Heliyon 9 (2023) e19915

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Executive Functions and Theory of Mind in Teachers and Non-Teachers

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ABSTRACT

Human teaching is a key behavior for the socialization of cultural knowledge. Previous studies suggest that human teaching behavior would support the development of executive and ToM skills, which in turn would refine the teaching behavior. Given this connection, it raises the question of whether subjects with professional training in teaching also have more efficient executive and ToM systems. To shed light on this issue, in the present study we compared the performance of professional teachers ($N = 20$, age range = 35–61 years) with a matched control group of non-teachers ($N = 20$, age range: 29–64 years) on tasks measuring working memory (Sternberg Task), cognitive flexibility (Wisconsin Card Sorting Test), executive control (Attention Network Test), along with online ToM skills (Frith–Happé Animations Task), emotion recognition (Reading the Mind in the Eyes Test) and first-order and second-order ToM (Yoni Task). We found that teachers were significantly more accurate on tasks involving cognitive flexibility ($p = .014$) and working memory ($p = .040$), and more efficient on tasks requiring executive control of attention ($p = .046$), compared to non-teachers. In ToM tasks, differences in accuracy between teachers and non-teachers were not found. But, teachers were slower to respond than non-teachers (about 2 s difference) on tasks involving emotion recognition ($p = .0007$) and the use of second-order affective ToM ($p = .006$). Collectively, our findings raise an interesting link between professional teaching and the development of cognitive skills critical for decision-making in challenging social contexts such as the classroom. Future research could explore ways to foster teachers' strengths in cognitive flexibility, working memory, and executive control of attention to enhance teaching strategies and student learning outcomes. Additionally, exploring factors behind slower response times in affective ToM tasks can guide teacher-training programs focused on interpersonal skills and improve teacher-student interactions.

1. Introduction

Teaching is a complex behavior, key to the efficient socialization of knowledge and skills [1–3]. This behavior has a high adaptive value, as evidenced by its expression in humans and animals [4–8]. Typically, an animal interaction is referred to as teaching when an animal changes its behavior in the presence of a naïve animal at an initial cost to itself, to set an example so the other individual can learn more quickly [5]. Examples of teaching behavior in animals can be observed in different species. For instance, wild meerkats teach pups prey-handling skills [6], wild chimpanzees teach tool skills by providing learners with termite fishing probes [8,9], and leader ants employ a bidirectional feedback teaching mechanism to instruct follower ants on the route from the nest to a food source [7,10]. These examples highlight the presence of teaching behavior in animals without the use of complex cognition.

In the case of humans, teaching behavior is expressed from the first year of life through basic actions such as pointing to inform [11], and evolves until reaching more complex behaviors in later stages of development, such as the use of demonstrations, direction of attention and explanations [12]. According to Csibra [13], the goal of teaching behavior in humans is not only the correction of

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https://doi.org/10.1016/j.heliyon.2023.e19915
Received 29 March 2023; Received in revised form 22 August 2023; Accepted 5 September 2023

behaviors or modeling but also serves as a tool for the transmission and socialization of cultural knowledge. Thus, the definition of human teaching becomes more complex, involving high-order social cognition processes. For instance, Ziv and Frye [14,15] defined human teaching as an intentional activity that is carried out in order to increase the knowledge (or understanding) of another who lacks knowledge, has partial knowledge, or has a false belief. Similarly, Tomasello [16,17] states that human teaching is a form of altruism involving the intention to donate their knowledge to help others learn a new skill, acquire new knowledge, or deepen their understanding.

Interestingly, a common thread among the definitions of human teaching is the recognition that we would require an understanding of the mental states of others to perceive and recognize their knowledge gaps or lack of understanding [18,19]. This ability to attribute inner mental states to like thoughts, desires, and intentions to others and to appreciate how these may differ from our own, is known in cognitive science as a theory of the mind (ToM) [20]. This understanding of the mental states of others has a cognitive dimension, as when we make inferences about what the other is thinking (e.g., false belief detection), and an affective dimension, as when we infer what the other is feeling (e.g., empathizing with someone) [21]. Neuroimaging studies show a common brain network between cognitive and affective ToM processes formed mainly by the medial prefrontal cortex (mPFC) and the bilateral posterior temporoparietal junction (TPJ) [22–24]. Empirical studies linking human teaching behavior with ToM skills are very scarce and usually focused on the expression of these behaviors in children. For instance, Davis-Unger and Carlson [25] explored the relationship between teaching and ToM in 3.5-, 4.5-, and 5.5-year-old children. They found that individual differences in ToM were significantly correlated with the number of strategies used by children when teaching. Similarly, Ziv et al. [26] explored the relationship between teaching and ToM in 3-, 4-, and 5-year-old children. They found that the development of children's teaching strategies and their contingency are closely tied to the development of ToM.

Thus, these studies seem to support the theoretical link between teaching behavior and ToM in humans. However, it is clear that in order to teach effectively, it is not enough to detect a knowledge gap or a false belief in others. Once this detection has been made, it is necessary to implement concrete actions to help solve the detected problem, including the development of a teaching plan for the achievement of learning, recurrent monitoring, and assessment of learning, as well as implementing flexible changes in the teaching strategy if the strategy does not seem to be working, among other actions [27]. The cognitive processes underlying these types of actions are known as executive functions (EF). EF is an umbrella term for a set of higher cognitive skills involved in goal-directed problem-solving, the generation of adaptive behaviors, and reasoning, planning, and efficient resolution of problems [28,29]. The central aspects of EF are working memory, inhibitory control, and set shifting/cognitive flexibility [30,31]. Working memory refers to the systems necessary in order to keep things in mind while performing complex tasks (e.g. when performing a mental calculation) [32, 33]. Inhibitory control is the ability to control one's attention, behavior, thoughts, and/or emotions in order to override a strong inner predisposition or outer temptation and instead do what is more appropriate or necessary (e.g., when we keep studying without being distracted by cell phone sounds) [29]. Set shifting/cognitive flexibility is the ability to see things from a different perspective, to complete tasks that involve sorting things along two or more different dimensions, and to direct attention according to changing needs, i.e. a rule to learn and then switch to the newly introduced one, make transitions and adapt to changes in the environment (e.g., when at work we are asked to leave the task at hand and to quickly adapt to a new task requested) [34,35]. Neuroimaging studies are consistent in showing that EFs are associated with prefrontal neural networks. The main areas that form this network are the dorsolateral prefrontal cortex, the inferior frontal gyrus, the ventrolateral prefrontal cortex, and the orbitofrontal cortex [36]. As with ToM skills, the link established between teaching behavior and EF is eminently theoretical. The only empirical study reported along these lines is that of Davis-Unger and Carlson [37] who explore the role of the ToM and EFs in developing teaching skills of 3.5- and 5.5-year-old children. They found that EF was a significant predictor of teaching efficacy over and above ToM, which suggests that ToM may be a necessary prerequisite for teaching to occur; however, EF skills appear to play a vital role in children's teaching efficacy. In summary, both ToM and EF are important factors in the development of teaching skills in young children and their interaction is likely to contribute to the effectiveness of teaching behavior.

