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The Teaching Instinct

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Abstract Teaching allows human culture to exist and to develop. Despite its significance, it has not been studied in depth by the cognitive neurosciences. Here we propose two hypotheses to boost the claim that teaching is a human instinct, and to expand our understanding of how teaching occurs as a dynamic bi-directional relation within the teacher-learner dyad. First, we explore how children naturally use ostensive communication when teaching; allowing them to be set in the emitter side of natural pedagogy. Then, we hypothesize that the capacity to teach may precede to even have a mature metacognition and, we argue that a teacher will benefit from the interaction with her student, improving her understanding on both contents of knowledge: her own and her student's. Thus, we propose that teaching may be the driving force of metacognitive development and may be occurring as an instinct from very early ages.

1 Both sides of Natural Pedagogy's equation

Children participate in several cultural activities that are structured by adults and serve as learning experiences. These learning instances do not only occur in traditional educational settings; for instance, in classrooms guided by a teacher; they are also present all along the children's life. Therefore, everyday activities are moments of potential learning. On example could be guided participation activities: collaboratively preparing a grocery shopping list before going to the supermarket, could potentially become a situation in which a child learns to read, or acquire new vocabulary, or planning skills. Likewise, even a simple conversation between an adult and a child or between two children may present children with the opportunity to review how

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questions and answers' structures work or to learn how to take turns, giving them, also, the possibility to exercise executive functions and to engage in selective attention.

The quantity and the quality of new information that children could incorporate from these learning situations differ depending on the communication signals used by the adult in charge of the activity. In particular, *ostensive cues* have a mayor leading role in establishing a relevant dialogue (Gergely and Csibra 2005; Tan and Schafer 2005; Yoon et al. 2008; Wu and Kirkham 2010; Wu et al. 2014). Ostension boosts learning when is part of this transmission and rules these interactions (Csibra 2010; Gergely and Csibra 2003; Gergely et al. 2007). In this respect, the *natural pedagogy theory* has proposed that human communication using ostensive cues is adapted to transmit knowledge which is hard to acquire by pure observation. This adaptation results, then, in a communicative system tailored for fast and efficient transfer of new and relevant information from knowledgeable to unknowledgeable interlocutors (Gergely and Csibra 2005). Since infancy, children are sensitive to this specific communication protocol, allowing, for example, the emergence of triadic interactions between adults and infants about novel elements they jointly attend to (Gergely et al. 2007; Csibra and Gergely 2009).

One major concern regarding this description of pedagogy is that, inevitably, it always positions children at the receptive side during knowledge transfer. This theory implicitly builds on a clear directionality between who is teaching, an adult, and who is learning, the child.

But are children mere recipients of knowledge or can children be the transferers and not the transferred to? This puzzle raises the question of whether a child has intuitions about the optimal channels to convey cognitively opaque information to their interlocutors. Here, we outline our first hypothesis: Children can use ostensive cues to communicate relevant information; they can be the teachers in the equation. In fact, teaching may emerge at very early ages as an instinct, to establish a channel of communication that will eventually not only benefit the interlocutor but also the child. This would mean that children could also be set in the emitter side of *natural pedagogy*. Hence, natural pedagogy becomes a much more complex equation; which not only describes and establishes a theory about how humans learn throughout development, but may also be expanded to study and explain how we teach.

2 The Natural Cognitive Ability

Teaching is proposed to be *a natural cognitive ability*, acquired at an early age without any apparent instruction (for a review, Strauss and Ziv 2012). This theory was grounded in three major claims: First, teaching strategies appear to be developmentally reliable, which would indicate that they follow a similar developmental path among children from different social environments. Accordingly, several findings suggest a developmental trajectory from one year of age through adulthood (Wood et al. 1995; Ashley and Tomasello 1998; Strauss et al. 2002; Liszkowski et al. 2006, 2008; Akagi 2012; Bensalah et al. 2012; Mevorach and Strauss 2012). During toddlerhood and early childhood, children's teaching relies on demonstration, mainly through non-verbal communication. For older children, teaching involves more complex strategies, explanation and demonstrations, which are based mostly on speech (Strauss and Ziv 2012; Strauss et al. 2002; Calero et al. 2015). In addition to changes in strategies, between 5

and 7 years of age children present a higher understanding in relation to their pupil's mistakes and respond accordingly (Wood et al. 1995; Strauss et al. 2002).

