an excess of glucose is present, it is stored as glycogen in the liver, and when the amount of blood glucose drops below the baseline, glycogen is released from the liver into the bloodstream (Benton et al., 1996). Thermoregulation is yet another physiological process that also maintains homeostasis around a baseline via a feedback loop. The average temperature set point for humans is 98.6 degrees Fahrenheit. When the preoptic area/anterior hypothalamus (POA/AH) receive messages regarding changes in temperature from thermoreceptors in the skin, a cascade of hormonal responses trigger physiological changes to increase or decrease our core temperature as needed (Satinoff and Rutstein, 1970; Van Zoeren and Stricker, 1977). For example, if a body's internal temperature drops below the baseline, individuals shiver to produce body heat, and then produce thyroid hormone to raise overall metabolic activity, which subsequently raises body temperature (Barnes et al., 1976). For both blood glucose and thermoregulation, fluctuations around the baseline are met with compensatory actions to maintain homeostasis. Similar to our body's physiological processes, social baseline theory proposes that our neural and cognitive processes also operate around a baseline.

Social Baseline Theory and Evidence

Social baseline theory asserts that the baseline for neural and cognitive processes is to assume close proximity to social resources. It is not the case that the presence of other individuals brings us above our baseline and adds cognitive processes to represent added social resources, but rather, social resources put individuals at their baseline. To study the neural and cognitive processes of an individual alone is to study them below their baseline. In an economy of action framework, when individuals are meeting their social baseline, they will expend minimal cognitive effort. However, when individuals are alone, or below their social baseline, you would expect to see additional neural, cognitive, and behavioral processes to compensate for the deficit. In other words, individuals will spend more cognitive effort and energy when they are alone rather than when they are situated in their baseline social network.

An illustration of this principle can be found in taking a Bayesian perspective of cognitive processes. In a Bayesian approach to decision-making, individuals calculate the costs and benefits of an action based on previous knowledge and experience, or priors. As individuals acquire new experiences and situations, the priors are updated (Anderson, 1998). If the social environment is meeting an individual's baseline expectations, there is no need to expend energy or use cognitive processes to update the priors. However, if individuals are below their baseline, specifically, alone or without social support, they will expect to expend more energy in updating priors to calculate the least costly decisions or actions. There is, in fact, physiological and neural evidence to support this social baseline approach, which we review in turn.

In thermoregulation, the physiological responses to regulate temperature, as described above, function through a feedback mechanism. Behaviorally, individuals can also function to maintain core temperature prospectively (Stearns and Stephen, 1992; IJzerman et al., 2015). When it is winter, individuals do not wait to step outside and shiver before acting, but rather put on coats, gloves, and scarves before leaving the house. Since raising body temperature is metabolically expensive, this predictive response is bioenergetically less costly.

Similarly, social environments can reduce the cost of thermoregulation. There is evidence that animals will also behave prospectively to thermoregulate by utilizing their social environments, and this action is metabolically efficient. For example, in cold temperatures, Chilean rats' metabolic rate is reduced by almost half when huddling in groups of three or five compared to an alone condition (Nunez-Villegas et al., 2014; IJzerman et al., 2015). In this case, animals utilize their social environments to efficiently regulate even the most basic of physiological processes, thermoregulation, to protect homeostasis around a baseline.

Moreover, there is evidence that suggests humans incorporate expectations about their social networks in order to efficiently thermoregulate. In one study, researchers continuously measured participants' peripheral body temperature while they were socially excluded or included. Participants' finger temperatures dropped relative to baseline during social exclusion but increased relative to baseline during social inclusion (IJzerman et al., 2012). These results could be due to the stressful nature of social exclusion and the positive nature of social inclusion, as previous research shows that stress results in peripheral vasoconstriction, while positive affect results in peripheral vasodilation (Rimm-Kaufman and Kagan, 1996). Social baseline theory also provides a framework for understanding these results. Cutaneous vasoconstriction and vasodilations are part of the homeostatic process of thermoregulation. Peripheral vasoconstriction reflexively serves as a defense mechanism to conserve internal body temperature, and vice versa for peripheral vasodilation (Alba et al., 2019). In social baseline theory, social inclusion indicates a positive social environment, and the presence of added positive social support would have pushed individuals above their baseline social expectations. Presumably, a positive social support condition might also signal to individuals that less conservation of resources is required, leading to vasodilation and a rise in finger temperature. On the other hand, the negative social support condition would have signaled added costs to acting in the environment and fewer available resources, resulting in vasoconstriction and a lower finger temperature.

Social networks may also influence behavioral decisions regarding another physiological resource, glucose consumption. In a correlational study, individuals that reported more social isolation also reported consuming more sugary beverages on average (Henriksen et al., 2014). This effect remained even after controlling for physiological factors such as weight and mood. Again, if our cognitive baseline is to expect a social environment, isolated individuals that fall below that baseline would need to stockpile physiological resources to compensate for expected costs of acting.

Finally, there is neural evidence to support social baseline theory. In a seminal study, researchers used fMRI to measure neural activity in participants expecting a mildly painful electric shock (Coan et al., 2006). They found that neural circuits typically associated with emotion regulation, for example, the dorsolateral prefrontal cortex (dlPFC), were *less* active when social support was provided. This finding was recently replicated; participants under threat of electric shock showed significantly less neural activity in both the dlPFC and dorsal anterior cingulate cortex (dACC) when holding hands with a partner relative to an alone condition (Coan et al., 2017).

Furthermore, these findings have been extended to actual pain experiences, rather than just threat-related neural activity. Holding hands with a partner reduced activity in a pain-related neural circuit, and this reduction in activity mediated self-reported pain intensity and unpleasantness (López-Solà et al., 2019). These results are initially surprising. Typically, adding extra cognitive processes during neuroimaging should increase the activity in involved neural circuits. Instead, introducing the presence of a socially supportive environment *decreased* activity in associated neural networks. Again, such results suggest that the baseline neural and cognitive states are to assume social support. When an individual is deprived of social support, as in the alone condition in the above hand holding studies, then extra cognitive processes are required, rather than the reverse.

In sum, both physiological and neural studies provide initial support for social baseline theory. Thermoregulation studies indicate that both animals and humans will behave prospectively to conserve physiological resources around a baseline, and that social environments are incorporated into an economy of action framework regarding said physiological resources. More importantly, there is strong neural evidence that participants' baselines are, in fact, social. This necessarily means that to study individuals while alone is to study them with extra costs to functioning in the environment, and therefore added cognitive and neural processes to a baseline.

EXTENSIONS OF SOCIAL BASELINE THEORY

Social baseline theory can be extended beyond physiological processes and neural mechanisms of behavior to explain previous findings in basic cognitive processes, such as visual perception, memory, and joint attention, reviewed in turn below. This brief review is not intended to be comprehensive, but to illustrate how social baseline theory can integrate and predict social influences in basic cognitive tasks. More importantly, social baseline theory should be expanded to include a discussion on individual differences. It does not necessarily follow that all individuals have the same social baselines nor that all social influences are necessarily positive. As such, we highlight research suggesting that early life experiences can set individual social baselines, and discuss how social interactions can cause transient fluctuations in individual baselines. Finally, these considerations still focus entirely on the effect of social baseline theory at an individual level. We propose that future research in both social baseline theory and social cognition should consider methodologies that incorporate and measure dynamic social interactions.

Social Baseline Theory in Cognitive Processes

In visual perception, individuals overestimate the slant of hills. For example, on average, a 25° hill is reported to appear 45° (Proffitt et al., 1995; Schnall et al., 2008). Anecdotally, this phenomenon is illustrated by the famous Lombard Street in San Francisco, which appears incredibly steep but measures, in fact, around 18°. Additionally, there is a growing body of evidence that suggests that both hill and distance perception are sensitive to physiological resources. Hills appear steeper and distances farther away when individuals are less physically fit, elderly, fatigues, and have lower blood sugar (Proffitt et al., 1995; Proffitt, 2006; Schnall et al., 2010). In fact, measures of individual differences in physical fitness will predict distance estimates before any interventions in a lab; individuals who are more physically fit will perceive objects to be closer than those who are less physically fit (Zadra et al., 2010). This evidence strongly suggests that changes in conscious visual experiences are due to changes in physiological resources. In other words, the visual system is sensitive to a body's ability to act in the world, which is reflected in the conscious visual experience of the environment around us.

As previously discussed, social baseline theory asserts that social resources will serve as a signal that cognitive and physiological loads are lower than when acting alone. Therefore, in terms of visual perception, social baseline theory would predict that the presence of supportive social resources would result in a smaller overestimation of hill slant. Alternatively, the presence of negative social resources will increase cognitive load, and would increase the slant of the hill. This prediction is supported by research. Schnall et al. (2008) found that when individuals imagined supportive others, they reported that hill slants appeared less steep than those who imagined a negative individuals. It seems that even within basic cognitive processes, such as visual perception, our minds are not only sensitive to cognitive loads and the cost of acting in the environment, but they also incorporate our social environments into these cost and benefit calculations.

Social effects have also been documented in another basic cognitive process, memory. In memory recognition tasks, social groups outperform individuals (Clark et al., 2000; Rossi-Arnaud et al., 2011). This is expected, and the results fit within a social baseline framework. The presence of others in a memory task allows a distribution of the cognitive load among individuals, which would result in improved performance. In collaborative memory tasks, individuals will typically encode items separately, and recall items either alone or in collaborative groups. Unsurprisingly, collaborative group recall surpasses individual recall (Andersson and Rönnberg, 1996; Weldon and Bellinger, 1997). However, group recall often will fall short of pooled individual efforts; that is, the sum of separate individual efforts at recall will surpass the average recall of the same individuals in a group (Andersson and Rönnberg, 1996; Weldon and Bellinger, 1997). On the surface, these findings appear contrary to social baseline theory. Still, further investigations into collaborative memory tasks reveals that the decline in group recall is because groups likely create less successful cues during encoding and inhibit successful memory retrieval strategies (Basden et al., 1997; Finlay et al., 2000; Barber et al., 2010; Rajaram, 2011). In fact, when investigating friend versus non-friend pairs, the decline in collaborative group recall was less pronounced for friend groups versus non-friend groups (Andersson and Rönnberg, 1996). Social effects on cognitive processes are not always positive, but these findings highlight the importance of investigating cognitive processes from a social baseline perspective. To quote previous researchers, "Humans routinely encode and retrieve experiences in interactive, collaborative contexts. Yet much of what we know as researchers comes from research on individuals working in isolation" (Barber et al., 2010).

Finally, literature on joint action provides a particularly strong case and example of social baseline theory. In joint action, individuals are required to coordinate their actions to achieve a common goal, which necessarily includes sharing representations on the environment, and predicting their own and others' actions (Sebanz et al., 2006). Humans have evolved to function optimally in our ecological niche, and as social animals the cognitive mechanisms for joint action would have evolved to coordinate behaviors in a social environment (Marsh et al., 2009). van Schie et al. (2004) found that when monitoring others' performances in task sharing, the same neural mechanisms were activated as if the individuals were performing the action themselves, with errors in others' actions resulting in increased neural processing. Furthermore, evidence suggests that individuals may automatically represent others' intended action goals. For example, reaction times in "go-nogo" tasks were significantly slower in the presence of others, even when individual participants were responding to different stimulus-response instructions and had no visual information regarding others' actions (Sebanz et al., 2003, 2005). In other words, even in tasks not requiring collaborative actions and even when others' actions were not visible, individuals still were representing others' actions in the social environment.

Individual Differences in Baselines

While research supports that individuals' baselines are on average social in nature, the theory does not claim that all social baselines are identical. Indeed, one must consider that there are individual differences in social baselines. Once again, a Bayesian perspective is useful when considering individual baselines. When relying on others in the face of a threat, humans trust that they are operating in a social environment that provides support. However, this is risky, because if our relational partners are not in fact engaging in some amount of vigilance on our behalf, then individuals place themselves at increased risk by relaxing our own vigilance processing. So how do people know who to trust? According to Bayesian theory, our brain places "bets" on the reliability of a social resource based on a prior probability distribution of past social experiences, and the deployment of personal resources are in turn based on this prediction. In this way, one's history of relationships may account for individual differences by influencing priors. Early familial support and attachment (Coan et al., 2013) and social capital (Lee, 2013; Liu et al., 2013) could be viewed as sources of useful information for these priors. Subsequently, maternal attachment and social capital have interactive effects on physiological behaviors, epigenetics, and neural responses to threat. In this section, we discuss how information from our social environment helps form our priors that in return produces an individual and unique social baseline that alters responses to the environment.

