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From Theory of Mind to Epistemic Cognition. A Lifespan Perspective

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Abstract

Although a sizeable body of research now exists in epistemic cognition, it tends to stand apart from other aspects of cognition and cognitive development. Here it is proposed to situate epistemic cognition in a context of its roots and development as a dimension of cognitive development more generally. The present paper draws a strong continuous link between the earliest understanding of other minds, examined under the Theory of Mind, and the tasks that confront adults throughout the lifespan – that of interpreting evidence and coordinating it with what they already take to be true. The primary focus is the How question of knowledge change. To gain insight into this question, it is proposed to focus on epistemic activity in action. It is suggested here that the standards for knowledge formation and revision, which are closely connected with epistemic understanding of theory-evidence coordination, change developmentally. Another major change proposed is that the process increasingly comes under conscious control.

Keywords: Epistemic cognition, cognitive development, argumentation, theory of mind

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1. Problem

How do people know? How do people form beliefs? How do people revise beliefs? Are there developmental differences in this regard? These questions have long been a concern of psychologists, philosophers and educators. Their answers can be found in writing on the topic of epistemic cognition (Bendixen & Rule, 2004; Greene, Muis, & Pieschl, 2010; Greene, Sandoval, & Bråten, 2016; Muis, Bendixen, & Haerle, 2006; Perry, 1970). Following Chinn, Buckland, and Samarapungaran (2011) and Greene et al. (2016), epistemic cognition is defined here as "cognition of or relating to knowledge" (Greene et al., 2016, p. 3). Although a sizeable body of research now exists under this heading, it tends to stand apart, with few connections to other aspects of cognition and cognitive development. Here I propose a broader view, situating epistemic cognition in a context of its roots and development as a dimension of cognition and cognitive development more generally. My primary focus is on the mechanism question, the 'How' question of knowledge change. I propose that this change only comes about through application of one's epistemic cognition in practice, which consists of forming and revising claims. This is a continuous process through life and there is reason to think that the nature of the process changes, with mechanisms and standards for knowledge formation and revision changing developmentally. A major change, I propose, is that the process increasingly comes under conscious control. To gain insight into the how question of knowledge change, I propose focusing on epistemic activity in action – the application of epistemic cognition.

Available models of the developmental progression of epistemic cognition offer a very general stage-like description of this progression with little attention to mechanism. They began with Perry's (1970) study of Harvard undergraduate students, hardly a broad sample of the population. For many years, research following Perry's work continued the study of adolescent and adult samples, with no reference to the developmental origins of their thought. An assumption that epistemic beliefs emerge abruptly in adolescence and remain unchanged thereafter – a non-developmental account – seems unwarranted, considering the cognitive development that occurs along so many other dimensions during the years between early childhood and adolescence. Researchers are thus left with few answers to the key questions of how epistemic conceptions emerge and how they continue to develop. Although researchers have gone on to address many other important questions, such as how epistemic cognition is related to academic performance (Muis, Kendeou, Franko, 2011; Stømsø, Bråten, & Britt, 2011), little work has been done to further our understanding of its development. Largely standing today is the 2004 conclusion drawn by Bendixen and Rule, "Currently there is neither a unified model of epistemological understanding to guide research, nor a single model that clearly articulates the relationship between personal epistemology and how epistemological beliefs change and develop" (p. 69). A fuller developmental account is essential not only for expanding understanding at a theoretical level but also for its educational implications, by identifying means to support development of sophisticated epistemic cognition.

It is not the case that little is known about cognitive development in the first decade of life, and more specifically development potentially relevant to epistemic cognition. In particular, there is now an extensive literature, particularly in the field of developmental psychology, on children's theory of mind (ToM), addressed to how young children understand their own and others' minds. However, like epistemic cognition research, ToM research has been confined to a particular age range – in the case of ToM the first years of life − with very little work addressed to older children. Research on older children's higher-order ToM tends to have an atheoretical quality, placing more emphasis on the application of second-order understanding and how it affects other aspects of development rather than on the development of a comprehensive theory addressing issues such as how change occurs (Miller, 2012). In understanding developing knowledge about knowing, then, there exists a conspicuous gap consisting of the decade between early childhood and adolescence. My aim is to fill this gap by identifying a continuous development and in doing so to examine the nature of the process of change.

