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"Cognition and Emotion at play: The contribution of inhibitory control and emotion understanding for peer action coordination."

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ABSTRACT

At the forefront of our research lies an exploration of peer action coordination, a domain traditionally explored solely through the lens of cognitive processes. It has been theorized that emotions might play a role in action coordination, as emotional cues can provide critical information for action planning and execution (Vesper et al., 2017). However, whether and how emotions contribute to coordinating action with a partner has not been investigated in depth until recently. In a previous study, emotion understanding was linked to peer action coordination, as children better at recognizing and interpreting emotions were also better at coordinating their actions during a cooperative sensorimotor task (Viana et al., 2020). The current study planned to replicate and extend this study from Viana and colleagues (2020) by investigating a comprehensive model containing cognitive and emotional components and how these explain the variance within peer action coordination across middle childhood. 108 children between 6 years and 11 months and 10 years and 10 months of age were assessed for their emotion understanding with the Test of Emotion Comprehension (TEC), their inhibitory control with the Attentional Network Task (ANT), and their individual and peer action coordination with a sensorimotor game. Contrary to our expectations, our findings revealed that emotion understanding and inhibitory control had no significant association with peer action coordination. Instead, age and gender emerged as the primary indicators, explaining 38% of the variance in our data. Our results are discussed in light of the literature debate on whether possessing individual representations of skills translates into using them in complex social interactions such as peer action coordination. Future research may analyze quantitatively and qualitatively the way children interact during cooperative games, uncovering the subtle dynamics that go beyond the final performance on the task.

SUMMARY

The study of peer action coordination is essential for understanding how children navigate and manage social interactions, particularly in collaborative settings. Peer action coordination requires children to align their behaviors, intentions, and goals with others, a process fundamental to effective teamwork, social harmony, and the development of social skills (Cirelli et al., 2014). Emotion understanding (EU) and inhibitory control are hypothesized to play significant roles in this process, although their exact contributions remain understudied (Vesper et al., 2017). EU - the capacity to recognize, interpret, and reason about one's and other's emotions - is critical for successful social interactions (Belacchi & Farina, 2010). It enables children to respond adaptively to peers' emotional states and social cues, facilitating coordinated actions (Viana et al., 2022). Inhibitory control, part of executive functions, involves suppressing impulsive reactions and distractions, allowing for more thoughtful and goal-aligned behaviors within social interactions. Its role in supporting children to adhere to shared goals and maintain task focus during collaborative activities is of particular interest. As there is limited research available on how cognitive and emotional processes contribute to peer action coordination, this study aims to explore the potential impacts of EU and inhibitory control on children's performance during a sensorimotor game played together. By examining these relationships within Italian children and building on the initial findings of Viana et al., (2020) with Brazilian children, the research can contribute to a cross-cultural discussion on the relations between cognition, emotion, and peer action coordination. The initial two chapters lay the groundwork by elucidating the theoretical foundations and developmental aspects of joint action, setting the stage for an investigation of the interplay between cognitive mechanisms like inhibitory control and affective competencies like emotion understanding. The third chapter outlines the research design and analytical methods used to explore the study's hypotheses. In the fourth and fifth chapters, findings are presented, followed by their discussion. Lastly, limitations and further directions are discussed in detail.

1 INTRODUCTION

In analyzing social interaction and collaborative efforts, the ability to synchronize actions with others is acknowledged as a fundamental aspect of human behavior. This capacity, called cooperative action coordination or joint action, is crucial for various social activities such as dance and teamwork. At the heart of the present study lies a quantitative design exploring the extent to which school-age children combine perceptual input with coordinated body movements to align their actions with others during collaboration. This involves physical synchronization and a complex integration of cognitive, emotional, and social functions. Traditionally examined within affective or cognitive spheres separately, our research seeks to explore a comprehensive model that encompasses both affective and cognitive aspects that, to the best of our knowledge, have not been previously studied together. More specifically, we aim to investigate the extent to which emotion understanding and inhibitory control relate to children's performance to coordinate their actions with peers during a sensorimotor game. By assessing the connection between emotion understanding and peer action coordination, while further expanding on these insights by exploring the potential moderating effect of inhibitory control on this relationship, we aim to explore emotional and cognitive skills' contributions to children's peer action coordination at a more comprehensive level.

1.1 Individual Action Coordination

Before delving into how we coordinate our actions with others, taking a step back and thoroughly describing the mechanism at the root of any action is necessary. Individual action coordination is a fundamental aspect of human behavior and is essential for everyday activities such as walking, grasping objects, or even typing on a keyboard. Unlike joint action, which involves synchronizing actions among multiple individuals, individual action coordination focuses on the internal mechanisms and cognitive processes that enable a single person to execute coordinated and purposeful actions (Shumway-Cook & Woollacott, 2006). These processes involve integrating sensory information, motor planning, and execution of movements in a smooth and precise manner.

In exploring individual action coordination, one can take the action of guiding a ball through a maze as an example. The process begins with visual perception, where the maze layout - including walls and openings- is identified, enabling the estimation of distances, and planning the ball's trajectory. At this stage, relevant information is extracted from the environment and automatically coupled to the action (Adolph & Kretch, 2015; Gallivan & Goodale, 2018), as seen when an opening in the maze influences the movement towards it. After perceiving the maze, the individual engages in motor planning, using the gathered information to devise a plan of action for guiding the ball through it. This step involves selecting the right movements and drawing on past experiences and learned patterns, known as motor-action schemas. These schemas act as a blueprint to achieve the goal efficiently (Gençer, 2018; Prinz, 1997). Once the motor plan is established, the execution of planned movements follows. Motor commands are relayed to the corresponding muscles, facilitating the precise coordination of hand, arm, and wrist movements. This coordination is crucial for managing the ball's position, orientation, and speed (Smits-Engelsman et al., 2003). The process demands sharp hand-eye coordination and fine motor control. Success relies on synchronizing these movements with visual and proprioceptive feedback, allowing for real-time adjustments and refinement of the action plan (Poljac et al., 2009).

From a developmental standpoint, humans can smoothly control their separate limbs from infancy to adulthood, alongside the maturation of the neural and physical systems. As children grow, they demonstrate an increasing capacity to regulate their physical movements consciously and show notable progress in purposeful coordination. Bimanual coordination and manual tracking improve steadily from 5 to 9 years of age, reaching full development by age 15 (Haddad et al., 2012). Visuo-manual tracking performance improves gradually alongside the feed-forward control development (Van Roon et al., 2008). By age 10, individuals are skilled enough to create a predictive target motion model and efficiently rely on both feed-forward and motor feedback-based information for accurate motor movement (Smits-Engelsman et al., 2003).

1.2 Joint action

When acting together, the presence of a social partner significantly influences an individual's environment, introducing a dynamic where one's perceptions and actions become integrated with those of others. This creates a shared influence in the environment, much greater than individuals' actions summed together. Building on this, Sebanz et al., (2006) define joint action as a synchronized endeavor among individuals aiming for a shared goal. This definition underscores joint actions' cooperative and purposeful aspect, highlighting an essential interdependence among participants. Such activities necessitate collaboration, as they cannot be achieved alone (Warneken et al., 2006). Therefore, the success of joint action relies on the intertwined contributions of all involved, demonstrating that the collective outcome is a product of integrated efforts rather than isolated actions.

1.2.1 A minimal architecture model for joint action

This concept is further elaborated in the minimal architecture model for joint action (Vesper et al., 2010), which outlines how to represent individual and shared goals and tasks within a collaborative setting. In joint action, the goal involves incorporating another agent or force known as "Agent X." Agents often also represent Agent X's task, which may differ from their own. Prediction involves generating internal models to anticipate how actions affect the environment and individuals' tasks. Monitoring assesses whether tasks are being achieved as intended and if actions are unfolding according to plan; it also involves managing aspects related to each remit and that of others involved in the joint action (see Figure 1). Additionally, agents may deploy strategies to facilitate smoother coordination during collective activities. For instance, adjusting one's behavior to make it more predictable or using objects/tools to clarify the task distribution helps synchronization during collective activities (Vesper et al., 2010).

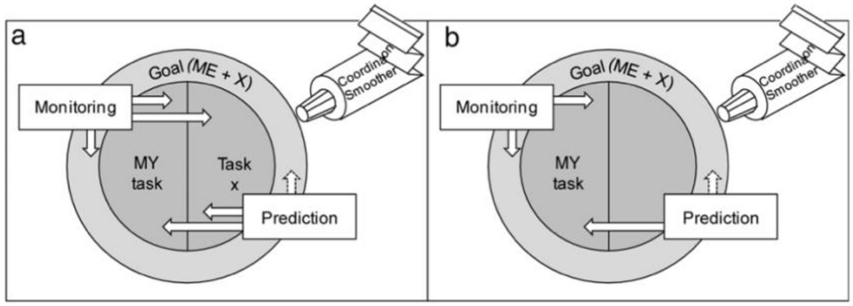


Figure 1. "A minimal architecture" theoretical model by Vesper and colleagues (2010). a) in joint action; b) in individual action

Starting from the representational elements described in the "minimal architecture" theoretical model (Vesper et al., 2010), the literature has investigated the dynamical mechanisms responsible for joint action by exploring mental representations and sensorimotor information shared by the two agents.

1.2.2 Shared representations

At the core of successful joint action lies the concept of shared representation of the collective goal. However, working in proximity does not ensure this shared perspective; it needs the deliberate communication of the objective among the parties involved (della Gatta et al., 2017). Coordination and performance are enhanced when participants have a clear and common goal (Maisto et al., 2024). Beyond the alignment on the collective goal, effective collaboration also relies on mentally representing the partner's tasks and agents, incorporating this insight into their action plans (Milward et al., 2017). Eventually, the other's abilities and costs are weighted and pondered, leading to strategies that prioritize overall efficiency for achieving the shared goal, sometimes at the expense of equitable task distribution (Strachan & Török, 2020; Van Der Wel, 2015). In essence, shared representations form a critical scaffold for joint action, encompassing both the collective goal and an understanding of each participant's role and tasks.

1.2.3 Shared sensorimotor information.

In the study of joint action, shared sensorimotor information is crucial for enabling smooth coordination among individuals. This area includes key mechanisms that support the complex interactions in collaborative tasks, helping participants to synchronize their actions seamlessly. At the ground of this synchronization is the sensorimotor mechanism known as motor resonance- which comes into play when we sway in rhythm during conversations or clap in unison at a concert (Tschacher et al., 2023). This process is driven by the activation of similar sensorimotor neural circuits when observing the actions of others, essentially mirroring those actions internally (Cheng et al., 2022; Ocampo & Kritikos, 2011). The mirror neuron system forms the basis of associative learning and comes into play whenever we observe others' actions while being aware of the goal (Bolt & Loehr, 2021).

Complementing motor resonance, joint attention serves as a foundational sensorimotor mechanism in joint actions. It enables two individuals to collectively focus on the same perceptual object, often by looking at it together and being aware of each other's focus (Maye et al., 2017). This shared attention, which involves coordinating the gaze direction and attention, helps people act together. Developed early in life, this skill lays the foundations for more complex social abilities, such as verbal communication and understanding others' perspectives (Tomasello et al., 2005).

Another dimension of shared sensorimotor information is sensorimotor communication. A form of non-verbal purposeful interaction where subtle changes in kinematics, gestures, or facial expressions convey meaningful information in a social context (Pezzulo et al., 2019). This type of communication is particularly useful in tasks requiring simultaneous execution of different or complementary actions. In this context, a simple yet purposeful hand gesture allows parties to communicate intentions and facilitate real-time prediction of the co-actor, thereby coordinating a strategy of action (Vesper & Sevdalis, 2020).

In summary, coordinating actions within a joint context involves much more than summing the individual's action coordination mechanisms. It requires a complex interplay of shared gaze, motor resonance, effective sensorimotor communication, mentalizing, and perspective-taking abilities, all geared toward accomplishing a shared objective (van der Wel et al., 2021).

1.3 Typical development of joint action

Building on the foundational understanding of joint action mechanisms, we now turn our attention to the development of these processes across different stages of childhood. Given the focus of this thesis, the following sections will specifically explore the typical developmental phases of joint action, omitting discussion on atypical populations.

1.3.1 Infancy

In their earliest months, babies display an inherent inclination towards faces. They react to human faces and voices, participating in simple social exchanges such as smiling and cooing, mostly with their primary caregiver. These basic behaviors are crucial early signs for more intricate joint actions. They demonstrate the infant's responsiveness to social cues and their evolving capacity for interpersonal exchanges. Infants begin to exhibit an awareness of attention directed towards themselves as early as two months, primarily in response to their primary caregivers' faces. This awareness later expands to include attention to body parts and actions performed by them. By around four months, infants respond to attention directed towards them and attempt to direct others' attention to themselves with purposeful vocalizations (Reddy, 2003). This stage forms the basis for the agency in actions, future communication skills, and the ability to engage in joint actions. Infants begin to engage in simple joint actions with their primary caregivers between six and nine months while gradually developing motor control. These interactions often take the form of dyadic, passive turn-taking, such as back-and-forth vocalizations or imitating simple actions (Kinard & Watson, 2015).

As infants approach nine months of age, their ability to participate in joint actions becomes more evident as they engage in reciprocal actions that form the basis for cooperative tasks (Warneken et al., 2006). However, these interactions often remain dyadic and ritualized, indicating that while infants can participate in joint actions, they still rely heavily on the structure provided by their caregivers. Around the same time, joint attention is often initiated by the caregiver's gaze shift from the infant's face to a third object. Infants then follow this shift, demonstrating their growing understanding of shared focus (Carpenter & Liebal, 2011).

From 12 to 18 months, infants can perform more complex joint activities, such as perceiving others' attention to distal objects, by the end of the first year. Finally, interactions are triadic, involving the infant, caregiver, and an object (Cirelli et al., 2014b). Overall, the development of joint action in infants involves a progression from basic attention to others' actions and directed attention toward themselves to more complex interactions involving cooperation, shared focus, and the ability to engage in joint attention with caregivers.

1.3.2 Early Childhood

Between the first and second year, children start to show the ability to coordinate actions deliberately with their peers. This period is characterized by continued joint attention and action development in various contexts. Children's performance in non-ritualized contexts still develops, indicating a transition from structured to more spontaneous forms of interaction (Brownell, 2011). This stage is crucial for building the foundation of more advanced social skills and understanding the dynamics of cooperative play.

Between 24 and 28 months, there is a noticeable surge in children's ability to engage in varied and complementary coordinated acts. Children begin to participate in games that involve a common theme or goal, requiring more complex turn-taking, object manipulation, and social coordination. Children at this age exchange gaze, laugh together, throw and retrieve objects, and chase each other on the playground. This stage reflects significant advancements in motor skills and the ability to understand and respond to the intentions and actions of others (Eckerman & Peterman, 2004). As children approach two years and a half of age, they can sustain joint action in a broader range of contexts. They show improvements in motor coordination with others, engaging in activities like spontaneous drumming or timed button pressing (Endedijk et al., 2015; Meyer et al., 2010). Despite these advancements, challenges remain, particularly in joint activities that require higher-order cognitive skills such as perspective-taking, action planning, and flexible adjustment. This period marks a crucial phase in the onset of the development of executive functions and the ability to navigate complex social situations.

A significant aspect of joint action development in early childhood is the emergence of Theory of Mind (ToM) – the ability to reflect on one's mental state in relation to others. This cognitive skill is fundamental for understanding and predicting the behavior of others, which is essential for effective joint action. As children's conscious self-awareness grows, their joint actions become more autonomous and flexible, reflecting an increased understanding of social dynamics and relationships (Tomasello et al., 2005).

1.3.3 Middle Childhood

In middle childhood, action coordination continues to evolve, incorporating complex strategies and advanced functioning. By the age of 4 to 5 years, children start to develop an integrated understanding of their own action space and that of their co-actors. This is a crucial criterion for adult-like joint action in children (Milward et al., 2017; Saby et al., 2014). Traditionally, this ability has been examined through the joint Simon task. In this task, participants respond to stimuli on either side of a keyboard based on a conditional rule. The task involves two scenarios: the target appears either in a position that is spatially congruent or incongruent. In the joint version of this task, a partner participates, following an alternate rule. Studies, such as the one by Saby et al., (2014) show how participants consider their partner's task, even when it adversely affects their response, slowing them down. Children ages 5 to 7 start planning actions by considering others' perspectives. However, even at seven years old, egocentric tendencies often limit this ability (Paulus, 2016). Smooth coordination in joint actions is closely linked to inhibitory control, which helps suppress egocentric behaviors and promotes a more collaborative approach while facilitating turn-taking games (Meyer et al., 2015).

A significant difference in the action coordination of adult-like children, not observed in younger ones, is the implementation of strategies for motor coordination. An early strategy involves reducing behavioral variability, where individuals make their movements more predictable by limiting variability in responses and timing (Vesper et al., 2011). This strategy has been observed in both macaques and young children (Visco-Comandini et al., 2015). Satta et al. (2017) conducted a study on how children aged 6 to 9 coordinate their actions in an isometric task involving exerting hand force on a joystick to move a visual cursor from the center toward a peripheral target. The results revealed that at age 7, there is an attempt to synchronize one's action with a partner during joint action planning. Children become faster and less variable in their performance, making their actions more predictable for their playmates. By the time children reach the age of 8, they reach peak individual accuracy. They deploy a superior strategy at this critical stage: online monitoring during action execution (Satta et al., 2017). This strategy involves adjusting actions based on others' movements while the action is ongoing, allowing for dynamic adjustment instead of relying solely on predictions of others' actions (Wolpert et al., 2003). Alongside the importance of ToM, the literature has also shown evidence that inhibitory control development plays a relevant role in deploying the strategy of action monitoring.

2 THE ROLE OF EMOTION UNDERSTANDING AND INHIBITORY CONTROL IN PEER ACTION COORDINATION

While the role of the ToM in facilitating joint actions is well-acknowledged (Curry & Chesters, 2012; Frith et al., 2003; Knoblich et al., 2011; Kuhnert et al., 2017; Wellman, 2018; Wolpert et al., 2003), the significance of Emotion Understanding (EU)—the "affective component" of the ToM—warrants further exploration. EU mirrors the ToM in its function, focusing on the comprehension and attribution of emotional states rather than purely cognitive ones (Grazzani et al., 2018). This understanding involves not only recognizing but also predicting and responding to the emotions of others, an ability that is crucial for coordinated efforts. As theorized by Vesper et al. (2017), successful joint action hinges on understanding and anticipating collaborators' thoughts, feelings, and behaviors, encompassing the perception and appropriate response to social cues. This shared understanding and mutual responsiveness highlight the intertwined roles of cognition and emotion in achieving effective collaboration (Michael et al., 2020). Thus, exploring the role of the EU within joint actions offers a richer understanding of the dynamics at play in collaborative actions.