Second, teaching seems to be a universal human achievement. On the one hand, this suggests that it is a general feature of mankind, meaning that every person in the world is a potential teacher. On the other hand, and perhaps even more interesting, is the fact that if teaching occurs all around, all human beings are regularly and constantly exposed to teaching (Strauss and Ziv 2012).

Finally, the last major claim of this theory is that human teaching working with theory of mind (ToM) may be a species-unique characteristic (Strauss and Ziv 2012). Meaning that only nonhuman animals may teach without a ToM. The importance of ToM for human teaching will be discussed in detail in the last sections of this manuscript; particularly, because teaching appears to emerge before toddlerhood despite the low performance that children show at these ages in classical ToM tasks (Bensalah et al. 2012; Davis-Unger and Carlson 2008a, b; Strauss et al. 2002). In fact, during the preschool period, children begin to understand teaching situations, and their own possibilities to perform as teachers and learners, whatever the status of the adult, or the child, with which they have to interact with in a given paradigm (Bensalah et al. 2012; Calero et al. 2015). Nevertheless, toddlers' performance in false belief tasks progresses during this stage of development but does not mature until much later. This data enables us to raise the question of whether ToM is relevant to teach, or if teaching is significant to develop a mature ToM.

The literature listed so far describes teaching as an activity which comprises either children conveying *episodic* knowledge, or *generic and generalizable* knowledge. These differences in the content of knowledge taught by children led some authors to call these transfers of information *proto-teaching,* and *(true) teaching activities*, respectively. Regardless of the name, since infancy, children can recognize a knowledge gap between two persons and engage in an activity, namely (proto)teaching, which when finished, will allow both parts to have similar contents of knowledge. This ability of very young children to engage in complex social behaviors, such as recognition of a knowledge gap, at the same time that they fail critical tests of belief reasoning, like false belief tasks, has been described before. Seemingly, infants may pass through a state of mindreading quite implicit and even 'automatic', cognitively efficient but unable to track belief states in others (Onishi and Baillargeon 2005; Apperly and Butterfill 2009; Heyes and Frith 2014).

Proto-teaching's scenarios both suggest that children are not just copying a situation experienced before, and that they are acting spontaneously. In these cases, *children teach*, through demonstrations, hidden properties or aspects of the elements without any previous instruction on how to do it, meaning that they are not just copying the actions that someone has taught them before, or behaviors previously observed. Preverbally, these expressions occur as gestures which convey relevant data to solve a task. Moreover, children spontaneously provide relevant information to others, not because of a request, but to inform an adult about something that is opaque to them. For example, children can tell adults, without being asked to, about the location of an object they were looking for and was moved without the adult knowing (Liszkowski et al. 2006, 2008).

Similar to emulation learning, in which a novel action is different from the behavior previously observed but with the same outcome (Gergely and Csibra 2006), *(proto)teaching* may not be an infant's use of '*blind*' imitation to spread and transmit

relevant information, but a vehicle to inform what seems to be opaque to the interlocutor. This entails that through pedagogy, children would be able to transfer opaque knowledge fast and efficiently. Moreover, if in fact children can teach maintaining a 'cultural faithful transmission' and use properly the cues to do so; this would strongly support the idea that children *use ostensive cues* not only to learn knowledge that is generalizable and relevant, but also to brand it as such.

Blind imitation has been described as a '*wasteful and error-prone social transmission process'* (Gergely and Csibra 2006), because the lack of any proof correction mechanism may lead to an erroneous maintenance of cultural information. For this reason, we proposed that children are not 'blind imitating' and acting solely by requests when they teach. Nevertheless, we can't rule out completely that children may be in part using what they may have experienced or learnt in the past when they teach. However, from a cognitive perspective, even if they are partially using their previous experiences from when they were at the receiving side of the equation, this will still be interesting. Because, even if they are 'somehow imitating', it will require that children engage in a change of perspective and switch from learner to teacher at very early ages (Strauss et al. 2014). Moreover, by doing so, they contribute to what has been proposed before as the main purpose of teaching; a vehicle to efficiently transmit information within and across generations (for a review Kline 2015).