2. A model of development of epistemic cognition: What develops?

Drawing on Chinn's et al. (2011) model of Epistemic Cognition, I propose that the epistemic standards that individuals employ change developmentally. Epistemic processes refer to strategies and other activities by which one can achieve knowledge. Epistemic standards refer to the standards used to evaluate knowledge claims (Chinn et al., 2011). The literature on epistemic cognition has focused on examining people's beliefs about knowledge and knowing – known as their epistemic beliefs (Greene et al., 2016; Kitchener, 2002). The model proposed here extends the literature significantly by proposing the examination of application of people's epistemic beliefs (epistemic activity in action), rather than focusing on epistemic beliefs themselves. Agreeing with Sandoval (2005) that students' beliefs about their own knowing may differ from their beliefs about scientists' knowing, I extend this idea by proposing that the application of students' epistemic beliefs in practice may differ from their epistemic beliefs. I further advocate that the distance between epistemic activity in action and epistemic cognition decreases as one acquires increasing awareness and control of each. Given the focus of the present work on epistemic activity in action, the development of epistemic standards is a focus, although it is acknowledged that other components of epistemic cognition (i.e., epistemic processes, values) also develop and interact with epistemic standards (Clement et al., 2015). Insights from research in ToM, testimony and argumentation contribute to addressing the question of what develops in the epistemic realm and supports knowledge change.

2.1. Epistemic standards change developmentally

2.1.1. Epistemic standards in early childhood

The origins of epistemic cognition are identifiable in the early childhood achievements examined under the theory-of-mind literature (Kuhn, Cheney & Weinstock, 2000). Even young children form and revise beliefs. They are just not aware of doing so. For example, preschoolers have the tendency to report they have always known information they have just learned (Taylor, Esbensen & Bennett, 1994). What influences young children to adopt and revise beliefs? A growing literature on testimony provides insights regarding young children's standards in judging the credibility of the source of new information. Standards that young children employ include an informant's expertise, age, power, group membership and relationship with the child, with children showing preference for informants who are experts in the domain that the information is related to, to older informants, to authority figures and to those who have close familiarity with or belong to the same group (Harris & Carriveau, 2011; Mills, 2013). For example, children prefer to seek and endorse information from native-accented speakers (Kinzler, Corriveau & Harris, 2011). Other epistemic standards employed by young children include an informant's record of accuracy (Harris & Carriveau, 2011) and an informant's confidence about their knowledge (Jaswal & Malone, 2007).

Research examining young children's reasoning with peers also offers insights regarding standards that young children employ in modifying their beliefs. This line of research shows that even three-year-olds use evidence (e.g., this is ice) to justify their claims (Köymen, Rosenbaum & Tomasello, 2014). Notably, research shows that young children's standards change with age. Remarkable differences have been reported between the age of three and four. While three-year-olds show preference for egocentric standards, such as familiarity with the informant (Corriveau, Harris, et al., 2009), four-year-olds prefer more objective and more germane standards, such as the informant's history of reliability. For example, four-year-olds show preference toward informers who have been reliable in their past performance, even when they have to reject familiar individuals who weren't reliable in recent judgments in favour of reliable strangers (Corriveau & Harris, 2009). Children by the age of four show greater sensitivity to the number and kind of errors made by an informant (Mills, 2013) and are able to distinguish experts based on their domain of expertise, showing preference for one expert over another depending on the issue they are dealing with and experts' domain of expertise, compared to three-year-olds (Koenig & Jaswal, 2011; Sobel & Corriveau, 2010). For example, when children were presented with a new dog, they preferred to ask the dog expert rather than a novice about the name of the dog (Koenig & Jaswal, 2011). Furthermore, five-year-olds show better understanding of how

relevant facts can be used to affect knowledge change in others, as evidenced by the production of more justifications in their dialogues. Importantly, they are also more open to changing their knowledge than three-year-olds (Köymen, Rosenbaum & Tomasello, 2014).

