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Cognitive Mechanisms Associated with Children's Selective Teaching

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Abstract Whereas a large body of research has focused on the development of children as learners, relatively little research has focused on the development of children as teachers. Moreover, even less research has focused on the potential cognitive mechanisms associated with high-quality teaching. Here, we review evidence that children's selective teaching is associated with at least three cognitive skills: the ability to represent mental states, the ability to infer mental states in real-time (i.e., what a pupil knows based on his or her behavior), as well as executive function skills. We note potential cultural differences in children's teaching and highlight the need for future research.

1 Introduction

A large body of research has shown that even before children enter formal schooling, they are not indiscriminate when learning from others (Harris and Corriveau 2011; Harris 2012). Faced with the decision to learn from teachers who make conflicting claims, children choose to accept information from a teacher who has been accurate rather than inaccurate in that domain in the past (Birch et al. 2008; Corriveau and Harris 2009a; Fusaro et al. 2011; Koenig and Harris 2005; Sobel and Corriveau 2010). They also attend to social cues about the informant, preferring to learn from an individual who is familiar to them (Corriveau and Harris 2009b; Corriveau et al. 2009a; b), a member of their social in-group (Corriveau et al. 2013; Kinzler et al. 2011; Jaswal and Neely 2006), and from someone who provides claims that are met with consensus (Chen et al. 2013; Corriveau et al. 2009a; b; Fusaro and Harris 2008). Moreover,

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children make inferences about an informant's competence based on the quality of the informant's information (preferring an informant who makes non-circular claims: Corriveau and Kurkul 2014; Mercier et al. 2014) and the manner in which the information is delivered (preferring an informant who speaks in the passive voice, and is confident: Corriveau et al. 2017; Sabbagh and Baldwin 2001). Taken together, these data suggest that children are highly selective when deciding which type of individual makes a good teacher.

Somewhat surprisingly, although much attention has focused on children's ability to evaluate the qualities of their teachers and their ability to recognize pedagogical interactions (Csibra and Gergely 2009; 2011), relatively less attention has been paid to the reverse relation: namely, children's ability to evaluate the qualities of the learner when deciding whether and how to engage in the teaching process (e.g. Strauss and Ziv 2012; Kline 2015). Understanding how children develop as teachers is important for both theoretical and practical reasons. Our teaching abilities greatly exceed the ability of other animals thought to engage in teaching (for a review see Thornton and Raihani 2008) and are implicated in human's extraordinary ability to engage in cumulative culture – the ability to transmit and refine knowledge over time (Dean et al. 2012). Thus, understanding how children develop as teachers and the cognitive mechanisms underlying this ability increases our understanding of cumulative culture. Secondly, children's understanding of teaching is related to their ability to reason about their teachers' pedagogical decisions. Learning from a teacher requires thinking about the teacher's selection of evidence (i.e., why the teacher provided this particular piece of information rather than other pieces of information; Shafto et al. 2014). Thus, studying children's development as teachers sheds light on their developments as learners. Finally, peer tutoring is frequently used in schools to support learning (Slavin 2015). However, the efficacy of peer tutoring depends on children's teaching abilities (Roscoe and Chi 2008). Thus, understanding how children develop as teachers may help improve children's teaching and, as a result, improve the benefits of peer tutoring.

Children begin to teach each other spontaneously from an early age (Strauss et al. 2002). At home, they teach their siblings, and at school, they teach their peers (Ashley and Tomasello 1998; Howe and Recchia 2009; Slavin 2015). Such teaching (e.g., peer tutoring) has been shown to be an effective instructional strategy in elementary schools (Kamps et al. 1994; Fantuzzo and Ginsburg-Block 1998). Despite the ubiquitous nature of children as teachers, the cognitive mechanisms associated with this communicative act are largely unknown.

In the current manuscript, we highlight the developmental trajectory of selective teaching in early childhood, and focus on three cognitive skills we believe are necessary for selective teaching: an understanding of mental states, the ability to infer knowledge from the learner's actions, and executive function skills. We offer insight into these topics through various lines of research conducted across multiple laboratories.

2 The Development of Children's Understanding of, and Engagement in, Teaching

Imagine that you are playing a game for the first time with two friends. One friend appropriately rolls the dice and moves her piece forward, according to the rules. The

other friend rolls the dice, but moves her piece in the incorrect direction. What do you do? Do you teach both friends the rules, or focus on teaching just one of the friends? It is likely that you would suggest focusing your efforts on friend #2. Based on her mistake, you recognize that there is a gap in knowledge between the two of you, and you teach in order to reduce that gap. An indiscriminate approach to teaching would mean that you were constantly correcting individuals who knew as much – or perhaps more - about a particular domain as you do. Young children do not start out as indiscriminate teachers. Nevertheless, their understanding of, and ability to engage in teaching that is efficient and responsive to their pupil's knowledge develops rapidly during the preschool years (see Strauss and Ziv 2012 for a review).

