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The Relationship between Theory of Mind and Executive Function: Are They Two Facets of the Same Process or Two Distinct Processes?

Isu Cho, *The University of Western Ontario*

Supervisor: Morton, J. Bruce, *The University of Western Ontario*

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Abstract

This dissertation examines the relationship between Theory of Mind (ToM) and Executive Function (EF). There has been debate on whether ToM and EF are two facets of the same process or are two distinct processes. Distinguishing between these possibilities empirically is challenging because the two abilities have similar developmental timetables and ToM tasks typically place high demands on EF, with the consequence that ToM and EF performance measures may be artificially correlated. Three experiments explored the nature of this relationship. Experiments 1 and 2 tested whether socio-cultural factors known to influence individual differences in EF (i.e., bilingualism, country-of-origin) extend to differences in ToM. If ToM and EF are two facets of the same process, then the pattern of differences in EF related to the socio-cultural factors and the pattern of differences in ToM should be comparable. Findings suggest that country-of-origin (but not language status) contributed to differences in EF (Experiment 1). In contrast, neither country-of-origin nor language status was associated with ToM (Experiment 2). Experiment 3 examined whether aging adults' performance in ToM tasks improves when EF demands are reduced. The results demonstrated that older adults showed intact ToM despite their deficits in EF when reducing cognitive load in a ToM task, implying that correlations between ToM and EF performance may be artificially elevated. Implications of these findings for understanding the relationship between ToM and EF, and suggestions for future studies, are discussed.

Keywords

theory of mind, executive function, bilingualism, culture, country-of-origin, children, spontaneous-response task, the elderly, aging, social cognition

Summary for Lay Audience

This dissertation examines the relationship between Theory of Mind (ToM: the ability to understand others' mind) and Executive Function (EF; a set of cognitive processes necessary for attaining a goal, including the abilities to control one's attention, plan a strategy, and remember an instruction). It is unclear whether these two abilities stem from one process or are distinct processes. Progress on these issues is slow in part because EF and ToM develop on similar timelines and are measured using similar tasks. Three experiments addressed these issues. Experiments 1 and 2 tested whether individual differences in children's EF related to socio-cultural factors (i.e., bilingualism and country-of-origin) extend to differences in ToM. Experiment 3 tested whether aging adults' performance in a ToM task changed when EF demands of the task were reduced. Results from all three experiments suggest that EF and ToM are distinct processes. Experiments 1 and 2 found that Korean children, regardless of their language status, outperformed Caucasian counterparts on an EF task, but were indistinguishable from Caucasian children on a ToM task. Experiment 3 found that older adults' performance in ToM improved when EF demands in the ToM measure were reduced. The results shed new light on a long-standing debate in Psychology.

Co-Authorship Statement

The first two independent studies presented in this doctoral thesis (Chapter 2 and Chapter 3) were designed and written in collaboration with my advisor, Dr. J Bruce Morton. Also, these studies were conducted in international collaboration with Dr. Hyun-joo Song and Jewan Park from Yonsei University, South Korea. Dr. Morton contributed to the study design, data analysis, and interpretation of the data.

The third independent study (Chapter 5), was designed and written in collaboration with Dr. Adam Cohen. He contributed to the study design and data analysis. This work was published in PLoS ONE on September 20, 2019 (citation information: Cho I, Cohen AS (2019) Explaining age-related decline in theory of mind: Evidence for intact competence but compromised executive function. PLoS ONE 14(9): e0222890. https://doi.org/10.1371/journal.pone.0222890).

In general, Dr. Morton contributed to the revising and editing of each of the chapters (except for Chapter 5).

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Chapter 1

1 Introduction

Across evolutionary history, there is a co-emergence of a variety of higher-order cognitive functions, including language, executive function (EF), social cognition, and symbolizing abilities. Together, this suite of cognitive functions distinguishes modern humans from non-human primates, including old/new world monkeys and great apes. Similarly, there is a rapid co-emergence of these cognitive functions in early childhood development. This raises challenging questions on the relationship between different cognitive domains, such as whether distinct cognitive functions co-emerge or one key domain (e.g., domain-general learning mechanism) emerges from which different cognitive functions develop.

On one view, the human mind consists of distinct modules (domain-specificity), each shaped by natural selection and specialized for solving different adaptive problems (Cosmides & Tooby, 1997). For example, ancestral human beings who had neural circuits that made them good at predicting what others want by using others' eye direction would increase their probability of getting along well with other group members, and this would increase their probability of survival due to successful social interaction. In contrast, not having those neural circuits would increase the probability of individuals being excluded from a group, and this would decrease their probability of survival. Since neural circuits are passed on to offspring, there will be more individuals with these circuits in next generation. Over countless generations, these neural circuits become "mind-reading" modules that modern human beings currently have. Likewise, other cognitive functions, such as perception and language, have evolved to distinct modules so that we have a diversity of distinct modules. These distinct modules enable humans to readily pay more attention to some specific information relative to others to solve specific problems.

An alternative view is that humans are equipped with domain-general (or domain-free) mechanisms that are applied to diverse problems. The 'new thinking' perspective proposes that the mind is like "a multi-purpose instrument (Heyes, 2012, p.2092)" because the human mind is capable of performing a variety of both specific (e.g., mind-reading; Buchsbaum, Bridgers, Weisberg, & Gopnik, 2012), and general tasks (e.g., problem-solving, planning; Chiappe & MacDonald, 2005).

Are theory of mind (or mind-reading; hereafter, ToM), the ability to predict behaviour from inferred mental states, and executive function (EF), supported by distinct modules or are they based on a single domain-general process? The current work examines the relationship between ToM, especially false-belief reasoning, and EF. Although ToM and EF have been suggested to be highly associated with each other, whether ToM and EF are truly interrelated is still controversial. The main focus of the current work lies in providing a comprehensive overview of the relationship between ToM and EF and a greater understanding of the relationship via empirical research.