2.1 Emotion Understanding (EU)

Emotion Understanding (EU) can be defined as the ability to comprehend the nature, causes, and consequences of one's own and others' emotions (Harris, 2008).

According to Castro et al., (2016), EU comprises emotion recognition and emotion knowledge. On the one hand, emotion recognition is the process through which we perceptually detect emotional expressions by integrating visual and auditory cues from the face, the body, and the voice. First, it involves recognizing that an emotion is being expressed and understanding the specific emotional content. This includes identifying prototypical expressions commonly associated with specific emotions, like smiling for happiness and shouting for anger. It also extends to labeling non-prototypical, real-life emotional displays that might be mixed, suppressed, or hidden. Moreover, emotion recognition encompasses using contextually relevant cues to identify and label emotions accurately.

On the other hand, understanding emotions involves more than just recognizing them. For instance, a child might be able to identify that their friend is sad based on their facial expression without comprehending the reason behind this sadness or how to provide support.

That is why understanding emotions includes having emotional knowledge. This means acknowledging and comprehending the various causes that can lead to these feelings, such as external events or situations, internal desires, beliefs, and expectations. This component also includes awareness of the consequences and functions of emotions, understanding how emotions can motivate actions, communicate desires, and impact the outcomes of interactions- for instance, expressing anger causes people to dislike you. Additionally, emotional knowledge carries notions of cultural rules and norms, which dictate how emotions are expressed and recognized within different cultural contexts. Lastly, emotion knowledge means relying on a comprehensive understanding of various emotion regulation strategies suitable for different situations.

2.1.1 Typical Developmental Trajectory of EU

Through extensive literature over the last 30 years, Pons and Harris (2000) have found that children's understanding of emotion encompasses nine different components (Pons & Harris, 2000). The emergence of each element is gradual and hierarchically structured, with earlier components necessary for developing more complex ones (Pons et al., 2004). Essential features of emotional knowledge develop early in life and continue to improve throughout childhood, while more complex aspects emerge later. Evidence supports a three-stage developmental progression from understanding more external aspects of emotions to a deeper understanding that integrates more mental representations and reflective aspects of emotions (Pons et al., 2004; Rocha et al., 2015).

The external dimension of EU comprises three components characterized by emotion recognition, understanding the concept of external cause, and the understanding that emotional experiences depend on people's desires. Initially, around the ages of 2 to 3, children develop the ability to recognize basic emotions such as sadness, anger, and happiness, primarily through facial expressions. This foundational skill in emotion recognition sets the stage for more complex emotional understanding. As children approach 3 to 4 years of age, they start to grasp the concept of external causes behind emotions. They recognize that certain situations can elicit specific emotions in both them and others, marking the beginning of their understanding of cause and effect in the emotional domain. As they develop a less egocentric perspective, they realize others may experience similar feelings in specific circumstances - for example, feeling happy when receiving a new toy or experiencing sadness when losing a pet. Between the ages of 3 and 5, the component of desire becomes evident in their emotional understanding. Children realize that emotions are not just reactions to external events but are also deeply tied to personal desires and the desires of others. For instance, they may comprehend that achieving a desired outcome, like winning a game, makes them happy. They also understand that people's desires can be different from their own. For example, they comprehend that two children can react oppositely towards the same food- depending on their preference.

The mental dimension of the EU comprises three components, and it is characterized by the comprehension of how people's beliefs influence emotions, the impact of memory on emotions, and the understanding that emotions can be regulated. By the time children reach 4 to 6 years old, they begin to grasp that people's personal beliefs influence emotions. This stage marks a deeper understanding of the mental aspects of emotions, where children learn that emotions are shaped not just by the objective aspects of a situation but by how it is perceived and interpreted. For instance, if unaware of the hungry wolf, they might understand that a bunny is still happy while eating its favorite carrot. The connection between memory and emotion becomes clear to children between the ages of 3 and 6. They understand that emotions can diminish over time and that certain situations can trigger memories of past emotions. As children approach 6 to 7 years of age, they start to understand that emotions can be regulated. They conclude that the emotional response toward situations can change depending on when they reflect on them. For instance, they learn that an effective strategy to mitigate sadness is redirecting the thoughts away from the loss by either thinking or doing something else.

Finally, the reflective dimension of EU comprises 3 components, and it is characterized by understanding the difference between hidden and expressed emotions, understanding the mixed nature of emotions and the application of moral implications to emotional experiences. The ability to hide emotions emerges around the ages of 6 to 7. Children at this stage become aware of the discrepancies between their felt emotions and the emotions they express outwardly. They learn that emotions can be concealed from others, a realization that later extends to understanding that others might also hide their genuine emotions. From age 8, children begin to realize that it is possible to experience multiple emotions simultaneously, even if they seem contradictory. They comprehend that a single situation can trigger conflicting thoughts because it clashes with their complex and multifaceted understanding of various aspects. This realization can elicit mixed feelings. The final component in children's emotional understanding development is morality, which typically becomes prominent later in their development. Children begin to associate moral dimensions with their emotional experiences, understanding that actions with moral implications can lead to corresponding emotional responses, such as feeling guilt or shame over wrongdoing or pride and joy in virtuous actions. Although shame and guilt expressions already appear early in preschool, children consider them the cause of emotions only later, when moral implications finally surpass desire-based emotions.

2.1.2 EU across cultures

Research has consistently shown that the ability to understand emotions is a universal human trait. However, studies have also pointed out subtle differences in how this ability develops across various cultures. For example, Italian children may better recognize the difference between real and apparent emotions than German children, possibly due to cultural values and parental practices (Molina et al., 2014). Even within non-western cultural backgrounds, the trajectory of emotional understanding appears consistent across cultures, although specific components may emerge earlier or later in development. Chinese preschoolers demonstrate similar overall developmental trends but may excel at distinguishing between real and apparent emotions while struggling to understand the connection between reminders and emotion (Tang et al., 2018). A study comparing the EU of Western with Quechan children found that while there was a cross-cultural difference in overall scores, both cultures showed the same developmental trajectory (Tenenbaum et al., 2004). This indicates a universal developmental trajectory for emotional understanding and some culture-specific differences in some dimensions.

2.1.3 EU in Italian children

A 2020 study by Cavioni and colleagues (Cavioni et al., 2020) examined EU in Italian children, testing 1478 children aged 3 to 10. The results revealed an age-related effect across all dimensions of EU, showing that children become increasingly more adept at correctly identifying emotions as they grow older (Figure 2). For instance, between the ages of 3 and 4, only half of the children could recognize emotions by facial expression. Still, from age five onward, most could identify facial expressions and external causes of emotions. By age 7, most grasped the role of desires and hiding emotional states, while by age 9, a fair amount understood mixed and moral emotions. The study also discovered that high external component scores obtained from age 3 reached a ceiling effect at age 7. Mental components showed a similar upward trend across the years but reached their ceiling effect at 10.

Table 2. Descriptive statistics for the developmental periods of the test of emotion comprehension by age-interval (N = 1,478).

		External		Mental		Reflective		Total TEC	
Age (years)	Months	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
3	36–41	0.93	0.69	0.76	0.64	0.47	0.63	2.16	1.23
	42–47	1.08	0.82	0.74	0.7	0.69	0.73	2.5	1.41
4	48–53	1.48	0.96	1.18	0.88	0.7	0.7	3.37	1.66
	54–59	1.89	0.85	1.34	0.92	0.81	0.77	4.04	1.78
5	60–65	2.23	0.68	1.56	0.82	1.04	0.81	4.82	1.48
	66–71	2.31	0.68	1.68	0.8	1.02	0.85	5.01	1.5
6	72–77	2.46	0.65	1.72	0.91	1.16	0.8	5.33	1.51
	78–83	2.68	0.53	1.97	0.86	1.35	0.8	6	1.36
7	84–89	2.69	0.47	2.27	0.85	1.63	0.89	6.59	1.51
	90–95	2.8	0.4	2.35	0.74	1.65	0.86	6.8	1.35
8	96–101	2.92	0.27	2.31	0.78	1.81	0.99	7.04	1.34
	102–107	2.97	0.16	2.41	0.72	1.92	0.88	7.3	1.23
9	108–113	3	0.04	2.45	0.55	2.3	0.82	7.75	0.93
	114–119	2.9	0.3	2.42	0.67	2.13	0.81	7.45	1.21
10	120–125	2.95	0.22	2.60	0.55	2.31	0.79	7.86	1.19
	126–131	2.98	0.15	2.61	0.54	2.32	0.77	7.91	1.16

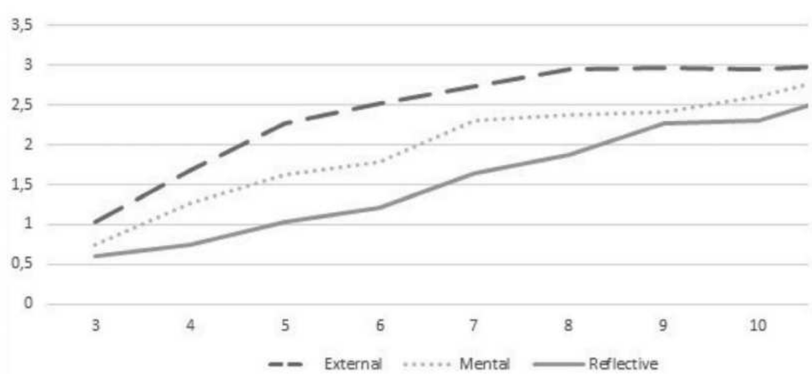


Figure 3. TEC scores for external, mental, and reflective dimensions by age-groups.

Figure 2. TEC score of external, mental, and reflective stages by age groups. (Cavioni et al. 2020)

Interestingly, mental components developed in stages with stable scores over specific age intervals before rapidly increasing in the tenth year. In contrast to other dimensions, the reflective dimension never plateaued; Gender differences were found insignificant across all test components. This outcome aligned with existing literature on Western and non-Western cultures. Finally, Italian performances appeared similar to Chinese, Brazilian Portuguese, German, Norwegian, and British populations. No particular pattern emerged among Italian participants when comparing them with others from different backgrounds (Harris & Cheng, 2022).

2.1.4 EU and its role in social development

EU extends beyond a mere aspect of emotional growth, but it influences children's social development by equipping them with valuable skills for navigating complex social interactions. It allows children to pick up emotional cues, filter out exogenous information, and prepare them to respond adequately (Halberstadt et al., 2001). It especially turns out to be critical in distressing situations, such as conflict, when negative emotions are expressed, as it allows one to "read the situation" most suitably. For instance, a child with excellent emotional knowledge can more easily recognize if their friend is upset because they were excluded from a group game. They would likely provide comfort and support and attempt to include them (Belacchi & Farina, 2010). Indeed, the EU has been identified as a predictor of social competence- an important component for fostering effective interactions (Denham et al., 2003; Trentacosta & Fine, 2010). A great EU correlates with positive social markers, such as peer popularity and adoption of prosocial roles within the classroom (Roazzi et al., 2015). On the contrary, poor EU has been associated with more internalizing and externalizing problems later in childhood and adolescence. A limited ability to comprehend emotions correlates with anger and aggression expression in the classroom (Denham et al., 2002).

While research shed light on the connection between EU and various aspects of social competence, such as cooperative actions and prosocial behaviors (Rose-Krasnor, 1997), we still know little about its relationship to another facet of social competence: action coordination.

2.2 Emotion Understanding and peer action coordination

Emotional cues have been theorized to influence action coordination by providing crucial information for planning and executing actions (Vesper et al., 2017). Although the contribution of emotions to coordinating actions in social interaction has not been extensively explored until recently, one study indicated that children with higher performance in recognizing emotions and understanding their causes and consequences also exhibited greater coordination during a cooperative sensorimotor task (Viana et al., 2020); Viana and colleagues (2020) investigated the relationship between EU and peer action coordination in Brazilian children aged five years and 7 months to 9 years and 8 months. The study included 68 children from middle-class families. Children’s individual and cooperative action coordination was measured by their performance at the Labyrinth ball game. Their EU was assessed through TEC-I.

The study presented in this thesis is mainly based on the study of Viana and colleagues (2020). It aims not only to replicate its design with an Italian sample but to address some potential gaps that help us better understand the mechanism behind the association between EU and peer action coordination. Inhibitory control is one of these factors.

2.3 Inhibitory Control

Inhibitory control is a cognitive function that involves the ability to suppress automatic responses to achieve specific goals or perform tasks more effectively (Carlson & Moses, 2001). It is considered a central executive cognitive function, along with working memory and cognitive flexibility (Diamond, 2013). Inhibitory control involves deliberately suppressing attention to distractions or impulsive actions, and it comprises two components: motor inhibition and interference inhibition (Mirabella, 2021; Tiego et al., 2018). Motor inhibition is the suppression of preplanned motor action, often measured through go/no-go or stop-signal tasks where participants must respond to "go" stimuli while not responding to "no-go" stimuli. Interference inhibition assesses the ability to handle reaction conflicts from irrelevant but incompatible stimulus attributes, preventing incorrect responses (Kang et al., 2022). This is assessed using various task paradigms like Stroop, Simon, Flanker, and ANT/Fish tasks (Anderson, 2002). For example, the ANT or Fish Task (Rueda et al., 2004) requires the child to resist the impulse to respond immediately and handle visual and attentional interferences to complete the task (Gandolfi et al., 2014).

2.3.1 Typical developmental trajectory of inhibitory control

The developmental trajectory of inhibitory control spans from infancy into adulthood, showcasing a complex interplay of neurocognitive growth and environmental interaction. The early signs of inhibitory control are observed in the latter half of the first year of life when infants begin to exhibit the rudimentary ability to withhold actions (Morasch & Bell, 2011). For instance, 8-month-old children can prevent or stop behaviors in response to their parent's requests. This early capacity to inhibit physical responses sets the stage for more sophisticated forms of self-regulation.

As children enter the preschool years, a pivotal phase for the development of inhibitory control begins. Research indicates that before reaching 36 months, children's inhibitory processes are less distinct (Escobar-Ruiz et al., 2023). However, as they surpass this age milestone, a more evident differentiation between response and interference inhibition emerges. Initially, it involves mastering the restraint of impulsive or predominant behaviors (response inhibition). As they grow older, children advance to a higher level of cognitive inhibition, where they learn to filter out impulsive reactions and manage attentional distractions (Rueda et al., 2005). By age 3, they begin to exhibit more sophisticated forms of inhibition, such as interference suppression. Notably, children between the ages of 3.5 and 4.5 — over an average span of 18 months— demonstrate substantial progress in both simple and complex inhibitory tasks (Sadeghi et al., 2022). After this period, the pace of development in inhibitory control begins to stabilize, particularly between the ages of 5 and 6. Simple inhibition shows consistent developmental patterns across different age groups, while complex inhibition continues to evolve until about the age of 7 (Geeraerts et al., 2021). This stage is essential for integrating inhibitory control with working memory, broadening the scope of a child's executive functions (Zelazo et al., 2003, 2013).

Inhibitory control continues to solidify during middle childhood, with significant gains observed from 5 to 8 years of age (Brocki & Bohlin, 2004). During this time, children become increasingly capable of managing complex tasks that demand suppressing distractions and coordinating multiple cognitive processes. The ability to resolve conflict and inhibit irrelevant stimuli becomes more refined, indicative of the maturing prefrontal cortex and its neural networks (Aron, 2007; Bari & Robbins, 2013; Durston et al., 2002). The maturation of inhibitory control typically culminates around the age of 12, aligning with broader executive function development. Despite the foundational developments in childhood, enhancements in inhibitory control during adolescence are relatively minor, suggesting a plateau in this executive function (Brocki & Bohlin, 2004). This leveling off may reflect the transition from structural growth to functional optimization within the prefrontal cortex. By adolescence, these executive domains integrate into a cohesive "executive control" system, enabling more nuanced and sophisticated decision-making and self-regulation (Fernández García et al., 2021).

2.3.2 Interplay of Theory of Mind and Inhibitory control

Empirical evidence underscores a robust and positive correlation between inhibitory control and ToM capabilities, indicating that individuals who excel in tasks requiring inhibitory control also tend to perform better in ToM assessments (Cassetta et al., 2018). Inhibitory control is essential for understanding others' mental states and engaging in complex social interactions, as it involves suppressing our egocentric view to interpret another person's thoughts and intentions accurately. This interconnectedness significantly influences one's capacity to fully attend to the perspectives of others during conversations, allowing for accurate deduction of thoughts and emotions while responding appropriately to the context. As a matter of fact, individuals with better inhibitory control tend to exhibit enhanced ToM abilities, as they are more proficient in inhibiting impulsive responses and considering alternative viewpoints (Chasiotis et al., 2006).

The development of ToM and inhibitory control are closely linked during the formative years of early childhood, with advancements in inhibitory control abilities appearing to predict the progression of ToM understanding (Symeonidou et al., 2023). The maturation of brain regions and cognitive processes associated with inhibitory control and understanding others' perspectives underscores these two share similar parallel growth and implications in social cognitive development (Carlson & Moses, 2001).

In summary, the capacity to inhibit one's perspective to consider and understand the mental state of another is not only a remarkable cognitive achievement but a necessity for effective social interactions.

2.3.3 Interplay of inhibitory control and emotion understanding

Controlling impulsive reactions is crucial for children as it aids in accurately identifying emotions and comprehending complex social scenarios. By allowing a moment of pause, children can suppress erroneous beliefs and reflect on the broader context of an emotional event, thereby deepening their EU (Diamond, 2013; Morra et al., 2011; Rhoades et al., 2009).

Empirical evidence supports a significant relationship between inhibitory control and EU, a key aspect of the Theory of Mind (ToM) affective component. Research highlights this connection by demonstrating notable correlations between these cognitive and emotional domains in preschool-aged children (Blankson et al., 2012; Leerkes et al., 2008). Emphasizing the importance of executive functions in developing EU, Oh & Lewis, (2008) revealed that various executive functions (EFs), such as inhibitory control and task switching, are crucial for developing emotional knowledge. Denham and colleagues, (2012) extended this line of inquiry by examining how inhibitory control of attention and behavior contributes to emotional knowledge in young children. Their findings indicate that early assessments of inhibitory control at preschool age can predict later the same year emotion knowledge and other factors accounting as relevant for school readiness, shedding light on the one-way influence of Executive Functions (EFs) on the development of emotion understanding. Consequently, emotion understanding is closely tied to the development of executive functions, with inhibitory control playing a pivotal role.