This change during the third to fourth year of life takes place at the same time as major developmental milestones are observed in children's cognitive development, as manifested in their achievements in the false belief task. This co-incidence supports the more general position proposed here that development of epistemic cognition should be situated in cognitive development more generally.

2.1.2. Epistemic standards in middle childhood

The epistemic standards employed by elementary-school children remain predominantly egocentric. Barzilai and Zohar (2012), examining via think-alouds how elementary school students judged the trustworthiness of websites, found that the predominant epistemic standard employed was personal authority – asking, for example, their Mom. More objective and rigorous epistemic standards, such as website author's expertise, scientific evidence or author biases were very rarely employed. Yet, during elementary school years, there is a developing appreciation of the epistemic standard of judging epistemic products (e.g., arguments, models) on the basis of their fit to evidence. Pluta, Chinn, and Duncan (2011) asked elementary school students to generate a list of criteria to evaluate scientific models and found that a quarter reported criteria relating to model fit with evidence (although other criteria were more commonly reported). Although elementary-school students show a developing appreciation for data to support their claims, they show preference for data from their own knowledge or experience rather than more objective scientific evidence (Amsel & Brock, 1996; Anderson, Chinn, Change, Waggoner, & Yi, 1997; Kuhn & Moore, 2015). Kuhn and Moore (2015) examined how elementary-school students used evidence in their dialogues to convince their peers to change beliefs about a social science and a physical science topic. They found that, even though a list of relevant shared evidence was available, about 90% of the evidence that students employed came from their personal knowledge and experience. Similar results were observed in research examining how elementary-school students deal with evidence that disconfirms their prior beliefs. Amsel and Brock (1996) examined children's behaviour when, in their experimentation, they encountered findings that contradicted their prior beliefs; they found that children in elementary childhood failed to use the new evidence to change their beliefs. Students typically are biased in evaluating evidence; they tend to ignore evidence that contradicts their knowledge or distort evidence to fit their existing theories (Chinn & Brewer, 1993). Much of the research on scientific reasoning reports similar results (Lehrer & Schauble, 2015; Sandoval, Sodian, Koerber, & Wong, 2014).

2.1.3. Epistemic standards in adolescence

In adolescence, attention to objective data increases, although data based on personal knowledge remains a more predominant epistemic standard. Subjective epistemic standards, such as agreement with one's own knowledge, are predominant in adolescents' judgments about the trustworthiness of sources (Mason, Boldrin, & Ariasi, 2010) and about the veracity of knowledge claims (Mason, Ariasi, & Boldrin, 2011). Iordanou and Constantinou (2015) examined how 15- and 16-year-olds argue with peers who hold opposing views on a socio-scientific issue, in a knowledge-rich learning environment. Participants' dialogue transcripts were analyzed in terms of the overall use of evidence, the amount of evidence per argument and per counterargument, the function of evidence use and the accuracy of the evidence employed. Only a quarter of adolescents' dialogue units contained evidence. Adolescents employed evidence most of the time to support their own position rather than to weaken the opposing position. In terms of the epistemic standards employed, these older adolescents, like middle-school students (Kuhn & Moore, 2015), used undocumented evidence claims from personal knowledge to support their claims. Eighty percent of adolescents' dialogue units made claims based on personal knowledge.

Besides limited use of evidence in argument production, limited employment of rigorous epistemic standards regarding evidence-claim coordination has been documented during argument evaluation. Iordanou, Muis and Kendeou (2014) examined, using the think-aloud methodology, the processes that

adolescents engage in when reading a text, focusing particularly on on-line processing of evidence. Adolescents rarely judged the credibility of evidence using epistemic standards such as the number of empirical studies which support a particular finding, the methodology used to produce a finding (e.g. whether the scientific method was used) or the fit of a claim to evidence.

2.1.4. Epistemic standards in adulthood

The growing literature examining college students' judgments of trustworthiness of different information sources provides some insight regarding adults' epistemic standards. Adults show the ability to evaluate experts from different disciplines (e.g. biologist, chemist, earth scientist), by estimating the extent to which they might possess relevant knowledge about a specific science topic (Bromme & Thomm, 2015) – an ability not shown by young children. Undergraduate students consider official documents as more credible sources of information than newspapers (Bråten, Strømsø & Salmerón, 2011). However, they place unwarranted faith in textbooks (Wineburg, 1991).