Children's *understanding* of teaching develops between ages three and five. Three-year-old children understand that teaching is directed at naïve learners and that being knowledgeable rather than being older or labelled as a teacher determines whether one can teach (Ziv and Frye 2004). Moreover, 4-year-old children expect teachers to provide complete and relevant information. Children who are taught about a novel toy's functions subsequently focus their free exploration time on the taught function. By contrast, children who did not receive such instructions explore the other possible toy functions (Bonawitz et al. 2011). By age 5, children distinguish successful learning that occurred due to explicit teaching rather than from successful imitation, highlighting teaching as an explicit communicative act (Ziv et al. 2008). Indeed, by 6 years old, children define teaching as a communicative act that causes belief change (Sobel and Letourneau 2016). Moreover, 5-year-olds understand that teaching is a special communicative act: one that provides learners with generic and representative information. Five-year-old children spontaneously use more generic language and provide more representative and helpful information when they are asked to teach an ignorant learner (Gelman et al. 2013; Gweon et al. 2014; Rhodes et al. 2015).

During the preschool years, children's *actual* teaching also develops rapidly. While younger children rely on non-verbal communication (demonstration), older children rely on verbal teaching strategies (Strauss and Ziv 2012; Strauss et al. 2002). When asked to teach a game to a naïve learner, 3-year-old children demonstrate how the game works, whereas 5-year-old children explain the rules of the game (Strauss et al. 2002). In addition to changes in the strategies children use when teaching, between 5- and 7-years-old children also change the way they respond to their pupil's mistakes when teaching. During that time, children's teaching becomes more nuanced and more connected to observable changes in the learner's knowledge. Wood et al. (1995) found that only 24% of five-year-olds but 68% of seven-year-old children engaged in contingent teaching, adjusting the amount of support they provided to the child they were teaching based on that child's performance (i.e. providing more support if the learner struggled and less support if the learner was successful). This change in the process and content of children's teaching is accompanied by change in children's description of their teaching behavior (Strauss et al. 2002). When asked how they knew their pupil learned from their instructions, three-year-old children mentioned that they had taught the pupil whereas five-year-old children mentioned changes in the learner's behavior (Strauss et al. 2002). In sum, as children age, their understanding of, and engagement in teaching, becomes more nuanced and increasingly linked to observable changes in their pupil's understanding.

The aforementioned studies highlight the resolution of a "knowledge gap" between a teacher and a learner as a core motivation for teaching. However, it is unlikely that it is the only motivating factor. Teaching is costly. It requires an investment of time and resources on the teacher's part (Fogarty et al. 2011; Thornton and Raihani 2008). Thus, depending on the situation, children may decide that even though there is a knowledge gap between themselves and a learner, it is not necessary for them to teach (because the learner could learn more effectively on her own or from other people) or that it is not their responsibility to teach this individual (because it is not a collaborator or in-group member or because it would violate cultural norms about who can teach). Indeed, Ronfard et al. (2016) recently showed that children are less likely to transmit information they were taught if they believe the learner might be able to acquire that information on her own. However, because previous studies on children's development as teachers have always asked children to teach a clearly naïve pupil (including Ronfard et al. 2016), it is unclear how frequently children will choose to teach a naïve learner if they are placed in a situation where a learner would benefit from being taught because there is a knowledge gap.

In an initial exploration of this question, we presented 3- to 6-year-old children with puppets who differed in their knowledge state while attempting to play a game (Ronfard et al. 2015). One puppet was described as an expert, who 'knew how to play the game'; the other puppet was described as a novice, who 'had never seen the game before'. Both puppets hesitated before making their move, saying 'I wonder what I should do'. If children taught, we recorded their teaching behavior. If children did not teach, the puppet once again hesitated, and repeated their statement about wondering what to do. We watched to see whether or not children spontaneously taught – and, if so, if they taught both puppets equally, or if they selectively focused their instruction on the novice puppet who had never seen the game before.

Based on the standard mentalistic definition of teaching as reducing a knowledge gap between the teacher and learner (e.g., Strauss et al. 2002; Ziv and Frye 2004), we had made two predictions. We had predicted that children would teach the naïve puppet more frequently than the knowledgeable puppet (because it was clearly ignorant about how to play the game) and we had predicted that if children taught the knowledgeable puppet they would wait until the puppet hesitated a second time and thus demonstrated a lack of knowledge. Somewhat surprisingly, although all children could recognize the knowledge difference between the two puppets only about 50% of children aged 3–6 spontaneously taught *at all* and children were not more likely to teach the naïve puppet than the knowledgeable puppet (Ronfard et al. 2015). Moreover, the decision to spontaneously teach was not related to the child's temperament. If children engaged in spontaneous teaching, we found the expected age-related changes in children's decision to engage in selective teaching. That is, whereas 3-year-olds were most likely to teach both puppets, regardless of the knowledge state of the puppets (what we called undifferentiated teaching), 6-year-olds were highly selective when making this decision (what we called differentiated teaching). When they just taught one puppet, they focused their efforts on the naïve puppet who had not played the game before. And when they taught both puppets, they modified the timing of their instruction, teaching the novice puppet almost immediately whereas they taught the expert puppet on the second request for information only (i.e., once it seemed plausible that the puppet had forgotten how to play).