However, the literature also highlights some inconsistencies. For example, in Martins and colleagues's study (2016) the connection between inhibitory control, set-shifting, and emotion understanding was examined in 4½-year-olds while accounting for factors such as IQ, language ability, and Theory of Mind. Surprisingly, inhibitory control did not emerge as a significant predictor in their model explaining emotion understanding. Other studies also yielded mixed findings, with some measures of inhibitory control showing significant correlations with emotion understanding, while others did not (Grazzani et al., 2018). These divergences in the literature signal the complexity of the relationship between inhibitory control and emotion understanding, suggesting that while inhibitory control is a crucial component, it operates within a broader, multifaceted network of cognitive and emotional processes influencing the development of emotional knowledge. Such findings advocate for further empirical inquiry into the intricate interdependencies between the two constructs when investigating the development of emotion understanding in childhood.

2.4 Inhibitory control and peer action coordination

Inhibitory control is important for aligning individual actions towards shared goals and essential for social and cooperative behaviors in early and middle childhood. It enables the suppression of personal impulses to maintain harmony and coherence within a group. It is critical in diminishing self-centered views, thereby improving the understanding of others' actions (Brownell, 2011). Furthermore, while coordinating actions, one needs to adapt to the partners' actions in real-time, where momentarily pausing one's actions allows feedback integration, enhancing joint coordination (Huyder et al., 2017).

Research reveals that enhanced inhibitory control in young children correlates with increased social competence and reduced competitiveness in group settings, underscoring its role in nurturing cooperation (Ciairano et al., 2007; Huyder & Nilsen, 2012). Similarly, Giannotta and colleagues (2011)'s study with 250 children aged 8 to 12 showed that an individual's and their partner's inhibitory control could predict cooperative behavior during joint tasks, like puzzle-solving, highlighting its importance in effective collaboration. In summary, research has consistently shown that inhibitory control is crucial in promoting social competence and cooperative behaviors among children.

As for joint action per se, the nuanced role of inhibitory control in joint actions becomes evident in the context of turn-taking and synchronized behaviors in toddlers. Better inhibitory control was linked to more successful coordination, especially in tasks requiring complex movements or precise timing (Meyer et al., 2015). In preschoolers, the interplay between inhibitory control and ToM becomes crucial for joint action success (Milward et al., 2017). Through tasks designed to assess these cognitive abilities, the study revealed that children's performance in joint activities was influenced by their capabilities in inhibitory control and ToM, suggesting that while related, these processes independently contribute to joint action coordination.

Altogether, this body of research emphasizes the importance of inhibitory control in promoting social competence and cooperation from early childhood to preschool years. However, questions about its significance in coordinating older children's joint action still need to be answered. It calls for further investigation into whether inhibitory control continues to play a critical role or if older children adopt alternative strategies for joint action tasks (Satta et al., 2017). Understanding this transition is vital for comprehending the developmental trajectory of joint actions.

2.5 The current study

2.5.1 *Rationale of the study*

Understanding the complex relationship between emotions, cognition, and social interaction in children is a crucial aspect of developmental psychology. Emotions are important cues for planning and carrying out actions, shaping individuals' behaviors in social situations (Michael, 2011). At the heart of this process is emotion understanding, which involves recognizing, comprehending, and reasoning about emotions—a crucial skill for successful social interaction and communication (Vesper et al., 2017). Despite its importance, the precise impact of EU on coordinating actions has only been recently explored. One such gap is the limited exploration of the role of inhibitory control for the potential relationship between EU and social coordination. Inhibitory control, a fundamental component of executive functions, involves suppressing impulsive responses and ignoring irrelevant stimuli, enabling more deliberate and goal-oriented actions. While previous research has underscored the relevance of inhibitory control in facilitating cooperative tasks among preschoolers (Ciairano et al., 2007), its specific contribution to the nuanced processes of action coordination in social settings, particularly the EU, has not been sufficiently examined.

Our study builds upon the work of Viana et al., (2020) that found a correlation between EU and peer action coordination among Brazilian children. By conducting a similar study with Italian children, we aim to assess whether these findings can be replicated in an Italian sample, exploring potential similarities and differences in the developmental trajectories of EU and its impact on peer action coordination. Furthermore, we intend to delve deeper into the mechanisms that underpin the relationship between EU and action coordination by investigating the potential role of inhibitory control. While Viana et al., (2020) have shed light on the association between the EU and action coordination, our study will advance this line of inquiry by examining the moderating role of inhibitory control in this dynamic. This investigation will enhance our understanding of the extent to which the ability to understand emotions and inhibit conflicting information contributes to this coordination.

The existing literature lacks a comprehensive exploration of EU, inhibitory control, and action coordination within a single study. However, given the correlation between EU and inhibitory control found in previous studies (Denham et al., 2012; Li et al., 2022), we anticipate a significant relationship between these constructs and children's capacity for cooperative action coordination. Our research aims to provide empirical evidence on how EU and inhibitory control individually impact children's cooperative abilities and whether inhibitory control may work as a moderator in the relationship between EU and cooperative action coordination.

2.5.2 Aim of the study

This project aims to understand the extent to which children's EU and inhibitory control impact children’s peer action coordination. To address this question, the project has two main objectives: 1) to replicate with an Italian sample the study by Viana and colleagues (2020), which found a positive relationship between children's peer action coordination and their EU; 2) to Expand on the findings from Viana and colleagues (2020) by exploring the role of children's inhibitory control on the interplay between their EU and peer action coordination.

2.5.3 Research questions and hypotheses

In particular, the research will address the following research questions:

RQ1: To what extent does emotion understanding impact children's peer action coordination?

HP1: We expect children with better emotion understanding to be likely to coordinate their actions with peers better, even when age and individual action coordination are taken into account.

RQ2: To what extent does inhibitory control impact peer action coordination?

HP2: We expect children with better inhibitory control to be likely to coordinate their actions with peers better, even when age and individual action coordination are accounted for.

RQ3: Does Inhibitory control moderate the relationship between Emotional Understanding and peer action coordination?

HP3: We predict inhibitory control to moderate the relationship between emotion understanding and peer action coordination. Precisely, we expect children with better inhibitory control and emotion understanding to exhibit better action coordination with other peers, compared to children with good emotion understanding but worse inhibitory control.

3 METHODOLOGY

The study utilized a cross-sectional correlational design involving children aged from 6 years and 11 months to 10 years and 10 months (M=8 years and 8 months; SD=1 year and 1 month). To comprehensively explore emotion understanding, inhibitory control, and action coordination, three distinct tasks were employed: respectively, a test of Emotion Comprehension, an Attentional Network Task, and a sensorimotor table game called Labyrinth Ball Game. The children played the labyrinth ball game twice - once alone and once with a peer, allowing for observation of their individual and cooperative performance. Children were paired with a same-gender peer who was not nominated as a friend or "non-friend," and had similar skills in emotion understanding and individual action coordination performance. Other demographics of the sample were assessed.

3.1 Participants

The study included 118 participants from four primary schools in Northern Italy. Specifically, 53 children were sampled from two private schools (38 in Montanaro and 15 in Novara) and 65 from two public schools (14 from Novara and 51 from Sesto Calende). It is important to note that due to technical issues during the ANT administration, 3 participants were excluded. Additionally, 10 participants (8.47%) were excluded based on the criteria for dyad formation in the cooperative play session: 2 participants could not complete the first level of the labyrinth ball game within five attempts on their own, and 8 participants were excluded to balance the number of same-gender participants within the same grade, based on their unmatched individual performance. As a side note, we would like to specify that to ensure inclusivity, all excluded children were allowed to participate in a cooperative session with other excluded children, though their data were not included in the study. This adjustment reduced our final sample size to 108 (N=108). The participants were, on average, 8 years and 8 months old (SD = 1.14 years), consisting of 50 females and 58 males, with detailed gender and age frequencies presented in Table 1.

Table 1. Frequency of Participants by Age and Gender

Age	F	M
6-7	1	3
7-8	9	17
8-9	20	20
9-10	8	8
10-11	12	10

A significant majority (87.96%) reported Italian as their first language. All children showed consistent responses to check questions and could fluently repeat instructions, backed by parental reports of sufficient Italian proficiency for test participation. The cultural background was predominantly Italian, with 95.23% born in Italy and the others from Bangladesh, Germany, Brazil, and Pakistan, each representing 0.93% of the sample.

Parental data included 108 mothers and 102 fathers, with average ages of 42.32 (SD=5.69) and 45.86 (SD=6.14) years, respectively. About 26.85% of the children were only child or lacked sibling data, while 70.37% had at least one sibling. Most children (76.85%) came from families where both parents were born Italian. Families where both parents were born abroad accounted for 12.04%, with specific percentages for countries like Morocco (2.78 %), Romania (1.85%), Albania (1.85%), Bangladesh (0.93%), Pakistan (0.93%), Brazil (0.93%), China (0.93%), Egypt (0.93%), USA (0.93%). Mixed-nationality parentage was observed in 5.56% of families, with the father being the foreign-born parent in 3.70% of these families and the mother in 1.86%.

Within our mothers' sample, the educational level of mothers predominantly aligns with higher education; 12.96% hold middle school diplomas, 38.89% have high school diplomas, and 43.52% possess degrees from higher education degrees (Degree of I, II levels or Doctorate), and 4.63% opted not to disclose this information. For the fathers participating in the study, the educational level distribution is as follows: 18.81% achieved a middle school diploma, 53.47% completed high school, and 27.72% acquired a higher education degree. A small fraction (0.98%) did not disclose this information. Overall, mothers in the sample educationally showed a higher qualification level than the regional average, with 43.52% holding higher education degrees, contrasting with the 34.9% of center-north regions. Fathers, however, had slightly lower educational attainment compared to the regional male average, with 27.72% holding higher education degrees against 37.8% of center-north regions.

Employment-wise, 77,78 % of families had both parents employed. The family occupation levels, categorized into low, middle, and high income based on job types and averaged across parents, indicated that the sample predominantly fell into the middle to high-income category, with 47.22% in middle-high income jobs such as back office employee (*Annuario statistico italiano 2023*, 2023). A more detailed demographic figure showing generally high educational background, particularly among mothers, and a middle-high Socioeconomic Status (SES) is detailed in (Appendix A).

3.2 General Procedure

The ethical instances in Norway - The Norwegian Centre for Research Data (Sikt) (reference n. 29780) and the Internal Ethical Committee at the Department of Psychology of the University of Oslo - approved the study. Before the start of the data collection the study was preregistered on as Predicted (See Appendix B). Only after the ethical approval, recruiting and data collection initiated. Data were collected in two public elementary schools of Sesto Calende (VA) and Novara and two private elementary schools of Montanaro (TO) by me and five other psychology students from the University of Turin between October and November 2023. The teachers introduced the project to the parents during the school meeting, and the information letter and consent form were forwarded digitally by the parents' representatives on the classroom chats. Parents returned the signed consent forms and demographic sheets printed in enclosed envelopes. Finally, all children with parental consent were informed about the study's purpose and asked for their verbal consent on their first day of testing.

During school hours, children were taken to a room assigned for the experiment one by one. The data collection took, in total, approximately 50 minutes per participant, divided into three different sessions: the first two were individual sessions, and the last was in the company of a peer. During the first session, children were asked if they had one best friend in their class and if there was someone they did not agree much with. Then, children were administered the

Attentional Network Task (ANT) ((Rueda et al., 2004) and the Test of Emotion Comprehension (TEC-I, Italian version (Albanese & Molina, 2008). The order of the tasks administration in this session was randomized, and it took an average of 15 minutes per task. In the second session, children played the labyrinth ball game alone, lasting an average of 12 minutes. Afterward, the information regarding their 1- gender, 2- best friend, "unfriend" nomination, 3- highest TEC developmental stage, and 4- individual action coordination performance was used to create dyads. Each child was paired with another peer of the same gender who was not nominated as best friend or "unfriend" and who matched at best a similar level of individual labyrinth ball game and TEC performance. In the third and last session, children play the labyrinth ball game again, but this time in dyads with a peer, lasting a maximum of 10 minutes.

3.3 Measures

3.3.1 Demographics

Parents were asked to fill out a short demographic form attached to the consent form (see Appendix C). First, the demographic survey asked for information regarding the child, such as the name, date of birth, gender, nationality, spoken language, and whether the child attended kindergarten and preschool. In the second part of the demographic survey, parents were asked to fill in information regarding their birth year, occupation, and level of education. This information was used to draw a rough picture of the sample's Socioeconomic- Status.

3.3.2 Best friend/ "unfriend" nomination

Since the level of friendship could impact how children would cooperate, children were not paired with best friends or children they did not like in order to avoid advantages or rivalry when interacting (Chung et al., 2018). For this reason, children were asked in the first session if they had a best friend in the class and if there was someone they did not much agree with. If children indicated no one, the field was left empty, whereas if they indicated multiple nominations, they were asked to refer to only one. We believed this nomination would give us sufficient insight into the friendship dynamics within the classroom. It allowed us to avoid pairing the participants with someone they nominated as best friends or disliked peer.

3.3.3 TEC-I Test of Emotion Comprehension

The Test of Emotion Comprehension is a non-diagnostic test that assesses EU in children between 3 and 11 years old. The original version was designed by Pons and Harris (2000). The TEC has been translated into 27 languages and has shown good test reliability across cultures and robust construct validity (Cavioni et al., 2020; Rocha et al., 2015). Its Italian translation, "Il Test di comprensione delle Emozioni," was standardized in 2008 (Albanese & Molina, 2008). It was later utilized in Italian studies investigating EU in children (Grazzani et al., 2018; Molina et al., 2014).

Briefly, TEC-I comprehensively investigates nine different components of EU in children: 1- the recognition of basic emotions (5 items); 2- understanding the impact of situational variations on emotions (5 items); 3- understanding the desire-based emotions (8 items); 4- understanding the effects of belief on emotions (2 items), 5- as well as memories (3 items); 6- understanding the impact of the control of emotion expression (1 item), 7- and hiding of emotions (1 item); 8- understanding the mixed nature of emotions (1 item) and finally 9- understanding moral and reflective emotions (3 items) (Pons & Harris, 2000).

The test consists of cartoonish scenarios represented in 23 graphic tables. In the first five items related to emotion recognition, the child must identify a specific emotion by pointing to the correct one out of four possibilities. For instance: "Can you point at a person that feels happy/sad/angry/normal/scared?" (Figure 3).

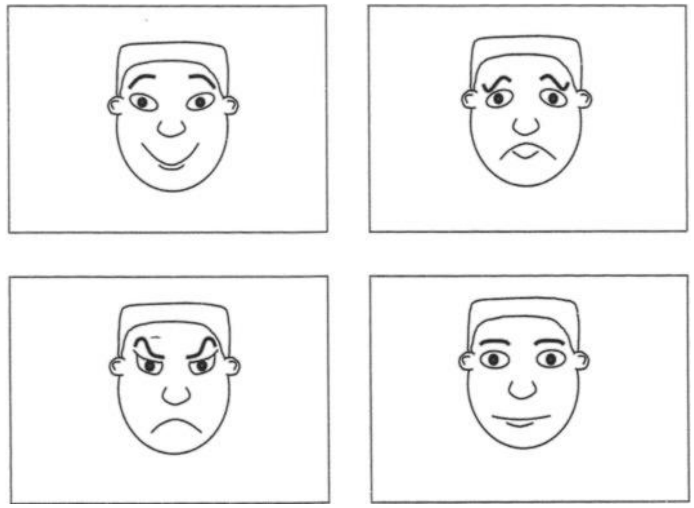


Figure 3. Component I: Emotion Recognition; Table 1, of the TEC-I male Italian version by Albanese and Molina (2008)

The remaining items contain a little story with emotional content where the protagonist's face is left blank. At the end of each story, the researcher asks the child to point out what facial expressions the protagonist is most likely to have among those four. For example: "This is Alberto. Alberto is looking at the nice bike that he just received for his birthday. At the same time, he wonders if he will fall and hurt himself because he cannot ride the bike yet. How does Alberto feel in this situation? Does he feel happy, sad, and scared, happy and scared, or scared?" (Figure 4).

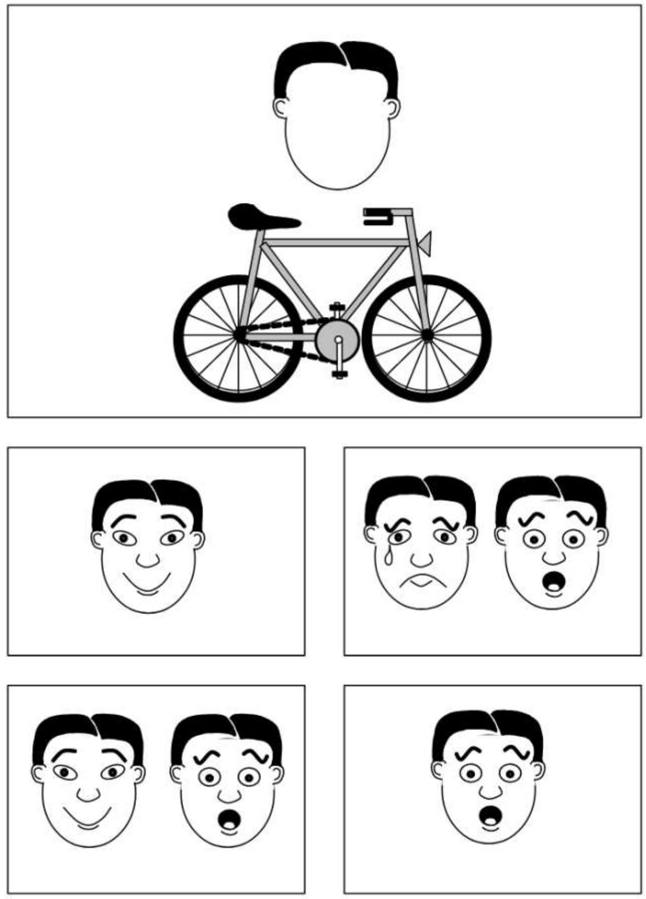


Figure 3. Example of cartoon scenario and emotional outcomes (Component VIII: Mixed).

Figure 4. Component VIII: Mixed emotions; Table 20, of TEC-I male Italian version by Albanese and Molina (2008).

The test was administered individually, with the administrator sitting adjacent to the child; all questions were administered in a neutral but engaging tone to avoid giving clues on the correct alternative. If the child was unable to answer, the administrator helped them. For example, if the child did not understand, the administrator repeated the story along with the options. If the child chose multiple or a different answer from the four options, he was asked to select the most adequate option. If the child gave only a verbal answer, they were asked to point at the corresponding image. On the other hand, if the child spontaneously pointed at the image, it was not necessary to verbally name the choice because the administrator did it for them. The administrator duly reported answers on an online sheet, along with notes.