Examining undergraduate students' dialogues with peers to gain insight into their epistemic activity in action, Iordanou and Constantinou (2014) have observed that even adults do not employ evidence consistently to support their claims. In Iordanou and Constantinou (2014) study, adults' percentage of usage of evidence which functioned to support their claims was only 25% and the percentage of usage of evidence which functioned to weaken other's claims was even less − 18%. Kuhn (2016) in an effort to gain a better understanding of the factors underlying the limited use of evidence in argumentation, examined whether individuals' limitations in conceptions of both evidence and causality may constrain their potential to employ evidence in argumentation. In that study, adults were presented with a scenario and were asked to choose among three options the one that could serve as the strongest evidence against an opponent's claim. Findings show that half of the adult participants chose the option which included no evidence and simply made a contrasting causal assertion, showing limitations in appreciation and application of epistemic standards pertaining to evidence-claim coordination, even in adulthood. Similarly, Kuhn et al. (2000) found that only half of a group of adults consisting of undergraduate students, college students and professionals reached an evaluativist way of thinking, that is an understanding that knowledge evolves through coordination of theory with data. The only exception was the group of experts − all of whom exhibited an evaluativist mode of thinking.

Limitations in reasoning about evidence have been observed not only in laypersons' reasoning but also in scientists' reasoning, such as confirmation bias in interpreting evidence in order to provide support to favourite theories. Yet, despite these limitations, experts' epistemic standards are more in line with the rigorous standards employed in formal science. Scientists employ rigorous epistemic standards and practices (e.g., peer review, statistics), while they also reflect and revise those standards that make the distinction of the strongest theories at a particular time and the growth of knowledge possible (Chinn & Buckland, 2012). Self-reflection on the way of knowing and the standards that one employs is according to Habermas the most comprehensive way of knowing, and one of the highest criteria employed by doctoral examiners to judge thesis quality, compared to either the empirical-analytical way of knowing which places emphasis on facts, the objective elements of knowing, or the historical-hermeneutic way of knowing which stresses interpretation, the more subjective elements of knowing (Clement et al., 2015).

2.2. Epistemic understanding of evidence and theory-evidence coordination both develop

Underlying age changes observed in epistemic standards is changing epistemic understanding regarding evidence and its coordination with theory, which also undergoes development. Three-year-olds make highly subjective judgments (Wildenger, Hofer & Burr, 2010) and attribute thinking as reflection of external reality. One of the landmarks in this developmental progression of epistemic understanding of evidence and evidence-theory coordination is the understanding that evidence is different from a claim, which is reflected in pre-schoolers' success in the False Belief task by the age of four (Perner & Davies, 1991). This success reflects understanding that different information leads to different beliefs. This

understanding also entails the understanding that evidence is different from information; information only becomes evidence in relation to a claim.

During middle childhood, the understanding that one piece of evidence is amenable to different interpretations is achieved (Lalonde & Chandler, 2002). The understanding that different individuals can assign different meanings to the same stimulus (Carpendale & Chandler, 1996) reflects achievement of more mature understanding than earlier success in ToM tasks, since it involves an understanding that different beliefs could result from the same input, not different inputs. In other words, middle-school children realize not only that people can form different beliefs when they have access to different information, as was the case with ToM tasks, but also when they have access to the same information. Middle school students showed also a better understanding of evidence, reflected in their ability to distinguish between causes and reasons, than pre-schoolers. Astington, Pelletier and Homer (2002) found that seven-year-olds exhibited better ability in distinguishing between the cause of a situation and a person's reason for believing it than pre-schoolers; this ability was related with second-order false-belief understanding, that is, their awareness that people have beliefs about the content of others' minds. Yet, understanding of human knowing is not yet fully developed, as it is not applied consistently nor with appropriate justification (Eisbach, 2004). Also, even though middle-school children are able to understand multiple interpretations of simple stimuli, which offer clear-cut dual interpretations, such as ambiguous pictures (Lalonde & Chandler, 2002), nonetheless, when explicitly asked to respond to stimuli that do not offer any facilitative, perceptual cues of the existence of alternative interpretation, as is the case in most real-life situations, they are not able to do so. Sandoval and Millwood (2005), examining high school students' written explanations for problems on natural selection, found that adolescents made noninterpretive references to data (e.g., the graph shows X). This finding suggests that even high school students believe that "claims are not distinct from data but are somehow embodied in them, that a particular graph or table or other inscription directly represents some aspect of the natural world and consequently has but one meaning" (p. 49, Sandoval & Millwood, 2005). Children's limited understanding of the fact that physical or other phenomena are not self-explanatory, but rather are amenable to different interpretations, is also reflected in their preference for direct observation as a means for knowing. When elementary school students were asked to explain how they could become more certain about what happened in a historical event or about the cause of frog deformities, for which there are contradictory accounts, most students reported that eyewitness accounts (e.g. talk to anyone who was around at that time) would be sufficient to provide an explanation. Only a few elementary school students reported that investigation and interpretation of evidence can provide insights to what happened or what is the cause of the problem, respectively (Iordanou, 2016; Kuhn, Iordanou, Pease & Wirkala, 2008).