In contrast to the study of teaching behavior and its association with EF and ToM skills in children, there is no comparable research in adults. This noticeable lack of emphasis on neurocognitive studying of teaching behavior in adults, results in a significant knowledge gap regarding the cognitive and neural mechanisms that underlie human teaching [19,38,39]. However, there are some studies that indirectly investigate teaching behavior in adults by studying the effect of teaching-learning interactions on teacher-student brain dynamics. For instance, Holper et al. [40] used functional near-infrared spectroscopy (fNIRS) to evaluate the prefrontal hemodynamic activity of adult pairs -one plays the role of teacher and the other as a student-during the performance of a classic teaching model (Socratic method). They found that in successful pedagogical interactions, teacher and student prefrontal activity was positively correlated, while in poor pedagogical interactions, they observed a decoupling of prefrontal hemodynamic activity between teacher and student. Takeuchi et al. [41] found similar results using fNIRS to record the prefrontal hemodynamic activity of adult pairs during a teaching-learning task. They report that the left prefrontal activity changed synchronously in both teachers and students after improving the teaching-learning interaction. In turn, Zheng et al. [42] measured the frontal, temporal, and parietal hemodynamic activity of professional teacher-student pairs. They found that better results of teaching were associated with higher coupling between the right temporal-parietal junction activity of the professional teacher and the anterior superior temporal cortex activity of the student. Besides, they reported that the coordination of brain activity between teacher and student could anticipate the quality of the teaching result observed later. Similarly, Liu et al. [43] found that the coupling between left prefrontal activities of teacher-student pairs can predict the teaching effectiveness early in the teaching process only when the communication mode was face-to-face, and the student had previous knowledge about what would be taught. The general pattern emerging from these studies highlights a potential association between effective teaching behavior in adults and the recruitment of prefrontal and temporoparietal brain regions. It is important to note that these brain regions are also central components of the neural networks underlying EFs and ToM.

While the empirical evidence presented so far is scarce, it consistently shows a direct relationship between teaching behavior, ToM and EFs in children and indirectly also in adults. Based on these findings, we propose to investigate what happens to the development of ToM and EFs in adults with professional teaching training. This idea is supported by proposals such as that of Calero et al. [44] who put forward the idea of a virtuous cycle between the refinement of teaching behavior and the development of higher-order cognitive skills such as EFs and ToM. Therefore, the question arises whether long-term training of teaching behavior has an ameliorating effect on other cognitive processes not directly trained, such as ToM and EF. To the best of our knowledge, no studies have been conducted thus far that directly examine the performance of expert teachers in tasks related to executive functions (EFs) and theory of mind (ToM). Nevertheless, there is educational research suggesting that expert teachers would have a more efficient use of executive and socio-affective cognitive resources during teaching practice. For instance, Livingston and Borko [45] proposed that expert teachers are better at converting knowledge into forms that adapt to diverse student abilities and backgrounds, as well as designing lessons to respond to the unpredictability of classroom events, rather than to predict and control them. Similarly, Hiver et al. [46] suggested that expert teachers have better monitoring and control over events that occur during the teaching process. Finally, Rodriguez and Fitzpatrick [47–49] propose five key dimensions of expert teacher awareness that contribute to effective teaching, namely, awareness of learner, awareness of context, awareness of self as a teacher, awareness of teaching practice, and awareness of interaction. From these proposals, it can be inferred that expert teachers require the efficient dynamic integration of fine executive processes and social cognition during the act of teaching.

The purpose of this study is to examine whether professional teachers with experience and extensive training in teaching show better performance in terms of their EFs and ToM skills compared to a group of adults without professional training in teaching. By exploring these differences, we aim to assess the unique impact of long-term professional teaching training on the development of these cognitive skills, which may shed light on the importance of pedagogical training and its influence on the cognitive and social functioning of educational professionals. With the aforementioned evidence in mind, we establish the following hypotheses: (a) the accuracy in set shifting/cognitive flexibility and working memory, as well as the efficiency of the executive control of attention, will be greater in teachers than non-teachers; (b) accuracy in cognitive and affective ToM skills will be greater in teachers than non-teachers. In order to assess these hypotheses, we collected the behavioral responses of professional teachers and a comparably matched cohort of non-teaching professional adults, as they participated in six cognitive tasks outlined as follows: i) Wisconsin Card Sorting Test [50]: participants are required to sort a deck of cards based on changing rules, adapting their response strategy to match the shifting rule, providing insights into set shifting/cognitive flexibility; ii) Sternberg Task [51]: participants are presented with a set of stimuli, followed by a probe item. They must determine whether the probe was part of the initial set, providing insights into working memory capacity; iii) Attention Networks Test [52], participants are presented with five arrows and must indicate in which direction the central arrow points regardless of which direction the flanking arrows point, providing insights into the efficiency of alerting, orienting, and executive control of attention; iv) Frith–Happé animations task [53]: Participants view short animations depicting geometric shapes moving with intent. They are then asked to infer the mental state of the shapes, providing insights into online ToM capabilities; v) Reading the Mind in the Eyes Test [54]: Participants view a series of eye photographs and choose the corresponding mental state, providing insights into emotion recognition and affective ToM; vi) Yoni task [55]: Participants are required to deduce a character's thoughts or emotions using the least linguistic and visual hints available. The inferences required can be about the mental state of one or two targets, providing insights into first-order and second-order cognitive/affective ToM. According to our hypotheses, we expected that professional teachers have superior set shifting/cognitive flexibility, working memory, and executive control of attention capacities, along with greater cognitive and affective mentalization skills than the control group, which would hint at a potential enhancing relationship between the professional development of teaching behavior and the strengthening of higher order cognitive skills and social cognition.

2. Materials and Methods

2.1. Participants

Forty subjects, 20 experienced teachers (male/female = 7/13, age range = 35–61 years, mean age = 48.30 years, SE = 2.04) and a sample of 20 non-teachers (male/female = 7/13, age range = 29–64 years, mean age = 45.55 years, SE = 2.15) were recruited for a behavioral experiment. The group of teachers had an average of 20.65 years of professional experience (age range = 10–39 years, SE = 2.01), while the group of non-teachers had an average of 17.30 years of professional experience (age range = 6–33 years, SE = 1.83). According to Chilean salary tables (https://cpeip.cl/asignaciones-carrera-docente-2023/and https://www.mifuturo.cl/buscador-de-estadisticas-por-carrera/), both groups are placed in the medium-high socioeconomic status (SES). The groups were equivalent in sex, age ($U = 223$, $p = .542$, $r_B = 0.115$, 95% CI = [−4, 10]), years of professional experience ($U = 231$, $p = .408$, $r_B = 0.155$, 95% CI = [−3, 9]), SES, and fluid intelligence measured with the Raven advanced progressive matrices [56,57] ($U = 162$, $p = .308$, $r_B = -0.190$, 95% CI = [−11, 4]). We defined "experienced teacher" as an adult with university studies in pedagogy, which works as a full-time teacher in a school and has been qualified as "Expert" by the teaching career system of the Ministry of Education of Chile (MINEDUC). According to the Center for Improvement, Experimentation, and Pedagogical Research of the MINEDUC (www.cpeip.cl/carrera-docente-progresion-tramos), the "expert" qualification defines a teacher who has experience, pedagogical skills, and disciplinary knowledge above what is expected for a good professional teaching practice. In terms of teaching areas, the sample was composed of teachers of language (7), mathematics (6), science (2), humanities (1), and other disciplines (4) (e.g., art, foreign languages, physical education). On the other hand, we defined "non-teacher" as a professional adult with university studies other than pedagogy that has never been taught in educational contexts. As for the professions of the participants, the sample was composed of professionals in the social sciences (10), engineering & technology (4), medical sciences (4), natural sciences (1), and humanities (1). All participants were native Spanish speakers and self-reported having normal vision and hearing (or corrected to normal), without antecedents of neurological/psychiatric disorders. All participants gave written informed consent before being tested. The Ethics Committee for Research in Social Sciences and Humanities of the University of Chile approved the study (ethics approval number: 001–2020).

2.2. *Task*

To evaluate different dimensions of executive functions and theory of mind, we have carefully chosen six widely utilized tasks in the field of cognitive neuroscience, which have satisfactory levels of reliability and validity [29,36,52,58–65]. Below, we provide a comprehensive description of each task selected.