In the following sections, prior literature on ToM, EF, and the relationship between ToM and EF is reviewed.

1.1 Theory of Mind

Theory of Mind refers to the ability to understand others' mental states, such as beliefs, wishes, intentions, knowledge, desires, and so on, in order to predict their behavior even if their mental states are different from our own. Since such states are not observable but enable individual to make predictions based on the inference of the mental states, it has been viewed as a theory (Premack & Woodruff, 1978).

False-belief understanding, one of the dimensions of ToM and the focus of the current work, is more dependent on higher-order social cognitive abilities than other dimensions of ToM (i.e., emotion or desire understanding). For example, desire understanding simply involves recognizing another person's subjective attitude toward the world. Successful false-belief understanding, however, requires that an individual realizes that: (1) another person has a representation of the world; and (2) the contents of the others' representation may reflect reality or may be different from the reality (Wellman, Cross, & Watson, 2001). Thus, false-belief understanding is generally considered a higher-order form of

ToM reasoning and is often used as a marker of ToM development (Carlson, Moses, & Hix, 1998a; Devine & Hughes, 2018; Liu, Wellman, Tardif, & Sabbagh, 2008).

One task frequently used to measure false-belief understanding in children is a “change-in-location” false-belief task (Wimmer & Perner, 1983). In one popular variant, the “Sally-Anne task”, a child participant with a story about two characters (Sally and Ann) who know that a ball is in a basket. During Sally’s absence, Ann moves the ball from the basket to a box. The critical question is where Sally will look for the ball when she comes back. To correctly answer the question, children need to distinguish between their own true belief about the location of the ball and Sally’s false belief that the ball is still located in the basket. Another widely used false-belief understanding task is the “unexpected-contents” false-belief task (Gopnik & Astington, 1988). In a popular variant, the “Smarties task”, a child is shown a candy box (i.e., “Smarties”), but then discovers upon opening it that the box actually has unexpected contents (e.g., crayons) instead of expected contents (i.e., smarties). After closing the box, the child is asked about what another person ‘X’ who has not seen inside the box would think is inside it. Since X does not know that the box actually contains crayons, X would falsely believe that the candy box contained candies as it appears.

Four- and five-year-old children often give correct answers to the critical questions in false-belief tasks, whereas younger children give answers corresponding to their own beliefs or reality, rather than another person’s belief (Gopnik & Slaughter, 1991; Wimmer & Perner, 1983). Preschool-aged children show consistent and robust development of false-belief understanding, irrespective of ToM task types and countries of origin (Wellman et al., 2001). The development of false-belief understanding continues and becomes increasingly complex through adolescence and young adulthood (Blakemore, 2012; Dumontheil, Apperly, & Blakemore, 2010).

At the other end of the lifespan, the ability to understand others’ false beliefs typically declines (but see Happé, Winner, & Brownell, 1998; MacPherson, Phillips, & Della Sala, 2002; Saltzman, Strauss, Hunter, & Archibald, 2000 for exceptions). For example, in one of the typically used false-belief tasks for adults (a modified version of the “change-in-location" false-belief task for children), adults are presented with a story or video demonstrating a protagonist's false-belief or true-belief/the reality of a situation. For example, the protagonist sees that an object is located in Location A. The object is then moved to Location B during the protagonist's absence (false-belief condition) or presence (true-belief condition). Adult participants are then asked to predict where the protagonist would look for the object. The correct answer depends on conditions (i.e., false-belief condition: Location A; true-belief condition: Location B). Older adults made more errors in the false-belief condition compared to young adults, whereas, in the control condition that did not involve any mentalizing skills, they made fewer errors (Bailey & Henry, 2008) or they did not differ in performance from young adults (German & Hehman, 2006; Phillips et al., 2011). This is surprising given that older adults have accumulated considerable social experience and wisdom (Randall, 2013; Tentori, Osherson, Hasher, & May, 2001). One possibility is that age-related ToM decline is linked to the deterioration of EF (German & Hehman, 2006; Phillips et al., 2011). Questions concerning the relationship between ToM (specifically, false-belief understanding) and EF in older adults will be addressed in detail in section 1.3.

In conclusion, false-belief understanding follows an inverted U-shape across the lifespan. It rapidly develops between the ages of 3- and 5-years, continues to develop through adolescence and early adulthood, and then declines in late adulthood. This developmental trajectory is very similar to that of EF (Carlson & Moses, 2001; Carlson, Moses, & Breton, 2002; Frye, Zelazo, & Palfai, 1995; Hughes & Ensor, 2005), suggesting perhaps that ToM and EF are fundamentally linked.

1.2 Executive Function

Executive function (EF) is an umbrella term that refers to a set of cognitive processes that support goal-directed behaviour (Baddeley, 1996; Miyake & Friedman, 2012), including working memory, planning, inhibitory control, attention, and shifting.