Scoring was based on a binary system: children received one point for each correct response and zero for incorrect or non-given ones. A minimum number of correct responses was needed for a child to be considered proficient in a specific component. For example, in Component 1, regarding the recognition of emotions, a child had to correctly answer at least four out of five items to be deemed competent. Detailed information on the criteria for key items and the allocation of components can be found in the provided answer sheet and codebook in (Appendix D). It is important to note that not all items contributed to the attribution of the component. A lot were control items, and they served the purpose of familiarizing the child with the scenario. The final score ranges from 0-9 and reflects how many components the child has demonstrated proficiency in, with one point allocated for each achieved component. Finally, besides the final score, the developmental stage was also reported. Following the Italian standardization criteria, children with a final score ranging from 1-3 belong to the (1) External dimension, from 4- 6 to (2) Mental dimension, and from 7- 9 to (3) Reflective dimension (Molina et al., 2014).

3.3.4 ANT- Attentional Network Task as a measure of Inhibitory Control

The Attentional Network Task (ANT) is a computer-based task initially developed by Fan and colleagues (2002) to test the efficiency of all three attentional networks in adult:1) alerting, 2) orienting attention, and 3) inhibiting conflicting information. Later, the ANT was adapted for children (Rueda et al., 2004). The method has been validated as reliable and suitable for children between 6 to 10 years old (Ishigami & Klein, 2015). In the current study, we employed a concise adaptation of the ANT, akin to the one by Miljeteig (2016), which reduced the testing time to 10 minutes: the overall number of trials, intertrial, and fixation period are, indeed, shorter than the original task. The shortened duration was strategically chosen to help the child's engagement and to accommodate another task that could be administered within the same session. Notably, we excluded the neutral condition, where the middle fish is presented alone, aligning with other studies that reported its outcomes were similar to those of the other conditions (Abundis-Gutiérrez et al., 2014; Rueda et al., 2012).

In the current study, children were tested individually, sitting in a quiet room on a 15.6-inch laptop, 53 cm from the screen. The task was administered using Psytoolkit, an online open-source platform with timing recording comparable to E-prime (Kim et al., 2019; Stoet, 2010, 2017).

First, children were introduced to a video game through a short story. There once was a fisherman who asked children for help catching animals. They could catch the animal in the middle in the series of five by identifying the direction the middle fish or bird was pointing and pressing the correspondent arrow key on the keyboard. Sometimes, the animals faced all the same direction (congruent condition), and sometimes, the middle one faced the opposite way (incongruent condition), demanding the child's attention for accurate identification (as shown in Figure 5).

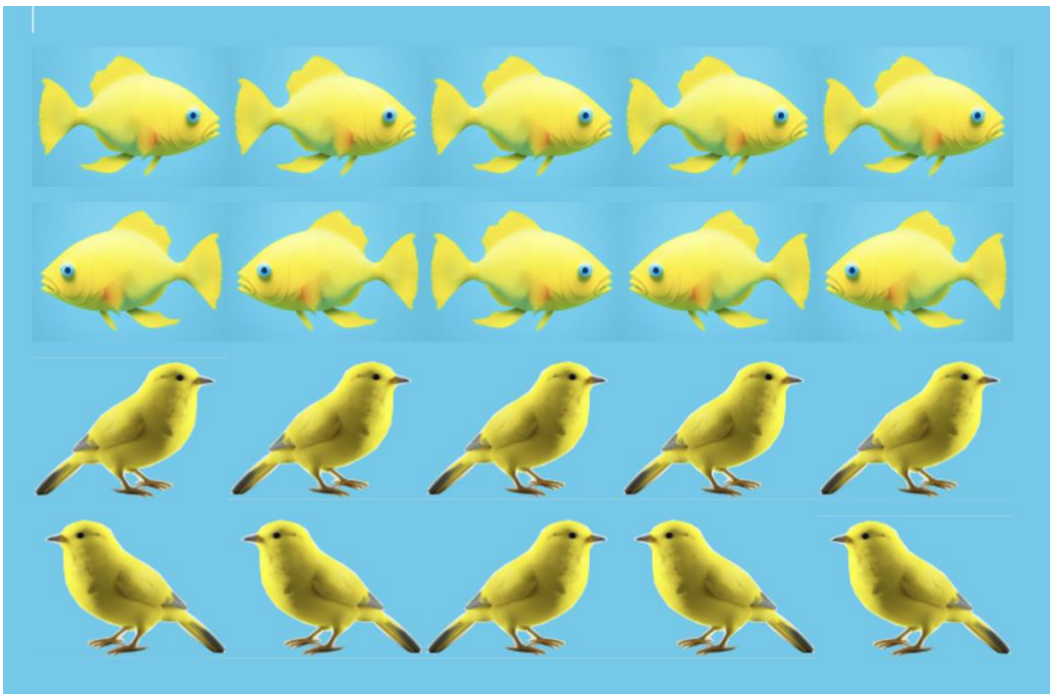


Figure 5. ANT Stimuli; target array, current study version.

Each experimental trial followed a fixed order. First, a fixation cross was presented on the screen – to catch the child's attention at the center of the screen for either 400 or 500 milliseconds (ms). Afterward, a cue might have followed for 100 ms. There were four cue conditions: some trials had no cue (no-cued), some had a central cue- an asterisk appeared at the place of the fixation cross, some had a double cue- two asterisks appeared simultaneously above and below the fixation point, and some had a spatial cue – which pointed where the target array would appear. After the cue or no cue was displayed, a fixation period of 450 ms followed. Then, the target array of animals was displayed on the screen until the response was detected or 3000ms elapsed. Five identical yellow fishes or birds lined up in a row, occupying a visual angle of 8.84° or 689,75 pixels (px), were presented 150 px either above or below the center of the screen. After responding, the participant received auditory and visual feedback from the computer for 600ms. For correct responses, a simple illustration of a boy/girl cheering with a fish/bird net in their hand while a pleasant "bleep" sound was presented. A single negative tone and no animation followed incorrect responses. The intertrial interval was 800 ms. For a schematic overview of each experimental trial, see (Figure 6.)

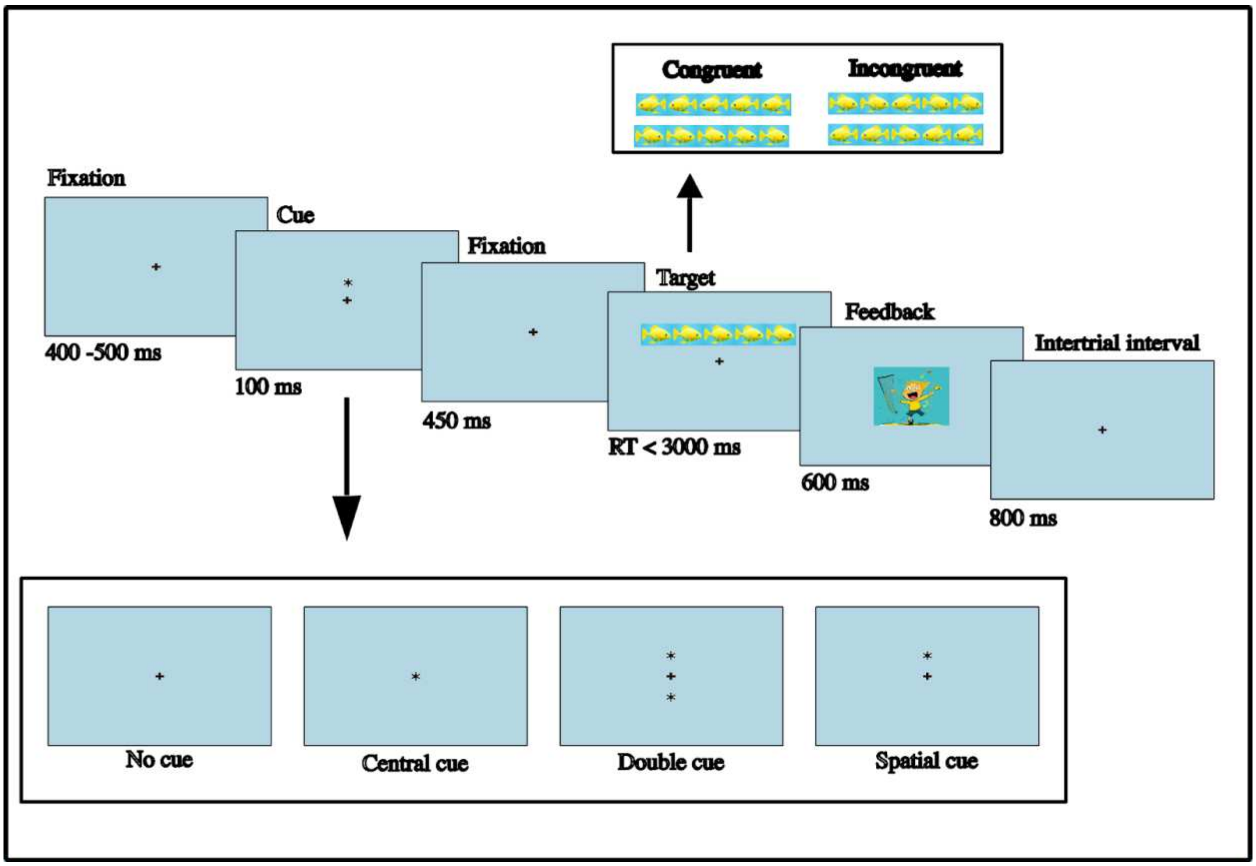


Figure 6. Overview of an ANT experimental trial; current study version

After children were introduced to the story, instructions were given. They were told to use the hand to write with and were shown how to place their index and middle fingers on the keys. They were then asked to repeat the commands to ensure comprehension and proceeded with two familiarization blocks.

The first practice block comprised a minimum of 8 trials. Each condition was repeated until two correct responses were given. Unlike the experimental blocks, the child had a maximum of 6000ms to answer during the first practice block. The experimenter was on the child's side, engaged and supportive in the game and assisting with the child's demands. Once the first training was completed, the experimenters clarified that from that moment onward, children had to proceed alone. Then, the experimenter took a back sit, laterally to the screen, but where still she could see the participants' hands. The second practice block was concise and identical to the experimental block. It presented four random trials. This familiarization blocks accustomed children to be autonomous in the task by letting them familiarize themselves with the 3000ms response time window.

After the practice sessions, four experimental blocks were administered in succession, each comprising 32 experimental trials. During the blocks, the experimenter did not interfere with or address the children's comments or questions during the experimental blocks. Breaks were scheduled in between blocks. During inter-blocks, children were encouraged with general comments that did not refer to the child's performance. For instance, "Oh, you caught so many animals already! Can you guess what you will catch next?". Children were also gently reminded to use their dominant hand in the inter-blocks in case they used both hands or switched over hands.

Overall, the session consisted of at least 12 practice trials and four experimental blocks of 32 experimental trials. Each trial represented one of the eight conditions in equal proportions: two target types (congruent or incongruent) X four cues (no cue, central cue, double cue, and spatial cue). Responses were given by pressing the left and right arrows on the laptop keyboard. For each trial, accuracy and reaction times were recorded.

For each participant, performance metrics across conditions were then calculated. Error rates (pe) were determined by the ratio of incorrect responses and responses exceeding the time limit to the total number of trials for each condition. Beyond accuracy, median and average reaction times (RT) for correct responses across various conditions were computed. To mitigate the impact of distraction caused by the negative feedback from incorrect responses, RTs immediately following incorrect responses were excluded from these calculations. RTs outside the 150 ms to 3000 ms range were also disregarded, as they likely represented false hits (for RTs shorter than 150 ms) or misses (for RTs longer than 3000 ms), thus not accurately reflecting attentive responses (Hermansen et al., 2017). Additionally, outliers—defined as RTs deviating more than three standard deviations from a participant's average RT for a condition—were trimmed. This procedure aimed to reduce the influence of non-systematic distractions or anomalies, ensuring a more accurate evaluation of attentional network performance.

After establishing the primary metrics for assessing performance, we focused on evaluating the three attentional networks described by Rueda et al. (2004). However, this thesis concentrates specifically on the inhibitory control network. Our primary interest was examining how well individuals can handle conflicting information and ignore distractions to stay focused on a task. To assess inhibitory control, we looked at the median difference in reaction times (RTs) between trials with conflicting cues (incongruent) and trials with consistent cues (congruent). A smaller difference in RTs indicates better inhibitory control, meaning the participant was less distracted by conflicting information. We also analyzed inhibitory error rates, which measure the difference in mistakes made between incongruent and congruent trials.

3.3.5 Labyrinth ball game

The labyrinth ball game is a wooden table game suitable for children from 6 years old and can be played by two children simultaneously. The game involved maneuvering a steel ball throughout a labyrinth without falling into the holes. The child balanced the ball using the two side knobs to tilt the board (Figure 7). It, therefore, requires fine motor skills and problem-solving abilities similar to the ones implemented in some of the studies by Doise and Mugny (1984). In the present study, as in the original by Viana and colleagues (2020), each child played it twice, first individually, then with a peer, while video recorded.

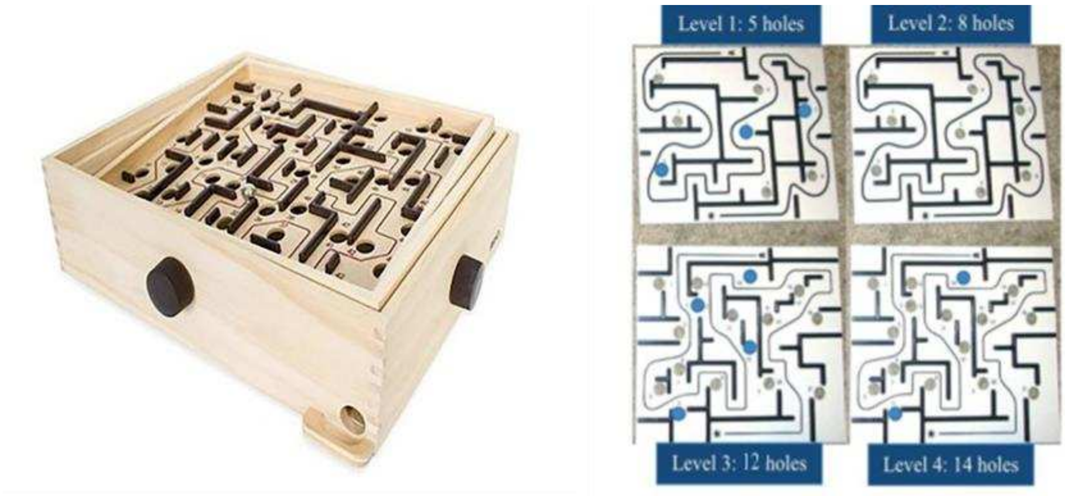
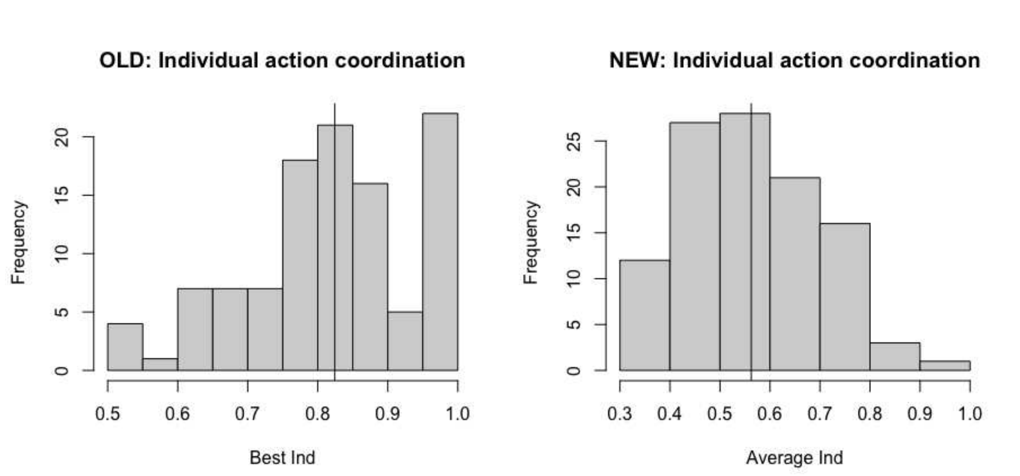


Figure 7. Left: Labyrinth ball game (BRIO- 34000); Right: the four levels layout

Children played the game through 4 levels of increasing difficulty. As shown in Figure 7, the first and second levels involved the same path but with five and eight holes, respectively. The third and fourth levels had a slightly more complex path than the first two and had 12 and 14 holes, respectively. This indicates a total of 39 holes in the game. After the testing, the child's performance was assessed by watching the video recordings.

In our original plan, consistently with the design of Viana and colleagues (2020), we calculated the children's performance as the sum of their best attempts across the 4 levels. Nevertheless, different from our expectations, most children outperformed the task, managing to complete almost or all the levels within the given 5 attempts. This created a noticeable ceiling effect, which skewed our variables distribution far from normal ones (Figure 8)



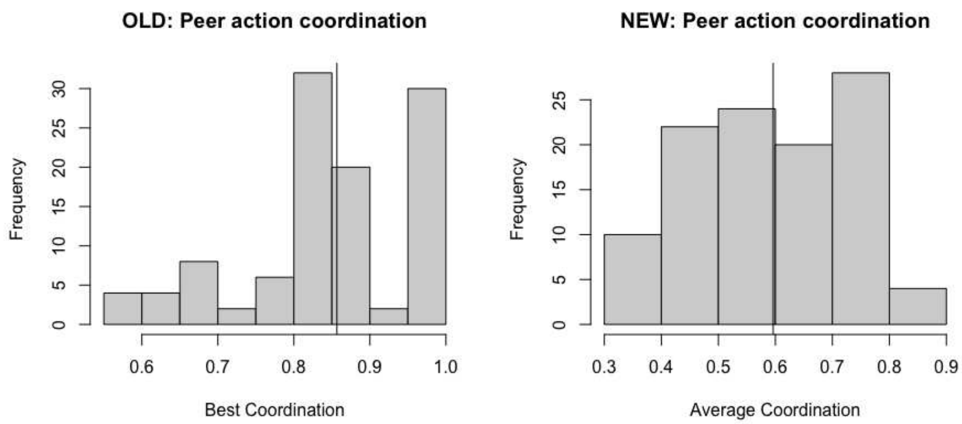


Figure 8. Frequency distribution of Individual and Peer action coordination performances. To the left, when it was calculated from their best attempt per level. To the right when it was calculated from the average score across the 5 attempts per level.