2.2.1. *Wisconsin Card Sorting Test (WCST)*

We utilize the WCST [50] as a means to evaluate the subjects' proficiency in executing adaptable set shifting tasks (cognitive flexibility). During the task, participants are presented with a row of four reference cards (from left to right: two green circles, four yellow triangles, three red crosses, and one blue star) and below them a target card that changes trial by trial, varying in shape (crosses, circles, triangles, or stars), color (red, blue, yellow, or green) or number of elements (one, two, three, or four). The task of the subjects was to find the pattern that linked the target card to one of the reference cards. The sorting pattern could be the similarity in shape, color, or number of elements. Once the participant identifies the correct pattern, it must be maintained in the subsequent trials. After the subject has sorted 10 consecutive cards, unexpected shifts in the sorting principle occurred, forcing the participants to search for a new pattern. Overall, 60 WCST trials were administered.

Prior to the experiment, participants read the instructions to perform the task. As depicted in Fig. 1A, each trial began with the presentation of a fixation cross in the center of the screen (1 s), followed by the visual presentation of the four reference cards and the target card (10 s or until the participant answers). During this period, the participant must answer by clicking with the mouse on one of the four reference cards. After responding, a feedback message on the screen indicating whether the answer was correct or not (1.5 s).

For subsequent analyses, we calculated the average accuracy percentage and the average RT of correct responses during the entire task as a measure of overall performance, and the percentage of perseverative errors as a specific measure of set shifting/cognitive flexibility [66]. A perseverative error occurs when a participant continues to respond based on a previous sorting rule despite feedback suggesting that the rule has changed.

2.2.2. *Sternberg Task (ST)*

We employ the well-known Sternberg memory task [51] to assess subjects' ability to maintain and manipulate information (working memory). The ST is divided into three phases: encoding, maintenance, and recall. During the encoding phase, a list of items is rapidly presented. Here, we used lists of 3, 5, or 7 letters. After a few seconds of maintenance, a probe item is presented, and the participant must respond as quickly as possible whether the probe item was included in the initial list.

Prior to the experiment, participants read the instructions to perform the task. As depicted in Fig. 1B, each trial began with a fixation cross in the center of the screen (duration between 1 and 1.5 s), followed by the presentation of a sequence of letters (3, 5, or 7 letters), presented one at a time, in the center of the screen (1.2 s per letter). Then, a maintenance period represented by a question mark was presented (delay period = 3 s). After this period, a probe letter was presented, which remained on the screen until the participant answered. To respond, the subject had to indicate, as quickly as possible, whether or not the probe letter was in the sequence previously seen, by pressing the left mouse button if the probe letter was present or pressing the right mouse button if it was not. The participants performed 60 trials (20 trials per length of encoded item list). The trials were presented in random order. The probe was on the list in 50% of the trials. For further analysis, we calculated the average accuracy percentage and the average RT of correct responses during the entire task as a measure of overall performance.

2.2.3. *Attention Network Test (ANT)*

The ANT [52,67] was used to assess the efficiency of the participants' alerting, orienting, and executive control of attention networks. The latter network is of particular interest because it involves top-down inhibitory processes that are central to the assessment of executive functions. The task involves discerning the orientation of a central arrow (target) flanked by two additional arrows on either side. The presentation showcases five horizontal black arrows on a gray backdrop. In the congruent condition, the surrounding arrows align with the target's direction, whereas in the incongruent condition, they oppose it. Additionally, a neutral condition is incorporated, featuring arrowhead-free lines. These rows of arrows may appear above or below a central fixation-cross displayed on the screen. Participants are asked to indicate in which direction the central arrow points. A visual cue (depicted as an asterisk) is exhibited to evaluate alerting and orienting before the arrows become visible. The alerting trials encompass a "no-cue" condition where the asterisk is absent, and a "double-cue" condition where it emerges, both above and below the fixation cross. The orienting trials involve the asterisk appearing in the same position as the fixation cross (center-cue), or above/below the fixation cross (spatial-cue), furnishing accurate information about the arrow's location to assist with orientation at a perfect 100% accuracy rate.

Before the experiment began, participants reviewed the instructions in order to carry out the task. The experimental session encompassed an initial practice phase consisting of 24 trials, with feedback provided, followed by three subsequent experimental phases, each comprising 48 trials without feedback (resulting in a total of 144 experimental trials). The arrangement sequence of the trials was randomized. As illustrated in Fig. 1C, during the experimental phases, each trial was initiated by the appearance of a fixation cross at the screen's center, persisting for a variable duration ranging from 400 to 1600 ms. Subsequently, a visual cue emerged for duration of 100 ms, or no cue was presented. This was followed by a brief fixation interval of 400 ms. Afterward, a row of five arrows was exhibited for a duration of 1700 ms or until the participant provided their response. Once the participant responded, the stimuli vanished, and a post-target fixation period of varying duration was displayed. The duration of this period depended on both the initial fixation period's length and the participant's reaction time (RT). This variable post-target fixation period was calculated as 3500 ms minus the sum of the initial fixation period's duration and the participant's RT. Following the post-stimulus fixation period, the subsequent trial was initiated. To specify the orientation of the central arrow (whether it's left or right), participants utilized the respective left or right mouse button for input.

For subsequent analysis, trials that contained incorrect responses or had RTs exceeding 1000 ms or falling below 200 ms were left out [68]. The rationale for this decision lies in the fact that, due to the nature of this task, RTs over 1 s may indicate disengagement from the task, while RTs below 0.2 s may suggest anticipatory responses or simple guessing rather than meaningful responses. The mean RTs were computed for each of the six combinations, formed by the interaction of four warning conditions and three target conditions. Efficiency scores for each attentional network were then calculated as follows [69]: alerting network = [RT no-cue − RT double-cue], orienting network = [RT center-cue − RT spatial-cue], and executive control network = [RT incongruent − RT congruent]. Regarding the alerting and orienting networks, higher values denote greater efficiency. Conversely, elevated scores within the executive control network signify lower efficiency.

2.2.4. *Frith–Happé Animations Task (FH)*

We apply the FH task [53] to dynamically assess the online mentalizing capabilities of the participants. During this task, participants viewed a series of short, soundless animations featuring two geometric shapes (triangles) moving around the screen. The animations consisted of three types: i) Random animations, characterized by purposeless movements of the triangles that offered limited insight into their interaction, goals, or intentions (e.g., bouncing); ii) Goal-Directed animations, in which the triangles' interaction conveyed a clear behavioral purpose (e.g., dancing) and demonstrated their intentionality; iii) ToM animations, in which the interactions between the triangles suggested that one triangle was anticipating or manipulating the "mental state" of the other (e.g., tricking), providing a window into the representation of mental states.