Different tasks are used to measure EF of individuals of different ages. One task used to measure EF in children is the day/night Stroop task (Gerstadt, Hong, & Diamond, 1994). In this task, children are shown two cards, one white card with a sun drawn on it and a second black card with a moon drawn on it. They are then instructed to say “day” for the moon card and “night” for the sun card. Similarly, in Luria’s hand game (Luria, Pribram, & Homskaya, 1964), children first learn two different hand gestures (e.g., making a fist and pointing with an index finger). They are then instructed to make the opposite gesture to the experimenter’s gesture (e.g., when the experimenter makes a fist, the children need to point with a finger). These two tasks are considered measures of response inhibition because they require children to inhibit a prepotent response in favour of an alternative behaviour. Another common task for measuring EF in young children is the Dimensional Change Card Sort task (DCCS; Zelazo, 2006). In this task, children are presented with two boxes, each marked with a bidimensional target (e.g., a red rabbit and a blue truck). In pre-switch trials, children begin by sorting test cards that match each of the targets on a single dimension (i.e., blue rabbits and red trucks) according to one dimension (e.g., colour; all the red cards should go into the box with a red rabbit and all the blue cards should go into the box with a blue truck). Following 5 to 10 pre-switch trials, children are instructed to switch and sort the cards by the second dimension (e.g., shape; all the rabbit cards should go into the box with a red rabbit and all the truck cards should go into the box with a blue truck). The post-switch, therefore, requires children to inhibit the use of an old rule and shift and use a new rule.

For adolescents and adults, one commonly used measure of EF is the Stroop task. In the task, participants are given a list of words (e.g., red, blue, green, and so on) and are instructed to not read the words but instead name the colour of the font. In some cases, the colour of the words is matched with the meaning of the words (e.g., the word ‘red’ written in red) and in other cases, the colour of the words is mismatched with meaning (e.g., the word ‘blue’ written in red). The former cases refer to congruent trials and the latter cases refer to incongruent trials. Participants are typically faster and show more accurate on congruent trials compared to incongruent trials (Jensen & Rohwer, 1966; MacLeod, 1991) possibly because incongruent trials require over-practiced word reading to be inhibited in favour of color naming. One representative task for measuring working memory capacity is the memory span task. In this task, participants are presented with a list of items (including letters or numbers) and they are then asked to recall the items in correct order (forward) or in reverse order (backward). The highest number of correctly recalled items is considered as individual's working memory span. Finally, one common measure of adults' flexibility is the Wisconsin Card Sort Task (WCST; Grant & Berg, 1948). In the WCST, participants are asked to sort cards with diverse symbols according to either colour, shape, or the number of the symbols. The only feedback available to participants is whether each match they make is correct or not so that participants have to infer how to match the cards correctly based on the feedback and change their strategy when a specific match is incorrect.

With these various EF tasks, it has been found that EF rapidly improves in preschool-aged children (Diamond & Taylor, 1996; Hughes, 1998) as they age. For example, children aged between 3 and 5 years show rapid development of EF even after controlling for verbal ability (Carlson, 2005). EF continues to develop through elementary school age and adolescence. During elementary school years, children show marked improvement in working memory (Siegel, 1994) and set-shifting (Cepeda, Kramer, & Gonzalez de Sather, 2001; Rosselli & Ardila, 1993). For example, children show sharp improvement in various working memory span tasks between the ages of 4 ½- and 8-years and gradual improvement after the ages of 10 years (Case, 1992). In addition, elementary school children become progressively insightful about their own mental processing and can exert greater conscious control over their thoughts and actions (Flavell, Green, & Flavell, 2000).

During adolescence, EF continuously and gradually develops (Huizinga, Dolan, & van der Molen, 2006; Kleibeuker, De Dreu, & Crone, 2013; Peters, Van Duijvenvoorde, Koolschijn, & Crone, 2016). For example, working memory develops until the age of 21 and set-shifting and inhibition develops until the age of 15 (Huizinga et al., 2006). Although EF subcomponents seem to show different developmental courses, EF reaches its peak during adolescence. Through adulthood, EF performance stabilizes (Peters et al., 2016) or even slightly decreases (e.g., on divergent thinking tasks, Kleibeuker, De Dreu, & Crone, 2013; on spatial divergent tasks, Kleibeuker, Koolschijn, et al., 2013). One reason why EF development may be so protracted is that the prefrontal cortex (PFC), an area of the brain associated with executive functioning, is slow to develop. Like EF, the PFC continues to develop until early adulthood (Crone, Donohue, Honomichl, Wendelken, & Bunge, 2006; Huttenlocher & Dabholkar, 1997; Moriguchi & Hiraki, 2013; Morton, Bosma, & Ansari, 2009).

In late-adulthood, although people vary substantially in cognitive aging (Cabeza, Anderson, Locantore, & McIntosh, 2002; Rosen et al., 2002), in general, aging is associated with a decline in EF. Older adults show deficits on attentional tasks (e.g., showing larger cost effects of dividing attention during a dual task, McDowd & Craik, 1988; Verhaeghen, Steitz, Sliwinski, & Cerella, 2003), working memory tasks (Salthouse & Babcock, 1991), and inhibitory control tasks (e.g., showing slower reaction times to target stimuli while ignoring irrelevant stimuli, McDowd & Shaw, 2000; West, 2004). As mentioned earlier, structural and functional changes in the PFC that occur with age (e.g., cortical thinning in the PFC with age, age-related changes in the PFC activity) may play a role in age-related decline of EF (Burzynska et al., 2012; Chao & Knight, 1997; Rypma & D'Esposito, 2000; West, 1996).

In sum, EF rapidly develop in childhood, and some of EF subcomponents (i.e., inhibition, shifting) mature and stabilize in early adolescence, whereas other EF subcomponents (i.e., working memory) continue to develop into early adulthood. As seniors age, the opposite pattern is observed, with prominent age-related decline in across multiple domains of EF. Thus, the development of EF follows an inverted U-shape, similar to the developmental course of ToM.