Experiences in early childhood with caregivers form our attachment styles, which in turn form the basis through which individuals approach later relationships (Bowlby, 1969). Children who experience warm, supportive caregivers responsive to their needs develop a secure attachment style, whereas children whose caregivers do not meet their needs will develop an insecure attachment style (Ainsworth, 1978; Bartholomew and Horowitz, 1991). These early life experiences shape expectations about future relationships. From a Bayesian perspective, they set our priors such that secure individuals expect others to be reliable and supportive, and vice versa for insecure individuals, which has been demonstrated in research. For example, individuals with secure attachment styles are more likely to seek social support and perceive provided support as positive, whereas insecurely attached individuals do not (Collins and Feeney, 2004). Like attachment styles, we argue that early childhood experiences and the larger environments within which individuals are situated can shape our social baselines such that each individual has their own unique social baseline.

Recently published research in thermoregulation provides support for individual differences in social baselines. In a pre-registered, replicated study (IJzerman et al., 2018), participants held either a warm or cold cup, ostensibly to rate it on a consumer survey, recalled the first five people that came to mind, and finally rated how close they felt to each person. Participants also answered an attachment style questionnaire [Experiences in Close Relationships (ECR)], from which researchers derived a set of items to measure individual differences in positive and negative relationship experiences. In the cold condition, individuals that reported positive relationship experiences were more likely to recall closer others, and vice versa for the warm condition. This is consistent with previously discussed research in social thermoregulation (Fay and Maner, 2012; IJzerman et al., 2013). However, individuals that reported negative relationship experiences showed the opposite effect. Those individuals were *less* likely to recall close others in the cold condition, and vice versa for the warm condition. These effects are viewed as compensatory effects (IJzerman et al., 2018), and can be explained by individual differences in our social baselines. For individuals with positive relationship experiences, their priors are such that others represent a reliable source of social support. In other words, they have a higher social baseline and so they are more likely to recall closer individuals. On the other hand, individuals with negative relationship experiences will not expect others to be a reliable source of social support or warmth, and so others represent an extra added cost to functioning in the environment. In the cold condition, which presumably invoked the potential for a metabolically costly physiological response, participants with a lower social baseline were less likely to think of close others because of this potential cost. This highlights the importance of investigating individual differences in social baselines. Without measuring previous experiences in relationships, and considering individual differences in these priors, it is likely the social thermoregulation effect would not have been replicated.

Individual differences in personality traits related to interacting with social environments will also produce varying individual social baselines. One such example is extroversion; Esyenck's biologically based theory of extroversion suggests that extroverts typically seek out interactions in social environments because they have a lower physiological arousal baseline than introverts (Matthews and Gilliland, 1999). In socializing and interacting with others, extroverts are energized, thereby raising their arousal baselines. Introverts, on the other hand, have higher arousal baselines and so at times prefer to withdrawing from social stimulation. Much as in the research of physiological thermoregulation, differences in extroverts and introverts come from individual's utilizing the social environment to regulate physiological arousal. This theory is supported by physiological evidence. Results in EEG studies show that extroverts have lower baseline cognitive activity levels than introverts (Beauducel et al., 2006; Hagemann et al., 2009). Differences in arousal levels between extroverts and introverts also have behavioral implications. For example, extroverts are less successful in vigilance tasks, which benefit from higher levels of arousal (Beauducel et al., 2006; Cox-Fuenzalida et al., 2006). Interestingly, these effects are predicted by social baseline theory. Social groups allow individuals to offload visual tasks to the group. Extroverts, when tested alone, are below their social baseline and unable to offload the cognitive load of the task. As such, their social baseline is not met, their physiological arousal levels are lower than baseline, and they perform worse on vigilance tasks. Conversely, when introverts' are tested alone, they are closer to their social and arousal baselines, and so their performance in the vigilance task does not suffer compared to extroverts.

Additionally, personality traits, such as extroversion, also alter individuals' responses within social environments. Extroverts not only report larger social networks, but they also are more likely to seek social support resources and perceive more available social support in their networks (Swickert et al., 2002). In other words, there are individual differences that mediate a response to social support. For example, there are gender-specific differences following a social exclusion task (Seidel et al., 2013), and those higher in trait anxiety exhibit significant differences in self-report measures and neural response following social exclusion (Heeren et al., 2017). Even more ephemeral changes in an individual's behavior, such as physical perspective and cognitive stance, are associated with perceptual differences of another's pain and pleasure (Fusaro et al., 2019). Individual differences not only set different social baselines, but these differences also alter how we respond to provisions of social support and social processes, such as social inclusion and exclusion.

Evidence of individual baselines is present in neural research as well. Similar to physiological measurements of individual baselines, neural activity is dependent on one's social environment. Enormous individual differences exist in coping with environmental stressors and creating and maintaining relationships with others. In a moment of threat, these differences include how one perceives and interprets a situation; one may perceive a loud crash during the night as someone breaking into their house, or as their cat knocking over a lamp, thus interpreting the sound as threatening or just annoying. This difference in interpretation leads to significant differences in cascading biological and neural reactions.

For instance, social environments characterized by supportive relationships regulate hypothalamic-pituitary activity, such that higher self-ratings of general health correspond with decreased hypothalamic activity during supportive hand holding in a threat task (Brown et al., 2017). Therefore, associations between an individual's social support and health outcomes are partly mediated through the social regulation of hypothalamic sensitivity to threat. This may indicate that hypothalamic sensitivity to threat depends on the individual and the individual's response to social support. And thus, how an individual responds to social support in the face of threat has downstream health outcomes.

Furthermore, the environment in which one develops influences an individual's social baseline. In one study, Gonzalez et al. (2017) used a validated measure of life history that quantified the relative harshness and instability experienced during an individual's development. They then investigated the interaction between life history, neural activity during negative stimuli, and oxytocin receptor gene (OXTR) polymorphisms on mental health outcomes. Findings suggest that economic privilege and specific types of epigenetic variability may calibrate social motivational neural systems for better or worse. For individuals with epigenetic predispositions that decrease the expression of certain oxytocin receptors, a stressful environment during critical periods of development interacts with these predispositions such that those individuals are more likely to develop anxiety and depression. In other words, the environment, both social and otherwise, that characterizes an individual's development has a significant effect on one's anxiety and depression dependent on the additional individual variability of one's genes. Environmental demands during early development can have ontological phenotypic effects that culminate in subsequent mental and physical effects.

We argue that personality, attachment style, personality, and life history, including genetic predispositions, are important latent variables that compose an individual's traits, but it is not a comprehensive list of individual differences. Rather, any early life experiences and individual traits that alter expectations regarding the reliability and usefulness of social resources in the environment will produce a unique social baseline for each individual. Because of varying social baselines, the same social environment will produce differential effects on physiology, cognition, behavior, and neural mechanisms. Furthermore, we expect these individual differences in social baselines to be lasting, akin to a biological set point, but certainly do not claim social baselines are permanently fixed.

Environment's Effect on the Individual

While individuals have a semi-permanent set point for their social baselines, the immediate environment can cause fluctuations around these set points. Early environments affect individuals by influencing and updating priors, turning gene expression on and off, and ultimately determining one's baseline. Aside from individual differences, the immediate context of social relationships also has a powerful transient influence on our cognitive and neural processing and can temporarily alter the set point of an individual's social baseline (see **Figure 1**). Importantly, social affiliates are often part of the immediate environment, and one's relationship with individuals and groups determine the quality of social resources one receives. It is important to note that social resources are not always positive; social environments, while mostly beneficial, might also incur a cost. Furthermore, social environments are not static, but necessitate dynamic responses to others.

Both threat and attachment figures are critical parts of the environment influencing how one then allocates cognitive resources, for better or worse. In the case of a *strong, positive* attachment figure, social relationships (i.e., social resources) buffer environmental threats, likely by changing how individuals perceive the threats. A trusted and interdependent conspecific can provide help in identifying and acquiring resources (e.g., food, shelter), vigilance for environmental threats, and help in caring for offspring, to name a few. These conspecifics *share* in the work for personal and genetic survival. This shared problem-solving, also known as load sharing (Coan, 2008), is a process by which individuals distribute effort in responding to environmental demands. In contrast to risk distribution, which mainly relies on an optimal number of conspecifics, load sharing relies on the relationship between said conspecifics. By sharing a goal with trusted conspecifics, the perceived energy required to achieve that said goal is also shared. Animals share in caring for young (Ehrenberg et al., 2001), acquire food together (O'Brien et al., 2005), and contribute to being vigilant for enemies (Davis, 2010). However, there must be a foundation of shared goals, such as a desire to perpetuate one's own genes, in order to motivate animals and humans alike to work together and share resources. This makes social relationship economically beneficial because they help achieve goals with shared cognitive resources.

We argue that social relationships, alongside load sharing, create a unique interaction and utilization of one's social environment. These differences have been investigated, namely, in two ways: (1) by observing individual responses to a stimulus and (2) how two or more individuals react simultaneously and dynamically with each other to the same stimuli. We discuss how the interplay between an individual and his or her social environment can have positive and negative impacts for the individual and the overall social relationship.

Social *environments* are malleable to the extent that social *relationships* are malleable. By changing how one individual perceives and interacts with a partner, positive and negative effects of threat perception and allocation of resources may change as well that constitute, in part, social baselines. In this respect, by studying an individual in isolation (as opposed to dyadic measurements), we can isolate and specify individual variables that may contribute to overall health and well-being. Johnson et al. (2013) introduced an empirically supported therapy strongly focused on repairing adult attachment bonds to distressed romantic partners. They observed a significant decreases in the neural activation and downstream regulation of neural threat response post-intervention when holding the hand of their romantic partner, particularly in brain regions associated with moderating negative affect (Etkin et al., 2011) and supporting cognitive reappraisal (Ochsner and Gross, 2005), such as the dACC and prefrontal cortex (Johnson et al., 2013). Additionally, prior research suggests that PFC-mediated work is computationally, biologically, and neurally costly (Halford et al., 1998; Dietrich and Horvath, 2009); therefore, a decrease in PFC-activity post-intervention also suggests conservation in cognitive resources. By improving the bond and interdependence between participant and romantic partner, social regulatory processes also improved by changing the way the brain encodes and responds to threats, likely harnessing more social and cognitive resources provided by the romantic partner and maximizing the benefits of load sharing. In other words, improvement in relationship quality with relational

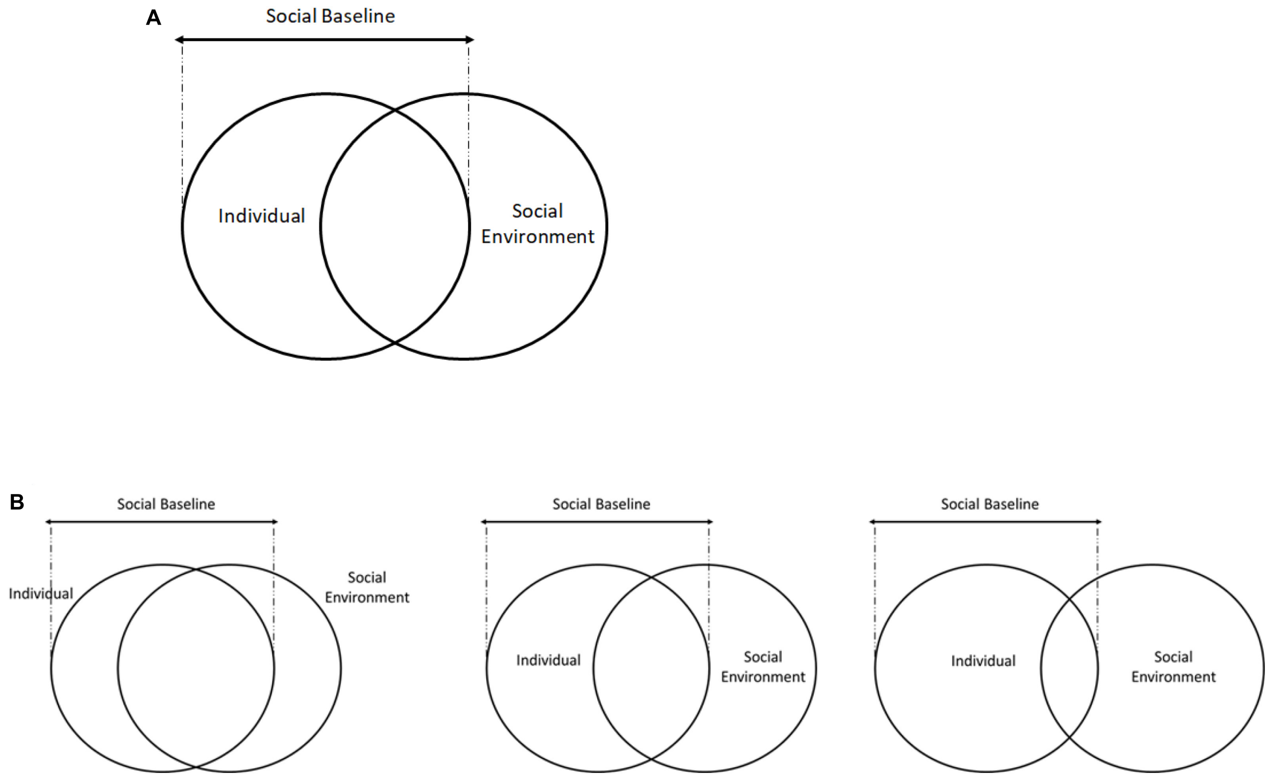

FIGURE 1 | The individual and social environment overlap represent social baselines. Early life experiences and personality traits are part of the individual differences that constrain social baselines to a range **(A)**, while social environments and dynamic interactions will cause temporary fluctuations in baselines around the set point **(B)**. In **B**, the middle represents the social baseline set point as determined by early life experiences and personality traits. The left circle indicates a transient increase in the incorporation of the social environment and social resources into the self due to changes in the current social environment, while the right circle demonstrates the opposite.

partners resulted in a higher social baseline, which translated into decreased threat perception when in proximity to the relational partner.