Prior to the experiment, participants read the instructions to perform the task. As depicted in Fig. 2A, each trial began with a fixation cross in the center of the screen (duration between 1 and 1.5 s), followed by the presentation of a clip (range = 26–48 s, mean = 39.13 s). At the end of the video, three response alternatives were displayed on the screen to categorize the video that was just

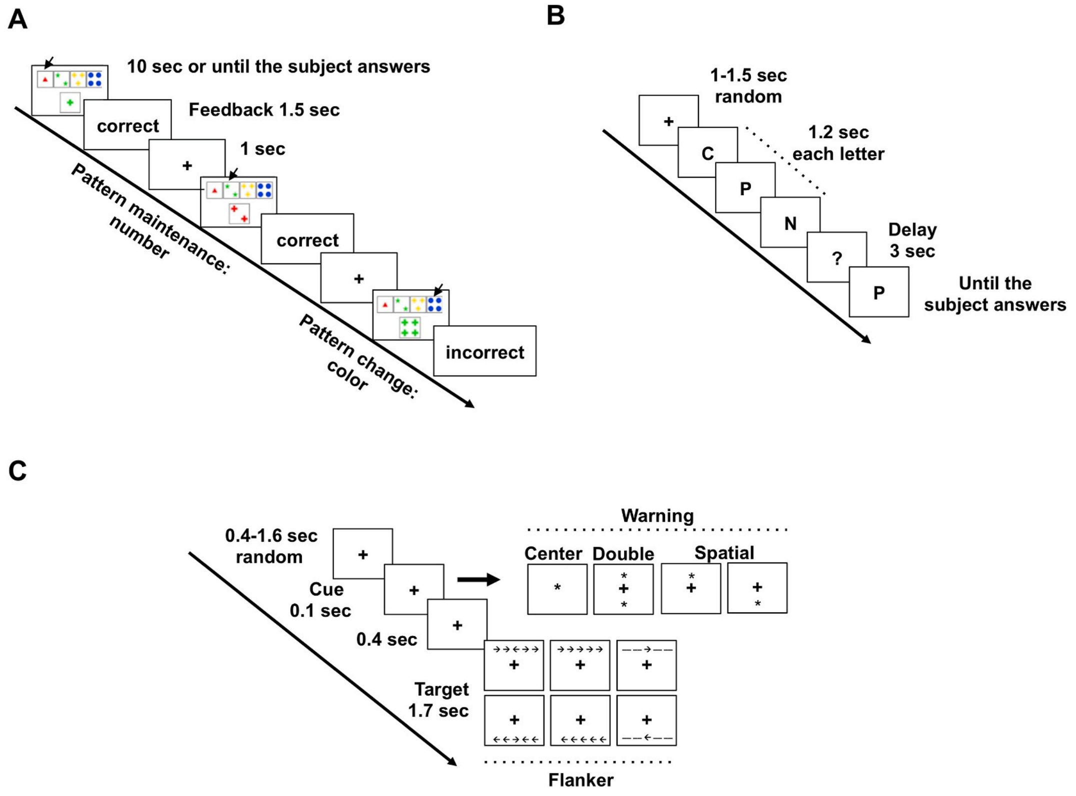

Fig. 1. Executive function tasks. (A) Wisconsin Card Sorting Test (WCST): Maintenance and pattern change is illustrated. (B) Sternberg task: The letters retention, delay, and retrieval period are displayed. (C) Attention Network Test (ANT): The four cues conditions (no cue, center, double and spatial) and three flanker conditions (incongruent, congruent and neutral), along with the timeline for each trial, are depicted.

watched. These options were: a) "No Interaction" (Random), b) "Physical Interaction" (Goal-Directed), or c) "Mental Interaction" (Theory of Mind). The three alternatives remained on the screen until the participant responded. To provide their answer, the participant had to press the corresponding letter to the selected alternative (A, B, or C) on the keyboard. The participants performed 12 trials (4 trials per interaction type). The trials were presented in a pseudo-random order. Participants earned 1 point for each correct categorization, resulting in a maximum score of 4 points per condition (Random, Goal-Directed, and ToM). For subsequent analyses, we calculated the average score and the average RT of correct responses for each interaction type.

2.2.5. Reading the Mind in the Eyes Test (RMET)

We used the RMET [54] to assess the subjects' ability to accurately attribute emotions and mental states to other people. The task consists of thirty-six monochrome photographs of individuals' eye regions (19 males and 17 females), with each image encircled by four words depicting different emotional states (such as "Ashamed," "Nervous," "Suspicious," and "Indecisive"). Participants are tasked with selecting the word that most accurately characterizes the individual depicted in each picture. As the RMET mandates a compulsory choice from four alternatives, the baseline level of accuracy by chance is 25%.

Prior to the experiment, participants read the instructions to perform the task. As depicted in Fig. 2B, each trial began with a blank screen (0.2 s), followed by the presentation of an image of a pair of eyes and four single-word descriptors, which remained on the screen until the participant answered. To respond, the participant must click with the mouse on one of the four words. For further analysis, we calculated the average accuracy percentage and the average RT of correct responses during the entire task as a measure of overall performance.

2.2.6. Yoni Task (YT)

We applied the YT [55] to assess participants' ability to make first-order (tracking the mental state of one target) and second-order (tracking the mental states of two targets) cognitive and affective ToM. During this task, participants are presented with four images surrounding a central character (referred to as Yoni). In the cognitive ToM trials, participants must determine which of the four surrounding images represents the thoughts or desires of "Yoni". In the affective ToM trials, participants need to make similar decisions regarding which image represents what "Yoni" likes, loves, dislikes, or doesn't love. Overall, 98 trials were administered, 84 ToM trials and 14 control trials where participants are only required to identify the physical characteristics of the images.

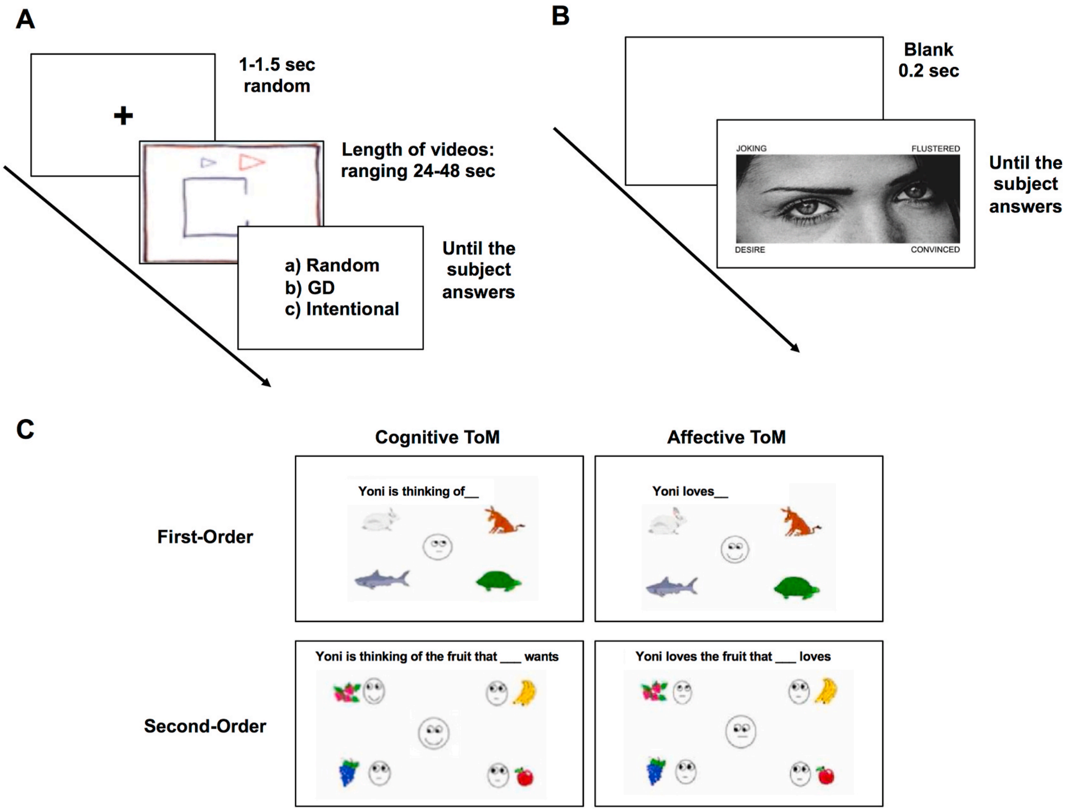

Fig. 2. Theory of mind tasks. (A) Frith-Happé animation task: A video presentation is illustrated followed by alternatives to determine the type of interaction observed. (B) Reading the Mind in the Eyes task (RMET): An example of a stimulus consisting of an image of the eye area accompanied by four words representing different affective or mental states is shown. (C) Yoni task: Samples of first-order and second-order cognitive and affective stimuli are presented.