1.3 The relationship between Theory of Mind and Executive Function

The fact that ToM and EF follow similar developmental trajectories suggests that these abilities may be closely related. One possibility is that ToM and EF both rely on use of the same higher-order representations. For example, Cognitive Complexity and Control theory (Frye, Zelazo, & Burack, 1998) stipulates that ToM, especially false-belief understanding, is simply one form of a domain-general reasoning skill involving use of higher-order rules. For example, in the "change-in-location" false-belief task, one is able to predict where another person will look for an object using if-if-then rules, without inferring his/her mental states (e.g., "*if* he/she saw that the object was located in a box A, *if* he/she did not see that the change of the object's location (from the box A to a box B), *then* the box A"). Thus, false-belief understanding may involve use of general higher-order rules that are not unique reasoning about mental states.

An alternative possibility is that ToM and EF are grounded in common domain-general working memory and inhibitory control processes (Moses, 2001). For example, in false-belief tasks, one has to suppress salient information regarding reality or one's perspective/belief (inhibitory control) and hold in mind not only one's own mental state but the mental state of another person (working memory). Thus, EF has been proposed to be closely related to ToM.

Empirically, ToM and EF are often correlated. For example, preschoolers' performance on false-belief tasks and EF tasks are correlated even when age, gender, and verbal ability are partialled out (Carlson & Moses, 2001; Frye et al., 1995). Although there are mixed results on the direction of the relationship with a longitudinal study design (e.g., early EF predicts later false-belief understanding: Hughes, 1998; Hughes & Ensor, 2007 vs. early ToM including false-belief understanding predicts later EF: McAlister & Peterson, 2013), the results suggest a close association between ToM and EF. A strong link between ToM (specifically, false belief understanding) and EF has also been found in middle childhood (children aged 6-11 years; Austin, Groppe, & Elsner, 2014; Devine et al., 2016). Relatedly, ToM and EF appear inter-related in children with autism. For example, autistic children show deficits on not only ToM tasks but EF tasks (Ozonoff, Pennington, & Rogers, 1991; Rumsey & Hamburger, 1990), and the developmental trajectories of ToM and EF in autistic children are similar (Ozonoff & McEvoy, 1994).

The strong relationship between false-belief understanding and EF can also be found in adulthood. It has been suggested that the age-related deterioration of false-belief understanding is associated with the decline of EF. For example, adults' performance on a false-belief task is significantly correlated with EF, specifically, working memory, inhibitory control, and speed of processing (German & Hehman, 2006). Indeed, there is evidence that EF statistically mediates the age-related decline of ToM (Bailey & Henry, 2008; Charlton, Barrick, Markus, & Morris, 2009; Phillips et al., 2011). These findings are suggestive of a highly interdependent relationship between ToM and EF.

Regarding how EF relates to ToM, two general possibilities have been proposed (Carlson & Moses, 2001; Carlson et al., 2002), but there have been controversies over it. According to emergence account, EF is necessary for the emergence of ToM ability so that EF is required for children to understand mental state concepts, such as beliefs, wishes, and intentions. Empirically, there is evidence supporting this account in that early EF predicts later false-belief understanding (Hughes, 1998; Hughes & Ensor, 2007) despite the empirical results favouring the opposite pattern (i.e., early ToM predicts later EF; McAlister & Peterson, 2013). On the other hand, expression account posits that EF is necessary to display one's mentalizing ability. According to this account, children already have ToM competence, but the EF demands that a ToM task requires to perform may impede their successful performance on a ToM task. The evidence showing that children's performance on a ToM task increased when the inhibitory control demands that the ToM task imposes were reduced (Carlson, Moses, & Hix, 1998b) seems to favour the expression account. Another piece of evidence, however, is inconsistent with the expression account in that lowering EF demands of ToM tasks did not influence children's performance (Wellman et al., 2001). Thus, it is still unclear on how ToM and EF relate to each other.

At the same time, it has been proposed that ToM and EF are distinct processes. According to one evolutionary theory (Tooby & Cosmides, 1997), ToM is supported by a module dedicated to solving specific social cognition problems. In this account, over successive generations, the human social environment puts evolutionary pressure on the individual's capacity to solve social challenges (e.g., identifying others who would cooperate and who would cheat; Cosmides, 1989; Trivers, 1971), which has evolved into a ToM module.

Empirically, considerable evidence suggests that ToM and EF are distinct. For example, autistic children show deficits in ToM tasks, but not in control tasks that involve non-mental reasoning but require similar EF loads to ToM tasks (Charman & Baron-Cohen, 1992; Leslie & Thaiss, 1992), implying that ToM is a specialized and independent module. In addition, neuroimaging studies (Saxe & Kanwisher, 2003; Saxe, Schulz, & Jiang, 2006; Saxe & Wexler, 2005) identify the right temporo-parietal junction (rTPJ) as a brain area uniquely engaged by mentalizing tasks. Thus, given the inconsistent findings on the relationship between ToM and EF, it is uncertain whether the two abilities are based on one common process or are distinct processes.

1.4 Empirical challenges to testing the nature of the relationship between Theory of Mind and Executive Function

ToM and EF have similar developmental timetables. However, it is unclear whether the close co-development of ToM and EF is merely coincidental or indicative of a close fundamental link. Making matters more complicated, tasks used to study ToM in children and adults typically place high demands on EF, with the consequence that ToM and EF might appear to be correlated due to methodological artifacts. For example, in standard false-belief tasks (in other words, elicited-response or explicit false-belief tasks), participants have to provide a verbal response indicating another person's belief. Consequently, these types of tasks impose high cognitive demands (i.e., inhibiting a prepotent response, generating an explicit response), leading to increased similarity between ToM and EF performance measures. It is conceivable, therefore, that ToM and EF are statistically correlated but not causally associated.