Social relationships can also have negative effects on threat perception and resource allocation. Co-rumination is a repetitive and cyclical discussion of a problem between two or more interdependent people without an objective to solve said problem. This process may heighten threat perception and response (Parkinson and Simons, 2012) and is associated with an increase in emotional distress (Calmes and Roberts, 2008; Smith and Rose, 2011). Thus, it might require more resources on the part of both partners in a dyad to combat stressors, which would lower each individual's social baseline. As a result, each individual in the dyad group would not pool social resources, and as such, each individual has a heightened threat response to stressors in the environment. However, these studies still investigate effects from an individual's perspective. They help us isolate particular psychological mechanisms of functioning but miss the dynamic interaction of social groups. Understanding this dynamic interaction is important because we can make psychological inferences from physiological and neural influences—the extent to which one dyad member's physiology or neural underpinnings predicts the other dyad member's physiology at a future time point (Thorson et al., 2017). This importance is compounded further by our assertion that an individual's cognitions are influenced within the social context.

In sum, we see individualized baselines in multiple domains: blood cortisol levels, thermoregulation, hypothalamic activity, and neural reactivity. Our baselines determine the physiological and cognitive responses we observe. While humans, in general, assume social support, there are individual differences in how one seeks out, receives and gives social support, and generally utilizes social resources. The following section moves away from the individual and describes how specific social environments may impact these individual differences and how in return, our individual baselines may determine how we respond to our environment.

Dynamic Extension of Social Baseline Theory

The above research is an example of environments' effects *on an individual.* However, we also argue that individual and social environments are not completely separate entities, but instead are co-existing and reciprocal systems that produce downstream reactions throughout the social context, not just on one individual. For example, research on the relationship between the self and another conspecific indicates that the concept of the self often incorporates others (Galinsky et al., 2005; Beckes et al., 2013). Self-expansion theory posits that the more familiar we are with a particular person, the more we perceive that person as ourselves (Aron and Aron, 1996). This concept of the "self-other overlap" extends to neural systems. Self-focused neural threat activity is robustly correlated with friend-focused neural threat activity but not stranger-focused neural threat activity (Beckes et al., 2013). Increasing levels of overlap between neural representations of self and other suggest that an individual may not be completely separate from more familiar conspecifics. Additionally, enfacement theory posits that synchronous stimulation and movement of self and other create a subjective illusion in which the other appears as the self (Porciello et al., 2018). Participants exposed to synchronous stimulation showed more merging of self and the other than participants exposed to asynchronous stimulation (Paladino et al., 2010). This multisensory integration can affect social perception and create a sense of self-other similarity or discrepancy. Recent research on the enfacement effect also provides evidence that a social environment can evoke changes in self-identification (Paladino et al., 2010; Tajadura-Jiménez-Jiménez et al., 2012; Porciello et al., 2018). The incorporation of stimuli in the social environment into the concept of the self extends to an individual's social baseline (see **Figure 1**).

The social environment contains a multitude of threatening situations that produce a physiological stress response. By measuring joint and dyadic responses between two conspecifics, we can also investigate how a dyad may actually coregulate, as opposed to investigating how any one individual regulates responses to the environment. This coregulation, or synchrony, may reflect a homeostatic, regulatory process in which interdependent dyads, such as romantic partners, jointly pull each other toward a baseline level characterized by greater stability in the system.

Research on the physiological synchrony and dynamics between dyads suggest that the interplay between a dyad's physiological responses is associated with positive and negative individual and interpersonal functioning outcomes (Pauley et al., 2015; West et al., 2017; Mckillop and Connell, 2018). Linkage in multiple systems was positively associated with indices of relationship connectedness, such as the amount of time spent together and the ability to identify the emotions of one's partner (Timmons et al., 2015). However, synchrony in cortisol levels of marital partners is negatively associated with relationship satisfaction (Timmons et al., 2015). Additionally, mothers' stressful experiences are considered "contagious" to their infants, and members of close pairs, like mothers and infants, can reciprocally influence each other's dynamic physiological reactivity (Waters et al., 2014). Dyadic interactions may also highlight more complex associations between one's social environment and individual outcomes. For example, marital satisfaction may buffer spouses from their partners' negative mood or stress state (Saxbe and Repetti, 2010). Physiological linkage may confer benefits but also may put couples at risk if they become entrenched in patterns of conflict or stress. Overall, this evidence suggests that any effects should be considered in light of dynamic responses among one's social environment, particularly between dyads.

Emerging research of social networks offers a valuable extension of dyadic processes and a more thorough understanding of the relationship between an individual and not only their assumed social environment, but also within an ecologically valid context. Recent work by Morelli et al. (2018) highlights the importance of studying not just the individual within the social environment but also the social environment as a whole. Participants identified different types of relationships with members of their proximate social environment and completed self-report measures of personality. A dynamic social network was created based on these measurements. By examining individuals within a social context, they found that those high in well-being (i.e., life satisfaction and positive emotion) were central to networks characterized by fun, whereas individuals high in empathy were central to networks characterized by trust (Morelli et al., 2018). This provides evidence that well-being is socially attractive, whereas empathy supports close relationships. We posit that individuals who have higher quality social relationships with multiple conspecifics in their environment have more social resources and are, therefore, more likely to have a higher social baseline. Furthermore, this emphasizes the importance of studying psychological constructs within a social context.

SUMMARY AND CONCLUSION

Social baseline theory suggests that, as a social species, our baseline assumptions in physiological, cognitive, and neuropsychological processes are situated in social contexts. In other words, in an economy of action framework our baseline defaults to expect social resources and social support. As such, it may be the case that there are not separate cognitive processes devoted specifically to the social environment, but cognitive processes may be automatically situated in social environments. We have reviewed evidence that suggests that our social baselines have surprising influences on our physiological, neural, and cognitive processes. These results suggest that cognitive processes are *generally* situated within our social baseline and that even in environments that are not inherently social, there may still be social effects.

How far can social baseline theory be extended, and which cognitive and behavioral processes operate outside of social baseline theory? We recognize that social baseline theory may not extend to all cognitive processes. We venture that one example of a cognitive process outside of the influence of social baseline theory is color perception but hesitate to name a list of potential candidates. Social baseline theory hinges on an economy of action framework, which includes conserving physiological and cognitive resources. As such, social baseline theory will extend to cognitive processes to the extent that these processes are resource dependent. However, some cognitive processes would not necessarily rely on physiological and cognitive resources, and so we would not expect social baseline theory to impact such processes.

While being situated in a social environment is the default assumption, social baselines are not ubiquitous for everyone. In fact, there is research that suggests that there are individual differences in the extent to which we are socially situated, and that our social baselines might indicate positive or negative experiences. For individuals with previously positive and supportive social and environmental experiences, their social baseline indicates that others are reliable and will lower their cost of acting in the world. The opposite is true for individuals with previously negative and unsupportive social and environmental experiences. For them, their social baseline indicates that others are unreliable, and so others represent an added cost to acting in the environment. Furthermore, researchers must also consider variability in our social environments, broader environments, and the dynamic responses that occur between an individual and their social environment. Just as individual differences alter the set point of social baselines, previous experiences and overall environments will also create momentary fluctuations in social baselines. From a Bayesian perspective, our priors are not entirely fixed or static, and variability in our social environments or in dynamic responses to individuals will also update our social baselines. Ultimately, investigations into social baseline theory, individual differences, and group and social dynamics are of the utmost importance, as they not only provide support for social baseline theory but might provide a framework for explaining contradictory findings on the effects of social environments.

Future Theoretical and Methodological Directions

We propose that in order to advance the field, researchers should consider leaving an isolationist approach and embrace an approach that encompasses a theoretical perspective grounded in Bayesian statistics. Because of the aforementioned individual, social, and environmental differences, this suggests that researchers should consider previous experiences that could influence the priors under investigation. This also suggests that certain methodologies could help the field move past an isolationist approach, for example, social network analyses, larger environmental and social contexts, and dyadic and group interactions. This section specifies theoretical and methodological recommendations for future conceptualization and research into cognitive processes that may be influenced by social factors.

A theoretical Bayesian perspective may be useful in conceptualizing the dynamic interaction and temporal nature of a social environment. Our social relationships and environments are not static. So, like physiological mechanisms where individuals have a baseline but fluctuate around that baseline, the reliability of an individual's relationships and environments *in the moment* will also affect their physiological, behavioral, and neural responses. In environments that are positive and where individuals are trustworthy, this may push us above our social baseline such that individuals will be more likely to offload the cost of acting in the environment, and vice versa for environments and social interactions that are negative. From a Bayesian perspective, this indicates that it is not just individuals' past experiences that set priors but also our current social environments and interactions—including dyadic interactions with others. That is, our priors will constantly be reinforced or updated given the current situation, which we argue is innately social by context.

Theory grounds sound methodology. We argue that ecological and Bayesian theory provide a solid foundation and framework for understanding human processes. We recommend that these cognitive processes should be studied with social situations in mind in order for a more ecologically valid understanding of human functioning. Additionally, social influences on cognitive processes should be contemplated in a more complex manner that includes the dynamic interplay of group influences. Therefore, we propose the following methodological recommendation for evaluating dyads and groups within a social context.

The first methodological recommendation is to consider both prior and current social context when evaluating outcomes. We argue that past information—including socioeconomic status, prior relationships, attachment history, and life history—are all necessary when understanding current cognitive processes because they determine our social baseline and give context for current measurements. Given that there are many variables to consider, we propose exploratory analyses to investigate whether these variables significantly predict processes or behaviors under investigation. A replication study should then be done to confirm findings.

The second methodological recommendation is to measure social variables in the research setting. This, at a minimum, requires the researcher to consider perceived social support and current social interaction between researcher and participant while moving toward a more ecologically valid design that includes dyads and larger groups. Thorson et al. (2017) provide a guide for considering theoretical and conceptual concerns when designing, implementing, and analyzing dyadic psychophysiological studies. Specifically, different theoretical questions require different physiological measures. For example, researchers interested in co-regulation will want to look at the degree that one partner's physiology predicts another's at a following time point (Butler and Randall, 2013; Helm et al., 2014). On the other hand, researchers interested in coupling or synchrony will want to investigate the correlation between two partners' physiology at the same time point instead (Kinreich et al., 2017). Cacioppo et al. (2007) have provided three dimensions along which psychophysiological relationships can be assessed—generality, specificity, and sensitivity—in order to better understand which physiological response relates to a psychological process. Much of these recommendations center on affective and physiological responses. However, we recommend incorporating these methodological considerations when investigating cognitive processes.

In conclusion, given the evidential support for social baseline theory, we urge researchers to consider that resource-based cognitive processes are generally situated in our social environments, often in surprising and unexpected ways. As such, we suggest a shift away from the assumption that cognitive and social processes are entirely separate, and propose instead that individual differences in our social baselines and the dynamic fluctuations in our social environments inherently shape our cognitive processes. Further research into variations in our social baselines can only serve to deepen our understanding of human behavior and the mind.

AUTHOR CONTRIBUTIONS

EG and SM-D conceptualized, drafted, wrote, and edited the article together, with EG taking slightly more lead and responsibility on the project.