These data demonstrate that children's decision to teach is not solely motivated by the recognition of a knowledge gap. Indeed, recent research indicates that children are sometimes more likely to teach a knowledgeable learner than a naïve learner even when the knowledgeable learner explicitly states that she already knows the information to be taught (Kim et al. 2016). Thus, when deciding whether to teach, children consider additional factors beyond the existence of a knowledge gap between themselves and the learner and these additional considerations sometimes trump the learner's lack of knowledge.

Taken together, the data reviewed in this section highlight some similarities and a puzzle. All of the data reviewed indicates relatively consistent age-related changes in the type of teaching children engage in. Even when we presented children with a more challenging task – but arguably a more ecologically valid one – where they were part of a dyad where they might engage in spontaneous teaching, their decision to account for the learner's knowledge state when teaching varied with age. However, we found that across our age range approximately half of the children chose not to teach either puppet. This suggests that whether a pupil is knowledgeable or not is not the only factor children consider when deciding to teach but if they do decide to teach the knowledge status of the learner influences children's how they teach (particularly for older children).

Thus, an important future direction for research on teaching is investigating why some children are motivated to teach a naïve, albeit unfamiliar, pupil whereas others are not. We believe that a number of factors are likely to play an important role in children's decisions about whether or not to teach a naïve learner: the social context (e.g., collaborative vs. competitive), the learner's group affiliation (e.g., in-group vs. out-group), the complexity of the task (e.g., simple vs. complex), children's confidence in their own ability to teach (e.g., whether there are others who are better informed than they are and who are available as teachers), as well as cultural expectations about teaching (e.g., whether it is appropriate for them to teach). Importantly, we believe that the extent to which children weigh these different factors may differ across cultures and development. Understanding the factors that children consider when deciding whether to teach will help researchers better understand the environmental conditions that facilitate knowledge transmission over time.

3 Cognitive Mechanisms Associated with Children's Teaching Behaviors

The data reviewed above indicates age-related changes in children's development as teachers. Here, we explore three cognitive mechanisms likely associated with such changes: children's understanding of mental states, children's ability to infer knowledge from mistakes, and children's executive function skills. All are likely to support children's ability to teach. Children's understanding of mental states is likely to help children *represent* their pupils' understanding: whether their pupil does or does not understand a topic and how much they understand about a topic. Children's ability to infer knowledge from pupils' mistakes makes use of their ability to represent other people's mental states to *respond* to mistakes in real-time. Finally, children's executive function skills are likely to be important across the entire teaching process, allowing children to *decide* on a teaching strategy, and then effectively *implement* it. Below, we

provide evidence for the relation between these cognitive mechanisms and children's teaching.

3.1 Relations between Children's Teaching Behaviors and their Understanding of Mental States

Research has posited a strong theoretical link between Theory of Mind (ToM) development and teaching (Ashley and Tomasello 1998; Wood et al. 1995). ToM is the ability to understand other people's mental states, including desires, beliefs, knowledge, intentions and emotions, and that others' mental states can be different from one's own (Wellman and Liu 2004). Wellman and Liu (2004) developed a 5-item ToM scale to measure children's explicit ToM ability, finding that children's understanding of mental states develops in a relatively consistent fashion (but see Liu et al. 2008; Shahaein et al. 2014; Shahaein et al. 2011; Wellman et al. 2006, for cultural differences in this developmental trajectory). Such age-related changes in children's explicit understanding of ToM align nicely with the age-related changes in the development of children's teaching strategies. Wood et al. (1995) argued that ToM could support teachers to reason about learners' performance in response to previous instructions and also about modifying future instructions based on learners' developing knowledge state. Research to date has tested this hypothesized relation but has mostly focused on the relation between children's understanding of False Beliefs (FB) and their teaching. This is because FB understanding allows children to understand that learners have a mistaken belief and therefore to intervene and "fix" such mistaken beliefs. However, as we note later, other components of ToM are likely to be implicated in other aspects of the teaching process.