3 Little Teachers

In an effort to examine the hypothesis that *teaching is an instinct to humans*, a recent study examined whether children may ostensively communicate relevant information to others by combining the theories of teaching as natural cognitive ability and natural pedagogy. Namely, the authors investigated if children can teach using ostensive cues (Calero et al. 2015). Particularly, the goal was to begin to explore whether children can be at the emitter side of the natural pedagogy equation. Through a relatively simple experimental setup, the conditions were created in order for children to switch from students to teachers. This basic protocol included four steps: First, children learned the rules and how to play an inference game from an adult teacher who told them that in order to win the game they had to find the sneezer flower. During the second step, the adult presented the child with two color flowers, one made a monkey sneeze, and the other did not. Both flowers were presented separated and together to the puppet three times, and then, the child had to choose, base on her inference, the flower that made a monkey puppet sneeze. Being an easy game, all children passed these steps and entered the third one; in which, a second 'naïve' adult appeared in the room to play. The adult teacher presented to the new (adult) student the same game, rules and played with two different color flowers. Children observed this person play. She would make a mistake when choosing the flower. The adult student picked the flower that didn't make the monkey sneeze, and she would lose. After this incorrect decision, the first experimenter left the room with the excuse of looking for more flowers to play. This is critical for the paradigm to work, each child learned and played the game correctly, and now, they had witnessed somebody else making a mistake. They had the 'correct' content of knowledge while this second person did not and, by removing the first adult (teacher) from the scenario, they were set in a context in which they could decide to communicate the

rules to the unknowledgeable interlocutor, to teach or not to teach. This set up allowed children to be in a new and significant position, they could switch from students to teachers. As predicted, since the age of 3 years old, children became significantly more ostensive in moments which had pedagogical relevance; they used ostensive cues while teaching the correct rules to win the game, establishing eye-contact, raising the eyebrows and speaking with a different pitch and prosody (Calero et al. 2015).

Interestingly, even though all participants were capable of teaching, their use of ostension presented different patterns depending on the age (Calero et al. 2015). During early childhood (3 to 5 years old), children sustained the ostensive channel during the entire pedagogical episode. They engaged specially in eye-contact, and maintained it, whenever they were discussing 'relevant' information. This behavior was properly quantified in the study; children looked at the second experimenter during the whole teaching episode, and kept looking at her until it finished (Calero et al. 2015). Development allowed older children (6 to 8 years old) to be able to teach their interlocutors using a much more complex set of abilities. If we consider ostensive cues along with speech and gestures, as *instruments* that children may use to convey information, then, older children showed a refined pattern of orchestration. In the same way that when playing a symphony, the musicians use their instruments coordinate and harmonically; 6 to 8 years old children combined simultaneously referential gestures, ostension and speech in order to teach. At these ages, instead of locking in eye-contact with the adult for the entire pedagogical episode, they used it as a check point to verify whether the second adult 'followed' their teaching or not. For example, a child would talk and describe the rules and the elements present in the game and, at the end of this explanation, she would look up to her student (the second experimenter), like checking in with the pupil, to then continue with the next part of the explanation, or, she would point to where the flowers used to be (the position of the elements was always the same but they were removed after playing) and then, she would engage in eye-contact with the pupil. This older group showed a more refined use of the different channels of communication during teaching episodes. Moreover, when they were exposed to a modified learning experience, which for example, included a minimized use of ostension and gesturing by the adult teacher, these children would adjust their own teaching in order to correct the shortcomings from their adult teachers. Children's response was not to imitate the first adult when they had to transfer information. Instead, children increased the use of both ostension and gestures during the pedagogical events (Calero et al. 2015). This change and subsequent boost during teaching strongly suggest that children are not imitating what they have just learnt or experienced, but they are emulating it. Our proposition here is that children do not only seem to understand what the 'relevant' parts are, but also the 'correct use' of the channels needed to pass that information. The latter suggests that *children seem to have intuitions on how to transmit relevant information efficiently* from very early ages. When presented with the possibility, children were able to position themselves in the emitter side of the natural pedagogy equation: *Children changed perspectives and switched from learner to teacher*.