The understanding that evidence supports claims has its roots in early childhood – even young children draw on evidence from their personal experience to support or contradict claims (Köymen, Rosenbaum & Tomasello, 2014; Wildenger, Hofer & Burr, 2010). Yet, this understanding is not fully developed even by adulthood. Research in the area of argumentation shows that the epistemic understanding that evidence can be employed to offer support to theories precedes the development of the understanding that evidence also plays the important role of weakening claims (Iordanou & Constantinou, 2014, 2015; Kuhn, Zillmer, Crowell, & Zavala, 2013). The understanding that evidence can be used to weaken claims is related to understanding that evidence can have different interpretations and that evidence can have different functions in relation to different claims.

2.3. Epistemic beliefs about standards vs. application of epistemic standards

Examining the development of epistemic cognition reveals two paradoxes. The first is the commonly encountered one of a discrepancy between beliefs and their expression in action. In other words, there appears to be a discrepancy between individuals' beliefs regarding epistemic standards and the application of epistemic standards in practice. For example, although children might show to endorse the epistemic belief that experts in a domain are more reliable than non-experts, as seen in their preference between experts when

there are clear differences between them concerning the degree of their prior knowledge, children generally adopt in non-problematic fashion, during epistemic action, information from experts in different knowledge domains (Harris & Koening, 2006). Elementary school students appear to adopt the epistemic belief, when asked, that the epistemic standard of model fit with evidence is useful to evaluate scientific models (Pluta, Chinn, & Duncan, 2011), nonetheless, there is evidence that they do not employ this epistemic standard in action (Iordanou, Muis, & Kendeou, 2014; Sandoval et al., 2014). In ToM tasks, when judging others' mental states, adults underestimated the probability that a more ignorant other would search incorrectly as a result of holding a false belief, even though they were aware of the difference between their own and the other's perspective (Zhang et al., 2010; Birch & Bloom, 2007). In addition, in tasks entailing evaluation of texts, Stømsø, Bråten and Britt (2011) found that, although some undergraduate students reported that they endorse the epistemic belief of justification of knowledge based on evidence, when asked to indicate the criteria on which they have based their judgments of trustworthiness in epistemic action, they reported both advanced criteria – content – but also less advanced ones – their own opinion. Similarly, Iordanou, Muis, and Kendeou (2014) reported a discrepancy between adolescents' and adults' epistemic knowledge and their epistemic activity in action. In that study, although some individuals acknowledged that they endorse the epistemic belief that evaluation and interpretation of evidence is central for knowing, when directly asked how they could become more certain about their knowledge, they did not engage spontaneously in evaluation of evidence during epistemic action, when they were reading a text. Focusing on a particular age, we also observe lack of consistency in the application of epistemic standards. For example, pre-schoolers do not show consistency in using the epistemic standard of an informant's history of errors, including the number and kind of errors made when choosing informants (Mills, 2013); neither do they show consistency in assigning test questions correctly to different experts (Aguiar, Stoess & Talyor, 2012). In the examples presented above an inconsistency between individual's epistemic beliefs about standards and the application of those epistemic standards has been observed, as well as an inconsistency in the application of epistemic standards. Individuals' epistemic action is not always consistent with their epistemic beliefs.