Due to the ceiling effect, we decided to explore how children performed in the task across all attempts, and not just their best ones. This was done considering that the new procedure still reflected their performance throughout the game. Hence, differently from what was specified in the pre-registration, in this thesis, individual and peer action coordination was operationalized by the average scores across the five attempts in each level, followed by a summing of their average scores in the four levels. The total scores were then divided by the maximum number of points (39). Therefore, performance was expressed as a ratio ranging from 0 to 1, with 1 indicating a perfect performance throughout the game. The same scoring method was applied for the individual and dyadic conditions. Thus, in the result section, the reported analyses are based on this new scoring procedure for individual and peer action coordination performances. Analysis based on the pre-registration plan can be consulted in (Appendix E).

3.3.5.1 Individual Action Coordination

First, children played the Labyrinth ball game alone, and their performance indicated their level of individual action coordination. Children were instructed to use both knobs to maneuver the ball from the start to the end of the labyrinth. After the children repeated the instructions successfully, they played the first level. The experimenter did not interfere or address children while playing but gave a neutral voice-over commentary of where the ball fell progressively. If children completed the first level within five attempts, they played all the other levels, regardless of their success. However, if they failed to do so, they did not proceed further in the game.

3.3.5.2 Peer action Coordination

Finally, in the last and third sessions, children played the Labyrinth ball game with a peer in order to assess their peer action coordination performance. Each dyad was formed by using the following criteria: 1) Gender: 2) Not a best friend or un-friend; 3) TEC developmental stage; 4) Individual Action Coordination performance. We looked at the 5) overall TEC score in case of ambiguity. The decision to control same-gender dyads and friendship levels in the study aimed to eliminate potential biases and ensure a fair comparison of cooperative performance (Viana et al., 2020). As for gender bias, research suggests that children's play can vary significantly with peers of the opposite gender (Fabes et al., 2003) while controlling the level of friendship aimed to avoid pre-existing relationships' influence, which could skew results by introducing elements of favoritism or rivalry (Chung et al., 2018). Ultimately, pairing children with similar TEC scores and individual coordination skill levels allowed for an equitable comparison of their cooperative performance (Viana et al., 2020). It is crucial to highlight that our research approach provided considerable flexibility in forming the dyads. By matching children with similar levels of development and allowing for adjustments based on classroom dynamics, we minimized the exclusion of participants when forming dyads. Effectively, children were excluded from pairing if they: 1) failed to reach Component I: Emotion Recognition, to avoid floor effect; 2) failed to complete the first level of the labyrinth ball game individual session within five attempts, to avoid floor effect; 3) if the number of participants of a given gender in the classroom was uneven, the children with the least matchable TEC and labyrinth ball game performance scores were left out. This approach facilitated a more inclusive study and ensured that the pairing process was adapted to the class formations, making the data collection more feasible.

During the cooperation session, each child controlled one knob as they aimed to maneuver the steel ball jointly past the holes. No restriction was put on the participants' movements, but if in case one child attempted to take over the other's knob. In that case, children would be reminded that they were supposed to play together and were suggested to guide their companion verbally instead. The dyads played through all levels, with a maximum of 5 attempts per level.

3.4 Analytic Plan

The analysis was performed on a final sample of 108 participants. Due to availability and time constraints, the optimal sample size of 152 participants estimated by the priori power analysis (G*power 3.1(Faul et al., 2007)) was not reached. Given our final sample size, a sensitivity power analysis indicated our study is sensitive enough to test 2 out of 4 predictors and detect an effect size of f^2=0,147 with an alpha of 0.05, a power of 0.95 or an effect size of f^2=0,0919 with the same alpha level and a power of 0.80. The power analysis results can be found in the (Appendix F).

The preregistered analytical plan involved four linear models in R (R Core Team, 2022). All were built with the lm() function. For all four models, the baseline model included children's age (Age) and individual action coordination (Indi) as preliminary predictors of peer action coordination.

Table 2. Linear regression models to explain the variance of peer action coordination

Model	Formula
MBaseline	**lm** (Coop~Age+Indi)
M1	**lm** (Coop~Age+Indi+TEC)
M2	**lm** (Coop~Age+Indi+ TEC+ Inhib)
M3	**lm** (Coop~age+Indi+ EU+ Inhib+ TEC*Inhib)
	Coop: cooperative action coordination; age: age in months; Indi: individual action coordination; TEC: measure of Emotion Understanding; Inhib: Inhibitory control.

We planned to compare the baseline model with each of the other models. The first model tackled the first hypothesis, explaining cooperative action coordination (Coop) as a function of Emotion understanding (TEC). The second model addressed the second hypothesis, explaining cooperative action coordination (Coop) as a function of Emotion Understanding (TEC) and inhibitory control (Inhib). Assuming that both factors contributed significantly to the variance of peer action coordination, the third model explored the best fit for an interaction model between Emotion Understanding and Inhibitory control (TEC*Inhib). Analysis of covariance (ANCOVA) was estimated for each model with the function car::Anova (Fox, 2003). Finally, the model comparison was performed by performance::compare_performance (Lüdecke et al., 2021).

4 RESULTS

This chapter presents the results of our investigation into peer action coordination. The analysis begins with correlation assessments, examining initial associations among the tested variables such as cooperative and individual action coordination, emotion understanding, inhibitory control, age, and gender. We then proceed to test our three hypotheses by constructing linear regression models. ANCOVA is utilized to determine the influence of emotion understanding and inhibitory control on peer action coordination while adjusting for their impact through age and gender as covariates. Finally, exploratory analysis delves into discovering new insights and patterns within the data, going beyond initial hypotheses to explore potential interactions and effects like the interplay between gender and age on peer action coordination and a possible connection between inhibitory control and individual action coordination.

4.1 Preliminary analysis

4.1.1 Correlation analysis

A correlation analysis was conducted on the numerical variables to preliminarily investigate their relationship (see Table 3). The variables included were: The cooperative action coordination performance at the Labyrinth ball game expressed from (0-1) (Coop); The Individual action coordination performance at the Labyrinth ball game expressed from (0-1) (Indi); Age, expressed in months; TEC score as a measure of Emotion Understanding (TEC); and Inhibitory control measured by the difference in reaction times (milliseconds) between incongruent and congruent trials in the Attentive Network Task (Inhib), as well as the difference in error rates between incongruent and congruent trials in the Attentive Network Task (Inhib pe). As a reminder, a smaller difference across incongruent and congruent conditions, either in Reaction times or error rates, indicates a better inhibitory system.

Table 3 Correlation matrix among tested variables

	Coop	Indi	Age	TEC	Inhib	Inhib pe	Gender
Coop	-	0.124	0.185	0.155	-0.059	0.148	0.476**
Indi	0.124	-	0.238*	0.200*	-0.254**	-0.067	0.269**
Age	0.185	0.238*	-	0.530**	-0.355**	-0.109	-0.155
TEC	0.155	0.200*	0.530**	-	-0.217*	-0.230*	-0.133
Inhib	-0.059	-0.254**	-0.355**	-0.217*	-	0.338**	0.056
Inhib pe	0.148	-0.067	-0.109	-0.230*	0.338**	-	0.076
Gender	0.476**	0.269**	-0.155	-0.133	0.056	0.076	-

Table 2: Correlation Coefficients. One asterisk (*) denotes $p < 0.05$, and two asterisks (**) denote $p < 0.01$.

The correlation analysis revealed a strong positive correlation between Age and the TEC (r=0.530; p = 0.000), as well as a moderate negative correlation between Age and Inhibitory control (r=-0.355; p = 0.000), and a weak positive correlation between individual action coordination performance and Age (r=0.238; p =0.001). These results outline an incremental development across the cognitive, affective, and sensorimotor skills.

As for other correlations, Individual action coordination was weakly but positively correlated with measures of TEC (r=0.2; p = 0.038) and weakly negatively correlated with Inhibitory control (r= -0.217; p =0.024). The correlation matrix also revealed a weak yet significant negative relationship between TEC and the inhibitory control measures (r=0.217; p =0.03). No significant correlation was found between cooperative action coordination and the other variables (p>0.05).

4.1.2 Gender differences

A graphical analysis revealed a noticeable difference in cooperative performance based on gender, with boys outperforming girls in the game, which we did not foresee. Consequently, we decided to explore potential gender differences across the other variables. We tested the distribution of females and males in a t-test and found a significant gender effect on individual and cooperative action coordination performances. On average, boys performed better than girls when playing alone and together. No gender effect was observed on emotion understanding and inhibitory control measures (Table 4)

*Table 4 Gender Differences in Investigated Variables. Mean values and standard deviations for female (F) and male (M) distributions are reported, alongside t-test results for significant differences between genders. Asterisks denote significance levels (*p<0.05; **p<0.01)*

	F mean	M mean	F sd	M sd	p-value	
Coop	0.525	0.66	0.12	0.12	2.19e-07	**
Indi	0.52	0.6	0.11	0.14	4.09e-03	**
Age	106.62	102.4	13.45	13.64	¿0.05	
TEC	7.7	7.38	1.18	1.23	¿0.05	
Inhib	125.1	134.8	96.96	77.77	¿0.05	
Inhib pe	2.17	2.7	3.76	3.26	¿0.05	

4.1.3 Testing the link between the preliminary predictors and peer action coordination

In line with our pre-planned approach, we developed a baseline model to represent the performance of cooperative action coordination as a function of age and individual action coordination. Unexpectedly, the initial predictors did not explain the variance (Pr (F) >0.05). Results of the analysis of covariance (ANCOVA) can be consulted at (Table 15; Appendix G). However, based on our preliminary analysis showing a notable gender effect on cooperative action coordination performance, we created a new baseline that took into account gender along with age and individual action coordination—with gender included in the model, age and gender - but not individual action coordination - significantly explained 30,3% of the variance of cooperative action coordination performance (Table 5).

Table 5 Baseline Linear regression Model: lm (Coop ~ Age + Indi +Gender).

Regression results using Coop as the criterion

Predictor	b	b_95%_CI	sr2	sr2_95%_CI	Fit
(Intercept)	0.26**	[0.07, 0.44]			
Indi	-0.10	[-0.28, 0.09]	.01	[-.02, .03]	
Age	0.00**	[0.00, 0.00]	.08	[-.01, .16]	
genderM	0.15**	[0.10, 0.20]	.26	[.12, .40]	
					R2 = .303**
					95% CI[.15,.41]

Note. A significant b-weight indicates the semi-partial correlation is also significant.
b represents unstandardized regression weights.
sr2 represents the semi-partial correlation squared.
Square brackets are used to enclose the lower and upper limits of a confidence interval.
* indicates p < .05. ** indicates p < .01.

Although individual action coordination was not a significant predictor of the variance, we kept it in the model as the literature suggests it is usually an important factor to account for cooperative action coordination.

4.2 Testing the link between EU and peer action coordination

Our initial hypothesis was examined through a linear regression model to elucidate the relationship between peer action coordination and emotion understanding while considering gender, age, and individual action coordination (Table 6).

Table 6 Linear Regression Model HP1: lm(Coop~ Indi +Age +Gender +TEC).

```
Regression results using Coop as the criterion


   Predictor      b       b_95%_CI sr2  sr2_95%_CI             Fit
 (Intercept)  0.22*   [0.03, 0.41]
        Indi  -0.11 [-0.29, 0.07] .01 [-.02, .04]
         Age  0.00*   [0.00, 0.00] .04 [-.02, .09]
         TEC   0.01 [-0.01, 0.04] .01 [-.02, .05]
     genderM 0.15**   [0.11, 0.20] .27  [.13, .41]
                                                       R2 = .315**
                                                    95% CI[.15,.42]


Note. A significant b-weight indicates the semi-partial correlation is also significant.
b represents unstandardized regression weights.
sr2 represents the semi-partial correlation squared.
Square brackets are used to enclose the lower and upper limits of a confidence interval.
* indicates p < .05. ** indicates p < .01.
```

Despite considering the TEC (TEC) as a potential correlate, its inclusion did not meaningfully enhance the model's ability to explain the observed variance (Pr (F)= 0.188). Results of the ANCOVA can be consulted in (Table 16; Appendix G). Consequently, the TEC was removed from the model.

In a secondary analysis, we investigated the specifics of the TEC developmental stages: External, Mental, Reflective, and if any were significantly associated with cooperative action coordination performance (Figure 9)

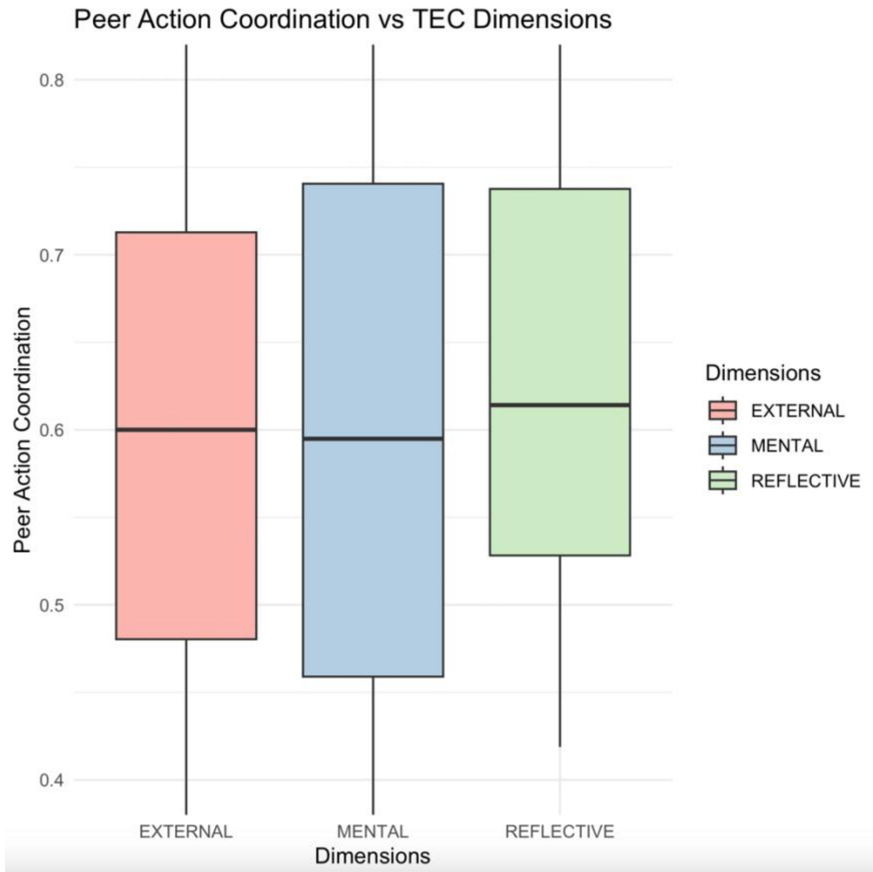


Figure 9. Peer action coordination across TEC Dimensions: External, Mental, and Reflective

A point-biserial correlation analysis revealed only one significant, albeit weak, positive correlation between cooperative action performance and the Reflective dimension (r= 0.19, p =0.048). Specifically, children who successfully reached the Reflective dimension exhibited an average cooperative performance of 0.624 (SD= 0.127) compared to those who did not, whose average performance was 0.57 (SD= 0.145). Nevertheless, when incorporating factors such as gender and age into a linear regression analysis, the reflective dimension's influence on the variance in cooperative action coordination performance was not statistically significant (Pr (F) = 0.117). Results of the ANCOVA can be consulted in (Table 17; Appendix G).

In another secondary analysis, we investigated the specifics of the TEC by examining its components to determine if any were significantly associated with cooperative action coordination performance (Figure 10).

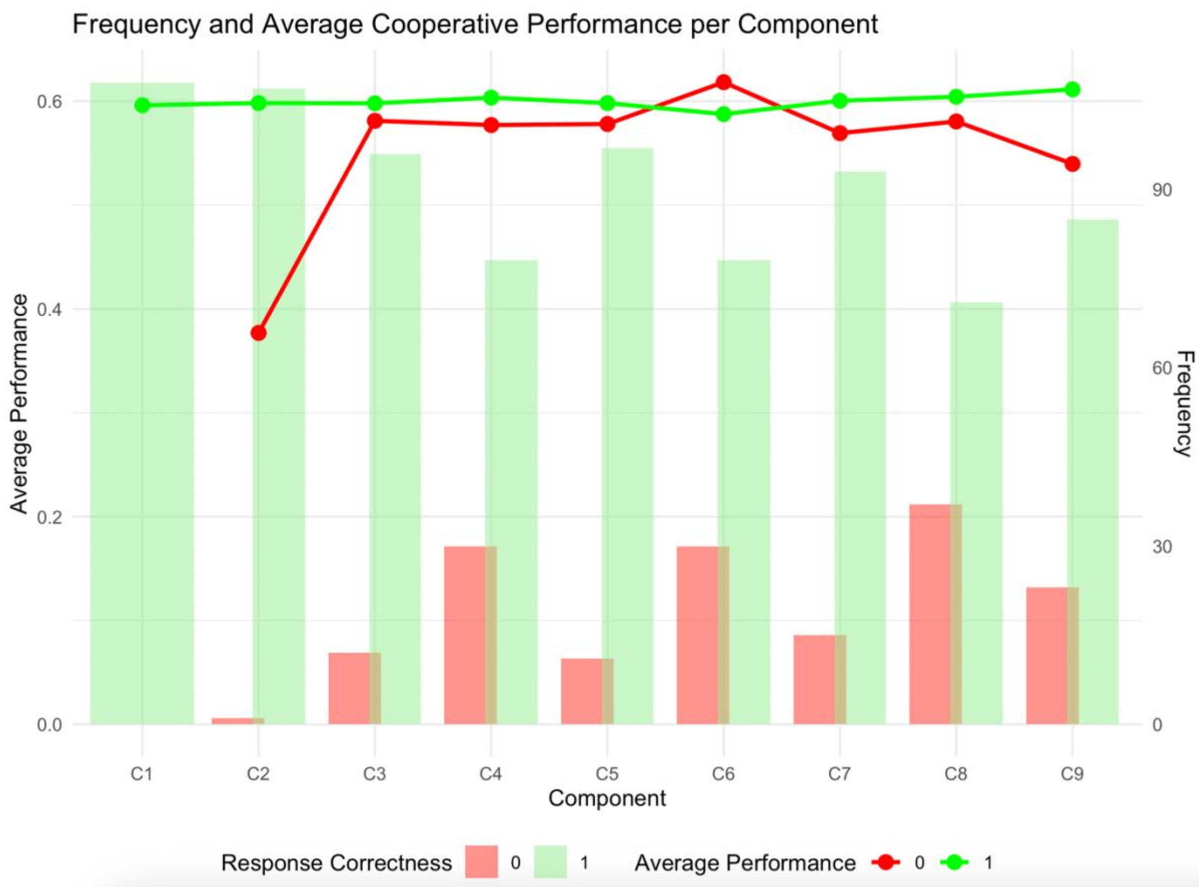


Figure 10. The bars represent the Frequency of Correct (1) and Incorrect Responses (0) per TEC Component; The green line represents the average cooperative performance of the children who passed Component (1). The red line represents the average cooperative performance of the children who failed Component (0).