Prior to the experiment, participants read the instructions to perform the task. As depicted in Fig. 2C, each trial shows a face named "Yoni" and four colored pictures placed around the "Yoni" referring to different semantic categories (e.g., fruit, animals, means of transport) or faces. Concurrently, an incomplete sentence appeared at the top of the screen (e.g., *"Yoni is thinking about the fruit that___wants"* or "*Yoni loves the fruit that___does not love*"). This screen remained visible until the participant provided a response. To select their answer, participants used the mouse to click on the alternative that best completed the presented sentence as accurately and swiftly as possible. After that, a new stimulus is presented. For subsequent analyses, we calculated the average accuracy percentage and the average RT of correct responses of each of the four conditions, namely, first-order affective ToM, first-order cognitive ToM, second-order affective ToM, and second-order cognitive ToM.

2.3. Procedure

Due to the restrictions imposed by the pandemic, the experiment was designed using E-Prime 3.0.3.80 and compiled using E-Prime Go 1.0.2.41, which allowed participants to run the experiment at home. To run the experiment, participants had to click on a link that allowed them to download the experiment to their PC. This link was sent by e-mail along with strict instructions on how to set up the environment to perform the tasks. The instructions for setting the workspace were: i) aside approx. 1hr 30 min without interruptions to perform the tasks; ii) a quiet room with a balanced light source; iii) put the cell phone on silent, without vibration mode, and place it out the visual space; iv) sit comfortably in around 60 cm (one arm's length approx.) from the center of the computer screen; v) put PC centrally on an empty desk. Exceptionally, if the participant did not have the required environmental conditions to carry out the study at home and if the sanitary restrictions at the time allowed it, they were offered to carry out the study in one of our offices. Except for this issue, the rest of the experiment was carried out in the same way regardless of the place where it was performed. Once the workspace was set, participants ran the downloaded application, and instructions for performing the tasks were displayed on the screen. Once participants completed the six tasks, their data was automatically uploaded to the E-Prime Go website, from where they were subsequently downloaded for analysis.

2.4. Statistical Analyses

The first step was to evaluate the assumption of normality and equality of variances of all variables with the Shapiro-Wilks test and Levene's test, respectively. The result of the analyses showed that these assumptions were not met in our data. Therefore, it was decided to use non-parametric statistics because they make no assumptions about the underlying distribution of the data. Thus, we can avoid potential biases or inaccurate conclusions that may arise from violating the assumption of normality. Specifically, the two-tailed Mann-Whitney U test was used to compare groups. The significance level was set at 0.05. The effect size was calculated using the biserial rank test (r_b). Along with the p-value and effect size, information on the confidence intervals for each result obtained is also provided. In addition to standard frequentist statistic, we also report the Bayes Factors (BF_{10}), as further quantification of evidence for and against our hypotheses [70]. For interpretation, BF_{10} between 0.33 and 3 indicates that there is no clear evidence in favor of the H_1 or H_0; BF_{10} between 3 and 10 indicates moderate evidence and >10 strong evidence for the H_1; whereas BF_{10} between 0.1 and 0.33 indicate moderate evidence and <0.1 strong evidence for the H_0 [71,72]. All statistical analyses were performed using GraphPad Prism software version 10 (www.graphpad.com) and the free JASP software (https://jasp-stats.org/).

3. Results

3.1. Set Shifting/Cognitive Flexibility

The results are illustrated in Fig. 3A. Performance on the WCST revealed that the mean ACC of the teachers was 75.15% (SE = 3.78) with an average perseverative error of 6.35% (SE = 1.19) and a mean RT of 2147.33 ms (SE = 155.52), whereas the control group the mean ACC was 56.70% (SE = 5.23) with an average perseverative error of 9.35% (SE = 1.02) and a mean RT of 2139.23 ms (SE = 198.87). Two-tailed Mann-Whitney U test revealed that ACC ($U = 99.5$, $p = .006$, $r_B = 0.502$, 95% CI = [3,35], $BF_{10} = 5.491$) and perseverative error ($U = 110.5$, $p = .014$, $r_B = -0.448$, 95% CI = [−6, −1], $BF_{10} = 1.967$) were significantly different between groups. Differences in reaction time were not found ($U = 195$, $p = .904$, $r_B = 0.025$, 95% CI = [−433.2, 513.12], $BF_{10} = 0.315$).

3.2. Working Memory

The results are illustrated in Fig. 3B. Performance on the ST revealed that the mean ACC of the teachers was 87.4% (SE = 2.44) with a mean RT of 1214.72 ms (SE = 96.24), whereas in the control group it was 75.05% (SE = 4.59) with a mean RT of 1305.61 ms (SE = 128.40). Two-tailed Mann-Whitney U test revealed that ACC was significantly different between groups ($U = 124.5$, $p = .040$, $r_B = 0.377$, 95% CI = [4.015e −5, 18], $BF_{10} = 1.868$). Differences in reaction time were not found ($U = 182$, $p = .640$, $r_B = -0.090$, 95% CI = [−249.8, 191], $BF_{10} = 0.355$).

3.3. Attentional Networks

The results are illustrated in Fig. 3C. The overall RT for all conditions in the teachers group was 632.75 ms (SE = 18.19), whereas in the control group it was 633.76 ms (SE = 17.49). The RTs for each condition in the teachers group were 634.52 ms (SE = 18.98) for no cue-congruent, 706.83 ms (SE = 19.57) for no cue-incongruent, 616.81 ms (SE = 24.64) for center cue-congruent, 712.06 ms (SE = 24.99) for center cue-incongruent, 601.56 ms (SE = 27.86) for double cue-congruent, 684.66 ms (SE = 22.77) for double cue-incongruent, 565.78 ms (SE = 18.98) for spatial cue-congruent, and 624.75 ms (SE = 19.72) for the spatial cue-incongruent condition, whereas in the control group it were 632.66 ms (SE = 20.88) for no cue-congruent, 714.92 ms (SE = 19.57) for no cue-incongruent, 614.22 ms (SE = 21.53) for center cue-congruent, 713.94 ms (SE = 18.06) for center cue-incongruent, 597.52 ms (SE = 19.01) for double cue-congruent, 718.09 ms (SE = 19.49) for double cue-incongruent, 573.95 ms (SE = 19.40) for spatial cue-congruent, and 668.31 ms (SE = 17.21) for the spatial cue-incongruent condition.

The mean scores of the alerting, orienting, and executive control networks for the teachers group were 6.29 ms (SE = 11.19), 45.54 ms (SE = 15.25), and 81.26 ms (SE = 12.53), while the mean scores for the control group were 16.92 ms (SE = 8.52), 36.56 ms (SE = 7.59), and 106.59 ms (SE = 6.23), respectively. Two-tailed Mann-Whitney U test revealed that the executive control network of teachers is more efficient than control group ($U = 126$, $p = .046$, $r_B = -0.370$, 95% CI = [−43.350, −0.290], $BF_{10} = 1.144$). The efficiency of the alerting and orienting network was not significantly different between groups (Alerting: $U = 193$, $p = .862$, $r_B = -0.035$, 95% CI = [−24.690, 17.480], $BF_{10} = 0.320$; Orienting: $U = 187$, $p = .738$, $r_B = -0.065$, 95% CI = [−27.235, 19,570], $BF_{10} = 0.320$).