Despite the strong theoretical link between ToM and teaching, only a few studies have empirically tested this relation. Early work by Strauss et al. (2002) showed a correlation between children's use of verbal teaching strategies and ToM – although note that they did not control for age in this analysis. Similarly, Davis-Unger and Carlson (2008) found that ToM was related with the time children spent on teaching and the number of strategies used. More recently, Ziv et al. (2015) found that ToM was related to children's developing teaching strategies as well as their contingent teaching, controlling for age and language ability. Thus, ToM appears to be an important cognitive prerequisite for more sophisticated teaching strategies.

Is ToM necessary for spontaneous teaching – or is it only necessary when examining the quality of the teaching behavior? As discussed above, there are reasons to think that children's decision about *whether* to teach, although influenced by the learner's knowledge state, may also be influenced by additional factors (i.e., in-group status of the learner). The use of such additional factors is likely independent from children's ability to represent the knowledge of the learner. Thus, children's decision to teach may not necessarily be related to children's understanding of mental states.

We were able to ask this question using the paradigm we describe above where we invited children to spontaneously teach a naïve and a knowledgeable puppet (Ronfard et al. 2015). We found no relation between ToM ability and the decision to teach. By contrast, the quality of children's teaching behavior did vary as a function of ToM ability, controlling for age. Whereas 90% of children who engaged in differentiated teaching also passed the false belief task, only about 30% of children who engaged in

undifferentiated teaching passed the false belief task. Note that although we find no relation between ToM and children's spontaneous decision to teach, it does not mean that such relation is absent. Instead, we believe that children's decision to teach is based on their evaluation of the learner's understanding as well as additional factors. Specifically, we can imagine that when deciding whether to teach children consider two factors: the existence of a knowledge gap between themselves and their pupil, and motivational aspects (e.g., is the pupil part of the in-group, whether facing a complex task or not). Whereas the first factor requires ToM, the second may not. Thus, researchers are likely to observe a positive and significant relation between children's decision to teach and their ToM when children have a clear motivation to teach the learner but not necessarily when they do not (e.g., when the pupil has a clear and positive relationship to the child and is facing a complex task that she cannot learn on her own rather than when the pupil has no relationship to the teacher and is attempting to complete an easy task).

One limitation of the research described above is that all studies included a very limited measure of ToM. Specifically, most research included one or multiple measures of false belief as a measure of ToM. To our knowledge, only one recent study has explored the relation between the 5-item ToM battery (Wellman and Liu 2004) and teaching understanding. Knutsen et al. (2017) found that children's understanding of teaching when reasoning about stories was related to total scores on the entire ToM battery. Future research should employ the entire 5-item ToM battery (Wellman and Liu 2004) in order to examine the more nuanced relation between the development of ToM and teaching behaviors, as it is possible that other developmental milestones in ToM development may also contribute to the development of children's teaching. Specifically, the understanding that others might have diverse beliefs might be necessary for inferring the knowledge gap between the learner and the teacher and engaging in spontaneous teaching. Similarly, understanding knowledge access – the recognition that only those with access to information possess that information – might be essential when deciding which information to convey to a learner.

Future research should also explore how children's metacognitive awareness above-and-beyond ToM ability also contributes to their understanding of teaching and their engagement in teaching. For example, children's definitions of teaching are related to their reflections about how they teach and how they have been taught (Sobel and Letourneau 2016). Such metacognitive awareness may provide insight into the mechanisms underlying children's understanding of teaching and may be especially important when children reason about how best to teach others. That is, their own experience of being taught may influence how they think about teaching and how they teach others.

3.2 Relations between Children's Teaching Behaviors and their Ability to Infer Knowledge from Mistakes

It is unlikely that ToM accounts for all of the variance in children's teaching abilities. Indeed, in our study, we found that 30% of children who passed the false belief task still engaged in what we called undifferentiated teaching. Thus, ToM is unlikely to be the only cognitive mechanism necessary for high-quality teaching in young children. We believe that a second candidate mechanism is children's ability to infer in real-time how

much a learner knows based on their behavior. That is, in order to teach in a manner that addresses the learner's lack of knowledge, children need to observe the learner's behavior, make an inference that the behavior was intentional, and note that the behavior is likely indicative of their knowledge about the task at hand. This is a relatively complicated process that most definitely goes beyond recognizing that a learner may have a differing mental state than the teacher. We call this mechanism the ability to infer knowledge (or ignorance) from mistakes. In sum, we hypothesized that the ability to represent the knowledge of the learner is a necessary but not a sufficient factor in children's selective teaching. Instead, selective teaching requires the ability to mentally *represent* what someone knows and to *infer* what someone knows from his or her mistakes.