1.5 The current work's research questions

The purpose of the current work is to examine whether ToM and EF are rooted in a common process or whether they are distinct processes. In an effort to lend clarity to this debate, two experiments examined individual differences in ToM and EF in the preschool period. In Experiments 1 and 2, the relation between ToM and EF was examined by testing whether socio-cultural factors known to impact differences in EF extend to differences in ToM. Language status and country-of-origin have been proposed as socio-cultural factors known to influence individual's EF. For example, there is evidence suggesting that: (1) bilingual children are advantaged in EF compared to monolingual children (language status; Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008); and (2) children from East Asian countries make fewer errors in EF tasks compared to Caucasian children from Western countries, like Europe and North America (country-of-origin; Oh & Lewis, 2008; Sabbagh, Xu, Carlson, Moses, & Lee, 2006). Thus, Experiment 1 tested the effects of language status and country-of-origin on EF. To that end, the performance of bilingual and monolingual preschool-aged children of varied national origin on an age-appropriate inhibitory control task was compared. Experiment 2 then tested whether effects of language status and country-of-origin (reported in Experiment 1) are observed in ToM.

If ToM and EF are based on a common process, then language status and culture should exert similar effects on EF and ToM. In other words, the pattern of results for EF due to the socio-cultural factors (Experiment 1) and the pattern of results for ToM (Experiment 2) are expected to be similar. However, if ToM and EF are distinct processes, then the effects of language status and country-of-origin on EF shown in Experiment 1 should not extend to ToM.

Experiment 3 examined whether aging adults with declining EF show impairment in ToM when tested using a ToM task that places fewer demands on EF. To that end, younger and older adults were compared on a spontaneous-response (or implicit) ToM task that imposes fewer demands on EF (Scott, 2017). For example, in spontaneous-response tasks, participants are not required to explicitly generate verbal responses, but reveal mental state evaluations through spontaneous actions such as looking behaviours and spontaneous helping behaviours. Therefore, Experiment 3 explored whether older adults who are experiencing age-related decline of EF show difficulty in belief-tracking when tested with a ToM task that places fewer demands on EF resources.

If ToM and EF are based on a common process, then reducing cognitive load required for performing a ToM task should be of no effect on the nature of the relationship between ToM and EF. Therefore, it is predicted that older adults believed to be experiencing age-related decline in EF should show deficits in belief-tracking even when using a spontaneous-response ToM task. However, if ToM and EF are distinct processes (but performance between ToM task and EF task are simply artificially correlated due to methodological artifacts), then the attempt to lower cognitive demands for performing a ToM task should lead to dissociation between ToM and EF in older adults. In other words, it is expected that older adults would show impairment in EF, but not in belief-tracking, implying that the strong relationship between ToM and EF reported in the existing studies is simply due to high cognitive loads that ToM ‘tasks’ require to perform.

The remainder of this dissertation is organized as follow. Chapter 2 (Experiment 1) explored the effects of socio-cultural factors (i.e., language status and country-of-origin) on EF. Chapter 3 (Experiment 2) examined whether socio-cultural effects on EF observed in Chapter 2 (Experiment 1) extend to ToM. Chapter 4 is for integrating and summarizing the results from Experiments 1 and 2. Chapter 5 (Experiment 3) explored whether reducing the cognitive demands of ToM tasks influences the relationship between ToM and EF. Chapter 6 discussed the results from the Experiments 1 to 3 with suggesting implications and future research in ToM and EF.

Chapter 2

2 The effects of individual difference in language status and country of origin on executive function

Four- to five-year-old children have difficulty inhibiting prepotent behaviours (Diamond, 2002). In modified Stroop tasks (Gerstadt et al., 1994), children are presented two images (e.g., a drawing of the sun and a drawing of the moon) and instructed to select the image that is weakly associated with a word (e.g., select the image of the moon in response to the word “day”). Young children typically err by selecting the image that is strongly associated with the word (e.g., a picture of the sun). Age-related advances in response inhibition occur throughout this period and are considered part of normative cognitive development (Kirkham, Cruess, & Diamond, 2003; Morton & Munakata, 2002; Zelazo, Frye, & Rapus, 1996).

Interestingly, there is evidence that young children who grow up speaking two languages are advantaged in response inhibition tasks compared to children who grow up speaking one language (Bialystok & Martin, 2004; Bialystok & Senman, 2004). In one landmark study, Bialystok (1999) administered an inhibitory control task to Chinese-English bilingual and English monolingual preschool-aged children. Bilingual children exhibited greater inhibition than monolingual children in that they were better able to suspend use of an initial sorting strategy and replace it with another. Response inhibition advantages favouring bilingual children have since been observed in a range of different tasks (Bialystok, 2010; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008).

According to the prevailing interpretation (Bialystok, 1999; Bialystok, Klein, Craik, & Viswanathan, 2004), bilingual children’s advantage in inhibitory control is linked to their experience managing two languages in daily life. On this view, continued experience exercising control in this way leads to improvements in inhibition that, in turn, generalize to problems outside the domain of language via domain-general control processes.

Whether differences in young bilingual and monolingual children’s inhibitory control are uniquely attributable to differences in language status is, however, hotly debated. Indeed, several recent studies reported no association between language status and children's inhibitory control (Dick et al., 2018; Duñabeitia et al., 2014), raising questions about the basis of previously reported language status effects favouring bilingual children.

One possibility – and the focus of the current study – is that performance differences previously attributed to the effects of language status may actually reflect the influence of uncontrolled confounding factors (Hartanto & Yang, 2019; Morton & Harper, 2009; Yang, Yang, & Lust, 2011). In Bialystok's (1999) landmark comparison of Chinese-English and English-speaking children, for example, group differences in inhibitory control were attributed to the effects of language status. Logically, however, reported group differences could have been attributed to differences in the country of origin of these children and their families. Indeed, children from East Asian countries, like Korea, make fewer errors in inhibition tasks than do Caucasian children from western nations, like Canada (Oh & Lewis, 2008; Sabbagh, Xu, Carlson, Moses, & Lee, 2006), perhaps because of differences in their respective collectivist and individualist cultures (Clarke-Stewart, Lee, Allhusen, Kim, & McDowell, 2006; Hofstede, 1980). Therefore, to address this possibility, the current work was conducted.