The second paradox appears in examining epistemic activity across the lifespan. Although very young children show competence with respect to a particular epistemic criterion, older individuals exhibit limitations in the application of the same criterion. For example, even though some research findings show that pre-schoolers are able to judge an informant's credibility based on the quality of the informant's argument rather than on his or her power (Castelain, Bernard, Van der Henst, & Mercier, 2015), other findings show that most undergraduate students do not engage in evaluation of arguments, examining, for example, whether scientific evidence supports a knowledge claim while researching information on the web (Mason, Boldrin, & Ariasi, 2010) or when reading a text (Iordanou, Muis, & Kendeou, 2014).

It is proposed here that the mechanism behind development of epistemic cognition, which explains the two paradoxes described above, is the development of individuals' epistemic awareness of their epistemic beliefs and conscious control of application of epistemic standards, an issue that we discuss below.

2.4. Understanding of epistemic standards and control of their application develop and support epistemic cognition in action

Studying students engaging in dialogic argumentation over time offers insights regarding how both knowledge and epistemic cognition change. Iordanou and Constantinou (2015), employing the micro-genetic method, a powerful method for understanding epistemic cognitive development (Sandoval, 2014), examined how students use evidence to influence the beliefs of their peers. Eleventh graders, working with a partner, engaged in electronic argumentative dialogues with classmates who held an opposing view on the topic and in some evidence-focused reflective activities, based on transcriptions of their dialogues. Another sixteen 11th graders, who studied the data base in the learning environment for the same amount of time as experimental-condition students but did not engage in an argumentative discourse activity, served as a comparison condition. The findings of this study were consistent with findings of other studies (Iordanou & Constantinou, 2014; Kuhn & Moore, 2015) in showing that after extensive engagement in argumentative

activities, students exhibited a shift from presenting their "right", self-evident theories of how things are, without providing any data to support their argument beyond presenting their personal opinions, to employing data to support their positions and offering alternative interpretations for a particular piece of evidence. In addition, students developed an appreciation of the epistemic understanding that evidence can be used to weaken others' claims, which appears to be a more challenging developmental achievement than understanding that evidence can be used to support one's own claims. Finally, students made more specific reference to evidence and its source after sustained engagement in argumentative activities, a finding which is also consistent with other studies (Iordanou & Constantinou, 2014), suggesting that the process of coordinating evidence with claims, and the awareness of the need to do so, came under increasing conscious control over time. The analysis of participants' dialogues over the course of the intervention provided further support to this suggestion. In particular, the micro-genetic analysis showed that, in addition to the increase observed in the use of evidence and the function of evidence employed, an increase was observed in students' meta-level statements regarding evidence (e.g., ''Give us some evidence'', ''You have not provided evidence'') over the course of the intervention, revealing a developing epistemological understanding of the epistemic standard of evaluating a theory based on its fit to evidence.

Similar results were observed in Chinn, Duschl, Duncan, Buckland, and Pluta's (2008) study, where middle school students engaged in argumentation and reflective activities aimed at constructing, revising, and evaluating scientific models on the basis of evidence, over the course of an academic year. By the end of the intervention, students in the experimental condition exhibited greater advances not only in their ability to effectively coordinate models and evidence, but also in their understanding of epistemic criteria. A shift was observed from non-evidential criteria (e.g., have words and pictures) to evidential criteria, linking models to evidence.

The findings of Iordanou and Constantinou (2015) and Chinn et al.'s (2008) studies have two important implications. The first implication is that dialogic argumentation can offer a suitable setting for studying students' epistemic activity in action and gaining a better understanding of how epistemic cognition changes. The second implication is that argumentation appears to be a promising pathway to support the development of epistemic cognition (Iordanou, 2016; Iordanou, Kendeou, & Beker, 2016; Sandoval, 2005). Engagement in argumentation is a fruitful way for making tacit epistemic beliefs, reflected first in epistemic action, explicit, as well as for changing epistemic beliefs (Iordanou, 2016). The work of Iordanou (2016) showed that engagement in dialogic argumentative activities supported the development of more evaluativist epistemic beliefs, that is an understanding that knowledge evolves through coordination of theory with data and through evaluation, the position found to be best supported by argument and evidence would be determined to have more merit compared to alternative positions (Kuhn et al., 2000).