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A Radical Reassessment of the Body in Social Cognition

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The main issue addressed in this paper is to provide a reassessment of the role and relevance of the body in social cognition from a radical embodied cognitive science perspective. Initially, I provide a historical introduction of the traditional account of the body in cognitive science, which I here call the cognitivist view. I then present several lines of criticism raised against the cognitivist view advanced by more embodied, enacted and situated approaches in cognitive science, and related disciplines. Next, I analyze several approaches under the umbrella of embodied social cognition. My line of argument is that some of these approaches, although pointing toward the right direction of conceiving that the social mind is not merely contained inside the head, still fail to fully acknowledge the radically embodied social mind. I argue that the failure of these accounts of embodied social cognition could be associated with so-called 'simple embodiment.' The third part of this paper focuses on elaborating an alternative characterization of the radically embodied social mind that also tries to reduce the remaining problems with 'simple embodiment.' I draw upon two turns in radically embodied cognitive science, the enactive turn, and the intersubjective turn. On the one hand, there is the risk of focusing too much on the individual level in social cognition that may result in new kinds of methodological individualism that partly neglect the social dimension. On the other hand, socially distributed and socially extended approaches that pay more attention to the dynamics within social interaction may encounter the risk of ignoring the individual during social interaction dynamics and simultaneously not emphasizing the role of embodiment. The approach taken is to consider several ways of describing and incorporating the (individual) social mind at the social level that includes language. I outline some ideas and motivations for how to study and expand the field of radical embodied social cognition in the future, as well as pose the ubiquitous hazard of falling back into a cognitivism view in several ways.

Keywords: radical embodied cognition, social interaction, embodied social cognition, meaning-making, sense-making, situatedness

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INTRODUCTION

Social cognition is an established research field that encompasses several theoretical approaches to describe and study how the social mind works. Hence, there is an intense and ongoing questioning about the role and relevance of the body in social interaction and cognition within cognitive science and related disciplines, and currently there is no single, simple answer to this question (Lindblom, 2007, 2015a). The mainstream study of cognition has since the inception of cognitive science in the mid-1950s mainly focused on studying individual's internal mental representations in form of symbol manipulation inside the head (e.g., Fodor, 1975, 1983; Newell and Simon, 1976; Gardner, 1987; Fodor and Pylyshyn, 1988). In that view, cognition is viewed as information-processing of these more or less explicit internal symbolic representations, being the "internal content" of the external world, and almost nothing outside "the skull" is taken into account. This is the still common and dominant view in the study of social cognition, suggesting that humans relate to each other in much the same way as they relate to other parts of the external world, i.e., by having more or less explicit internal (symbolic) representations of each other, which then are manipulated internally (e.g., Kunda, 1999; Quinn et al., 2003; Frith and Wolpert, 2004; Singer et al., 2004; Fiske and Taylor, 2013; Augoustinos et al., 2014). Accordingly, the body is only serving as some kind of input and output device, i.e., a physical interface between internal programs (cognitive processes) and the external world in this centralized view of cognition, where social cognition is considered to take place inside the skull. Thus, cognitive psychology in the form of 'the computer metaphor for mind' became equivalent to human cognition. Neisser (1967), among others, stresses that the actual task for cognitive psychologists was to understand the 'program,' and not the 'hardware.' Gardner (1987, p. 6) characterizes the core of cognitive science in its inception as follows: "*First of all, there is the belief that, in talking about human cognitive activities, it is necessary to speak about mental representations and to posit a level of analysis wholly separate from the biological or neurological, on the one hand, and the sociological or cultural, on the other.*" Altogether, this view falls into the category which here is referred to cognitivism.

Some Reasons for the Neglect of the Body, Criticism of Cognitivism, and the Re-turn to the Body

Historically, there are several reasons for the widespread neglect of the *body* in mainstream cognitive and social sciences (Lindblom, 2007, 2015a,b). On the one hand, it is a consequence of the Platonic-Cartesian heritage, which has resulted in the view of the mind being located in the brain as the internal locus of rationality, thought, language and knowledge (e.g., Fodor, 1975, 1983; Newell and Simon, 1976; Gardner, 1987; Fodor and Pylyshyn, 1988). Moreover, the opposite dimensions have been mapped on each other, resulting in the dualisms of, for instance, mind/body, mental/behavior, reason/emotion, and the subjective/objective. On the other hand, researchers commonly overlook the role of the body because they are afraid of slipping into *biological reductionism,* and therefore they generally prefer to view the mind as superior to and independent of the body (e.g., Segerstråle, 2003). The dichotomy between mind and body has in turn produced a disjunction between verbal and so-called non-verbal aspects of social cognition. and consequently embodied actions such as body posture, gaze and gesture are still commonly considered to be nothing but the visible outcomes of mental intentions and contents which are transmitted from one mind to another (e.g., Mehrabian, 1972; Burgoon et al., 2016). Furthermore, Trevarthen (1977) points out that a practical motive is another reason for the neglect of dynamical aspects, because bodily movements were difficult to observe properly with the technology of the time, and therefore cognitive science consequently became more of a static science of perception, cognition and action than a science of dynamic interactions. At the same time, cognitivism implies that context, history and culture are "murky concepts" (Gardner, 1987, p. 41) that would only cause problems in the effort to find the 'essence' of individual cognition. Instead, it was argued, these aspects could be addressed and integrated when cognitive science had achieved an understanding of the central inner mechanisms of individual cognition (Gardner, 1987; Lindblom, 2007, 2015a).

Starting in the late 1970s, several lines of criticism have arouse about the fundamental assumptions with cognitivism in the study of cognition. One addressed criticism is the need to extend cognitivism by taking into account the neurological aspects of cognition more seriously than before, which is aligned with the argument of the *biological implausibility* of the computer metaphor of mind (Maturana and Varela, 1987; Varela et al., 1991; Dreyfus, 1992; Johnson, 2007; Pfeifer et al., 2014; Ziemke, 2016). A second addressed line of criticism is the lack of connections between the external world and the internal representations that threatens its validity (Searle, 1980; Dreyfus, 1992; Lindblom, 2007, 2015a; Hutto and Myin, 2017). A critical aspect lies in the fact that it is unclear how changes in the brain's states are in structural correlation with the external world and become about it, i.e., having representational content, the so-called 'symbol grounding' problem in artificial intelligence (AI) (Harnad, 1990). Either this happens *via* the existence of an additional homuncular system that decodes between the "inner" and "outer" worlds, or "content" is the complex property that can be transferred between them. This also relates to the problem with the origin and content of mental representations exemplified in AI (e.g., Searle, 1980; Dreyfus, 1992; Ziemke, 1999, 2001; Hutto and Myin, 2017). Searle's (1980) debated whether the Chinese Room Argument addresses the lack of real understanding in the computer program itself, distinguishing between 'strong AI' and 'weak AI.' A third line of criticism is the lack of *situatedness* in these explanations, and instead it was argued that cognitive science must go beyond the formal representations and take the body and the surrounding world into account "*since intelligence must be situated it cannot be separated from the rest of human life*" (Dreyfus, 1992, p. 62). This 'rest of human life' refers to the body's influence on cognition, cultural factors, and common sense knowledge, which may be impossible to define explicitly. This aspect become rather obvious in traditional AI or so-called good old fashioned AI (GOFAI) were the cognitivism approach of programming a predefined world resulted in poorly behaving robots while acting in the fuzzy real world, although some computer programs, not robots, could master well-defined and specialized tasks like playing chess (Dreyfus, 1992; Clark, 1997; Pfeifer and Scheier, 1999; Ziemke, 1999, 2001; Lindblom, 2007, 2015a). Mental representations may not be necessary, since it appears probable that humans can, for instance, learn to swim, walk or catch a baseball by developing the necessary movements through practice, without any need to represent the bodily (and muscular) movements in the symbolic structure (Dreyfus, 1992; Thelen and Smith, 1994; Lindblom, 2007, 2015a; Wilson and Golonka, 2013). Moreover, Dreyfus (1992) points out that studies in developmental psychology have demonstrated that learning of specific details takes place on a background of shared sociocultural practices which seem to be picked up in everyday interactions not as facts and beliefs but as acquired socially and bodily skills for being-in-the-world, and these sensorimotor coordinations appear to underlie all the "higher" cognitive functions (Smith et al., 1999; Thelen, 2000; Thelen et al., 2001; Wilson and Golonka, 2013). A fourth line of criticism is raised from the 'turn to the wild' approach in cognitive science and human–computer interaction (HCI) (Suchman, 1987; Hutchins, 1995; Hollan et al., 2000; Rogers, 2012; Rooksby, 2013). Suchman (1987) stresses the impact of the momentary circumstances in a situation more than the importance of internal representations of plans. She introduces a new analytic model to study cognition where the relevant *actions* are driven by its context, reframing the issue of *interaction per se* in terms of sense-making practices (Rooksby, 2013). Hutchins (1995) emphasizes that there are unnoticed costs involved when we disregard culture, context and history in human cognition. Instead, we should be viewing it as a socio-cultural process and broaden the unit of analysis to a systems perspective. He argues that "cognitive science made a fundamental category error when it mistook the properties of a person in interaction with a social and material world for the cognitive properties of whatever is inside the person" (Hutchins, 2006, p. 1). Hence, the common theme in the criticisms raised above is that cognitivism, when studying cognition, seldom does a task analysis nor does it take into account what kinds of perceptual, embodied, situational, social and cultural resources and scaffolds are present to solve the actual task (Wilson and Golonka, 2013).

This has resulted in a turn, or rather a re-turn, to embodied and situated alternative views, which have been proposed by several scholars throughout the years. They argue, along similar lines, that cognitivism misinterprets the interrelated connections between brain, body and world in cognition and fails to realize the very nature of cognition (e.g., Maturana and Varela, 1980, 1987; Suchman, 1987, 1993; Varela et al., 1991; Dreyfus, 1992; Hutchins, 1995; Clark, 1997; Smith et al., 1999; Thelen, 2000; Thelen et al., 2001; Gallagher, 2005, 2015, 2017; Johnson, 2007; Lindblom, 2007, 2015a,b; Chemero, 2009, 2013; Wilson and Golonka, 2013; Hutto and Myin, 2017; Fuchs, 2018; Newen et al., 2018). These scholars, among others, emphasize the ways cognition is shaped by the embodied human's interactions with the surrounding material, social, and cultural world. Some of the most prominent advocators of the embodied cognition and *enactive* approach, Varela et al. (1991, p. 172–173, original emphases) explain the phrase *embodied action* as follows: "By using the term *embodied* we mean to highlight two points: first, that cognition depends upon the kinds of experiences that come from having a body with various sensorimotor capacities, and second, that these individual sensorimotor capacities themselves are embedded in a more surrounding biological, psychological and cultural context. By using the term action we mean to emphasize once again, that sensory and motor processes, perception and action, are fundamentally inseparable in lived cognition. Indeed, the two are not merely linked in individuals, they have also evolved together. In a nutshell, the enactive Varelian approach consists of two points: (1) perception consists in perceptually guided action and (2) cognitive structures emerge from the recurrent sensorimotor patterns that enable action to be perceptually guided." Varela et al. (1991) are strongly influenced by phenomenology, pragmatism as well as Buddhism. In other words, cognition is for *action* and *action-readiness* (Engel et al., 2013), and the subjective tactile-kinesthetic experience of one's own moving lived body is the bedrock of thinking (Sheets-Johnstone, 1999). This means that the self-experienced bodily understanding is the elemental and unsurpassable unity of embodied actions. Damasio (1995) points out that the brain and body form an indissociable organism. He claims that the separation between the mind and the brain is only mythical, the separation between them is most likely fictional. In recent years, the cognitive science field has introduced more elaborate views on cognition that Marsh (2006) refers to as DEEDS (Dynamical, Embodied, Extended, Distributed, and Situated) theories of cognition. In a similar vein, Barrett (2015) as well as Newen et al. (2018) refer to 4E-cognition (Embodied, Embedded, Enactive, and Extended), arguing that although they differ from each other in a number of significant ways, the DEEDS and 4E-approaches share and have in common the central idea that cognitive processes emerge from the unique manner in which an agent's (either human, animal or robot) morphological structure and its sensory and motor capacities enable it to engage successfully with its social and material environment in order to bring fourth adaptive and flexible actions. Hence, the two underlying assumption for the DEEDS and 4E approaches of cognition are: (1) the agent's embodied interactions matters for intelligence, and (2) the need for broadening the focus and scope of the agent's cognitive system "beyond the brain."

However, over the last decades, the main focus in most DEEDS and 4E approaches of cognition has until recently been on the relation between the individual body and its cognitive processes, in interaction with the physical environment, and there is a need to consider the fundamental situated and embodied nature of social interaction and cognition (e.g., Johnson, 2007; Lindblom, 2007, 2015a,b; De Jaegher et al., 2010; Fuchs, 2018; Newen et al., 2018). Lately, an increased interest has been further explored to the social dimension of embodied cognition that ranges from the role of *social embodiment effects* (Barsalou et al., 2003; Niedenthal et al., 2005), *mirror neuron systems* and *embodied simulations* that provide embodied explanations of the traditional concepts of "mindreading" and "theory of mind" (Gallese, 2004; Gallagher, 2005), *speech and gesture as an intertwined symbiotic system* (Lindblom, 2007, 2015a,b) to *participatory* aspects of social understanding and *sense-making practices* (De Jaegher and Di Paolo, 2007; De Jaegher et al., 2010; Kyselo, 2014) to *language* (Cuffari et al., 2015; Di Paolo et al., 2018).