In the current study, to disentangle confounded language status and country-of-origin explanations of the bilingual advantage, Korean monolingual kindergartners from Seoul, South Korea, Korean-English bilingual and English monolingual kindergarteners from Ontario, Canada were administered a modified Stroop task including congruent and incongruent trials. Our predictions were as follows. If the effect of language status on children's inhibitory control only exists, then Korean-English bilingual children should show higher accuracy on incongruent trials than Canadian English monolingual and Korean monolingual children. If there is the effect of country-of-origin only, then Korean children, irrespective of their language status, should demonstrate higher accuracy on incongruent trials compared to Canadian English monolingual children. If there are the effects of language status and country-of-origin on children's inhibitory control, Korean-English bilingual children would make fewer errors on incongruent trials compared to Korean monolingual children, who would be expected to make fewer errors than Canadian English monolingual children, but all the three groups would perform comparably on congruent trials. Furthermore, to better understand possible country-of-origin differences in children's inhibitory control, survey measures of cultural values (Individualism-Collectivism) and parenting attitudes (authoritarian and authoritative) were obtained from parents of all children.

2.1 Methods

2.1.1 Participants

Participants included 112 children aged between 3.5 and 5.5 years of age. This sample consisted of 36 Caucasian English monolingual speakers living in Ontario, Canada; 43 Korean monolingual speakers living in and around Seoul, Korea; and 33 Korean-English bilingual speakers living in Ontario, Canada. Of these 112 children, 3 were excluded from the analysis. These included two English monolingual children whose parents were not Caucasian, and one bilingual child whose parent classified them as monolingual. An additional 10 children had to be dropped for various reasons including: experimenter error (one Korean monolingual child); computer failure (one Korean monolingual child); incomplete Stroop data (one Korean monolingual child), and early withdrawal of participation[1] (seven Korean monolinguals). Thus, the final sample consisted of 99 children, and included 34 English monolinguals who lived in Canada and whose mother and father were Caucasian (18 females, M_{age} = 4.44 years, SD = 0.50), 33 Korean monolinguals who lived in Korean and whose mother and father were Korean (18 females, M_{age} = 4.30 years, SD = 0.57), and 32 Korean-English bilinguals who lived in Canada and whose mother and father were Korean (13 females, M_{age} = 4.71 years, SD = 0.58). Groups differed in age, F (2, 96) = 4.70, p = .011, with Korean-English bilinguals older than Korean monolinguals (p = .01), but no difference between English monolinguals and Korean-English bilinguals (p = .140) nor between English

[1] All seven Korean monolingual children withdrew from the study during the PPVT due to boredom. Since the Korean PPVT-R was conducted using a pencil-and-paper version whereas the English PPVT-4 was conducted using a tablet, it is assumed that the unequal data attrition among the groups is caused by the difference in methods of administering the PPVTs.

monolinguals and Korean monolinguals (p = .917). This study was approved by Human Research Ethics board at Western University and Yonsei University (see Appendix A).

2.1.2 Tasks and measures

2.1.2.1 Language status

Bilingual/monolingual language status was assessed in two ways. First, children were administered the English (and/or Korean) version of the Peabody Picture Vocabulary Tests (PPVT; English version of the PPVT - fourth edition, Dunn & Dunn, 2007; Korean version of the PPVT-Revised, Kim, Chang, Yim, & Beak, 1995), a standardized assessment of receptive vocabulary. Second, parents completed a daily language use survey on behalf of their children (Bialystok, 2010). The survey solicited information about children's daily language use in various contexts (e.g., with family, with friends, at preschool/daycare, when watching TV/movies, and when counting or doing math)[2]. Scores ranged from 1 (only his/her first language) to 5 (only his/her other language) for all questions. Parents were also asked to report the proportion of each day their child used their first language on average (see Appendix B).

2.1.2.2 Socio-economic status

Socio-economic status (SES) was assessed by means of a survey administered to parents (see Appendix B). The survey solicited information about the family's social and economic position in their local society, including the parent's subjective perception of their family's relative income level (i.e., compared to other families in the country you live in, your family income level is 1: not very much – 5: very wealthy), and paternal and maternal education level (1: No education, 2: Elementary, 3: High school, 4: College/professional school, 5: Undergraduate, 6: Graduate or Medicine).

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[2] Due to experimenter error, Korean monolinguals' language use when watching TV/movies and when counting/doing math was not measured.

2.1.2.3 Individualism-Collectivism

Parental cultural value orientation was assessed using Triandis and Gelfand's (1998) Individualism-Collectivism Scale (INDCOL; see Appendix C). The INDCOL Scale has 27 items that measures 4 different subscales: Horizontal Individualism (HI; 5 items), which reflects how much an individual values social autonomy; Horizontal Collectivism (HC; 8 items), which reflects how much an individual values social interdependence; Vertical Individualism (VI; 8 items) which measures how much an individual values opportunities for distinction; and Vertical Collectivism (VC; 6 items), which reflects how much an individual accepts social hierarchy and collective decision making. Parents responded to each the 27 items using a 9-point scale (1: Never or definitely no – 9: Always or definitely yes).