To our knowledge, only one study has explored the relation between children's ability to infer knowledge from mistakes and the quality of their teaching (Ronfard and Corriveau 2016). They presented preschoolers with four puppets who each played a simple game one at a time. The game involved red and black pieces and a square on a board. The game was 'won' if the red piece was placed in the square, and the game was 'lost' if the black piece was placed inside the square, or if either piece was placed outside the square. One puppet correctly played the game without making a mistake. The other three puppets all made different types of mistakes. Two puppets made *one mistake*: one puppet placed the correct piece outside the square, and the other puppet placed the incorrect piece inside the square. The final puppet made *two mistakes*: placing the incorrect piece outside of the square.

Immediately following the puppet's attempt at playing the game, we asked children to infer the knowledge of the puppet based on how well they had played the game. They asked children whether the puppet knew 'some things' 'everything' or 'nothing' about the game. Those ratings were used to compare how much children thought each puppet knew about the game. Children were first asked whether they recognized that a puppet who played the game correctly knew more than a puppet who made a mistake while playing the game. Thus, children's rating of the zero-mistake puppet were compared with children's ratings of the other three puppets, with children receiving a point if they rated the zero-mistake puppet's knowledge higher than the other puppets. To explore whether children recognized that puppets who make multiple mistakes know less than puppets who make only one mistake, the ratings across the three puppets who make a mistake were compared. Children received a point if they rated the one-mistake puppets higher than the two-mistake puppets, and a point if they rated the two one-mistake puppets similarly.

Children's ability to monitor the relative accuracy of the puppets – the ability to make nuanced judgments about what each puppet understood based on each puppet's unique mistakes - improved with age. Across the preschool years, children were better at selecting ratings that reflected the differences in knowledge between the puppets that made mistakes and the puppet that made no mistakes than between the puppets that made one mistake instead of two mistakes. However, there were observed age related differences on both comparisons. Five-year-old children were better than 3-year-old at providing ratings that reflected the differences in knowledge between the puppets that made mistakes and the puppet that did not and they were markedly better on providing ratings that reflected the smaller difference in knowledge between the puppet that made one mistake and the one that made two mistakes: Whereas all 3-year-old children gave

similar ratings to the puppets who made one mistake and to the puppet who made two mistakes, 26% of 5-year-old children provided higher ratings to the two puppets who made one mistake than to the puppet who made two mistakes.

Children were also asked to teach the puppets who made mistakes and the quality of their teaching was recorded. Consistent with prior research, younger children used non-verbal teaching strategies whereas older children used verbal strategies. Specifically, older children were more responsive teachers – providing instructions that directly addressed the puppets' unique mistakes more often than younger children. Five-year-old children used language to state what should be done and what should not be done (i.e., "don't put it on the outside, you did the red piece which is correct but you need to put it on the inside") 42% of the time whereas 3-year-old children did so 9% of the time. Moreover, when using a more stringent measure of children's responsive teaching – whether children only taught the rule associated with the puppet's single mistake rather than teaching both rules of the game (i.e., making a distinction between the knowledge the learners knew and did not know) – we found that 5-year-old children explicitly addressed the unique mistake of the learners 26% of the time, whereas 3-year-old children never did so. Importantly, children's provision of responsive instruction was associated with their ability to infer how much each learner knew based on their mistakes, independent of age.

These findings suggest that children's ability to infer knowledge from mistakes is an important factor in children's ability to engage in selective teaching. Note that one limitation of this study is that children's understanding of mental states (ToM) was not assessed, leaving open the possibility that the ability to infer knowledge from mistakes and ToM account for the same variance in children's developing teaching abilities. Future research should include both a measure of ToM and a measure of children's ability to infer knowledge from mistakes in the same paradigm to assess the relative contribution of each of these mechanisms on children's ability to engage in selective teaching.

3.3 Executive Function as an Additional Cognitive Prerequisite

We have focused our discussion of the cognitive skills required for teaching on children's ToM and on children's ability to infer knowledge from mistake. However, it is worth considering an additional cognitive skill –Executive Function (EF) – as it relates to children's teaching. Executive Function is an umbrella term for a number of skills used to evaluate and direct thought and action. These skills allow individuals to represent a problem, develop a solution, implement that solution, and evaluate its effectiveness (Zelazo et al. 1997; Diamond 2013). Consequently, EF as been theorized to play an important role in children's ability to teach (Davis-Unger and Carlson 2008) because teaching is a form of problem solving requiring children to continually update their representation of a pupil's knowledge as they plan, execute, and evaluate their teaching's impact on the pupil's understanding. Thus, according to Davis-Unger and Carlson (2008), although ToM may be necessary to understand how teaching occurs it is not sufficient to carry out teaching and to evaluate its effectiveness.