Taking a socially embodied view, the above embodied approaches to social cognition, look rather similar at first glance, but taking a closer look, there are fundamental differences. A central aspect is that although many of these embodied approaches are leaning toward the direction of conceiving the social mind as truly embodied, in many regards they still remain aligned, to various extents, to cognitivism.

Clark (1999) distinguishes between *simple embodiment* and *radical embodiment*. In simple embodiment, the traditional foundation of cognitivism is preserved, and the nature of embodiment is merely considered a constraint of the 'inner' organization and processing. Radical embodiment goes much further and treats the facts of embodiment as a fundamental shift in the explanation of cognition that is "*profoundly altering the subject matter and theoretical framework of cognitive science*" (Clark, 1999, p. 348). A similar line of argument is addressed by Gallagher (2015), who emphasizes that the ongoing discussion of what really constitutes embodied cognition is needed and may define important differences between embodied cognition theorists, but still holds the stance that the body plays a significant role in cognition. He points out that some scholars are making a more reactionary move, formulating a kind of disembodied version of embodied actions that leaves the body out of it, only focusing on what happens inside the brain. Gallagher denotes these efforts of putting the "body in the brain" as *body snatching.* He urges other proponents of embodied cognition to resist the invasion of body snatchers, i.e., challenging those who neglect the role of the radically enacted body in agent-environment interaction as the fundamental basis *per se* in cognition, a quest that I try to achieve in the rest of this paper, with a particular focus on the social mind.

Chemero (2009, 2013) points out that there are at least two different scientific traditions, which both are commonly referred to as 'embodied cognitive science'. Chemero denotes one of these traditions as radical embodied cognitive science, which has roots in American naturalism (e.g., the work of Williams James and John Dewey) and Gibson's ecological psychology, being anti-representationalist and anti-computationalist traditions of eliminativism and pragmatism. Chemero (2009) defines radical embodied cognitive science as "*the scientific study of perception, cognition, and action as necessarily embodied phenomenon, using explanatory tools that do not posit mental representations. It is cognitive science without mental gymnastics*" (p. 29). The other direction is the more mainstream version of embodied cognitive science, i.e., simple embodiment, which is derived from traditional theoretical frameworks that are referred to as cognitivism in this paper. Consequently, this is the answer to why simple embodiment, in various degrees, is compatible with cognitivism explanations. It should be noted, however, as Chemero (2009) correctly points out, that radical embodied cognitive science is not a radicalization of embodied cognitive science. Instead, the mainstream version of embodied cognitive science, i.e., simple embodiment, could be regarded as a "watering down" (ibid., p. 30) version of the more radical scientific tradition that dates back to scholars of pragmatism. This means that the influence goes the other way around than often presented or imagined in mainstream cognitive science, and clarifies why there has been a turn to pragmatism and enactivism within more radical embodied approaches of cognition.

Aim and Objectives

In this paper, I present and analyze several approaches of socially distributed, situated, embodied and enacted social cognition. My line of argument is that some of these approaches, although advocating toward the idea that the social mind is not merely contained within the head, fail to describe a radical embodiment view of the social mind. In the more positive parts of this paper, I suggest that this quest can be achieved by drawing upon the more radical and intersubjective accounts of embodied social cognition, which in several ways emphasize anti-representational explanations. It also shift the focus from the individual mind in social cognition to instead focus on what happens in the social interaction as such between interacting individuals in meaning-making practices, including languaging. A thesis that is emphasized is the idea that human cognition by nature is *relational*, in which the social and cultural scaffolds that human embodied beings are situated within and enculturated to, is the driving force for the emergence of our embodied social understanding and the human mind. Finally, in line with those arguments, I present some ideas and motivations for how to study and expand the field of radical embodied social cognition in the future, as well as pose the ubiquitous hazard of falling back into cognitivism in several ways.

SOCIAL EMBODIMENT EFFECTS, SOCIAL NEUROSCIENCE AND EMBODIED SIMULATIONS

Social Embodiment Effects

In the extensive literature on embodiment effects in social psychology, the work summarized by Barsalou et al. (2003) has identified four kinds of social embodiment effects, for which there is plenty of empirical evidence. They characterize social embodiment as "states of the body, such as postures, arm movements, and facial expressions, arise during social interaction and play central roles in social information processing" (Barsalou et al., 2003, p. 43).

Firstly, perceived social stimuli do not only produce cognitive states, but also bodily states. For example, it has been reported that high school students who received good grades in an exam adopted a more erect posture than students who received poor grades (Weisfeld and Beresford, 1982). In another experiment, subjects primed with concepts commonly associated with elderly people (e.g., 'gray,' 'bingo,' 'wrinkles') exhibited embodiment effects such as slower movement when leaving the experimental lab, as compared to a control group primed with neutral words (Bargh et al., 1996) (it should be mentioned that this study has been criticized due to problems with replication and priming, see Doyen et al., 2012). Subjects performing a lexical decision task, using verbs referring to mouth, hand or leg motion (e.g., "chew," "grab," or "kick") showed increased activation in corresponding mouth, hand, leg areas of motor cortex, although no overt action or movement was required (Pulvermüller et al., 2001). Secondly, the observation of bodily states in others often results in bodily mimicry in the observer. People often mimic behaviors, and subjects often mimic an experimenter's actual behavior, e.g., rubbing the nose or shaking a foot (Chartrand and Bargh, 1999). Moreover, mothers tend to open their mouths after their infants have opened their own during feeding (O'Toole and Dubin, 1968, and similar effects are widely documented in the literature). Thirdly, bodily states produce affective states, which means that embodiment not only facilitates a response to social stimuli but also produces tentative stimuli. Subjects rated cartoons differently when holding a pen between their lips than when holding it between their teeth (Strack et al., 1988). The latter triggered the same musculature as smiling, which made the subjects rate the cartoons as funnier, whereas holding the pen between the lips activated the same muscles as frowning and consequently had the opposite effect. Moreover, bodily postures influence the subjects' affective state; e.g., subjects in an upright position experienced more pride than subjects in a slumped position (Stepper and Strack, 1993). Fourthly, compatibility between bodily and cognitive states enhances performance. Several motor performance compatibility effects have been reported in experiments where subjects responded faster to 'positive' words (e.g., 'love') than 'negative' words (e.g., 'hate') when asked to pull a lever toward them (Chen and Bargh, 1999). Additionally, subjects holding warm coffee were more likely to evaluate an imaginary individual as warm and friendly than those subjects holding cold coffee (Williams and Bargh, 2008). In another study, passers-by evaluated job candidates by reviewing the resumes on either light or heavy clipboards. Participants with heavy clipboards rated the candidate as better overall and specifically as displaying more serious interest in the position. These participants also rated their own accuracy on the task higher than participants using the light clipboard (Ackerman et al., 2010).

Other research focuses explicitly on traditional conceptions in social psychology, such as attitudes, social perception, and emotions (Niedenthal et al., 2005). Niedenthal et al. (2005) suggest that social-information processing involves embodiment, with which they refer to "actual bodily states and to simulations of experience in the brain's modality-specific systems for perception, action, and introspection" (Niedenthal et al., 2005, p. 184). They address these topics from *online* (i.e., perceiver interacts with actual social objects, e.g., mimicking a happy facial expression) and *offline* (i.e., perceiver represents social objects in their absence, e.g., understanding the concept happiness or recalling a happy experience) cognition. They argue that distinguishing between online vs. offline is helpful in systematizing the findings within social psychology, and besides, it can function as a way to conceptualize the acquisition and the use of knowledge, as well as hopefully recognizing similarities between their underlying embodied mechanisms. They provide empirical findings from three identified categories.

First, embodiment of attitudes concerns the acquisition and processing of attitudes, emphasizing that empirical studies show that bodily postures and motoric activities, such as nodding heads (in agreement) or shaking heads (in disagreement) are related with positive or negative preferences and action predispositions toward objects (Tom et al., 1991). When participants offline generated the names of famous persons (e.g., 'Jane Fonda' or 'Clint Eastwood'), and then classified the celebrities according to whether they liked, disliked or were neutral about them, during the generating names phase, participants were instructed to either place their hands beneath the table and pushed upward (inclining an approach behavior) or on top of it and pushed downward (inclining an avoidance behavior). As a result, the participants directed to conduct an approach behavior named more celebrities they liked, whereas those that performed an avoidance behavior named more they disliked (Förster and Strack, 1997). Secondly, embodiment of social perception, is reported in the finding where mothers open their mouths in response to their infants' mouth opening during feeding. One example of a reported offline effect is when researchers created descriptions of fictional characters, based on personality descriptions of significant others the participants liked in their ordinary lives. Later, in the experimental situation, while the participants read the descriptions of the fictional characters, they tended to display positive facial expressions. When the participants instead read descriptions of the fictional characters based on persons they disliked, they were inclined to show negative facial expressions (Andersen et al., 1996). Thirdly, many examples of embodiment of emotions are reported in the literature, e.g., when somebody fakes an injury and grimaces in pain, observers also grimace (Bavelas et al., 1986). Regarding offline embodiment in emotion, is was demonstrated that participants' retrieval of pleasant or unpleasant autobiographical memories was influenced by the manipulation of facial expressions and postures. Adopting an erect posture and also smiling hastened the retrieval of pleasant autobiographical memories, compared to the speed of retrieving unpleasant memories (Riskind, 1984). In studies with Botox, temporary paralysis of the facial muscle that is responsible for producing a frown hindered processing, relative to pre-injection baseline, for angry and sad sentences, while processing for happy sentences was unaffected (Havas et al., 2010).

These examples, as well as many other similar and related studies (see Anderson et al., 2012; Glenberg, 2015 for a review of additional examples with links to various embodied metaphors in linguistics), demonstrate that there is a strong relation between so-called "embodied" and "cognitive" states in social cognition. In short, the bi-directional swapping between various components of an affection-resonance-emotion cycle changes automatically, both "online" and "offline," without any conscious mediating knowledge structures ("content") in attitudes, social perception and emotions (Lindblom, 2007, 2015a; Fuchs, 2018). Instead, Fuchs (2018) interprets the above social and emotional embodiment effects as an intercorporeal resonance, which favors an enacted perspective.

It has been suggested that mirror neurons function as the neuro-biological underpinning for these social embodiment effects or intercorporeal resonance and then embodied simulations may provide an embodied account of social understanding, without a grounding in internal representations, as discussed in more detail in the following section.