At this point, we can only hypothesize whether these adjustments and characteristics of teaching during early and middle childhood are the product of nature or social interaction. More likely, they are the combination of both. Even if teaching is a natural cognitive ability, it must be shaped by social interactions. In this way, the combination of 'genetics plus environment' allows this human instinct to emerge. The answer to this hypothesis will require much more research to be done in the future. One possible

direction could be to explore how teaching develops in populations with non-typically developed social cognition (Akagi 2012; Lucchina et al. 2017). Deficits in social communication are an evident clinical feature, for example, in subjects within the autism spectrum disorder (ASD) (Boyd et al. 2007; Nadig et al. 2010). Some reports suggest that, when proto-teaching is explored in this population, ASD children may be able to (proto)teach but that the developmental age of occurrence is delayed when compared with typically developing children (Akagi 2012).

Another interesting group to examine the influence of social interactions in teaching would be children who cannot fully extract the relevant information from the environment, for example, because the channels in which they receive information are somehow compromised. Children who are born deaf in hearing families (Lucchina et al. 2017) or blind in not blind families may present an interesting scenario to these questions.

4 Teaching as a Key Block for Cognitive Development

So far, we have discussed teaching as a natural and spontaneous activity, a human instinct and, moreover, that children can teach optimally using different channels of communication. Our second main hypothesis is that teaching supports the maturation of other cognitive abilities. In fact, *teaching may be acting as a catalyzer* for executive functions, theory of mind, and metacognition to develop. Which, once developed, would support the emergence of more refined and tailored teaching abilities, working as a *virtuous cycle*.

A relationship between the development of executive functions (EFs) and teaching has been suggested before (Davis-Unger and Carlson 2008b; Corriveau et al. 2017). EFs refer to a class of processes critical for purposeful, goal-directed behavior, including working memory, planning, and cognitive control (Diamond 2013; Jurado and Rosselli 2007). Considering in particular that Working Memory refers to holding information in mind and operating with it. It is an essential capability for reasoning and understanding concepts, for the organization of information, and for the proper use of conceptual knowledge for making decisions and future plans. Planning also covers the ability to identify and organize the steps and elements needed to achieve a predefined goal, which allows for decision-making, correction of errors, overcoming technical difficulties, among others. Moreover, Cognitive Control involves the capability to control one's attention and behavior to react in the more appropriate way. It is the capability to control impulses. As any teacher might know, all those examples are daily used in the classroom. But, although the recruitment of EFs for most other complex tasks has been largely proven (Follmer 2017; Mischel et al. 2010; Viterbori et al. 2015; Goldin et al. 2014), there is little evidence for a clear association between the development of EFs and the quality of teaching (Davis-Unger and Carlson 2008b).

The connection between *theory of mind* and *teaching* has been suggested before (Strauss et al. 2002; Kruger and Tomasello 1996). Knowing that other people are mental agents with thoughts of their own appeared to be a precondition for teaching (Strauss et al. 2002; Ziv and Frye 2004; Davis-Unger and Carlson 2008a, b; Kruger and Tomasello 1996). Thus in order to teach, the tutor 'would need an *online connection*' with the pupil. The core of this assumption is that teaching is intentional and aimed at bringing the knowledge level of another person in line with one's own. Therefore, for teaching to occur, the teacher must recognize a knowledge asymmetry between herself

and the learner, which could not happen without fully understanding the mental state of the pupil. This hypothesis was strongly supported by the proposition that teaching is possible *only* when a lack of knowledge can be explicitly recognized by the teacher (Olson and Bruner 1996).

Nonetheless, (proto)teaching may occur by the age of 12 months, when children may present an early inferential principle, referred as the 'teleological stance' (Gergely and Csibra 2003), which will develop to guide inferences about mental states, but not a fully developed ToM. Hence, infants can detect information that is relevant to an adult, and provide that information communicatively through gestures (Liszkowski et al. 2006, 2008). But, even when they deliver this knowledge, most likely, 12-month-olds can't establish an '*online connection*' with their interlocutor. This interaction between children and adults may present a unique scenario and, by correcting and guiding the adult's behavior, infants may begin to train that connection.