3.4. On-line Mentalizing Capacity

The results are illustrated in Fig. 4A. Performance on the FH task revealed that, on a 4-point scale, the mean scores by detecting random, goal-directed, and ToM interactions for the teachers group were 3.65 (SE = 0.109), 2.15 (SE = 0.167), and 3.45 (SE = 0.211) points, with a mean RT of 3502.57 ms (SE = 626.236), 4274.60 ms, (SE = 851.834) and 3514.07 ms (SE = 626.193) respectively, while

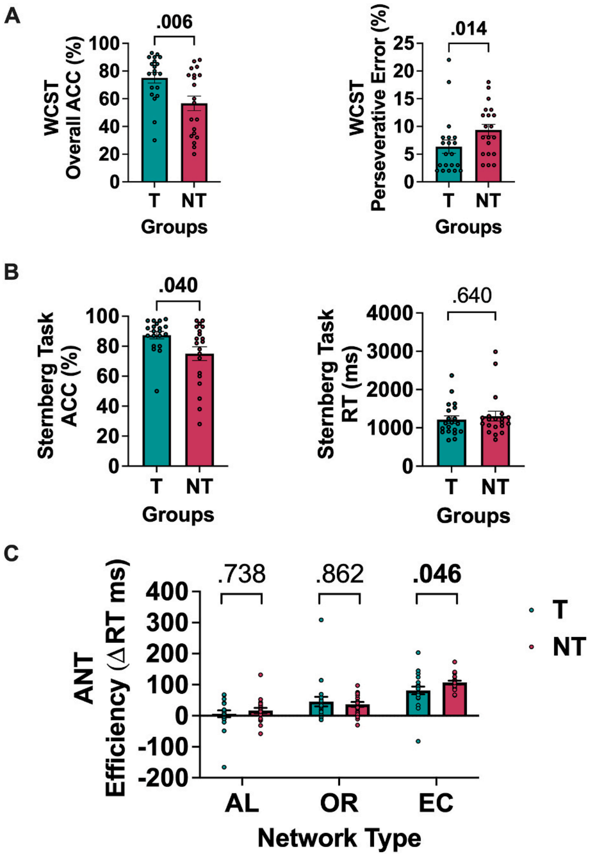

Fig. 3. Comparison between teacher and non-teacher groups in executive functions tasks. Green and pink bars represent teachers (T) and non-teachers (NT) respectively. (A) Wisconsin Card Sorting Test (WCST): The overall average accuracy percentage and the percentage of perseverative errors are presented on the y-axis, while the groups are indicated on the x-axis. (B) Sternberg task: The average accuracy percentage and reaction time in milliseconds (ms) are presented on the y-axis, while the groups are indicated on the x-axis. (C) Attention Network Test (ANT): The y-axis and x-axis indicate the average network efficiency and attentional network type. Efficiency of attentional networks calculated as the difference in reaction times (**Δ**RT). **Δ**RT are provided for the alerting (AL = no cue– double cue), orienting (OR = center cue–spatial cue), and executive control (EC = incongruent–congruent) networks. For the executive control system, the higher scores show less efficient executive control. Circles show individual values. Error bar indicates SEM. The square brackets above the bars show the exact p-value. Bold p-values indicate statistically significant differences (p < .05).

the mean scores for the control group were 3.60 (SE = 0.134), 2.35 (SE = 0.209), and 3.70 (SE = 0.164) points, with a mean RT of 3264.14 ms (SE = 457.306), 3295.59 ms (SE = 645.798), and 2976.93 ms (SE = 490.996) respectively. Statistical differences in the ability to detect random, goal-directed, and ToM interactions between groups were not found (random: $U = 196.5$, $p = .925$, $r_B = 0.018$, 95% CI = [−2.982E −5, 2.172E −5], $BF_{10} = 0.359$; goal-directed: $U = 171$, $p = .445$, $r_B = -0.145$, 95% CI = [−1, 5.775e −5], $BF_{10} = 0.386$; ToM: $U = 161.5$, $p = .301$, $r_B = -0.193$, 95% CI = [−1, 6.076E −5], $BF_{10} = 0.484$). Likewise, statistical differences in the response time between groups were not found (random: $U = 193$, $p = .862$, $r_B = -0.035$, 95% CI = [−858.2, 624.8], $BF_{10} = 0.320$; goal-directed: $U = 158$, $p = .265$, $r_B = 0.210$, 95% CI = [−536.3, 1899], $BF_{10} = 0.430$; ToM: $U = 170$, $p = .588$, $r_B = 0.105$, 95% CI = [−411.3, 856.1], $BF_{10} = 0.332$).

3.5. *Emotion Recognition*

The results are illustrated in Fig. 4B. Performance on the RMET revealed that the mean ACC in the teachers group was 59.65% (SE = 2.09) with a mean RT of 8573.71 ms (SE = 520.03), whereas in the control group it was 58.25% (SE = 3.70) with a mean RT of 6424.04 ms (SE = 649.11). Two-tailed Mann-Whitney *U* test revealed that RT was significantly different between groups ($U = 79$, $p = .0007$, $r_B = 0.605$, 95% CI = [922.1, 3407], $BF_{10} = 8.697$). Differences in ACC were not found ($U = 173.5$, $p = .479$, $r_B = -0.133$, 95% CI = [−8, 5], $BF_{10} = 0.356$).

3.6. *First-Order and Second-Order ToM*

The results are illustrated in Fig. 4C. In the first-order cognitive condition, the mean ACC for the teachers groups was 95.05% (SE = 4.14) with a mean RT of 3146.12 ms (SE = 180.95), while the mean ACC for the control group was 97.55% (SE = 1.69) with a mean RT of 3208.69 ms (SE = 253.41). Statistical differences both in ACC and RT were not found (ACC: $U = 199.5$, $p = .989$, $r_B = -0.002$, 95% CI = [−3.760e −5, 4.854e −5], $BF_{10} = 0.360$; RT: $U = 188$, $p = .758$, $r_B = 0.060$, 95% CI = [−685.7, 643.2], $BF_{10} = 0.330$). In the first-order affective condition, the mean ACC for the teachers groups was 95.45% (SE = 3.74) with a mean RT of 3680.52 ms (SE = 333.40), while the mean ACC for the control group was 94.20% (SE = 2.77) with a mean RT of 3162.05 ms (SE = 218.94). Statistical differences

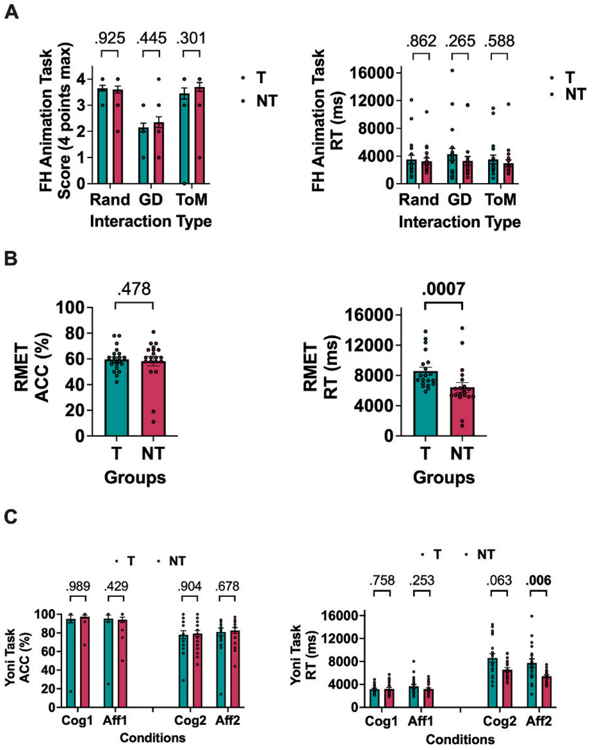

Fig. 4. Comparison between teacher and non-teacher groups in ToM tasks. Green and pink bars represent teachers (T) and non-teachers (NT) respectively. (A) Frith-Happé animation task: The average score and reaction time in milliseconds (ms) are presented on the y-axis, while the type of interaction (Rand: Random; GD: Goal-Directed; ToM: Theory of Mind) are indicated on the x-axis. (B) Reading the Mind in the Eyes task (RMET): The average accuracy percentage and reaction time are presented on the y-axis, while the groups are indicated on the x-axis. (C) Yoni task: The average accuracy percentage and reaction time are presented on the y-axis, while the conditions (Cog1 and Aff1: first-order cognitive and affective ToM; Cog2 and Aff2: second-order cognitive and affective ToM) are indicated on the x-axis. Circles show individual values. Error bar indicates SEM. The square brackets above the bars show the exact p-value. Bold p-values indicate statistically significant differences (p < .05).