Social Neuroscience and Embodied Simulation Theories

More detailed accounts of how the sensorimotor structures of the brain are involved in social cognition have been developed in several disciplines, often taking into account data from neurophysiological and neuroimaging studies. Fuchs (2018) argues that the continuous circular interaction emerges into the phenomena of emotional experience that cannot be solely located in the brain, as usually explained, but instead spans the whole body. Findings in social neuroscience provide strong evidence for a radically embodied interpretation of social understanding. Such an understanding may rely on the discovery of special kinds of visuo-motor neurons in the premotor cortex in the brain of macaques, so-called *mirror neurons,* which exemplify how perception and action might come together at the level of single neurons. Mirror neurons located in area F5 in the monkey brain become activated both when *performing* specific goal-directed hand (and mouth) movements and when *observing* or *hearing* about the same actions (e.g., Gallese et al., 1996; Rizzolatti et al., 1996). Because mirror neurons respond in both conditions, it has been argued that the mirror system functions as a kind of direct connection between 'action' and 'action-perception.' The succeeding disclosure of a mirror neuron system in the human brain (Gallese et al., 2004; Rizzolatti and Sinigaglia, 2010) demonstrates a *relational* character and reveals how the brain can map (not represent) intentional actions, implying, in turn, how deeply intertwined action, perception and cognition actually is (Gallagher, 2005; Gallese, 2017). This means that the mirroring mechanism enables the agent to grasp the meaning of the observed action by embodied (re)-activation without using internal representations. This means, even while only *observing* the actions of another individual, a neural 'triggering' event in fact takes place without any mediating representation in the observer, providing an 'intuitive' social understanding of the observed action (Lindblom, 2007). Subsequent work on the activation of the mirror neuron system has been performed in specific contexts, e.g., before and after drinking tea to investigate the understanding of intentions of others while watching their actions in different conditions (Iacoboni et al., 2005). Human subjects were exposed to three different stimuli; grasping hand actions without a context, context only, and in two different contexts (either 'drinking – to have tea' or 'cleaning – after having tea'). The obtained fMRI data shows that actions embedded in contexts generated a significant increase of activity in the pre-motor mirror neuron areas of the brain, indicating that the mirror neuron system is also involved in grasping the intention of others automatically. This means, the role of the mirror neuron system seems to be more complex than mere action-recognition, otherwise a similar response should have been displayed while watching grasping actions regardless of whether the context of the observed action was present or not. Furthermore, there were different activations between the 'drinking' and 'cleaning' contexts, which imply there are certain neurons in the human inferior frontal cortex that particularly 'grasp' the *why* aspect of the action. Thus, the study indicates that certain kinds of mirror neurons, so called logically related mirror neurons, may constitute the foundation for more advanced forms of bodily intentionality. The description of an action and the interpretation of the reason why that particular action is performed have been considered to rely on two different mechanisms in cognitivism. The mirror neuron system, however, provides an alternative solution, given that the logically related mirror neurons automatically trigger the motor acts that are most expected to follow the observed action in the particular context (Iacoboni et al., 2005). This means, the ability to infer the forthcoming new goal is already 'there' in the mirror neuron system. Hence, explaining intentionality by two different mechanisms is both unnecessary and biologically implausible in regards to parsimony. In other words, the cognitive processes that are achieved by the reactivation of the same neural structures used for physically sensing, moving and acting in the environment, is also used in sense-making/meaning-making activity in social perception, social interaction and social understanding. It has been speculated that the mirror neuron system might be a basic direct mechanism necessary for imitation and grasping others' intentions (Gallese et al., 2004; Rizzolatti, 2005; Rizzolatti and Sinigaglia, 2010; Gallese, 2017; Fuchs, 2018). As Rizzolatti (2005) and Fuchs (2018) point out, however, it is obvious that the mirror neuron system itself is unable to explain the whole complexity of speech, human language, intentionality, theory of mind, and mindreading, but actually clarifies one of the fundamental aspects of social interaction and communication, namely how the interacting partners are able to *directly share* the communicated meaning between them.

It is argued that the mirror neuron system serves as the underlying mechanism that enables the agent to understand the meaning of the observed action by so-called *emulation* or *simulation theories,* and there exist several approaches that address the social dimension (e.g., Gallese, 2004, 2005; Gallese et al., 2004; Svensson et al., 2007). Gallese's (2004) theory of the shared manifold of intersubjectivity proposes that all kinds of interpersonal relations, such as imitation, mind-reading, theory of mind, and empathy, depend, at a basic level, on the foundation of a shared manifold space, which then is characterized by routines of embodied simulations. Gallese (2004) addresses this issue from both an evolutionary perspective as well as from current findings in cognitive neuroscience, arguing "there is now enough empirical evidence to reject a disembodied theory of the mind as biologically implausible" (p. 166). This implies that during the course of ontogeny, the mirror neuron system and the embodied simulation processes might develop further, through maturation as well as socially and culturally scaffolded interactions, to more advanced forms of social interaction and social understanding, and language (Lindblom, 2007, 2015a).

SIMPLE EMBODIMENT AND THE ENACTIVE TURN: COGNITIVIST PITFALLS IN SOCIAL EMBODIMENT EFFECTS

The presented selected examples in the Section "Social Embodiment Effects," and additional ones in the extensive literature on social embodiment effects, provide a positive turn to consider the role of the body in social interaction and cognition. Barsalou et al. (2003) and Niedenthal et al. (2005) offer a framework of embodied simulation to explain the underlying mechanisms for the social embodiment effects, which is based on and slightly modified from Barsalou's (1999) Perceptual Symbol System (PSS). Pouw and Looren de Jong (2015) mention that the common strategy used in Barsalou et al.'s (2003) and Niedenthal et al.'s (2005) explanations is the mapping of the offline cognition into online cognition, triggering embodied simulation from social stimuli. The provided framework and the explanation offered is aligned with cognitivism, since it focuses on social perception, social information-processing, and social representations (although in a modal or perceptual format) rather than authentic socially situated interaction, ignoring the social affordances in dynamic social interactions in the wild. Barsalou et al. (2003) and Niedenthal et al. (2005) still continue to explain social cognition largely in terms of internal representations and the computational processes manipulating them, which adds a socially embodied icing to the traditional information-processing cake. Wilson and Golonka (2013) argue that this kind of research remains business as usual, with a couple of embodied 'bells and whistles', because all the hard work of generating behavior is done in the brain, it is just that this work can be biased by what the body is up to, i.e., simple embodiment.

It is argued that these strands are compatible with a 'simple' approach to embodiment, because studies that manipulate the subjects' bodily cues provide a narrow scope of embodiment that lack 'rich' social interactions unfolding and embedded in ecological practices, being aligned with simple embodiment (Semin and Smith, 2002, 2013; Goldman and de Vignemont, 2009; Marsh et al., 2009; Durgin et al., 2012; Meier et al., 2012). Marsh et al. (2009) present a roadmap toward more radically embodied social psychology research, in which the mere importance of socio-cultural situatedness (e.g., Hutchins, 1995) and human understanding is distributed across several individuals, instead of being localized 'in the head.' Their approach is theoretically grounded in Gibson's (1979) ecological psychology, where the relational meanings of the concept of affordances is central. The relationships are detected and enacted through the accurate body's physiology and a history of interactions. Marsh et al. (2009) also stress the importance of identifying general dynamical principles that coordinate and interconnect among elements in the emergence of meaning of social behavior, stressing that the unit of analysis should shift beyond the individual level to a systems level. These suggestions have several methodological implications for the envisioned study of action and body in the environment from a more *embedded* perspective in social psychology. They offer four suggestions for how to study body-based phenomena in relation to the affordable physical and social environment. First, is an increased interest in the study of 'doing,' from a more functional perspective of bodily actions. Secondly, is studying how behavior unfolds in time to examine the emergence of phenomena that are the outcome of persons' embeddedness in their environment. Thirdly, is an increased focus on joint participation in goal-directed actions, where the cooperation in joint participation in physical action is studied on both the individual and social levels. Fourthly, is studying the behavior of individuals in natural settings and investigate how humans attend to the affordances (features) in the environment and how these have an impact on behavior through the ways humans are creating and changing the environment to better fit their actions.

THE ENACTIVE TURN: TOWARD INTERCORPOREALITY, INTERACTION THEORY AND CRITICAL NEUROSCIENCE

When it comes to embodied simulations, Gallagher (2005, 2019) stresses that a radically social mind does not need any kind of embodied simulations as in the proposed versions of embodied simulation during online cognition (Gallese, 2004, 2005, 2017; Svensson et al., 2007). Instead, he argues that the understanding of the other person is *primarily* neither theoretical nor based on an internal simulation, since it is a kind of *embodied practice*. It should be noted, however, that Gallagher does not deny the cases when we use the ability of theoretical interpretations or/and simulation, since these occasions are, according to him, rather rare in proportion to the majority of our social interactions (Lindblom, 2007, 2015a). This means that embodied simulations at best explain some narrow and specialized situations of the social mind, which only *sometimes* are used in social interactions. Indeed, he advocates that in the cases when we lean more on advanced strategies, they are already shaped by primary embodied practices (Gallagher, 2005). The major problem, according to him, is the assumption, in both cognitivism and embodied simulations, that interaction and social understanding between two people is a process that takes place between two 'Cartesian minds.' By 'Cartesian minds,' Gallagher refers to the view which requires that one's understanding usually involves a retreat to a realm of 'theoria' or 'simulacra' into a set of internal operations that becomes decoded and externalized in another modality such as speech, gesture, or action. That is, there is always some kind of higher level processing (which is using some kind of "content" and representations) being carried out in cognition (Lindblom, 2007, 2015a). Similarly, Maturana and Varela (1987, p. 196), point out that the traditional metaphor of communication is wrong, since "biologically, there is no 'transmitted information' in communication." In a similar line, Shanker and King (2002) argue that the information-transmission metaphor fails to reveal the full story of social interaction, because it significantly oversimplifies and misrepresents what actually happens in social interaction. This view is aligned with Fogel (1993, p. 76) who states that "information is created in the interface between perception and action . . . It is that last point, the salience of the body . . . that is missing in many theories of meaning."

Gallagher (2005) argues that communication is accomplished in the very action of pragmatic embodied interaction, through the expressive movement of speech, gesture, and the environmental and contextual factors of the *interaction* itself. Therefore, the idea that the understanding of another person involves an attempt to theorize an unseen belief or simulate in mind-reading is challenged. Instead, he proposes that only when our 'second-person pragmatic interactions' or our evaluative attempts to understand others break down do we choose to use more specialized practices of third-person explanation and prediction, i.e., embodied simulation as such is mostly carried out offline, not online, using the vocabulary used by Niedenthal et al. (2005). I emphasize that it is of major importance to be aware of the different perspectives in these situations. This means, in order to interpret and understand other people in real-time interaction, Gallagher (2005) suggests that humans seldom need to move beyond the present embodied and expressive actions at hand in order to grasp and gain an understanding of the other person. In this regard, there is not any discrete process that involves perception plus simulation, but rather a direct intersubjective perception of what the other is doing (Gallagher, 2007). He argues that phenomenologically, when one sees another person's action or gesture, one *directly perceives* or immediately 'sees' the meaning in the action/gesture, without the need to simulate it. He presents brain-imaging studies, in which subjects were asked to simulate their own movements (first-person perspective) or another person's (third-person perspective) movement. The result shows that there is no additional brain activity in favor of an extra level or effort as a kind of simulation, meaning there is no evidence for viewing simulation as an 'extra' step (cf. e.g., Gallese, 2004) over and above the perception. Indeed, Gallagher's point is "that there is no evidence that perception and simulation are two separate systems. In other words, the neurological underpinnings of what could count as embodied simulations are part and parcel of the (re-)activations that correspond to the original perception from an embodied pragmatic perspective (Gallagher, 2005). This poses another problem, however, namely where to draw the line between perception and other (cognitive) processes. Subsequently, the need of an internal model is questioned, and as Gallagher (2005) explains, "[t]he required model *is* the action of the other, and it is already being perceived. Why would one need to 'read off' the meaning of an action on an internal 'as if' model, indirectly, when one is observing that very action performed by the other?" (ibid., p. 224). Gallagher (2007) mentions that proponents of embodied simulations stress that simulation involves the instrumental use of a first-person model to form third-person "as if" or "pretend" mental states, but he argues that this is not a possible explanation. He explains that we cannot control these re-active sensorimotor processes at a personal level, and for that reason we cannot use them as a model. Thus, there is no homunculus present. Another proposed idea that the brain itself, at a subpersonal level, is using these reactivations as a model (cf. Damasio, 1995), which does not make sense either according to Gallagher (2007). Thus, his major point is that "the neural systems neither activate themselves nor take the initiative, but are *activated by the other person's action.*" Thus, "the other person *has an effect on us.* The other elicits this activation... It is not us (or our brain) doing it, but the other who does it to us" (ibid., p. 8–9). Gallese' s (2014) reply to Gallagher's criticism of embodied simulations is that he interprets mirror neuron mechanisms and embodied simulations as instantiations of neural *reuse*, i.e., the dual firing/activation pattern of a certain group of mirror neurons in a certain situation, in which they either are executing an action or observing an execution by others. Gallese (2014) claims that according to this view, mental representations are entirely not required. Gallese (2014) suggests that with a foundation in the mirror neuron systems and by means of neural reuse, embodied simulations is an elemental way to comprise the "representation of the motor goals of others' actions by reusing one's own bodily formatted motor representations, as well as of others' emotions and sensations by reusing one's own visceromotor and sensorimotor representations" (Gallese, 2014, p. 7). According to Gallese (2014, 2017), embodied simulations therefore could offer a unified explanatory framework for social understanding, mindreading, theory of mind and cognition. However, Gallagher (2015, 2019) seems not to agree, and there is an ongoing discussion between these two scholars whether there is any room for representations (Gallese, 2017 denotes them B-formatted representations) or not in social interactions and social understanding. In a nutshell, from a radical embodiment perspective, it is desirable to reduce, or even ignore, the role of mental or internal representations altogether (Gallagher, 2005, 2007, 2015, 2019; Hutto and Myin, 2017), a stance that has been criticized by others (e.g., Gallese, 2004, 2005, 2014, 2017).