The increasing acquisition of awareness and conscious control of application of epistemic standards proposed here, and reflected in the Iordanou and Constantinou's (2015) findings as well as in findings from studies on testimony and ToM (Corriveau & Harris, 2009; Koenig & Jaswal, 2011; Mills, 2013; Sobel & Corriveau, 2010), are in line with other findings in cognitive development showing a developing metacognitive monitoring from childhood to adolescence (Kitsantas & Zimmerman, 2002; Roderer & Roebers, 2014; van der Stel & Veenman, 2010). ToM research examining adults' eye movements, while they were following a director's instructions for moving items, shows that adults initially interpreted the director's instructions egocentrically, just like children, but were faster and more effective in correcting a wrong interpretation (Epley, Morewedge & Keysar, 2004). Findings like this one suggest that adults' better metacognitive control is what enables them to "correct" their egocentric errors and exhibit superior behaviour than do children (Apperly, Warren, Andrews, Grant, & Todd, 2011).

2.5. Specificity of epistemic standards

There is ample evidence pointing to the domain-specificity of epistemic cognition (Muis, Bendixen, & Haerle, 2006). Individuals' epistemic cognition differs across domains (Kuhn et al., 2000) and advancement in epistemic cognition in one domain does not necessarily transfer in other domains (Iordanou,

2010; 2016; Hofer, 2004). In Iordanou's (2016) study, notable differences were observed in the epistemic standards employed between a social science topic and a physical science topic. When elementary school students were asked to justify their knowledge of a physical science topic – dinosaurs' extinction – and a social science topic – home-schooling −, the majority of the students reported scientific evidence to justify their knowledge in the physical science topic, while they employed claims from general knowledge or personal experience (e.g. "you don't have friends at home") to justify their knowledge in the social science topic. Domain differences were also observed in both participants' epistemic beliefs and epistemic activity in action between different knowledge domains in Iordanou et al.'s (2014) study. Young adolescents and adults in that study engaged in more epistemic processing of evidence in the history domain than in the science domain. In particular, they engaged more in judging an evidence's credibility while reading a text in the history domain, than in the science domain. Behind this domain-specificity of epistemic cognition, reside domain-specific challenges regarding the development of epistemic cognition. Kuhn et al. (2008) have suggested that in the social domain the major challenge in achieving sophisticated epistemic cognition is different from the challenge in the science domain. In a word, in the social domain, the challenge is to come to terms with the concern that human interpretation plays an unmanageable, overpowering role, while in the science domain, the major challenge is to recognize that human interpretation plays any role at all. In the science domain, the entry of human interpretation into what was previously regarded as direct perception of a single reality must be recognized and come to be understood in positive terms. Human construction of alternative possibilities (multiple representations of truth, or theories) needs to be coordinated with empirical evidence, in an ongoing process that constitutes scientific work. In the social domain, in contrast, human interpretation is more readily recognized and the danger is one of a permanent stall in a radical relativism, with the evil of subjectivity seen as overpowering the quest for any knowledge beyond subjective opinion.

Epistemic standards also must be examined as a function of context. Students' epistemic standards differ when reflected in essays versus dialogues. In the Kuhn and Moore (2015) study, middle-school students used more evidence from their own personal knowledge and experience in their dialogues, about 90%, than in their essays, 40%, suggesting the dialogue was a more authentic experience for them.

Finally, specific content also introduces variation in standards. Here, more research is needed. Bråten, Strømsø, and Salmerón, (2011) found that readers with low topic knowledge failed to employ the most appropriate epistemic standards, whereas Bromme and Thomm (2015) found that adults' judgments regarding reliable informants were not related to participants' prior knowledge, general science knowledge or their study subject. Similarly, Mason, Boldrin and Ariasi (2010) found that prior knowledge was not related to epistemic activity in action, whereas Iordanou, Muis, and Kendeou (2014) found that individuals' prior knowledge predicted their epistemic cognition in action.