both in ACC and RT were not found (ACC: $U = 170$, $p = .429$, $r_B = 0.150$, 95% CI = [−8.212e −5, 3.688e −5], $BF_{10} = 0.416$; RT: $U = 157$, $p = .253$, $r_B = 0.215$, 95% CI = [−257.7, 1004.5], $BF_{10} = 0.584$).

In the second-order cognitive condition, the mean ACC for the teachers groups was 78.05% (SE = 4.33) with a mean RT of 8602.63 ms (SE = 764.28), while the mean ACC for the control group was 79.30% (SE = 3.43) with a mean RT of 6552.60 ms (SE = 365.89). Statistical differences both in ACC and RT were not found (ACC: $U = 195.5$, $p = .904$, $r_B = 0.022$, 95% CI = [−12, 12], $BF_{10} = 0.318$; RT: $U = 131$, $p = .063$, $r_B = 0.345$, 95% CI = [−48.8, 3710.8], $BF_{10} = 1.094$). In the second-order affective condition, the mean ACC for the teachers groups was 81.10% (SE = 4.05) with a mean RT of 7729.52 ms (SE = 713.24), while the mean ACC for the control group was 82.65% (SE = 3.17) with a mean RT of 5420.72 ms (SE = 239.26). Two-tailed Mann-Whitney U test revealed that RT was significantly different between groups (RT: $U = 99$, $p = .006$, $r_B = 0.505$, 95% CI = [752.7, 3403], $BF_{10} = 3.584$). Differences in ACC were not found (ACC: $U = 184.5$, $p = .678$, $r_B = -0.078$, 95% CI = [−6, 5], $BF_{10} = 0.346$).

4. Discussion

The present study was designed to contrast the performance of expert teachers against a control group of non-teachers adults on tasks involving the use of shifting/cognitive flexibility, working memory, and executive control of attention, along with cognitive and affective ToM. Our results showed that expert teachers perform better than the control group on set shifting/cognitive flexibility, working memory tasks, and executive control of attention. In the case of cognitive and affective ToM skills, we found that although both groups are equally accurate in responding, expert teachers take longer to respond accurately to tasks that require performing complex affective inferences. Below we discuss the principal findings and their implications in more detail.

4.1. High performance of expert teachers in set shifting/cognitive flexibility, working memory, and executive control of attention

Behavioral data analysis revealed that, compared to the control group, expert teachers perform better on tasks that measure set shifting/cognitive flexibility, working memory, and executive control of attention. These results are in line with our hypotheses that proposed an advantage of the expert teachers over the control group in these cognitive processes. It follows from these findings that expert teachers would have a special facility to adapt their behavior quickly depending on the demands of the environment [73,74], a more refined mental workspace [75–77], along with efficient control of distracting stimuli that allows them to stay focused on the relevant aspects of the task [78,79]. Interestingly, previous studies have reported similar improvements in these cognitive processes in professionals working in activities that demand the constant use of a wealth of cognitive resources. For instance, de Freitas et al. [80] found that air traffic controllers perform above average in cognitive flexibility, strategic planning, and inhibitory control tasks. In a similar study, Causse et al. [81] measured executive functions of aircraft pilots and found that updating in working memory was predictive of flight performance and linked with weather-related decision-making relevance. On the other hand, Vaughan and Laborde [82] report that expert athletes performed better on tasks of attention, working memory control, and working memory capacity. Similarly, Medina and Barraza [83] found that expert professional pianists have more efficient executive control of attention than non-musicians. As for expert teachers, it is important to note that pedagogical practice is considered one of the most cognitively demanding jobs [84]. Based on the above, we propose that the extensive cognitive resources involved in expert teaching may contribute to improvements in set shifting/cognitive flexibility, working memory, and executive control of attention.

Additionally, these findings reveal another interesting point, namely, how the history of interactions between expert teachers and educational context not only refine the teaching behavior but also the cognitive processes necessary to sustain the practice of teaching in cognitively demanding social situations. This mutual determination between the development of cognitive processes and expert teaching practice can be exemplified as follows: in the classroom, expert teachers put into action a series of complex cognitive processes such as sustained attention to maintain the fluency of the discourse (attentional control), filtering irrelevant stimuli or distracting thoughts that could make them lose focus of what they want to teach (inhibitory process), keeping in mind what they were saying to integrate it with the new ideas they are presenting (working memory), efficiently shifting the focus of attention from the discourse itself to actively listening to their students' comments/questions and then responding coherently and returning to their discourse (cognitive flexibility), etc. Additionally, it is important to note that each of these cognitive processes is continuously required and integrated moment-by-moment during the course of the teaching activity. These and other experiences associated with the exercise of expert teaching seem to require efficient executive processes for optimal performance, which could be indicative of a process of "cross-fertilization" between long-term training of teaching behavior and refinement of executive processes [44].

Considering the high performance of professional teachers in tasks involving set shifting/cognitive flexibility, working memory, and executive control of attention, we hypothesized a possible transfer effect induced by long-term teaching training. However, in order to credit a transfer of learning, certain requirements must be met, such as that the trained and untrained skill share brain regions [85]. In the case of teaching behavior, there are no studies directly aimed at assessing the neural correlate of teaching. Nevertheless, there are studies showing the effects of pedagogical interactions on the teacher and student brain reporting involvement of prefrontal regions [40,41,43] and the temporoparietal junction [42] when teaching effectively. As for the set shifting/cognitive flexibility, working memory, and executive control of attention, the literature reports that these processes involve the action of prefrontal neural networks, including the dorsolateral prefrontal cortex, the inferior frontal gyrus, the ventrolateral prefrontal cortex, and the orbitofrontal cortex [36]. Taken together, these findings highlight the prefrontal networks as sensitive to effective teaching behavior, and also as a key brain region for the executive processes. Thus, we propose the dorsolateral prefrontal cortex (working memory/executive control), the ventrolateral prefrontal cortex (set shifting/cognitive flexibility), and the orbitofrontal cortex (working memory/executive control) as potential shared brain regions between expert teaching and the executive processes, adding one more data in support of the hypothesis of a transfer effect of the long-term teaching training over the efficiency of the executive processes. Lastly, the observation that cognitive processes such as shifting/cognitive flexibility, working memory and executive control of attention exhibit higher efficiency in professional teachers compared to non-teachers is an encouraging discovery. This could potentially indicate the transfer of learning resulting from extensive teaching training over the long term. However, it's crucial to emphasize that we cannot deduce causation from the current study due to its cross-sectional nature. Future research with experimental designs should directly address this hypothesis.