A point-biserial correlation analysis revealed only one significant, albeit weak, positive correlation between cooperative action performance and Component IX: Morality ($r= 0.213$, $p = 0.027$). Specifically, children who successfully answered Component IX exhibited an average cooperative performance of 0.611 (SD=0.139) compared to those who did not, whose average performance was 0.54 (SD= 0.160). Nevertheless, when incorporating factors such as gender and age into a linear regression analysis, the moral component's influence on the variance in cooperative action coordination performance was not statistically significant ($Pr(>F) =0.130$). Results of the ANCOVA can be consulted in (Table 18;Appendix G).

4.3 Testing the link between Inhibitory Control and peer action coordination

Our second hypothesis was examined through a linear regression model to elucidate the relationship between peer action coordination and emotion understanding while considering gender, age, and individual action coordination (see Table 7).

Table 7 Linear Regression Model HP2: lm (Coop ~ Indi+ Age +Gender +Inhib)

```
Regression results using Coop as the criterion


   Predictor      b       b_95%_CI sr2  sr2_95%_CI             Fit
 (Intercept)  0.27*  [0.05, 0.48]
        Indi  -0.10 [-0.28, 0.09] .01 [-.02, .03]
         Age 0.00**  [0.00, 0.00] .07 [-.01, .15]
       Inhib  -0.00 [-0.00, 0.00] .00 [-.00, .00]
     genderM 0.15**  [0.10, 0.20] .26  [.12, .40]
                                                       R2 = .303**
                                                   95% CI[.14,.41]


Note. A significant b-weight indicates the semi-partial correlation is also significant.
b represents unstandardized regression weights.
sr2 represents the semi-partial correlation squared.
Square brackets are used to enclose the lower and upper limits of a confidence interval.
* indicates p < .05. ** indicates p < .01.
```

When inhibitory control, measured by the difference in reaction times, was introduced in the model, it failed to additionally explain the variance in peer action coordination (Pr (F) = 0.905). Results of the ANCOVA can be consulted in (Table 19; Appendix G). Hence, inhibitory control was removed from the model. Similarly, when inhibitory control as the difference in error rates was introduced in the model, it also yielded non-significant results ((Pr (F)) = 0.103). Results of the ANCOVA can be consulted in (Table 20; Appendix G). Consequently, inhibitory control as difference in error rates was dropped.

4.4 Testing the Interaction between Inhibitory Control and EU in Peer Action Coordination

Finally, addressing our third hypothesis, we tested for the interaction between Inhibitory control and TEC. To this end, we developed a model that included gender, age, individual action coordination, and an interaction term for Inhibitory control and TEC (see Table 8).

*Table 8 Linear regression model HP3: lm(Coop ~ Indi + Age +Gender+ Inhib*TEC)*

Regression results using Coop as the criterion

Predictor	b	b_95%_CI	sr2	sr2_95%_CI	Fit
(Intercept)	0.28*	[0.02, 0.55]			
Indi	-0.11	[-0.29, 0.08]	.01	[-.02, .04]	
Age	0.00*	[0.00, 0.00]	.04	[-.02, .09]	
genderM	0.15**	[0.11, 0.20]	.27	[.13, .41]	
Inhib	-0.00	[-0.00, 0.00]	.00	[-.02, .02]	
TEC	0.00	[-0.03, 0.04]	.00	[-.01, .01]	
Inhib:TEC	0.00	[-0.00, 0.00]	.00	[-.02, .02]	
					R2 = .319**
					95% CI[.14,.41]

Note. A significant b-weight indicates the semi-partial correlation is also significant.
b represents unstandardized regression weights.
sr2 represents the semi-partial correlation squared.
Square brackets are used to enclose the lower and upper limits of a confidence interval.
* indicates p < .05. ** indicates p < .01.

When the interaction factor between Inhibitory Control and TEC was introduced in the model, it failed to additionally explain the variance in peer action coordination (Pr (F) = 0.436). Results of the ANCOVA can be consulted in (Table 21; Appendix G). Hence, the interaction factor was removed from the model. Similarly, when inhibitory control, as the difference in error rates, was tested in interaction with TEC, it also yielded non-significant results (Pr (>F) =0.479). Results of the ANCOVA can be consulted in (Table 22;Appendix G). Consequently, the interaction factor was dropped.

4.5 Supplementary Analysis:

4.5.1 Accounting for Gender Age interaction*

Following the exploration of predictors explaining peer action coordination, our analysis extended to examine potential interactions between age and gender (see Figure 11).

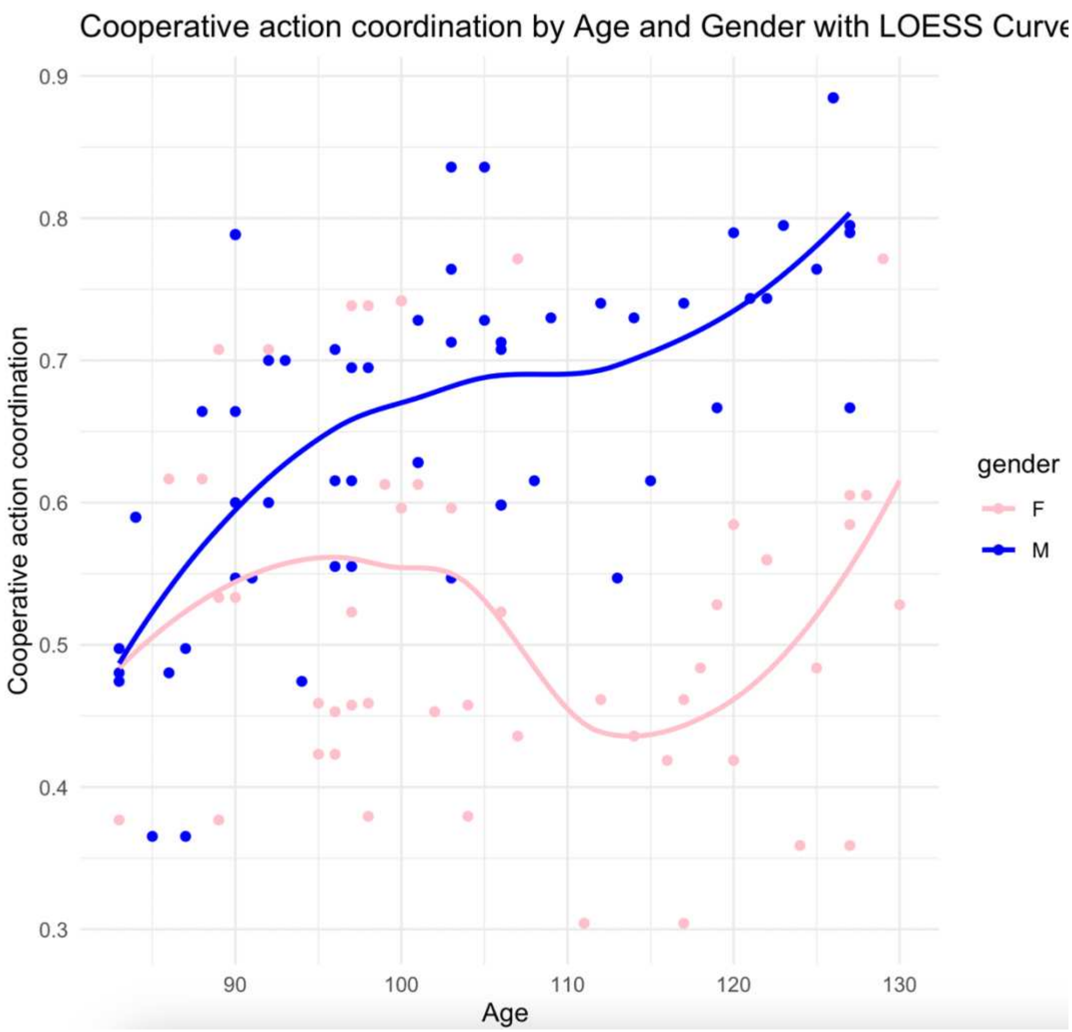


Figure 11 Scatter plot with LOESS smoothing curves depicting the association between age (expressed as a percentage) and cooperative action coordination performance, differentiated by gender. The plot highlights a non-linear relationship between age and coordination ability, with male (blue) and female (pink) participants exhibiting distinct developmental patterns.

To this end, we developed a model that included gender, age, individual action coordination, and an interaction term for age and gender. The exploratory model revealed that the interaction between age and gender significantly contributed to explaining the variance in the model (Pr (F) = 0.000), underscoring that while boys' performance improved by age, the girls' performance did not improve significantly. Results of the ANCOVA can be consulted in (Table 23; Appendix G).

4.5.2 The Final Model

To ascertain the most effective model, we employed the `compare_performance` function, which facilitated a thorough comparison of the linear models under consideration, listed in (Table 9).

Table 9 Linear regression models to explain the variance of peer action coordination;

Model	*Formula*
MBaseline	*lm (Cooperation~Age+Indi+gender)*
M1	*lm (Cooperation~Age+Indi+gender+TEC)*
M2	*lm (Cooperation~Age+Indi+ gender+Inhib)*
M3	*lm (Cooperation~Age+Indi+ gender+Inhib*TEC)*
M4	*lm (Cooperation~Age+Indi+ gender+ gender*age)*
	Cooperation: peer action coordination; Age: age in months; Indi: individual action coordination; TEC: overall score TEC; Inhib: Measure of inhibitory control, as difference in RT.

By looking at the lowest AIC index, we selected the comparatively best-fitting linear model to explain the variance of the observed cooperative action coordination performances. Results of the comparison of models can be found in (Table 24; Appendix G). The final model included age, gender, individual performance, and the interaction between age and gender, and it explained 38% of the variance of the cooperative performances (AIC=-164.4).

4.5.3 *Exploring links between Individual action coordination, Emotion Understanding and Inhibitory Control.*

For comparative purposes with the cooperative sessions' results, we explore the link between individual action coordination and the factors of TEC and inhibitory control, conscious that this exploration was not accounted for in our plan. Initial analyses revealed a modest yet statistically significant correlation in examining the relationship between individual action coordination and emotion understanding ($r = 0.20$, $p = 0.038$). Subsequent analysis employing ANCOVA, with age and gender as covariates, indicated that emotion understanding ceased to be a significant predictor of individual action coordination performance (Pr (F) = 0.24). Results of the ANCOVA can be consulted in (Table 25;Appendix G). Conversely, incorporating inhibitory control, operationalized through differences in reaction times, into the model revealed a significant contribution to the variance in action coordination performance (Pr (F) = 0.0432). Notably, inhibitory control accounted for an additional 3.5% of the variance beyond what was explained by demographic factors alone. Results of the ANCOVA can be consulted in (Table 26;Appendix G).

5 DISCUSSION

This project aimed to investigate the extent to which children's EU and inhibitory control influence their ability to coordinate actions with peers. Specifically, the project had two primary goals: 1) to conduct a replication study with an Italian cohort to corroborate the findings of Viana et al., (2020), which demonstrated a positive link between children's EU and their ability to work together with peers, and 2) to build upon the research by Viana and colleagues by examining whether children's inhibitory control moderates the relationship between their EU and collaborative interactions with peers. Results did not show children's EU and inhibitory control - or an interaction between both –to affect their peer action coordination. Furthermore, their individual performance did not influence their joint performance with their peer. Instead, the findings indicated how gender, age and the interaction between the two influenced peer action coordination. This suggests two distinct developmental trajectories for peer action coordination skills among genders.

5.1 The Impact of EU on Peer Action Coordination

The results from the examination of the influence of children's EU on their ability to coordinate actions with peers did not confirm our original hypothesis. Contrary to expectations and the outcomes reported by Viana et al., (2020), our findings did not support a direct positive link between children's level of emotion understanding and their peer action coordination in a cooperative sensorimotor game among school-aged children, even when accounting for factors like age, gender, and individual coordination skills. Even after an in-depth examination of the EU's different dimensions and components, the lack of correlation persisted. Further analysis delved into specific dimensions and components to identify if certain aspects of EU might have a more pronounced effect on peer action coordination. Although weak correlations were found in the reflective stage of EU and the component of morality, this correlation disappeared when factors like age, gender, and individual coordination skills were taken into account.

The divergence in findings between our study and that of Viana et al (2020) could be attributed to the differences in the respective samples' age ranges and developmental stages.

While Viana's study included children from 5 years and 7 months to 9 years and 8 months, our sample ranged from 6 years and 11 months to 10 years and 10 months. This difference is crucial as it effectively excludes first graders from our study while including fifth graders. This modification likely impacted our results given the developmental milestones achieved during these years, including changes in theory of mind and emotion understanding (Wellman, 2018) At the start of school, the child changes rapidly to overcome novel challenges: forming friendships, maintaining focus, suppressing their impulse responses, regulating their emotions in the presence of others, and collaborating with a peer on a project (Trentacosta & Fine, 2010). Significant developmental milestones mark this period in their cognitive and social development, which our study's age range might have partially missed.

Theoretical frameworks on EU development support this interpretation. According to the cross-cultural review of Harris & Cheng, (2022), children's EU evolves significantly during early schooling years, progressing from basic recognition of facial expressions to more complex concepts such as mixed emotions and moral emotions by age 9. This might explain why scores on the reflective component correlated with peer action coordination, different from the study of Viana and colleagues (2020) with younger children. Our study's oldest group likely reflects these ongoing developmental changes. By the age of 8 to 10, most children have generally moved beyond the foundational stages of EU. They are refining their abilities to interpret complex emotional states and engage in sophisticated social interactions (Cavioni et al., 2020). This maturation might explain the lack of a direct correlation between EU when including all components and peer action coordination in our study, as the participants may have already surpassed the critical period where such skills are rapidly developing and significantly impacting collaborative behaviors.

In other words, the lack of a significant link between EU and peer coordination in our study may be due to a ceiling effect, the uniformly high EU scores across our sample. This suggests that children in our sample, being slightly older than those in studies like Viana et al (2020), have reached a mature stage of EU, leading to limited variability in TEC scores. As a result, differences in EU may no longer significantly affect peer coordination among these children.

Interestingly, our results align more closely with a study on preschool-aged Brazilian children (Lucena, 2018). From the observation of the free play, she identified various access/receptive behaviors displayed by the children when adjusting their behaviors to those of their peer group, such as approach without conflict, cooperative, coordinated action, exhibition, approach with conflict, intermediation, imitative coordinated action, request, invitation, and offer. In that study, no substantial link was found between EU and cooperative coordinated actions despite older children displaying more coordinated actions with peers than younger ones.

Our findings contribute to the discussion between understanding emotional cues at a more conceptual level and effectively applying this understanding in real-time interactions. This distinction is critical, as highlighted, because even with an excellent emotion understanding at a representational level, the high cognitive demands of social situations may preclude using the most sophisticated conceptual skills (Apperly & Butterfill, 2009; Butterfill & Apperly, 2013; Samson et al., 2010). In addition, the essential role of language and executive functions in facilitating a child's ability to perceive and adapt to social contexts quickly might also be considered (De Rosnay et al., 2014; Grazzani et al., 2018). A finding that supports this theoretical framework is Fitzpatrick et al (2018)'s results, which indicated that individual assessment of ToM and facial expression recognition was only linked to spontaneous synchrony but not intentional synchronization, meaning when children were prompted to synchronize. In contrast, intentional synchrony was associated with clinical attentional and social responsiveness deficits, suggesting that individual assessments impact intentional synchronization in atypical but not typical populations. The underlying mechanism of intentional cooperative action coordination may depend on more complex factors, such as communication-dependent or cognitive strategies implemented in the interaction (Fitzpatrick et al., 2018; Lucena, 2018), which was beyond the scope of the present study.

Thus, our study adds to the ongoing discussion on the links between conceptual skills and their application in behaviors that demand comprehending others' thoughts and feelings in social interaction (Apperly, 2012; Liszkowski, 2013; A. P. Viana & Lucena Frédou, 2014). This debate centers on whether the capacity to understand others' emotional states and the ability to employ this understanding are related competencies. The literature in this area presents mixed findings. For instance, research by Grueneisen et al., (2015) and Viana et al., (2020) points to a beneficial impact of the conceptual grasp of ToM and emotional understanding of cooperative tasks. Conversely, studies like those by Meins et al (2006) indicate no significant link between the possession of ToM and emotional understanding abilities and their deployment in social situations.

Our findings, aligning with other diverse results seen in the field, suggest that the differences in children's use of these skills might not be directly related to their ability to represent these skills conceptually. This indicates a potential independence between the conceptual understanding of social and emotional skills and the practical application of such skills in tasks designed to test these representations (Meins et al., 2006; Viana et al., 2022).

5.2 The impact of Inhibitory Control on Peer action coordination

Our results on the influence of inhibitory control on peer action coordination did not support the initial hypothesis that better inhibitory control would lead to enhanced action coordination among peers, even when accounting for age and individual action coordination. Operationalized through differences in reaction times and error rates across conditions in the Attention Network Task, inhibitory control showed no correlation with, nor explanation for the variance in, peer action coordination.

The findings contrast with the existing literature in the field, which indicates that inhibitory control significantly influences joint actions, particularly at younger ages (Huyder et al., 2017). For example, better inhibitory control was associated with more effective coordination in toddlerhood, especially in tasks requiring complex movements or precise timing (Meyer et al., 2015). In preschoolers, individual differences in inhibitory control influenced joint action success. Additionally, a longitudinal study by Ciairano et al., (2007) revealed that children with better inhibitory control displayed more cooperative behaviors during a task over one year among various age groups. Similarly, Giannotta et al.,(2011)'s study involving children aged 8-12 showed that both the child's own and their partner's inhibitory control skills correlated with the level of cooperative behaviors exhibited during interaction.

A potential interpretation of our findings is that while inhibitory control has a role in coordinating cooperative actions during preschool years, its significance for cooperative interactions may be less influential in school-age children. Compared to preschoolers, older children develop more advanced communication and social strategies (Diamond, 2013), which could reduce the reliance on inhibitory control for effective peer coordination. This developmental progression suggests that the impact of inhibitory control on social cooperation could be more prominent at younger ages and less so at older ages (Fernández García et al., 2021). A hypothesis worth further investigation (Hughes & Ensor, 2007; Satta et al., 2017).