In terms of peer cooperation activities, 3-year-old children, who typically do not pass explicit false belief tasks, show a few signs of appreciating that their partner had a different role or a naïve perspective in the task, and even, make some adjustments in their behavior and language when teaching to their less knowledgeable interlocutors (Ashley and Tomasello 1998). By 3.5 years old, children are competent enough to change their behavior accordingly during teaching episodes. For example, they engage in more coordinated attempts with their partners to complete a cooperation task. However, they still do not pass the ToM tasks, even if they show Level 2 perspective taking skills (Ashley and Tomasello 1998).

In set ups in which teaching is part of the paradigm, and not a possible outcome of a cooperation task, all 3-year-olds who were presented with the possibility to switch from students to teachers, chose to teach. In fact, they were able to ostensively teach causal events to their adult pupils (Calero et al. 2015), even without a fully developed ToM.

The interaction between teaching and ToM can perhaps be described in terms of a functionalist definition of teaching. According to this view, teaching is guided by behavioral outcomes, providing opaque information to the interlocutor, and not by the understanding of the teacher of the student's mental state (Csibra and Gergely 2006; Kline 2015). Accordingly, one possibility is that, from infancy, humans start teaching as if it was an instinct, considering only partially their pupil's content of knowledge. If this was the case, then, children would teach indiscriminately to two very different interlocutors; an expert, who '*knew how to play the game*' and another, with a naïve perspective, who '*had never seen the game before*'. Even when 3-year-olds recognized the knowledge gap between the two interlocutors, they would teach both, the knowledgeable and the unknowledgeable one (Corriveau et al. 2017). This would suggest that 3-year-olds' decision to teach is not only motivated by understanding of their pupils' mental state, nor by their intentionality to close that knowledge gap. Moreover, in particular conditions, children selectively transferred information favoring the knowledgeable over the unknowledgeable interlocutor (Kim et al. 2016).

Altogether, we hypothesize that teaching precedes Theory of Mind and may provide an experience to consolidate it. Moreover, this enhancement towards the development of a full ToM may have an impact on the system(s) that children may use for belief reasoning since infancy. Teaching may be a suitable platform for the shift from a rudimentary but cognitively efficient belief system, towards another that is flexible but more demanding (Apperly and Butterfill 2009).

These ideas are in agreement with what has been argued before: '*teaching may be a driving force for the development of mental capacities*' (Csibra and Gergely 2006, 2009, 2011). But in addition, we propose that teaching should be understood as a complex *natural pedagogy's equation*, a process that facilitates sharing of new generalizable knowledge from adults to children and also, from children to adults (or to other children). This reframing of *natural pedagogy* enables children to move from solely observing and receiving information; towards a position in which they could also make productive inferences about unseen aspects of their context, namely, learn about the mental state of the interlocutors. They could then use that new understanding, not only to transfer data, but also to improve their own self-awareness about that information.

The functionalist definition of teaching separates itself from the mentalistic description, in which the development of the ability to understand mental representations is required. However, it does suggest that metacognition is a prerequisite to teach (Csibra and Gergely 2006; Davis-Unger and Carlson 2008a, b). Certainly, a possible role of metacognition in teaching could be related to the importance of metacognitive awareness during this activity (Karmiloff-Smith 1985; Gourgey 1998; Schraw 1998). Nevertheless, and without questioning the importance of metacognitive awareness for teaching once it is developed, we hypothesize that teaching may be a catalyst for metacognitive development as well. Namely, as described before for ToM, teaching may precede and help procure a better metacognition: A (deliberate) examination of one's own content of knowledge has a significant impact in the development of our metacognitive processes. We then propose that this active review happens before and during a teaching activity.

We revisit Seneca's intuition *docendo discimus* (when we teach, we learn) for the genesis of knowledge. Hence, the act of teaching may compel children, or adults, to make information, an idea, or even a belief, explicit. Consequently, we propose that teaching would force human beings to re-evaluate and understand significantly more their own content knowledge.

The evaluation of our hypothesis might introduce a challenge, though. Inferences about children's knowledge are prone to errors when they rely on a single measurement because they may reflect limitations of the channel used to express knowledge (Franchak and Adolph 2012). Therefore, exploring this hypothesis will require simultaneous measures of children's objective performance, explicit reports (metacognitive) and the content of teaching (communicated knowledge). By doing so, we will be able to learn how these elements of cognition synergize during development. One possible paradigm should examine, for example, the content of knowledge that children explicit during their role as students and teachers, at the same time that metacognition is independently being measured. By exploring children's behavior when they *justify* their decisions to a knowledgeable interlocutor and when they *teach* the same concepts to an unknowledgeable interlocutor, we will be able to evaluate an 'aloud' revision of their content of knowledge in these scenarios.