To test this hypothesis, Davis-Unger and Carlson (2008) explored the relative contribution of EF and ToM on a composite score of children's teaching performance (i.e., the number of different strategies children used, the number of game rules taught,

the amount of time spent teaching, the number of the pupil's errors the teacher recognized). When examined separately, both ToM and EF explained unique variance on the teaching composite, controlling for age, sex, and memory capacity. However, when both ToM and EF were included in the same model as predictors, only EF explained unique variance on the teaching composite. Davis-Unger and Carlson interpreted these findings to suggest that EF might play an important role in children's teaching. One limitation of these findings is that the dependent measure was a composite, combining multiple phases of the teaching process. Thus, it is challenging to determine the specific role of EF in teaching. It will be important for future research to investigate the relative contribution of EF to these different components of teaching. It is likely that EF skills are needed for children *to use their ToM* during teaching *and* to *decide on and implement* their teaching strategy. Indeed, EF is found to be critical for ToM development (Benson et al. 2013). Both the emergence and expression of false belief understanding require EF skills. Moreover, children's teaching is likely to be influenced by their metacognitive understanding of the teaching process, and metacognition involves EF skills. Thus, future research should explore the contribution of both EF and ToM in the development of teaching.

Earlier, we discussed our finding that children's ToM and their ability to infer knowledge from mistakes both predicted unique variance in children's ability to tailor the instruction to the precise mistake displayed by the learner. We argued that ToM measured children's ability to represent the knowledge of the learner while children's ability to infer knowledge from mistakes measured their use of this capacity in real time. The results of Davis-Unger and Carlson (2008) suggest the possibility that children's ability to infer mistakes from the pupil's behavior reflects the influence of EF on their teaching. That is, the relation between children's ToM and their ability to infer knowledge from mistakes might be mediated by children's EF skills. Future research should include measures of ToM, the ability to infer knowledge form mistakes, and EF in the same paradigm to explore this possible relation.

4 Cultural Differences in Children's Teaching

Before turning to open questions and future directions in children's selective teaching, we highlight one more important issue: the possible effect of cultural experience. That is, how children teach and the developmental trajectory of teaching may vary from culture to culture (Maynard 2004). This idea is not new, and indeed, is present in Vygotsky's (1980) seminal work on social interaction: the development of cognition is the product of children's interaction with other members in a social group and engagement with cultural materials such as language and tools. Thus, children's teaching strategies may be highly influenced by their own experience as learners in their cultural context. Surprising, there is very little work on cultural differences in children's teaching. Most empirical studies on children's teaching have been conducted with Western, Educated, Industrialized, Rich, and Democratic (WEIRD) societies (Henrich et al. 2010). Many anthropological and observational studies have highlighted vast differences in teaching practices across cultures (e.g., Lancy 2010; Paradise and Rogoff 2009; Rogoff 1991, 2003; Little et al. 2016), but to date, little work has explored the ways in which cultural environment may help to shape such differences. One notable

exception is Visscher (2010). She found that in two traditional Quechua communities where teaching is mostly non-verbal, adult and children's use of verbal instructions on three tasks (i.e., traditional basket weaving, assembling a textile puzzle, and assembling a Peruvian map puzzle) was predicted by individuals' exposure to formal (Western style) schooling (where verbal teaching predominates) and not age. This finding suggests that how individuals teach others may be strongly influenced by their cultural environments.

In addition to cross cultural differences in teaching styles based on the relative frequency of these teaching styles across cultures, there is known cross-cultural variability in the underlying cognitive mechanisms we have reviewed above. Several recent studies have highlighted variability in the development of ToM: whereas children from Western countries develop an understanding of diverse belief prior to an understanding of knowledge access children from China (Wellman et al. 2006) and Iran (Davoodi et al. 2016; Shahaein et al. 2011) develop an understanding of knowledge access prior to developing an understanding of diverse belief. Yet these same studies highlight some aspects of ToM that appear to be more universal: false belief understanding appears to develop around the age of 4 across all cultures tested. Thus, the extent to which we see variability in teaching understanding and behavior may depend in part on the importance of the precursors to false belief understanding in this process.

Just as there are documented differences in ToM across cultures, several studies have documented some differences in executive functioning across cultures (Sabbagh et al. 2006). For example, Sabbagh et al. (2006) found that Chinese preschoolers outperformed U.S. preschoolers on all seven of the executive function measures they administered. This difference between the U.S. and China is thought to be related to differences in parents' expectations for children's ability to control their impulses – Chinese parents expect children as young as 2-years-old to do so whereas U.S. parents expect such mastery in preschool (Chen et al. 1998; Ho 1994; Wu 1996). Moreover, impulse control is more highly valued in Chinese than U.S. preschools (Tobin et al. 1989).