2.1.2.4 Authoritative and Authoritarian Parenting Attitudes

Parental child-rearing attitudes was assessed by means of the short version of Block (1981)'s Child-rearing Practices Report (CRPR; see Appendix D). Parents answered each of the 68 survey items using a 5-point Likert scale (1: Strongly agree – 5: Strongly disagree). Following the method of Kochanska, Kuczynski, & Radke-yarrow (1989), authoritarian parenting attitudes were estimated from items measuring punishment orientation, high power parenting/control, and parental rejection, whereas authoritative parenting attitudes were estimated from items measuring parental acceptance, encouragement of independence/achievement, and low power parenting/induction.

2.1.2.5 Inhibitory control

Inhibitory control was measured by means of an age-appropriate modified colour-word Stroop task. The task was administered on a touch-screen tablet (ASUS Transformer Mini T102H tablet) running custom software implemented in Python using PsychoPy version. 1.85.6 (Peirce, 2009). Each trial presented two ellipses, one red and one blue. On half of the trials, the red ellipse appeared on the left; on half of the trials, it appeared on the right. The relative position of the two ellipses switched randomly from trial and to trial. Trials began with a white fixation cross, followed one second later by the two coloured ellipses, followed 500ms later by an audio recording of the word “red” or “blue.” Ellipses remained visible until the participant made a response. On incongruent trials, children were instructed to touch the blue (or red) circle when they heard the word “red” (or “blue.”) On congruent trials, children were instructed to touch the blue (or red) circle when they heard the word “blue” (or “red.”) The entire task consisted of 1 block of 12 incongruent trials (6 with the word “red” and 6 with the word “blue”) followed by one block of 12 congruent trials (6 with the word “red” and 6 with the word “blue”), with the order of trials within blocks randomized for each participant but block order fixed for all participants. To ensure children fully understood the rules for each trial type, each block started only after children responded correctly to two practice trials. On every trial, the tablet recorded the accuracy and latency of participant responses.

2.1.3 Procedure

Parents provided informed and written consent to their own and their child’s participation, and children provided verbal assent to their participation. Children were tested individually by trained research assistants in one session that lasted approximately 30-40 minutes. The full protocol included additional measures not reported here that were administered as part of a larger cross-cultural study of kindergarteners’ social cognition. English (or Korean) monolingual children were tested in a child development laboratory in Ontario Canada (or Seoul South Korea) by native English speakers (or a native Korean speaker). Korean-English bilingual children were tested in Ontario Canada in a quiet room in a local church by Korean-English bilingual speakers.

Two steps were taken to avoid inconsistencies in the administration of the protocol across experimenters and settings. First, all experimenters adhered to a common script that included a fixed set of task instructions for each component of the protocol. The script and survey measures were translated from English into Korean, and then back-translated into English, and corrected for inconsistencies. Second, English and Korean versions of the modified Stroop task that served as the core measure of children’s inhibitory control were implemented on touch-screen tablet computers (shipped from Canada to South Korea) and used for all testing.

Task order was pseudo-randomized across participants, and breaks were provided as needed. To avoid unnecessary test burden, Korean-English bilinguals were administered the English version of the PPVT at the beginning of testing and the Korean version of the PPVT at the end of testing. Parents completed the surveys in a private space as their children were tested nearby.

2.2 Results

2.2.1 Language status

Missing data included one Korean-English bilingual participant's Korean receptive vocabulary score (the child did not complete the test), one Korean-English bilingual participant's English vocabulary score (computer failed to save the data), and one Korean-English bilingual child's daily language use survey score (parent did not complete the survey). Descriptive statistics for receptive vocabulary and daily language use are reported in Table 1 and confirmed that monolingual and bilingual children showed daily language use and proficiency in one and two languages respectively.

2.2.2 Socio-economic status

Missing data included measures of perceived SES from two parents (one Caucasian Canadian parent, one Korean parent living in Korea), measures of paternal education level from four parents (two Caucasian Canadian parents and two Korean parents living in Korea), and measures of maternal education level from one parent (one Korean parent living in Korea). Data were missing either because the parent was single or refused to report. SES measures for the separate groups are reported in Table 1. Separate one-way analyses of variance (ANOVA) with group as a between-subjects factor confirmed no difference between groups in perceived relative economic status (p = .762) and maternal educational level (p = .270). Paternal education level, however, differed for the three groups, F (2, 92) = 3.94, p = .023, η_p^2 = .079, being slightly higher for fathers of Korean-English bilingual children compared to fathers of English monolingual children (p = .020). There was no difference in the education level of fathers of English and Korean monolinguals (p = .272) nor in the education level of fathers of Korean monolinguals and Korean-English bilinguals (p = .891). In sum, groups were of comparable SES.

Table 1. Participants' means (and standard deviations) of daily language use, Peabody Picture Vocabulary Tests (PPVT) scores, and socio-economic background questionnaire

Variable	Language group		
	English monolingual	Korean-English bilingual	Korean monolingual
Daily L1 (child's First language) Use			
With their family	1.00 (0)	2.41 (0.84)	1.15 (0.36)
With their friends	1.00 (0)	3.00 (0.95)	1.09 (0.29)
At preschool/ daycare	1.00 (0)	4.16 (1.11)	1.27 (0.57)
Watching TV/movie	1.12 (0.33)	3.09 (0.78)	-
Counting/doing math	1.06 (0.24)	3.47 (0.80)	-
Proportion of L1 use (%)	99.88 (0.48)	54.84 (21.11)	97.09 (4.77)
PPVT raw Scores			
PPVT-4: Eng.	85.91 (21.39)	56.48 (19.85)	-
PPVT-R: Kor.	-	35.48 (15.86)	52.52 (22.02)
Socio-economic Background Questionnaire			
Subjective SES	3.09 (0.72)	3.00 (0.76)	3.13 (0.61)
Paternal education	4.41 (0.80)	5.00 (0.84)	4.77 (0.92)
Maternal education	4.71 (0.80)	5.00 (0.57)	4.78 (0.87)

2.2.3 Inhibitory control

As is typical of 4- to 5-year-old children, 77% of the participants were either systematically correct (61% of the participants showed above 80% accuracy) or systematically incorrect (16% of the participants showed below 20% accuracy) on incongruent trials of the modified Stroop task, limiting the number observations required for response time analysis. Analysis therefore focused on accuracy.