Another potential perspective and a critical aspect of our research involved not controlling for inhibitory control levels within dyads, as done in the study where dyads were randomly paired. The lack of this control means we did not consider how each child's individual inhibitory control level within a dyad might affect their collaborative action coordination. It is plausible that when one child had high inhibitory control, and the other had low inhibitory control, it could have neutralized their combined performance, masking any potential positive influence of inhibitory control on peer action coordination. We can conclude that the dyad did not significantly benefit from one inhibitory control skill for mixed-ability children, contrary to Giannotta and colleagues (2011)'s findings, which found associations between inhibitory control and action coordination among school-age children.

Also, contrary to our hypothesis, no significant moderating effect was found between EU and peer action coordination. This may imply that better inhibitory control at the age of 7- 10 does not provide a significant advantage in children with good EU for determining their peer action coordination. This finding partially aligns with Milward et al., (2017)'s, which also reported no significant moderating influence of inhibitory control on ToM for joint actions but found independent effects of the two variables on joint actions.

Finally, contrary to our predictions, we found that individual action coordination performance did not correlate with the children's peer action coordination performance. The absence of a correlation between individual and cooperative performance in our study contrasts with the strong correlation found in Viana et al., (2020)'s research. Nevertheless, our finding could be explained by the line of literature that finds peer action coordination quantitatively and qualitatively different from individual action coordination. On one hand, school-aged children tend to enjoy tasks more and complete them more efficiently when working with peers than when alone (Azmitia, 1998; Gauvain, 2001). On the other hand, Ramani & Brownell, (2014) posit that cooperative endeavors are fundamentally different from individual performances. This divergence may be due to the nature and complexity of tasks, especially in older children. Factors such as task involvement and the distribution of responsibilities can significantly influence cooperative performance. Duran & Gauvain, (1993) suggest that during familiar tasks, aspects like shared understanding and joint responsibility may have a greater impact on cooperative outcomes than the individual capabilities of the children involved.

5.3 Age and gender differences in peer action coordination

While the findings from our study did not support our initial hypotheses, it effectively showed that age is crucial in developing peer action coordination. This finding adds to the existing developmental psychology literature, which consistently identifies age as a critical factor in developing social coordination abilities among peers (Meyer et al., 2015; Paulus, 2016). The literature demonstrates a rapid advancement in coordination skills at around 7 years old, marked by a notable decrease in self-centered behaviors and improved collaborative interaction abilities. This developmental milestone is not the endpoint but an essential phase within the continuous maturation process that extends into middle childhood (Giannotta et al., 2011; Li et al., 2022; Satta et al., 2017). A noteworthy aspect of this developmental progression is the emergence of sophisticated motor coordination strategies in older children, a phenomenon not typically observed in the youngest. As children approach and enter school age, there is a marked improvement in the speed, consistency, and predictability of their actions during peer interactions. This enhancement in motor skills facilitates smoother collaborative activities and significantly contributes to the overall task performance. By age 8, children peak in individual task accuracy, a crucial stage in their developmental journey. At this point, they start using advanced strategies, such as online monitoring during action execution (Satta et al., 2017). This strategy demonstrates a high level of social coordination that includes making real-time adjustments to one's actions based on the immediate movements of peers. This dynamic approach to coordination goes beyond simple predictive strategies and highlights a more flexible and responsive interaction style within peer groups (Wolpert et al., 2003).

Our study provided additional insight into the impact of gender on individual and group coordination, demonstrating that boys demonstrated superior performance to girls in both independent and collaborative situations. This observed difference aligns with prior research (Hands et al., 2009; Kuhnert et al., 2017) indicating variations in joint action tasks between males and females, potentially stemming from differences in sensorimotor coordination and problem-solving approaches across genders. Intriguingly, this gender effect, alongside the interplay between age and gender, diverges from the findings of Viana's study, which reported no significant gender differences in performance. This discrepancy raises questions about the underlying factors contributing to these divergent outcomes. One plausible explanation might be the differential familiarity with the Labyrinth ball game among boys and girls in our sample. Since neither study explicitly accounted for prior familiarity with the game, pinpointing the precise reason for this variation becomes challenging.

Furthermore, our findings revealed a compelling interaction between gender and age concerning peer action coordination, highlighting distinct developmental trajectories for boys and girls. Notably, boys consistently improved coordination skills with age, a pattern not mirrored by girls within the studied age range. This discrepancy suggests a divergent developmental timeline for girls, where significant advancements in coordination skills might occur outside the observed ages, hinting at either an earlier or later developmental progression (Hauge et al., 2023; Kaczkurkin et al., 2019).

One possible factor contributing to this gender-specific divergence in development could be the distinct play preferences observed between boys and girls, a widely studied phenomenon across various cultures (Barbu et al., 2011; Fiaes & Bichara, 2009; Pellegrini, 2009). Research has consistently shown that, across various cultures, boys engage more in physical activities. At the same time, girls engage more in social and contingency-based play, necessitating a deeper consideration of others' perspectives (Pellegrini, 2009; Pellegrini & Smith, 2003).

The study by Crozier et al., (2019) supports the hypothesis that gender-specific play preferences influence sensorimotor skill development in children. It found that although there were gender differences in coordinated sensorimotor performance among individuals without throwing experience, females with throwing experience achieved similar performance levels to males. This suggests that engagement in activities traditionally preferred by the opposite gender can mitigate initial performance disparities.

5.4 Limitations and Future Directions

A significant limitation of the study was the small sample size. This limited statistical power may have obscured potential relationships among the variables, affecting the interpretability and conclusiveness of the findings. Furthermore, excluding younger age groups from the sample limited the study's ability to provide insights about their development—the original design intended to include first graders. However, difficulties recruiting them at the beginning of the school year led to their exclusion from the study, resulting in an older children-dominated sample. This might have contributed to a ceiling effect observed in EU scores.

Another factor we did not consider in our study's design is the participants ' prior familiarity with the game used in our experiments. Some children mentioned owning and frequently playing at the game at home; others mentioned excitedly it was their first time playing. This variable of pre-existing familiarity introduces a potential issue, as it could significantly influence the children's performance regardless of their coordination skills. It may be wise to explore alternative sensorimotor games for future research, particularly within the Italian context. These games could be created explicitly for the study to ensure no prior exposure among participants.

By observing some comments from the children during the data collection, our study may have missed some of the complex social play dynamics in the classroom environment, which was indicated by spontaneous comments from children during cooperative play sessions. Some children showed excitement about playing with a friend, emphasizing existing play dynamics, while others had more subdued reactions even when they knew their assigned partner was in the same grade. These observations indicate that our measure of familiarity between pairs may not have been as accurate as intended. In our attempt to understand social preferences, we asked children to nominate their best friend and a peer they did not agree much with. However, this approach did not fully capture the complexity of children's social interactions within the classroom. Children play with a broader circle of classmates beyond their best friends, forming a network of usual playmates. The significance of this limitation becomes apparent when considering the impact of familiarity on cooperative action coordination. Regular play interactions allow children to become acquainted with each other's strategies for managing conflicts and emotions, facilitating smoother cooperative engagements (Coplan & Arbeau, 2009). Thus, the familiarity gained through repeated play interactions could be crucial in determining cooperative outcomes. This realization emphasizes the importance of considering children's entire play network, beyond just their close friends, to understand how existing play relationships can impact cooperative interactions.

In light of our findings, gender disparities in the developmental trajectories of cooperative skills need further investigation to understand underlying mechanisms. It is important to explore if these differences are consistent across cultures at comparable ages or influenced by cultural factors, such as gender-specific exposure to different types of games. Exploring cultures with less emphasis on gender-differentiated activities could provide new insights. Additionally, studying cross-gender dyads in cooperative settings may reveal adaptive strategies or unique challenges children face when engaging with peers of the opposite gender, enhancing our understanding of the social intricacies involved in developing cooperative abilities.

From a methodological perspective, future research could explore how children coordinate their actions with peers in natural play settings, such as free play observations during school recess or educational activities. Moving beyond the controlled experimental conditions of our study, this approach would include more ecological validity to how children spontaneously coordinate with peers without being prompted to perform a specific task. Such investigations would offer insights into children's natural social competencies and strategies in real-world interactions, providing a fuller understanding of peer action coordination in everyday settings.

Finally, future research may employ mixed-methods research for deeper insight into dynamics that quantitative measures might have overlooked. Exploring the role of different communication strategies in children's cooperative play offers an intriguing avenue for future research, particularly how these strategies relate to emotional understanding and inhibitory control. Delving into how children use verbal and non-verbal cues, whether task-focused or emotion-management-driven, could shed light on their collaborative dynamics and conflict-resolution skills. It is suggested that future studies adopt a mixed-methods approach to uncover the nuances of how communication styles are intertwined with emotional and cognitive competencies. Empathy-driven communication could harness a child's emotional insight to foster a more collaborative environment, while problem-solving strategies highlight inhibitory control's role in facilitating effective teamwork. This line of inquiry could provide valuable insights into the intricate ways in which children's emotional and cognitive abilities converge to support peer action coordination.

5.5 Conclusion

The findings from this study provided new insights into children's cooperative interactions. Contrary to our expectations, the findings did not support the hypothesis that EU and inhibitory control or interaction between both would affect peer action coordination. Instead, it highlighted a model explaining peer action coordination where gender, age, and interaction between these two were the significant factors. The unexpected findings from our study suggest that in older children, where EU and inhibitory control development have progressed and refined, these two factors are not significant in explaining cooperative action coordination. The results contribute to the current discussion on how having and using the ability to understand others are related competencies.

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Appendix A

Graphical representations of the Educational Background of Mothers and Fathers, and the average occupation category by family nucleus.

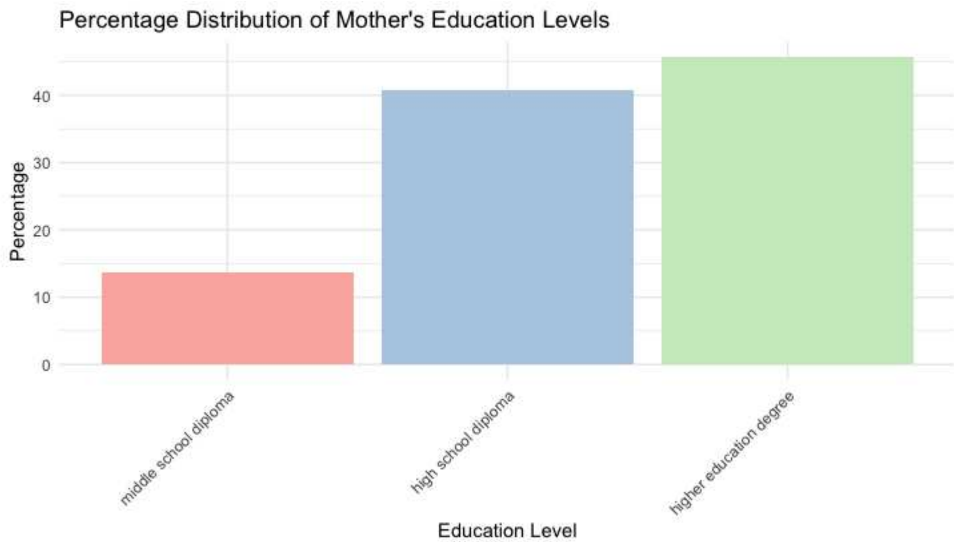

Figure 12 Percentage distribution of the education level of mothers: Middle school diploma; High school diploma; Higher education (degree I, II, or doctorate)

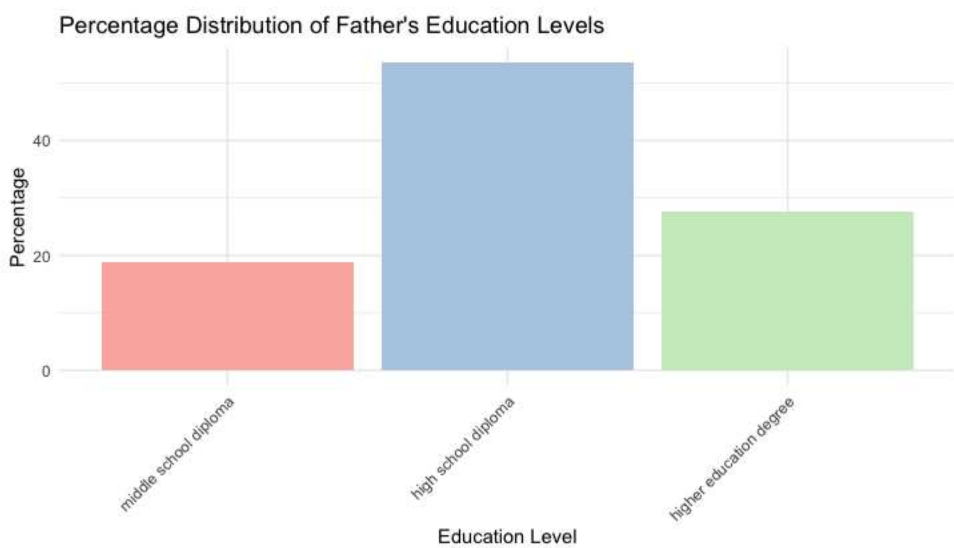

Figure 13 Percentage distribution of the education level of fathers: Middle school diploma; High school diploma; Higher education (degree I, II, or doctorate)

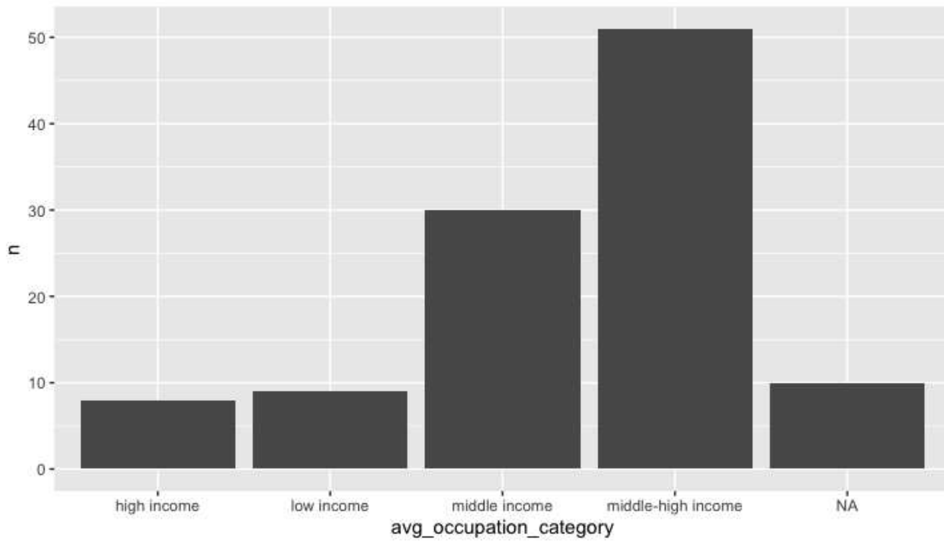

Figure 14 Average occupation category by family nuclei. Mothers and Fathers reported their occupations, which were then categorized into 1) low, 2) middle, 3) middle-high, and 4) high-income types of occupations on the basis of arbitrary assumptions on the average income of that profession. For example, professions like waitress, bartending, or nail-esthetician were classified as low-income occupations, while back-office employees, kindergarten teachers or educators were categorized as middle-income professions, and doctors, lawyers, or academics were categorized as high-income professions. Per family nuclei, both parent's professional "levels" were summed and divided by two, estimating an index of the average occupation category for each family nucleus.

Appendix B

The study "Emotions and Inhibitory at Play in Action Coordination" (#146549) was preregistered and made public on 10/10/2023, prior to the start of the data collection, on the As Predicted platform. Consultation is available at https://aspredicted.org/mn4mr.pdf.

Appendix C

Here is the original demographic sheet submitted, filled, and returned by the parents, along with the consent form for the study (English version).

Demographic questionnaire

Please provide the following information about your child:

Child name: ……………………………………………..
Gender: FEMALE / MALE
Date of birth: …………………
Place of birth: …………….
Class section: …………………………..
Italian nationality?: YES / NO
- **If 'no,' which: ………………………………………………..………………..……………**

First spoken language:………………………………………………………………………………
Did the child go to kindergarten? YES / NO
- **If 'no,' which solution did you adopt instead? ……………………………………………….**

Did the child go to preschool? YES/NO
- **If 'no,' which solution did you adopt instead? ………………………………………………..**

Please provide the following information about the child's family:

	Gender	Year of birth	Place of birth	Education qualification	Occupation (specify the best possible)
Parent 1					
Parent 2					
Sibling 1					
Sibling 2					
Sibling 3					
Sibling 4					
Other 1					
Other 2					

Appendix D

Text version of the online sheet: Questions, Answers, and scoring method of TEC-I Italian version by Albanese and Molina (2008). Correct answers are marked in **bold.** items accompanied by (_C) are control items, which do not contribute to the component score.

* TEC -femmine (id 339104) - 10.10.2023 11:26

* Variable   Label

TIME_EXP   Ora e data inizio dell'esperimento

PP   Codice identificativo

AGE   EtÃ in anni

GENDER Genere

M   Maschio
F   Femmina

ALL ITEMS that are accompanied by ***a _C*** *are control items and do not impact the score.*

---

q1   1. Guarda queste quattro immagini. Puoi indicarmi l'immagine di una persona che si sente triste?

1   Felice
2   Triste
3   Arrabbiata
4   Normale
0   Non risponde

n1   1. Note

q2   2. Puoi indicarmi adesso l'immagine di una persona che si sente felice?

1   Felice
2   Triste
4   Normale
5   Spaventata
0   Non risponde

n2   2. Note

q3   3. Puoi indicarmi adesso l'immagine di una persona che si sente arrabbiata?

1   Felice

4 Normale
3 Arrabbiata
5 Spaventata
0 Non risponde

n3 3. Note

q4 4. Puoi indicarmi adesso l'immagine di una persona che si sente normale?

1 Felice
2 Triste
3 Arrabbiata
4 Normale
0 Non risponde

n4 4. Note

q5 5. Puoi indicarmi adesso l'immagine di una persona che si sente spaventata?

1 Felice
4 Normale
3 Arrabbiata
5 Spaventata
0 Non risponde

n5 5. Note

COMPONENT 1: 1 point if at least 4/5 are correct. Otherwise 0

---

q6 6.[scoprire] Come si sente questa bambina? [indicare]

1 Felice
2 Triste
3 Arrabbiata
4 Normale
0 Non risponde

n6 6. Note

q7 7. [scoprire] Come si sente questa bambina? [indicare]

1 Felice
2 Triste
4 Normale
5 Spaventata
0 Non risponde

n7 7. Note

q8 8. [scoprire] Come si sente questa bambina? [indicare]

1 Felice
4 Normale
3 Arrabbiata
5 Spaventata
0 Non risponde

n8 8. Note

q9 9. [scoprire] Come si sente questa bambina? [indicare]

1 Felice
2 Triste
3 Arrabbiata
4 Normale
0 Non risponde

n9 9. Note

q10 10. [scoprire] Come si sente questa bambina? [indicare]

1 Felice
2 Normale
3 Arrabbiata
4 Spaventata
0 Non risponde

n10 10. Note

COMPONENT 2: 1 point if at least 4/5 are correct. Otherwise 0.