We are currently interested in possible cultural differences in preschoolers' developing teaching strategies and its cognitive underpinnings in US and China. There are several reasons to think that there might be differences. First, a large body of research has highlighted differences between China and the U.S. in parental and pedagogical beliefs about how children learn best in early childhood. Chinese caregivers and teachers emphasize knowledge mastery and performance, whereas U.S. caregivers and teachers emphasize play (Paine 1990; Pang and Richey 2007; Tobin et al. 2009). With the influence of Confucianism, Chinese people believe that education is an "essential component of virtues" (Pang and Richey 2007). The educational system in China promotes a strong academic-oriented pedagogy (Vaughan 1993; Pang and Richey 2007). Many parents in China are also enthusiastic about their children's academic achievements even from an early age. These parents thus believe that beginning academic work early is beneficial for a child's academic outcomes (Vaughan 1993; Pang and Richey 2007). Similarly, Johnston and Wong (2002) found that Chinese mothers believed that children learn best with instruction and that young children would not learn important things during play, whereas the U.S. mothers hold the opposite opinions. The above literature plausibly offers the hypothesis that Chinese

preschoolers might develop more sophisticated teaching strategies at earlier ages than U.S. children due to their greater exposure to more formal instruction.

The formal instruction in China is often distinctively different from the formal instruction in the U.S. (Tobin et al. 2009). In Chinese classrooms, it is usually the teacher who gives a lecture to children as a group, and all children are expected to behave similarly at the same time. Seldom do teachers vary their teaching style based on the needs of individual learners. By contrast, classrooms in US preschools and even elementary schools are play-oriented and child-centered, and teachers often vary their teaching style based on a learner's individual needs (Gardner 2006; Pang and Richey 2007). These cultural differences in teaching styles may lead us to an alternative hypothesis: namely, that U.S. preschoolers may develop more responsive teaching strategies earlier than Chinese children due to their greater exposure to differentiated teaching.

Moreover, the varying teaching styles may also lead to a different emphasis on the importance of ToM in the learning and teaching process. In China, the learner is expected to carry the burden of recognizing and adjusting to a knowledge gap – recognizing when they do not understand the lesson given by the teacher, and asking for help. By contrast, in the U.S., the teacher is expected to carry the burden of adjusting to a knowledge gap, often providing the same information in multiple ways in order to reach learners. Thus, it is plausible that although ToM may be an important cognitive prerequisite when exploring differentiated teaching in the U.S., the opposite pattern might emerge for China: we might see no effect of ToM on children's teaching strategies, but an important effect of ToM in children's learning through metacognitive monitoring.

Finally, it is likely that the differences in teaching and learning we mention above will vary widely within-culture, based on variability in teacher education, local curriculum, beliefs about learning and teaching, as well as the perception of social norms and the relative motivations for engaging in teaching. Specifically, we anticipate that we will see differences in children's selective teaching based on whether or not they have mainly been exposed to play-based learning versus direct instruction and lecturing. Thus, future research should explore the possible differences within cultures to identify the link between children's pedagogical input and output as well as the related cognitive mechanisms.

5 Conclusion and Future Directions

We have argued based on existing work that children's ToM, their ability to infer knowledge from mistakes, and their EF skills are prerequisite cognitive skills for teaching. ToM allows children to represent the knowledge state of the learner, the ability to infer knowledge from mistakes allows children to use this capacity to update their representation of the learner's knowledge (based on his or her mistakes), and EF skills allow children to plan, implement, and evaluate their teaching. We have also discussed an important distinction between children's decision about whether or not to teach a learner and their decisions about how to teach that learner. We suggested that additional considerations beyond the learner's knowledge state may influence children's decision to teach. Finally, we discussed the possibility that children's

development as teachers may be influenced by their social milieu. All children may rely on the same cognitive mechanism to teach. However, different exposure to learning and teaching environments may influence how children conceptualize the role of teachers and learners and the manner in which they choose to teach. Below, we elaborate on these points and suggest areas of future research.

Research on children's development as teachers – specifically on the prerequisite cognitive skills involved teaching – has become increasingly precise over the past decade. Pioneering work by Strauss et al. (2002) initially looked at the relation between false-belief understanding and children's use of verbal teaching strategies. We and others have extended these early findings by identifying the specific aspects of verbal teaching that are related to children's understanding of mental states. We found that children's use of verbal contrasts in their teaching and their ability to target the learner's mistake (i.e., not over-teach) is related to both false-belief and children's ability to infer pupils' knowledge.

However, there is still much that we do not know about the underlying cognitive skills associated with children's teaching. Teaching is a complex activity that involves multiple steps: identifying whether teaching is needed, planning which strategies to use when teaching, engaging in teaching behaviors, evaluating the effectiveness of that teaching, and using this evaluation to plan additional teaching. Currently, research has mostly focused on children's reasoning about when teaching is needed, and children's actual teaching behaviors. We look forward to future research investigating the cognitive skills required for the entire teaching process – especially those that are involved in children's reflections about the effectiveness of their teaching and their ability to use those reflections when engaging in future teaching with the same learning partner. We welcome research exploring how the mechanisms we highlight (EF, ToM, metacognition) are related, and how in turn, the cultural scripts influence how such mechanisms are deployed in teaching.