4.2. *Expert teachers display slower response times when making complex affective inferences*

Regarding the performance of expert teachers in cognitive and affective ToM, we found that the ability to make accurate inferences regarding the mental states of others was similar to the control group. These results contradict our hypothesis about the advantage that expert teachers would have over non-teachers in ToM tasks. Now, it is important to take into consideration that this absence of differences can be explained by the low sensitivity that tests to measure mentalizing skills have when comparing neurotypical populations. As Turner and Felisberti [62] state, empirical ToM research has focused primarily on children, autism spectrum disorder groups, and clinical samples. However, many of the standard tasks used in these studies often achieve peak effects when applied to neurologically typical adults. Being aware of this issue, in this study we selected ToM tasks that had been reported to be sensitive to variations in neurotypical adults [62]. Although we took this point into consideration when selecting our tasks, we did not observe differences in response accuracy between groups. With this in mind, we suggest that future research should innovate the way that ToM is measured in professional teachers and control groups. For example, it would be interesting to measure cognitive and affective ToM in teachers with more complex and naturalistic procedures, either by analyzing the quality of the inferences made by the teacher regarding the student's mental state after a brief pedagogical interaction [86] or in a similar situation but programmed in a virtual reality environment [87].

In contrast to the findings linked to response accuracy, we found marked differences in response times between the two groups in high-order affective ToM tasks. Specifically, we found that expert teachers displayed significantly longer response times than the control group when performing tasks requiring complex affective inferences. Strikingly, the difference was not a few milliseconds, but nearly to 2 s. This notorious difference leads us to think that it is not a simple delay in the response, but seems to be the expression of different ways of responding to situations that demand high-order affective ToM processes. In this line, there are proposals such as that of Apperly and Butterfill [88] suggesting that humans would have two systems for making inferences concerning the mental state of others, one cognitively efficient but limited and inflexible and the other highly flexible but cognitively demanding. One could speculate that the latter would be a process requiring conscious evaluation, which would trigger the emergence of a mental global workspace [89], hence slower responses, while the former would be an automatic and implicit process [90], which would be associated with faster responses. Although interesting, the idea of dual models of ToM processing has been criticized. For instance, Heyes [91] states that implicit mentalization is only the result of submentalization processes, a domain-general cognitive mechanism simulating the effects of mentalization in social contexts. Similarly, Carruthers [92,93] proposes that the mentalizing process involves a single system operating in a more or less conscious way depending on task demands. A similar idea can be found in the work of Cunningham and Zelazo [94,95], who suggest an iterative processing model for the evaluation of social situations. From this model, the distinction between more and less conscious processes is not based on different processing paths, but on the number of times that the same system iterates until reaching an evaluation or response. Thus, if the system performs a few iterations to reach an evaluation, then the process would be more automatic, while if the system increases the number of iterations in an evaluative cycle, then this will trigger more conscious and reflective monitoring processes. From a critical point of view, both the dual model and the iterative model provide valuable insights into understanding how subjects make inferences about the mental state of others. The dual model provides a straightforward framework for understanding the cognitive processes involved in ToM, yet oversimplifies the complex nature of ToM. In contrast, the iterative model stands out for it emphasizes the dynamic nature of the mentalizing processes, but further empirical research and clarification of its complex processes are needed to validate and refine this model.

Regarding expert teachers and their prolonged response time in high-order affective ToM tasks, we hypothesize that, during this type of task, teachers do more than just process the stimulus content and respond. We think that, unlike the control group, expert teachers engage in complex cycles of active-empathic perception [96–98], which would translate into slower, but better elaborated responses. Following the proposal of Cunningham and Zelazo [94,95], entering into active-empathic perception cycles would increase the number of iterations the system requires to reach a response. This effort to actively and empathically read the experience of the other would decrease the speed of response but would gain in terms of the quality of the response delivered. Our hypothesis finds support in the teaching brain model proposed by Rodriguez [48,49], which states that the answers delivered by an expert teacher are neither automatic nor solely based on the learner's perspective. They are the result of a sophisticated theory of the learner's mind and multiple meta-processes of the teacher's self. In other words, we suggest that the speed of an expert teacher's response to situations involving the elaboration of complex affective inferences would be a reflection of the way they act in similar situations in the educational context, where a slower but more emphatically elaborated response is more desirable than a quick response without empathic connection. Nevertheless, it is important to recognize that these interpretations are speculative and other factors may also be at play. For example, the similarity in the accuracy of expert teachers and control group in high-order affective ToM tasks would suggest that both have similar levels of understanding of the affective mental states of others. However, the longer response times of teachers would be explained by the fact that due to their professional training, they could be more prepared to make cognitive inferences about the learner's mind, which could induce a lack of familiarity with tasks that require making complex affective inferences, potentially leading them to use more cognitive resources to respond accurately, therefore slower in responding. Future research with experimental designs should directly address these hypotheses.

Finally, it should also be noted that this study has some limitations which are indicated below: i) Sample size: although the sample size of this study is similar to other research comparing expert subjects versus control group [99–102], we believe it is necessary to increase the sample size in future studies, which would undoubtedly improve the accuracy, statistical power, generalizability, and reliability of research findings; ii) Remote data collection: this method of data collection had advantages and disadvantages. On the one hand, it gives flexibility for data recording and improves the ecological validity of the study, but at the same time, it decreases the control of potential intervening variables that could affect the comparability of the data. However, we believe that we were able to counteract this potential adverse effect by taking several measures such as standardizing task instructions and strict instructions regarding the environmental/contextual conditions for performing the tasks, as well as selecting cognitive tasks with high attentional demand that ensure constant engagement of the subject to the task. However, we suggest that future studies be conducted under controlled laboratory conditions to achieve better management of potential intervening variables; iii) The selected cognitive tasks: Both EFs and ToM are multifaceted cognitive processes that certainly cannot be measured with a single cognitive task. Therefore, we selected six cognitive tasks widely used in cognitive science for the assessment of different aspects of EFs and ToM. With the selected tasks, we were able to assess set shifting, visual working memory, executive control of visual attention, and cognitive/affective ToM. Yet, several aspects of these cognitive processes remain to be assessed. For instance, other dimensions of cognitive flexibility, working memory, inhibitory processes, and mentalizing skills could be assessed with tests such as the Verbal Fluency Test, the Backward Digit Span, the Stroop task, and the Director task, respectively.

In conclusion, this study shows that professional teachers have superior cognitive skills in key areas such as set shifting/cognitive flexibility, working memory, and executive control of attention. These skills are critical to their performance in the educational environment and allow them to efficiently adapt to changing classroom needs. However, professional teachers are slower in responding precisely to tasks involving complex affective inference. Although their accuracy on these tasks does not differ from the control group, the difference in reaction time suggests that experienced teachers may need more cognitive resources to adequately process and understand emotional and affective aspects. These findings underscore the need for a comprehensive approach to teacher training and support that encompasses both cognitive skills and understanding and responding effectively to the emotional aspects of classroom interaction. Professional development programs that address these specific areas can help teachers strengthen their ability to effectively interpret and respond to students' emotional states, which in turn contributes to a more enriching and emotionally safe learning environment.

Author contribution statement

Paulo Barraza; Eugenio Rodriguez: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data will be made available on request.

Declaration of competing interest

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

Acknowledgements

This work was supported by grants FONDECYT 1201443 and PIA-CONICYT Basal Funds for Centers of Excellence Project FB0003. We are grateful to Robinson Lira from the Center for Improvement, Experimentation and Pedagogical Research (CPEIP) of the Ministry of Education of Chile, for his support in managing contact with expert teachers, Ivo Leiva for assistance in programming cognitive tasks and Paloma Carreño for assistance in recruiting control group participants.

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