It should be pointed out that the term *mirror neuron systems* could be leading us astray, because the term implies almost extraordinary abilities of single neurons in the form of achieving social perception by themselves, and these neurons may not be able to react to aspects of more complex situations of social perception and interaction (Fuchs, 2018). These concepts also ascribe a representational view of the mirror neuron system and embodied simulations, *via* some kind of internal imaging that is re-produced or "mirrored/simulated" onto the other. Therefore, Fuchs (2018) prefers to use the term social resonance system, because these "*neurons cannot mirror* [or simulate] *anything*" (p. 187). Consequently there is no representational image or simulation to be found. He argues that a mirror only reflects rays of light, and in order to perceive this light as a mirror image you need to be an embodied and conscious being, and there is no need to simulate anything. Indeed, the mutual linking between action and perception offers an 'intuitive' understanding of the observed action, i.e., what it means to do it, how it "feels" in the body and what the action really is about and for what purpose for the agent. Fuchs (2018) emphasizes that tentative interpretations of the social resonance system are that it contributes to perceive movements of conspecifics in terms of *goal-oriented actions*, intermodal connections that support action readiness, providing the basis for imitational learning. Thus, the social resonance system provides an *operative intentionality* of our body as a means to understand the intentional movements of the other agent, since our body by itself —without any representational content— "resonates" these into our own actions. This way of reasoning is aligned with Mearleau-Ponty's concept of *intercorporeality* (Fuchs, 2018). In other words, *intercorporeality* allows us to continuously perceive others as our own kind since our body is subliminally attuned to the others' gestures, facial expressions, emotions, and the intentions of their movements and actions through "interbodily exchange," without primarily being based on representational concepts as mindreading and theory of mind abilities as proposed by cognitivism (Fuchs, 2018).

At this point it should be noted that for the purposes of this paper, the jury is still out when questioning whether or to what extent the role of embodied simulations matters in radically embodied explanations of social understanding. I would like to emphasize, however, that embodied simulations theories offer a much more radically embodied explanation than representational conceptions of "mind-reading" and "theory of mind," because they stress the directly experienced embodied perception of intersubjectivity and social resonance of other human beings, without the need to create an internal symbolic model or mirror of the other person. I will not continue to discuss this issue here in more detail.

Instead, I shift the focus of my arguments on tentative ways of opposing body snatching (Gallagher, 2015) by stressing the claim that the brain, from a radical embodiment perspective, should be considered as a vehicle for action and its should be better to study its functions at the level of the whole brain-body-environment system (Kiverstein and Miller, 2015; Fuchs, 2018). A tentative approach to bridge the troubled water of radical embodiment in cognitive neuroscience and phenomenological experience is the raised quest for a pragmatic and radical embodied neuroscience (Engel, 2010; Kiverstein and Miller, 2015; Slaby and Gallagher, 2015; Di Paolo et al., 2017). Engel (2010) points out that there is plenty of evidence that supports the pragmatic and enactive view by findings on the important role of sensorimotor interactions and explorative activity for the neural development and brain plasticity. He mentions that it has been acknowledged for quite a long time that the nervous system's developmental processes are highly dependent on various kinds of activity. Engel (2010) envisions a conceptual shift toward a "pragmatic neuroscience," which in due course will result in different style of experimentation, and setting the scene for new "laboratory habits" (Engel, 2010, p. 237). An increasing number of researchers have begun to use more natural and contextual stimuli, and using more active subjects in the lab studies, since "world-making" rather than "world-mirroring" lies at the heart of enacted cognition (Di Paolo et al., 2017; Fuchs, 2018). Kiverstein and Miller (2015) outline and explain why a radical embodied cognitive neuroscience is considered necessary. They address the concept of the "embodied brain," arguing that neuroscience should turn more to Gibson's (1979) ecological approach to get a better grasp of the cognitive functions that the brain performs. They stress that there is a need for a shift from focusing on localizing different cognitive functions to specific brain structures, which they find problematic, to describing and studying cognitive functions at network levels of the whole interactive brain-body-system. They envision that the main contribution of applying such a system view, regulated through the organism's interaction with the environment, affords several possibilities for actions. Thus, their major claim is that cognitive functions in the brain is *context-sensitive*. For example, Lifshitz et al. (2017) mention that neuroscientific findings demonstrate that bodily posture, e.g., being upright versus lying down, profoundly alters baseline brain activity when measured by magnetoencephalography (MEG). Kiverstein and Miller (2015) also address the intimate interrelatedness of cognitive and emotional processes in the brain, stressing that emotions are dynamical and encompass the whole body of an organism that is engaged with its environment, in which emotions influence the regulation between the organism and the environment. Similar arguments have been proposed by Stapleton (2013) who advocates that human beings are "properly embodied," which means that sensorimotor interaction with the environment is not enough, the internal bodily system also matters to cognition. She suggests that the relationship between cognition and affect is more complex and important than previously understood, implying a more organismic and enactive paradigm of embodied cognition. In such a properly embodied cognitive science, the affective system is integrated in cognition in itself (Stapleton, 2013).

Additional enactivism accounts for what role the brain has in social cognition, if not being representational, and is known as the *interactive brain hypothesis* (IBH) (De Jaegher et al., 2016).

The starting point for IBH is that social cognition also needs causal relations between the brain and the *social environment*, and should include how several kinds of cognizers experience and grasp the world as meaningful in various situations, but also to take an interdisciplinary approach that spans developmental and evolutionary perspectives. IBH also offers a guide how to study social interaction, e.g., identifying what kinds of social events and social relations, kinds of brain activities, and certain instances of social cognition. They conclude that because there is a development of methods and techniques for examining activities in the brain during more free interactions than before, it is necessary to hypothesize about these questions, when the upcoming and envisioned brain studies may include joint actions and emergent collective patterns distributed over multiple brains/bodies/persons in several kinds of coordination (De Jaegher et al., 2016). Thus, the take-home messages under the banner of radically embodied and enactive neuroscience are twofold; first, do not consider the individual biological system (human or animal) that is studied experimentally for the fully embodied person. Second, try to find ways that encompasses the practices of socially situated and embedded humans in society (i.e., striving for ecological validity), otherwise do not claim that current social neuroscience approaches are able to study the human social mind in its full scope (Slaby and Gallagher, 2015).

Recently, Fuchs (2018) offers a tentative embodied and enactive perspective on the role of the brain in cognition. He presents a view of the human brain that goes beyond neurobiological reduction, in which the brain does not produce the mind. Fuchs portrays a convincing and detailed approach of the brain, emphasizing that the brain is an *organ of mediation and integration*, rather than of information-processing of mental representations. The human brain is "alleged to bring fourth . . . conscious human persons who exist to communicate with each other. It is indeed the case that and neuroscience cannot escape its inherent dependence on subjectivity, intersubjectivity, and the lifeworld . . . [it is] the familiar world of everyday experience in which we coexist with others remains our primarily and actual reality" (Fuchs, 2018, p. xix). If we take this stance, the common view of the brain as an invisible creator of mind or the place where the subject is located needs to be abandoned in favor of the function of the organ of the lived body that mediates our relationships with the surrounding, other people, and last but not least to ourselves. Fuchs (2018) reformulates the dichotomy of the mind (mental)-body (physical) problem into a *dual character of life* that is manifested in the entire body as a living organism. In Fuchs's enacted theory of *dual aspectivity,* the living being itself, i.e., the whole human being not the brain only, is the primary entity, in which the manifestations of life are considered. On the one hand, of the integrated subjective and intersubjective acts of the *lived body,* and on the other hand, of the physiological processes of the *living body*. The embodiment of a human being's life, through its dual (not dualistic) aspects of *lived* and *living body,* is the dialectic mediating entity through which the aspects of subjectivity and nature are interrelated and complementary, but do not completely overlap. The life acts (e.g., speaking, suffering, eating, playing) of the subjective lived body could be experienced from first (inner) as well as perceived from second (outer) perspectives of the person. Fuchs denotes the latter perspective as a "we-perspective," in which we perceive each other as living human beings and not objects. This means that the embodied (emotional, cognitive, or volitional) acts of the living body are not assigned to the sole "mental" sphere, because they are always embodied physical events. The physiological processes of the *living* or *objective body* could only be perceived from the third-person perspective that corresponds to the whole living organism's interactions with the material and social world. Thus, the complementary nature of the living and lived body could be considered as two sides of the same coin, where only one of them is visible at the current moment. Thus, all experiences are a form of living, where the whole human is an ontological and fundamental being-in-the-world (Fuchs, 2018). This means that the brain does not operate in isolation, because it is an organ of interrelations that spans the human person as the unit of a living organism, and could only be explained from that perspective.

This line of argument is well-aligned with radical embodiment and the enactive approach, in which social cognition is characterized by, and very often constituted by socially embodied interaction, and the dual aspect of the lived body (e.g., Sinha and Jensen de Lopez, 2000; Gibbs, 2001, Gibbs, 2006; Lindblom, 2007, 2012, 2015a,b; Lindblom and Ziemke, 2007, 2008; De Jaegher et al., 2010; Fuchs, 2018). This turn to the social and relational sphere is the topic for the next section.

THE INTERSUBJECTIVE TURN: PARTICIPATORY SENSE-MAKING AND LINGUISTIC BODIES

The appeal for a social dimension of radical embodiment has been pointed out by several researchers (Maturana and Varela, 1987; Fogel, 1993; Sinha and Jensen de Lopez, 2000; Gibbs, 2001; Shanker and King, 2002; Lindblom and Ziemke, 2003, 2007, 2008; Johnson, 2007; De Jaegher et al., 2010; Lindblom, 2012, 2015a,b; Cuffari et al., 2015; Slaby and Gallagher, 2015; Di Paolo et al., 2018). Although the social sphere of radical embodiment has not been mentioned explicitly so far in this paper, I will now explain *how* the social mind at an individual level is realized, and ways of describing and incorporating the individual social mind at the social level.

It should be noted, however, that there are two major problems with cognitivism that I want to address before taking the more radical turn on the social mind (Lindblom and Ziemke, 2008; Lindblom, 2015a). First, as already touched upon earlier, cognitivism considers human communication and social cognition as mostly exclusively private mental states in individual minds that ignores the dynamic, interactive, and subjective nature of intentional actions. This position is referred to as "methodological individualism: the assumption that social cognition depends on capabilities or mechanisms within an isolated individual, or on processes that take place inside an individual brain" (Froese and Gallagher, 2012, p. 437). However from a more embodied and enactive perspective, it is generally stressed that social interaction cannot be reduced to so-called 'social information transfer' (see sub-section "Social Embodiment Effects"). My main point here is that information is not an identified and discrete entity which can be sent, through signals, from one person across time and space to another person. Taking a more pragmatic and enactive turn, several researchers focus on the emergence of *meaning-making* or *sense-making* in the dyads and triads between humans, in which dynamically emerging, creative co-regulated socially embodied interactions serve as the basis for social understanding and social cognition. Secondly, Gibbs (2001) provides a tentative explanation for the methodological individualism within cognitivism from work in cultural anthropology. He emphasizes that the main focus on an individual's intentions in social interaction and cognition by most scholars rather reflects a Western white middle-class bias about the nature of selfhood than a universal phenomenon, because the underlying assumption of the individual mind is a view not shared across different cultures. Hence, it might be argued that individual intentionality is one of the 'holy cows' of Western thought. Thus, focusing too much on the assumption of methodological individualism, overemphasizes the individual's psychological state at the expense of the social and cultural context in which the actions unfold (Gibbs, 2001).