In addition, we believe that research on teaching would benefit from research with older children on more complex tasks. Thus far, the focus has been on the relation between ToM (particularly False-Belief understanding) and children's understanding of, and engagement in, relatively simple teaching tasks. The teaching tasks that have been used have focused on games with a few clear-cut rules. However, more complex teaching that requires children to consider how a learner might misinterpret ambiguous evidence may require different ToM skills. Specifically, such teaching might involve an interpretive ToM (Carpendale and Chandler 1996) – an understanding that evidence can be interpreted differently by different people.

At the start of this article, we described our preliminary research into children's decisions to engage in teaching and highlighted that children's decision to teach is likely to be influenced by more than the existence of a knowledge gap between themselves and a learner. We believe that research on these additional factors that children consider when deciding whether to teach is important because it has both theoretical and practical implications. Teaching is an important mechanism for knowledge transmission. In fact, it is argued to be a key component in the human ability to refine knowledge over time (Boyd and Richerson 2004; Dean et al. 2012; Tomasello 2009). However, these theories do not specify the conditions under which teaching is expected or more likely to occur between individuals, only that teaching ability is more likely to evolve when certain conditions are met (e.g., information is too complex to be

acquired through other means, and the costs of teaching are outweighed by the inclusive fitness benefits it conveys to the learner, see also Fogarty et al. 2011; Thornton and Raihani 2008). Earlier in the manuscript we suggested that children's decision to teach is likely to be related to aspects of the context (e.g., whether it is a competitive or collaborative context), aspects of the task (i.e., its difficulty), as well as personal characteristics of the teacher (e.g., their belief in their own ability to teach, and their tendency to transmit information to other people, which may be influenced by parental and cultural upbringing).

In addition to these factors, future research might also consider how the type of knowledge being taught influences children's decision to teach. For example, 3- to 6-year-old children are more likely to transmit information they were taught if it is presented using normative language (e.g., "Everyone does it this way") rather than instrumental language emphasizing the goal (Clegg and Legare 2016). Similarly, children's understanding of social norms impacts the extent to which they convey taught rules (Rakoczy et al. 2009). Exploring the different social and normative factors that children consider when making decisions about whether and what to teach will help clarify the role of teaching in the evolution of human knowledge. Moreover, it will help educators create educational environments that support children's spontaneous teaching of their peers – environments that catalyze peer learning.

We conclude by echoing Strauss et al. (2014)'s call for researchers to study interactions between teachers and learners as an iterative process. Current work has emphasized either children's developing cognitive abilities as teachers (e.g., Kline 2015; Strauss et al. 2002) or their receptivity to teaching (Csibra and Gergely 2009). It is time for research to investigate how learners and teachers interact together to optimize learning. From an early age, young children not only initiate teaching, but they also monitor and influence pedagogical exchanges (Corriveau 2015; Ronfard and Harris 2015). Such an achievement is remarkable because it greatly enhances the likelihood that teaching will increase a learner's understanding. We anticipate that such back-and-forth exchanges between teachers and learners are likely to differ by culture. In some cultures, teachers might expect learners to interrupt instruction and "guide" the teaching, whereas in other cultures such "interruptions" might be interpreted as rude (Pang and Richey 2007). For example, 3- and 5-year-old raised in non-WEIRD cultures appear to ask fewer information-seeking questions than their WEIRD counterparts partly because in those settings questions may be perceived as undermining authority relationships (Gauvain et al. 2013). Indeed, even within a single culture, there is well-documented variability in the extent to which children turn to others for information-seeking (e.g., Hart and Risley 1995; Isaacs 1930; Kurkul and Corriveau 2017). Such expectations about teachers' and learners' roles and responsibilities could be explored by having children evaluate learners' and teachers' interactions, or by watching teacher-learner child dyads interact naturally over a series of exchanges.

Moreover, we welcome research exploring the social factors involved in teaching decisions. Some work has highlighted children's evaluation of characteristics of the teacher when deciding who to learn from (e.g., their relevent expertise; Gweon et al. 2014), but to our knowledge no work has truly explored how social factors impact the iterative nature of teaching. Researchers exploring children's teaching might turn to the thriving literature on children's selective trust as a guide for exploring how various social factors influence children's interpretation of knowledge, and ultimately shape

their learning (e.g., Chen et al. 2013; Corriveau et al. 2009a, b; Corriveau and Harris 2010a, b; Kinzler et al. 2011). We believe the field of children's teaching is ready to begin incorporating such complexity. Such a change may help bridge the gap between this literature and classroom exchanges.

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