---

q11_1_**C** 11_1_**C.** A Cristina [indicare] piace la Coca-cola? [aspettare che la bambina dia la risposta]

T ADORA
F AIUTATA

n11_1_C 11_1_C. Note

q11_2_**C** 11_2_**C.** E a Paola [indicare] piace la Coca-Cola? [aspettare che la bambina dia la risposta]

T DETESTA
F AIUTATA

n11_2_C 11_2_C. Note

q11_3_**C** 11_3_**C.** [scoprire] Come si sente Cristina [indicare] quando scopre che la scatola contiene la Coca-Cola?

1 **Felice**
2 Triste
4 Normale
5 Spaventata
0 Non risponde

n11_3_C 11_3_C. Note

q11_4_**C** 11_4_**C.** E come si sente Paola [indicare] quando scopre che la scatola contiene la Coca-Cola?

1 Felice
2 **Triste**
4 Normale
5 Spaventata
0 Non risponde

n11_4_C 11_4_C. Note

q12_1_**C** 12_1_**C** A Daniela [indicare] piace l'insalata? [aspettare che la bambina dia la risposta]

T **DETESTA**
F AIUTATA

n12_1_C 12_1_C. Note

q12_2_**C** 12_2_**C.** E a Jessica [indicare] piace l'insalata? [aspettare che la bambina dia la risposta]

T **ADORA**
F AIUTATA

n12_2_C 12_2_C. Note

q12_3 12_3 [scoprire] Come si sente Daniela [indicare] quando scopre che la scatola contiene l'insalata?

1 Felice
2 **Triste**
4 Normale
5 Spaventata
0 Non risponde

n12_3 12_3. Note

q12_4 12_4. E come si sente Jessica [indicare] quando scopre che la scatola contiene l'insalata?

1 **Felice**
2 Triste

4 Normale
5 Spaventata
0 Non risponde

n12_4 12_4. Note

COMPONENT 3: 1 Point if 2/2 are correct. Otherwise 0.

---

q13_1_**C** 13_1_**C** Il coniglietto [indicare] sa che la volpe Ã¨ nascosta dietro il cespuglio?

T NON SA
F AIUTATA

n13_1_C 13_1_C. Note

q13_2 13_2. [scoprire] Come si sente il coniglietto [indicare]?

1 Felice
4 Normale
3 Arrabbiato
5 Spaventato
0 Non risponde

n13_2 13_2. Note

COMPONENT 4: Point 1 if 1/1 is correct. Otherwise 0.

---

q16_1_**C** 16_1_**C** [scoprire] Come si sente Francesca [indicare] quando guarda la foto della sua migliore amica?

1 Felice
2 Triste
4 Normale
5 Spaventata
0 Non risponde

n16_1_C 16_1_C. Note

q16_2_C 16_2_C

T FELICE
F AIUTATA

n16_2_C 16_2_C. Note

q17 17. [scoprire] Come si sente Francesca [indicare] quando guarda la foto del suo coniglietto?

1 Felice
2 Triste
4 Normale
5 Spaventata
0 Non risponde

n17 17. Note

COMPONENT 5: 1 point if 1/1 is correct. Otherwise 0.

---

q18 18. [scoprire] Francesca [indicare] puÃ² fare qualcosa per smettere di essere triste?

1 Mani
2 Fare
3 Pensare
4 Niente
0 Non risponde

n18 18. Note

COMPONENT 6: 1 point if 1/1 is correct. Otherwise 0.

---

q19 19. [scoprire] Come si sente davvero dentro Maria [indicare]?

1 Felice
4 Normale
3 Arrabbiata
5 Spaventata
0 Non risponde

n19 19. Note

COMPONENT 7: 1 point if 1/1 is correct. Otherwise 0.

---

q20 20. [scoprire] Come si sente Antonella [indicare] in questa situazione?

1 Felice
2_5 Triste/ spaventata
1_5 Felice/ spaventata
5 Spaventata
0 Non risponde

n20 20. Note

COMPONENT 8: 1 point if 1/1 is correct. Otherwise 0.

---

q21_1_**C** 21_1_**C** Elena puÃ² mangiare un biscotto senza chiedere prima il permesso alla sua amica o alla sua mamma?

T NON SI PUO'

F AIUTATA

n_21_1_C 21_1**_C** Note

q21_2 21_2**_C.** [scoprire] Come si sente Elena [indicare] per aver resistito alla tentazione?

1 Felice
2 Triste
3 Arrabbiata
4 Normale
0 Non risponde

n21_2_C 21_2_C. Note

q23 23. Come si sente Elena [indicare] per aver nascosto alla mamma di aver mangiato un biscotto senza chiedere il permesso?

1 Felice
2 Triste
3 Arrabbiata
4 Normale
0 Non risponde

n23 23. Note

COMPONENT 9: 1 point if 1/1 is correct. Otherwise 0.

Total SCORE ranges from 0-9.

Appendix E

The study initially planned to sum up the best attempts across levels to measure performance. Due to unexpectedly high completion rates, we switched to using average performance across all attempts. For transparency, we are also reporting ANCOVA analyses based on the preregistered plan. The variables investigated in the regression models are respectively: Coop: Cooperative action Coordination performance as sum of their best attempt in the four levels; Indi: Individual action coordination performance as as sum of their best attempt in the four levels; Age: age in months; gender; TEC: overall TEC score (0:9); Inhib: Inhibitory control as difference of RTs (ms); In summary, under the original analysis framework, gender and the gender-age interaction were the only significant predictors.

Table 10 ANCOVA on the Baseline Linear Regression Model as preregistered: lm(Coop~ Indi+Age)

```
> car::Anova(modbaseline2)
Anova Table (Type II tests)

Response: Coo_action_per
                 Sum Sq  Df F value   Pr(>F)
Indi_action_per 0.01067   1  0.8862 0.348686
Age             0.00011   1  0.0089 0.925060
gender          0.12692   1 10.5395 0.001573 **
Residuals       1.25242 104
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Table 11 ANCOVA on the Linear Regression Model as preregistered mod1: lm(Coop~ Indi+Age+gender+ TEC)

```
> car::Anova(mod1)
Anova Table (Type II tests)

Response: Coo_action_per
                Sum Sq  Df F value   Pr(>F)
Indi_action_per 0.00777   1  0.6461 0.423363
Age             0.00292   1  0.2432 0.622975
TEC             0.01406   1  1.1696 0.282003
gender          0.12922   1 10.7477 0.001424 **
Residuals       1.23836 103
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Table 12 ANCOVA on the Linear Regression Model as preregistered mod2: lm(Coop~ Indi+Age+gender+ Inhib)

```
> car::Anova(mod2)
Anova Table (Type II tests)

Response: Coo_action_per
                Sum Sq  Df F value Pr(>F)
Indi_action_per 0.01307   1  1.0774 0.3017
Age             0.00004   1  0.0036 0.9520
Inhib           0.00324   1  0.2670 0.6065
gender          0.12906   1 10.6415 0.0015 **
Residuals       1.24919 103
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

*Table 13 ANCOVA on the Linear Regression Model as preregistered mod3: lm(Coop~ Indi+Age+gender Inhib*TEC)*

```
> car::Anova(mod3)
Anova Table (Type II tests)

Response: Coo_action_per
                 Sum Sq  Df F value   Pr(>F)
Indi_action_per 0.00525   1  0.4353 0.510906
Age             0.00156   1  0.1297 0.719455
gender          0.12500   1 10.3641 0.001728 **
Inhib           0.00238   1  0.1970 0.658090
TEC             0.01320   1  1.0945 0.297978
Inhib:TEC       0.01782   1  1.4777 0.226972
Residuals       1.21816 101
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
>
```

*Table 14 ANCOVA on the Linear Regression Model with old- operationalization mod4: lm(Coop~ Indi+Age+gender Age*gender)*

```
> car::Anova(mod4)
Anova Table (Type II tests)

Response: Coo_action_per
                 Sum Sq  Df F value    Pr(>F)
Indi_action_per 0.00294   1  0.2632 0.6090170
Age             0.00401   1  0.3596 0.5500931
TEC             0.00928   1  0.8321 0.3638332
Inhib           0.00265   1  0.2379 0.6267651
gender          0.13095   1 11.7409 0.0008855 ***
Age:gender      0.10953   1  9.8208 0.0022590 **
Residuals       1.12645 101
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
>
```

Appendix F

Results of the power analysis performed with G*Power 3.1 (Faul et al., 2007)

```
[1] -A priori Analysis (d'=0.15; Power=0.95) Monday, October 02, 2023 -- 08:33:55
F tests - Linear multiple regression: Fixed model, R² increase
Analysis:     A priori: Compute required sample size
Input:        Effect size f²                    =      0,105
                    α err prob                        =      0,05
                    Power (1-β err prob)              =      0,95
                    Number of tested predictors       =      2
                    Total number of predictors        =      4
Output:             Noncentrality parameter λ         =      15,8550000
                    Critical F                        =      3,0580504
                    Numerator df                      =      2
                    Denominator df                    =      146
                    Total sample size                 =      151
                    Actual power                      =      0,9511147

[2] - Sensitivity Power Analysis (Power=0.95, N=108) Thursday, February 08, 2024 --
09:25:06
F tests - Linear multiple regression: Fixed model, R² increase

Analysis:      Sensitivity: Compute required effect size
Input:              α err prob                         =  0,05
                            Power (1-β err prob)              =  0,95
                            Total sample size                 =  108
                            Number of tested predictors       =  2
                            Total number of predictors        =  4
Output:           Noncentrality parameter λ          =  15,9028608
                            Critical F                        =  3,0845768
                            Numerator df                      =  2
                            Denominator df                    =  103
                            Effect size f²                    =  0,1472487

[3] -- Sensitivity Power Analysis (Power=0.80, N=108) Thursday, February 08, 2024 --
09:45:36
F tests - Linear multiple regression: Fixed model, R² increase

Analysis:      Sensitivity: Compute required effect size
Input:              α err prob                         =  0,05
                            Power (1-β err prob)              =  0,80
                            Total sample size                 =  108
                            Number of tested predictors       =  2
                            Total number of predictors        =  4
Output:           Noncentrality parameter λ          =  9,9205015
                            Critical F                        =  3,0845768
                            Numerator df                      =  2
                            Denominator df                    =  103
                            Effect size f²                    =  0,0918565
```

Appendix G

Here are the statistical test outcomes of the analysis performed on the linear regression models. Analysis of covariance (ANCOVA) was performed with the car:: Anova function (Fox, 2003). Linear models were compared with performance:compare_performance function ((Lüdecke et al., 2021), the model with the lowest AIC index was chosen as the best fit for our data. The variables investigated in the regression models are respectively: Coop: Cooperative action Coordination performance as average of attempts (0:1); Indi: Individual action coordination performance as average of attempts (0:1); Age: age in months; gender: (F-M); TEC: overall TEC score (0:9); REFLECTIVE: Reflective dimension on TEC (0-1); C9: Component 9: Morality on TEC (0-1); Inhib: Inhibitory control as difference of RTs (ms); Inhib pe: Inhibitory control as difference of error rates (pe) (0:1)

Table 15 ANCOVA on the Baseline Linear Regression Model: lm(Coop~ Indi+Age)

```
> car::Anova(modbaseline)
Anova Table (Type II tests)

Response: Coop
           Sum Sq  Df F value  Pr(>F)  
Indi      0.01403   1  0.7459 0.38974  
Age       0.05299   1  2.8173 0.09623 .
Residuals 1.97507 105                  
---
Signif. codes:  
0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Table 16 ANCOVA on the Linear Regression Model mod1: lm(Coop~ Indi+Age+gender+ TEC)

```
> car::Anova(mod1)
Anova Table (Type II tests)

Response: Coop
           Sum Sq  Df F value    Pr(>F)
Indi      0.01939   1  1.4147   0.23702
Age       0.07358   1  5.3684   0.02248 *
TEC       0.02408   1  1.7571   0.18792
gender    0.55616   1 40.5796 5.367e-09 ***
Residuals 1.41165 103
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Table 17 ANCOVA on the Linear Regression model: model_REFLECTIVE: lm(Coop~ Indi+Age+Reflective dimension of TEC (REFLECTIVE)

```
> car::Anova(model_REFLECTIVE)
Anova Table (Type II tests)

Response: Coop
            Sum Sq  Df F value   Pr(>F)
Indi       0.01789   1  1.3148  0.25418
Age        0.08315   1  6.1097  0.01508 *
gender     0.54509   1 40.0508 6.52e-09 ***
REFLECTIVE 0.03390   1  2.4907  0.11758
Residuals  1.40183 103
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Table 18 ANCOVA on the Linear Regression Model mod_c9: lm(Coop~ Indi+Age+ Component9 of TEC(C9)

```
> car::Anova(mod_c9)
Anova Table (Type II tests)

Response: Coop
          Sum Sq  Df F value    Pr(>F)    
Age      0.11873   1  8.7012  0.003929 ** 
gender   0.49615   1 36.3614 2.532e-08 ***
C9       0.03160   1  2.3161  0.131078    
Residuals 1.41906 104                     
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
>
```

Table 19 ANCOVA on the Linear Regression Model mod2: lm(Coop~ Indi+Age+gender+ Inhib)

```
> car::Anova(mod2)
Anova Table (Type II tests)

Response: Coop
          Sum Sq  Df F value    Pr(>F)    
Indi     0.01503   1  1.0784  0.301477    
Age      0.14004   1 10.0480  0.002009 ** 
Inhib    0.00020   1  0.0144  0.904867    
gender   0.53841   1 38.6314 1.103e-08 ***
Residuals 1.43553 103                     
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
>
```

Table 20 ANCOVA on the Linear Regression Model mod2_Inhib_pe: lm(Coop~ Indi+Age+gender+ Inhib_pe)

```
> car::Anova(mod2_Inhib_pe)
Anova Table (Type II tests)

Response: Coop
          Sum Sq  Df F value    Pr(>F)
Indi     0.01200   1  0.8834 0.3494595
Age      0.16739   1 12.3241 0.0006649 ***
Inhib_pe 0.03677   1  2.7071 0.1029531
gender   0.51459   1 37.8875 1.456e-08 ***
Residuals 1.39896 103
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
>
```

*Table 21 ANCOVA on the Linear Regression Model mod3: lm(Coop~ Indi+Age+gender Inhib*TEC)*

```
> car::Anova(mod3)
Anova Table (Type II tests)

Response: Coop
           Sum Sq  Df F value    Pr(>F)
Indi      0.01719   1  1.2373   0.26864
Age       0.07426   1  5.3455   0.02281 *
gender    0.54902   1 39.5220 8.339e-09 ***
Inhib     0.00014   1  0.0103   0.91948
TEC       0.02402   1  1.7294   0.19146
Inhib:TEC 0.00848   1  0.6102   0.43655
Residuals 1.40303 101
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
>
```

*Table 22 ANCOVA on the Linear Regression Model mod3_Inhib_pe: lm(Coop~ Indi+Age+gender Inhib_pe*TEC)*

```
> car::Anova(mod3_Inhib_pe)
Anova Table (Type II tests)

Response: Coop
              Sum Sq  Df F value    Pr(>F)    
Indi         0.01761   1  1.3115   0.25483    
Age          0.07119   1  5.3017   0.02336 *  
gender       0.52512   1 39.1073 9.716e-09 ***
Inhib_pe     0.05131   1  3.8215   0.05336 .  
TEC          0.03863   1  2.8767   0.09295 .  
Inhib_pe:TEC 0.00415   1  0.3093   0.57934    
Residuals    1.35618 101                      
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> 
```

*Table 23 ANCOVA on the Linear Regression Model mod4: lm(Coop~ Indi+Age+gender Age*gender)*

```
> car::Anova(mod4)
Anova Table (Type II tests)

Response: Coop
            Sum Sq  Df F value    Pr(>F)    
Indi       0.01515   1  1.2734 0.2617556    
Age        0.15660   1 13.1611 0.0004466 ***
gender     0.53934   1 45.3293 9.680e-10 ***
Age:gender 0.21020   1 17.6665 5.618e-05 ***
Residuals  1.22553 103                      
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Table 24Performance comparison of the tested linear regression models models; Final model selected: mod4

```
> performance::compare_performance(modbaseline_g,mod1, mod2,mod3, mod4)
# Comparison of Model Performance Indices

Name          | Model |  AIC (weights) | AICc (weights) |  BIC (weights) |    R2 | R2 (adj.) |  RMSE | Sigma
----------------------------------------------------------------------------------------------------------
modbaseline_g |    lm | -150.1 (<.001) | -149.5 (<.001) | -136.7 (0.002) | 0.303 |     0.283 | 0.115 | 0.117
mod1          |    lm | -149.9 (<.001) | -149.1 (<.001) | -133.9 (<.001) | 0.315 |     0.288 | 0.114 | 0.117
mod2          |    lm | -148.1 (<.001) | -147.3 (<.001) | -132.0 (<.001) | 0.303 |     0.276 | 0.115 | 0.118
mod3          |    lm | -146.6 (<.001) | -145.2 (<.001) | -125.1 (<.001) | 0.319 |     0.278 | 0.114 | 0.118
mod4          |    lm | -165.2 (0.999) | -164.4 (0.999) | -149.1 (0.997) | 0.405 |     0.382 | 0.107 | 0.109
>
```

Table 25 ANCOVA aov (Indi~Age+gender +TEC)

```
> car::Anova(modind_TEC)
Anova Table (Type II tests)

Response: Indi
           Sum Sq  Df F value    Pr(>F)
Age       0.06791   1  4.3432 0.0396084 *
gender    0.19413   1 12.4149 0.0006344 ***
TEC       0.02180   1  1.3942 0.2403845
Residuals 1.62625 104
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
>
```

Table 26 ANCOVA aov (Indi~Age+gender+Inhib)

```
> car::Anova(modind_InHIB)
Anova Table (Type II tests)

Response: Indi
           Sum Sq  Df F value    Pr(>F)
Age       0.07924   1  5.2019 0.0246010 *
gender    0.18728   1 12.2941 0.0006721 ***
Inhib     0.06382   1  4.1895 0.0431958 *
Residuals 1.58423 104
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

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