However, I will argue that many of the radical embodiment and enactivism approaches (Di Paolo et al., 2017; Hutto and Myin, 2017), as currently formulated, to some extent suffer from the same limitations as Piaget (1952, 1954) developmental theory, not paying sufficient attention to the role and relevance of culture and society in social cognition (Lindblom, 2015a). Piaget's main focus was on the individual child's construction of its reality, where he identifies three kinds of knowledge, each of them resulting from the child's interactions with the environment, namely physical, logical-mathematical, and social knowledge. In Piagetian terms, the child first develops as an individual being, and later on into a social being (Lindblom, 2007, 2015a). This is contrary to the Vygotskian approach, which views the child's individual development as the outcome of the social interaction of the human species and the child's interactions with other people in their particular culture. In his *general law of cultural development,* it is stated that "every function in the child's development appears twice: first, on the social level, and later, on the individual level" (Vygotsky, 1978, p. 56). In this section of the paper I will strongly emphasize the importance of the social context, which I refer to as *relational*, which has strong roots in the work of Dewey (1896, 1925/1981), Mead (1934), and Vygotsky (1977, 1978, 1979). I do not have enough space here to elaborate in more detail on how these above scholars in the late 19th century and the beginning of the 20th century emphasize that the human cognition and social understanding emerges and is enacted through social interactions, although they put varying emphases on the role of the embodiment (but see Lindblom and Ziemke, 2003, 2006; Lindblom, 2012; Lindblom, 2015a). To provide but one example, I present Vygotsky's (1978) account for the development of pointing in the child to illustrate the *relational* aspect of social interaction. He claimed that initially it is only a simple and incomplete grasping movement directed toward a desired object, and nothing more. When the caretaker comes to help the child, the meaning of the gesture situation itself changes, by obtaining another meaning, as the child's failed reaching attempt provokes a reaction, not from the desired object, but from the other person. The individual movement 'in itself' in its social context becomes a gesture 'for-others.' The caretaker interprets the child's reaching movement as a kind of pointing gesture, resulting in a socially meaningful communicative act, whereas the child their self at the moment is not actually aware of the communication ability. However, after a while the child becomes aware of the communicative function of their movements, and then begins addressing its gestures toward other people, rather than the object of interest that was their primary focus initially. Thus, "*the grasping movement changes to the act of pointing*" (Vygotsky, 1978, p. 56). This means, the intention of pointing does not reside within the child's individual mind, it emerges as an outcome of their on-going social interactions. Accordingly, by treating the child as an intentional being, caregivers 'bootstrap' and scaffold them into a socio-cultural environment, which partly rests on the 'illusion of intentionality.' The grasping example illustrates the role and relevance of social interactions and shared practice of whole embodied persons, especially during childhood, in the form of *embodied intersubjectivity* and *communicative intercorporeality* as a prerequisite for the emergence of the full-blown human mind. It should be mentioned that the newborn infant's brain possesses a unique potential, which requires not only interactions between brain body and environment, but also with other *human beings*, to realize the development of the embodied and enacted social mind. Fuchs (2018) addresses that these interactions form traces at a neural level, but not in the form of stored and localizable "representations," "memories" or "intentions" of the actions, but rather as "*dispositions to perceive, feel, and behave in certain ways*" (p. 181). These dispositions consist of a distributed network of neural connections, which resonates with the current situation at hand as well as other human beings. Today, many scholars follow in Vygotsky's and his followers footsteps by emphasizing that the human mind and advanced social understanding transcends the biological level, and that the shared social and cultural spheres of other human beings, are only acquired by active participations in these ecological practices. It is argued and shown that enculturation is of outmost importance for humans compared to any other species. Fuchs claims that all so-called higher cognitive functions "presuppose the *human being's enactment of life in a shared social world*" (p. xx, original emphases). These interactive and intersubjective experiences form the foundation for acquiring and internalizing the dispositions of the interactional patterns, cultural symbol systems, language, and social understanding in the child's society, and has a much stronger impact on social, emotional and cognitive abilities than was understood in previous research on human development. Fuchs (2018) points out that embodiment is the basis for corporeal resonance and intersubjectivity with other human beings, and the explanations of "mind-reading" and "theory of mind" concepts used in contemporary social cognitive psychology are misleading in several ways. He advocates a kind of cultural biology which is well aligned with Donald's (1991), Tomasello's (1999), and Rogoff's (2003) thesis that humans are "biologically cultural." Thus, 'culture' reinforces 'biology' as much as 'biology' reinforces 'culture,' which means that the divide between 'culture' and 'biology' is an artificial abstraction in human ontogeny and phylogeny. It should be pointed out, however, that the above scholars, to various extents, are using a cognitivism stance, and my major issue is to raise awareness to the important idea of putting enculturation as the major driving force for human development. Hence, Fuchs's claim that the brain is a *relational* organ and thereby enabling embodied intersubjectivity, social and cultural scaffolding that are the hallmarks of human enculturation, complements the above idea.

Lindblom (2015a,b), among others, has presented several examples of frame-by-frame analyzed images from different episodes of spontaneous social interaction captured *in situ*, analyzed from a more radical social embodiment perspective. One example is from a horse ranch that maintains and preserves Spanish mustang horses (Lindblom, 2015a), where a joint action was illustrated and analyzed. The other example is from an archeological excavation of an old burial ground where meaning-making as a socially distributed joint activity was used an illustrative example (Lindblom, 2015b). This kind of work illustrates how meaning-making activity emerges from bodily mediated and socially distributed actions. Accordingly, meaning and emotional significance is co-constituted in the interaction – not in the private boundaries of one or the other person's head (or brain) (Gallagher, 2016).

Although the above work by Lindblom (2015a,b) is a promising step in the right direction, it does not fully take the enactive interaction process as its point of departure. De Jaegher and Di Paolo (2007) offer a basis for a more detailed enactive interpretation of social cognition by extending the enactive concept of sense-making into the social sphere. Their starting point is the interactive process between individuals in social situations, following in the footsteps of Varela's et al.'s (1991) framework. Five core ideas, which are mutually supporting, defining the enactive paradigm are used, which are the concepts of autonomy, sense-making, embodiment, emergence, and experience (De Jaegher and Di Paolo, 2007; Di Paolo et al., 2010). Their novel notion in the social sphere is referred to as *participatory sense-making*, in which the responsibility of social understanding is moved beyond a single individual (De Jaegher and Di Paolo, 2007). Thus, the unit of analysis is expanded to the social interaction itself. They aim to figure out what the interaction process does for social cognition, by properly considering the situatedness and embodiment of the individual as well as not being 'methodologically individualistic.' The main topic for their participatory sense-making approach is to clarify *why* and *how* people interact, reducing the gap between the cognitive science and social science perspectives, characterizing how the individual and social levels are interrelated. For example, they mention that Gallagher's 'embodied practice of mind' Gallagher (2005) does not yet provide the richness of the social interaction process and its role in developing social understanding. In doing so, De Jaegher and Di Paolo (2007) suggest that *correlation* and *coordination* is the main mechanisms of social interaction, where interactional coordination, functional coordination, and interaction rhythm (timing), and rhythmic capacity are deliberations of these mechanisms. Consequently, they define social interaction as follows: "Social interaction is the regulated coupling between at least two autonomous agents, where the regulation is aimed at aspects of the coupling itself so that it constitutes an emergent autonomous organization in the domain of relational dynamics, without destroying the autonomy of the agents involved (though the latter's scope can be augmented or reduced)" in the process (De Jaegher and Di Paolo, 2007, p. 493).

They emphasize that the generation of social meaning is dependent on the individuals' sense-making process itself, in which the process of coordination between actions involved in participatory sense-making contributes to people's understanding of each other. In this way, social understanding is enacted – brought about within the interaction, supported and constrained by the elements and dynamics of interaction between the cognitive agent and the environment. As a result of the great importance of autonomy within the enactive approach, the social agent is an active participant within this unfolding process, and not a mere passive observer (De Jaegher and Di Paolo, 2007). They describe that throughout the engagement in the joint process of sense-making between at least two individuals, meaning is created and transformed *via* emergent patterns of coordination and breakdowns, which proceed to develop collective properties *via* stabilized patterns of joint activity. When the outcome from these patterns is mutually constructed, new meanings are then created in the interaction. De Jaegher and Di Paolo (2007) suggest that their dynamical and enactive view of participatory sense-making provide a novel theoretical two-way link between the individual and social perspectives, in which they envision a developmental route.

However, some problems with De Jaegher's and Di Paolo's (2007) participatory sense-making framework have been identified by Kyselo (2014). The first addressed issue regards the so-called body-social problem. Kyselo (2014) adopts an enactive approach to this problem, in which the problem is referred to as the quest of how bodily individual autonomy and higher, socially enacted forms of autonomy, are interrelated. Generally, Kyselo (2014) argues that participatory sense-making for social cognition is, to some extent, ambiguously formulated and explained concerning the role of social interactions for the individuation of identity. Her first concern is that the expanded unit of analysis of social interaction is a group identity, in which the whole autonomous system is more than the individual. Her second concern is that participatory sense-making also stresses the role of social interactions for the individual, by widening individual cognitive capacities through scaffolding (Kyselo, 2014). She argues that De Jaegher's and Di Paolo's (2007) definition of the body does not consider it as social. The identity of the individual is then defined not in social terms, but only in bodily terms. However, this is ironic, Kyselo (2014) argues, since in their very attempt to keep the individual from dissolving in participatory sense-making, they risk to reduce the role of the social. Kyselo (2014) then suggests that in order to overcome this dilemma, one has to admit that individuation of human identity is not fully determined in terms of bodies in isolation but requires that the body engages in *socially mediated* interactions. Hence, this view allows to combine both claims, stressing that individuals are *embodied interactors*. To conclude, taking an enactive approach where sense-making and autonomy implies each other, resulting in a view on human cognitive identity that is not only embodied, but primarily socially constituted (Kyselo, 2014).

The idea of participatory sense-making is extended and deepened in the enactive conception of *language* in form of a kind of adaptive, dynamical, and dialectical phenomena (Cuffari et al., 2015; Di Paolo et al., 2018). They propose that to fully encompass the phenomena of language, it must be approached in the situatedness of concrete enactments of certain kinds of participatory sense-making. They offer a detailed and comprehensive dialectical model of *languaging* that involves several steps and forms of social agency that both involves regulation of self and social interaction that encompasses the fundamental tensions that are essential in these dialogical organizations. This results in a new form of embodied agency that is denoted *linguistic bodies*. These linguistic bodies are both individual and social by nature, because they are transformed by and through the participatory use of language. This results in new forms of social autonomy, and this allows humans the transformative experience to fully participate in linguistic communities (Cuffari et al., 2015; Di Paolo et al., 2018). To summarize, the dialectical model of linguistic bodies provides a novel and much needed explanation of the role and relevance of a relational view and a socially enacted practice of language and its development from an autopoetic perspective that takes a holistic perspective that encompasses both the embodied agency and its linguistic community in society. This means that there is no inferential leap separating the embodied agency from a description of its form.

CONCLUDING DISCUSSION

I opened this paper by referring to the intense and ongoing questioning concerning the role and relevance of the body in social interaction and cognition within cognitive science and related disciplines, addressing that currently there is no single, simple answer to this question. Indeed, social radical embodiment is still an emerging framework that must be coherently developed and extended, both theoretically and methodologically, subsequently resulting in richer and deeper explanations and illustrations of socially embodied and enacted actions that are situated, enacted, embedded, and carried out in practice. An issue that has not been mentioned so far is the significant role of tools and artifacts as coordinators and mediators for socially, embodied, enacted practices. In favor of this argument, there is neurological evidence for the inclusion of external tools into the body schema, spread across the entire nervous system and its couplings with the environment, rather than solely in regions of the brain (e.g., Maravita and Iriki, 2004; Cardinali et al., 2009). Although tool use is an issue beyond the topic of this paper, I wish to mention that one of the successors of Vygotsky's (1978) work, Activity Theory, provides a broad conceptual framework for understanding and describing the structure, development, and context of human activity, focusing on the individual, artifacts, and other humans in everyday activity, as well as their interrelatedness (Leontiev, 1978, but see also the work on material engagements by Malafouris, 2013).

As a concluding remark, I would like to offer a tentative explanation to the paradox why so many accounts of mindreading concepts in folk psychological terms are present in our (Western) linguistic community, although many proponents of radical embodiment do their best to provide non-representational explanations of our social understanding of others. We as embodied agents bring fourth our own linguistic practice and habits. Therefore, it might be counterproductive to reject the folk psychological explanations of the human mind in terms of mindreading capacities, because we have enacted them by ourselves at a societal level. Johnson (2007, 2018) provides a promising answer to this paradox, which is in line with Fuchs's enacted theory of dual aspectivity (Fuchs, 2018). Johnson (2007) explains that a crucial underlying reason is that our lived experience emphasizes the dualistic view of mind and body. He argues "that our bodies hide themselves from us in their very acts of making meaning and experience possible. The way we experience things appears to have a dualistic character" (p. 2). It is therefore rather ironic that our body does impressive work for the most part "behind the scenes," so that we as human beings can focus on the objects of our interest. This way of working results in a sense of intentionality that appears to be directed "out there" in the world (Johnson, 2007). Thus, our experience of the whole embodied organism is misinterpreted and instantiated in folk psychological terms of "beliefs," "intentions" and so on, an enculturation process that has been manifested in our Western intellectual and cultural heritage.

Only the future will tell us whether the field of radically embodied cognitive science will expand to further directions. I would like to end this paper by seriously looking back. As pointed out by Di Paolo et al. (2017, paraphrasing Bruner, 1990), in the early inception of cognitive science in the mid 1950s, the focus soon shifted from discovering the meaning-making processes that human beings create out of their encounters with the material and social world to information processing, ending up in cognitivism. This path then lost its original target of cognitive science, since, the nuances of the phenomenological meaning and sense-making process of human beings could not be reduced to bits of information (Bruner, 1990; Johnson, 2007, 2018).

AUTHOR'S NOTE

Some minor content from this manuscript was published in-part for my Ph.D. thesis (Lindblom, 2007). This manuscript is an elaboration of the questions that I originally formulated and raised in the thesis, and here I present the further development of these questions.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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