3. Conclusions and future research

The question of how knowledge changes as individuals progress through the lifespan requires better answers. Research findings point to differences between children and adults in the way they make judgments. For example, Tenney, Small, Kondrad, Jaswal, and Spellman (2011) found that adults take into consideration information regarding informants' calibration, that is how well one's confidence matches one's likelihood of being correct, whereas children ignore this information and tend to rely more on an informant's confidence. The review presented here proposes that epistemic understanding of theory-evidence coordination develops gradually and different forms of understanding develop at different ages. Also, the present paper presents evidence showing that there is a discrepancy between epistemic beliefs and their expression in action. With age and expertise understanding of epistemic standards and control of their application develop and support epistemic cognition in action. There is a need for more developmental research, especially longitudinal studies, to enhance our understanding of the forms that epistemic cognitive development take and to explain why epistemic development occur or fail to occur.

To satisfy the quest for a better understanding of epistemic cognitive development, there is a need for new measures that would allow us to examine more deeply and thoroughly what develops (Chinn et al., 2011). Dynamic instruments that examine individuals' epistemic cognition as a dynamic, complex construct need to be employed. Some promising measures are think-aloud protocols (Hofer, 2004), eye-tracking techniques, collaborative discussions and computer-based learning environments (Greene, Muis, & Pieschl, 2010), all of them employed in micro-genetic investigations.

There is also need for a better understanding of the specificity of epistemic cognition. Research suggests that epistemic cognition has both general and context-specific elements (Muis, Bendixen, & Haerle, 2006; Sinatra, Kienhues, & Hofer, 2014). Some aspects of epistemic cognition, such as the appreciation of evidence, transfer across contexts (Iordanou & Constantinou, 2014; 2015), whereas other aspects, such as the epistemic criteria that individuals employ for adopting and revising claims appear to be domain specific (Iordanou, 2016; Kuhn et al., 2008). Taking into account the complex and multifaceted nature of epistemic cognition, future research needs to examine the specificity question of epistemic cognition at a more fine-grained level, addressing questions such as how epistemic standards vary across conditions and why this is the case.

Finally, there is a need for future research to examine how the development of epistemic cognition in action can be supported. Engagement in dialogic argumentation appears a promising pathway of supporting understanding that there is no single self-evident truth and that multiple interpretations may exist of the same phenomenon as the human mind plays an active role in ascribing meaning to the world (Carpendale & Lewis, 2006; Iordanou & Constantinou, 2015; Moshman, 2004; Walker, Wartenberg, & Winner, 2012). Engagement also in explicit reflection about the role of evidence in reasoning and about epistemic standards are promising means for supporting an appreciation of the role of evidence in forming and revising knowledge (Chinn & Buckland, 2012; Iordanou & Constantinou 2014; 2015). Future research should examine such methods further.

In summary, the purpose of the present paper has been to draw a strong continuous link between the earliest understanding of other minds and the tasks that confront adults throughout the life span – that of interpreting evidence and coordinating it with what they already take to be true, in a manner over which they exercise conscious control. Adults continue to do so imperfectly to be sure (Kuhn, 2016) but their skill has developed from earlier levels and has the potential to continue to develop. I propose that epistemic cognition builds on increasing awareness and epistemic understanding of theory-evidence coordination and of the role of the human mind in interpreting reality. The standards for knowledge formation and revision are closely connected with epistemic understanding of theory-evidence coordination and change across the lifespan, as well as control of their application. Competence in understanding theory-evidence coordination and the role of the human mind in knowing has its roots in early ToM achievements and proceeds gradually from there towards more and more mature and complete understanding, in a process that ideally never ends. Future research should go beyond a focus on what people believe and increase attention not only on how people choose what to believe, but on how these standards for choice themselves evolve and are applied within real-life contexts. Lastly, addressing the question of how researchers and educators can best support individuals' development in these respects promises to have profound consequences for people's lives.

Keypoints

- The How question of knowledge change is examined
- Evidence from ToM and evidence theory coordination literature are examined
- A focus on epistemic activity in action is proposed
- The standards for knowledge formation and revision change developmentally
- The process increasingly comes under conscious control

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