5 Children Teaching Children

The hypothesis that teaching may precede having a complete ToM and metacognition, and that it may also contribute to the development of these cognitive abilities brings

with it new possibilities. In this regard, peer tutoring may be an activity that will not only help students as an effective intervention by facilitating their academic growth (For a review Bowman-Perrott et al. 2013; Topping 2015), but it would also benefit the teacher (Dineen et al. 1977; Baron-Cohen 1991; Roscoe and Chi 2007; Topping 2015).

From the student's point of view, the importance of metacognitive monitoring and regulation, in cases where self-regulated learning and judgment of learning are involved, has been discussed extensively (Lockl and Schneider 2002; Koenig and Harris 2005; Metcalfe 2009; Koriat and Ackerman 2010; Krebs and Roebers 2010; Metcalfe and Finn 2013). Both metacognitive monitoring and control have been described as essential for studying for an exam, thinking on the progress toward learning, or selectively knowing what, when or how much to study, among others (Efklides 2008; De Backer et al. 2012). Also from a student's perspective, the importance of teachers modelling their own thought process was explicitely linked to students' improving their understanding, given that having a more competent teacher or partner is not a sufficient condition for cognitive growth to occur, but it is also important for children to be exposed to a higher level of reasoning (Schraw 1998; Hogan and Tudge 1999; Topping 2015). The more teachers model cognitive and metacognitive skills for their students, the more likely it is that their pupils would develop those skills (Butler and Winne 1995). Interestingly, this improvement appears when the role of teachers is assumed by both adults and children. Furthermore, the effectiveness of the 'modelling' in many situations has a better impact when children's models are presented rather than the one from adult teachers (Schunk 1989). This occurs because students seem to be able to model their cognitive and metacognitive processes in a simpler style, and they are able to provide a more powerful rationale for these skills within the student's zone of proximal development, compared to teachers. Therefore, looking to this side of the equation, there is a positive link between peer-tutoring and metacognition.

Additionally, we argue that the teacher will also gain from the process of peer tutoring. When undergraduates were asked to study verbal material to learn it for themselves, they performed significantly lower on a subsequent retention test than students who studied thinking that they would have to teach that same material to another person (Bargh and Schul 1980). We propose that these differences in performance may be the result of a different improvement in their understanding of their own content of knowledge. The simple proposition of a 'future switch' into teachers could have induced a significant change in the way these students review, study, and understand the material.

Peer interactions can be described as one of many child's guided activities (in agreement with Piaget 1932). Therefore, these interactions may play an important role in children's metacognitive and ToM development. Moreover, this may imply that the developmental outcome from these endeavors may be present from infancy. Children's ability to engage in joint attention activities, for example, which involve shared goals and intentions, and socially coordinated actions with others, could shape the aforementioned cognitive abilities (Baron-Cohen 1991; Charman et al. 2000; Tomasello et al. 2005). Although few, there have been examples showing that during middle childhood, children advance more in their understanding of a problem when they attempt to solve it with a peer than when they try to solve it by themselves (Ashley and Tomasello 1998; Roscoe and Chi 2007; Topping 2015).

Altogether, these observations could have a significant impact on the possible role of student's teachers at educational settings; reinforcing the implementation of peer tutoring

programs or including the possibility of students switching to the role of teachers, not only to obtain an improvement in school performance, but also, to impact on the development of these two important cognitive abilities, metacognition and theory of mind.

6 Final Remarks

The evaluation of the hypotheses that *teaching is an instinct to humans,* and that *the capacity to teach precedes having a complete development of metacognition and theory of mind* will allow a higher understanding of how teaching abilities develop and interacts with other cognitive abilities. In turn, this could have a direct and significant impact on the educational community, by having possible implications on the '*teacher effect*' (Pasquinelli et al. 2015); and '*learning-by-teaching*' mechanisms of action (Duran 2017).

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