We sought to disentangle language status and country-of-origin interpretations that are confounded in the previous literature. For this, we compared Korean monolingual children's Stroop task performance with that of Korean-English bilingual and English monolingual children (see Figure 1). All three groups showed a high rate of accuracy on congruent trials (Korean monolingual group: M = 80.81, SD = 33.56); however Korean monolingual (M = 92.68, SD = 12.97) and Korean-English bilingual children showed higher accuracy on incongruent trials than did English monolingual children. A 3 Group (Korean monolingual, Korean-English bilingual, English monolingual) x 2 Condition (incongruent versus congruent) mixed ANOVA confirmed a significant interaction of Group and Condition, F (2, 96) = 5.02, p = .008, η_p^2 = .095, which remained significant after controlling for group differences in age, F (2, 95) = 5.14, p = .008, η_p^2 = .098. To identify the source of the interaction, we performed two one-way ANOVAs, one that examined the effect of Group on congruent trial accuracy, and a second that examined the effect of Group on incongruent trial accuracy. There was no effect of Group on congruent trial performance, F (2, 96) = 0.13, p = .876, but there was a significant effect of Group on incongruent trial performance, F (2, 96) = 6.31, p = .003, η_p^2 = .116. Bonferroni-corrected pairwise comparisons confirmed both Korean monolinguals and Korean-English bilinguals had higher accuracy on incongruent trials than English monolinguals (p = .007 and p = .011 respectively), but did not differ from each other (p = 1.000).

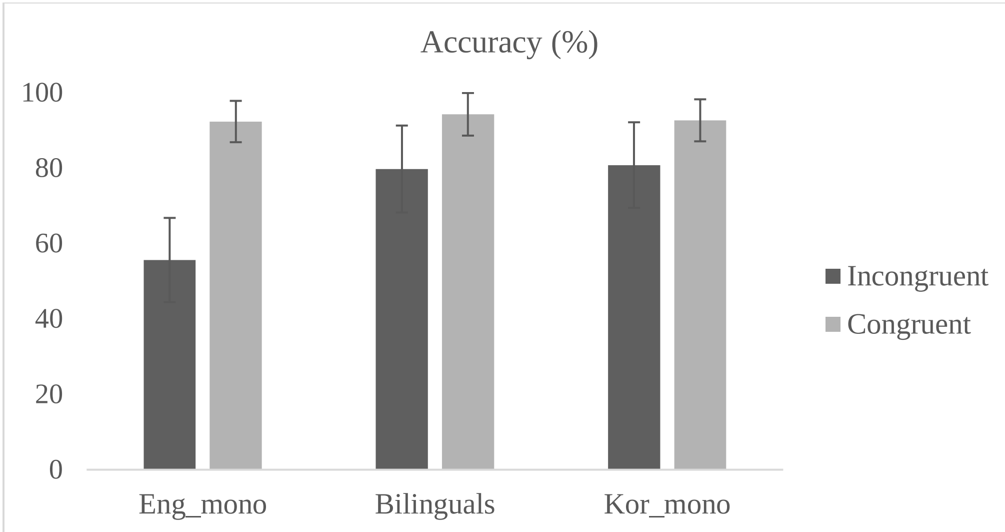

Figure 1. Mean accuracy in each condition during the Red-Blue Stroop task. Error bars represent 95% confidence intervals.

2.2.4 Individualism-Collectivism

The reliability statistics (Cronbach's α) for the four subscales from the INDCOL scales are .629 (HI), .785 (VI), .759 (HC), and .528 (VC), respectively, indicating high internal consistency for VI and HC, acceptable consistency for HI, but questionable consistency for VC.

Group means and standard deviations of the four subscales from the INDCOL scales are shown in Table 2 and Figure 2. Groups means were comparable for VC, F (2, 96) = 1.95, p = .148, and HI, F (2, 96) = 1.01, p = .368, but differed slightly for both VI, F (2, 96) = 5.43, p = .006, η_p^2= .102, and HC, F (2, 96) = 4.87, p = .010, η_p^2= .092. Bonferroni-corrected post hoc tests confirmed that Korean parents living in Canada and those living in Korea had significantly higher VI scores than did Canadian parents, p = .010 and p = .029, respectively, but did not differ from each other (p = 1.000). As well, Korean parents living in Korea had significantly lower HC scores compared to both the Korean parents living in Canada (p = .038) and Canadian parents (p = .016), who did not differ from each other (p = 1.000).

Table 2. Parents' means (and standard deviations) of scores for Individualism-Collectivism Scale (INDCOL) and Child-Rearing Practices Report (CRPR) per each sub-scale.

	English monolingual	Korean-English bilingual	Korean monolingual
INDCOL			
Horizontal Individualism	6.38 (1.11)	6.19 (1.33)	6.60 (1.01)
Vertical Individualism	4.43 (1.38)	5.29 (1.02)	5.17 (1.03)
Horizontal Collectivism	7.17 (0.78)	7.11 (1.11)	6.47 (1.08)
Vertical Collectivism	6.56 (0.86)	6.72 (0.98)	6.28 (0.87)
CRPR			
Authoritarian	67.71 (8.76)	80.75 (10.21)	84.34 (9.83)
Authoritative	118.33 (8.29)	114.41 (10.30)	58.65 (9.93)

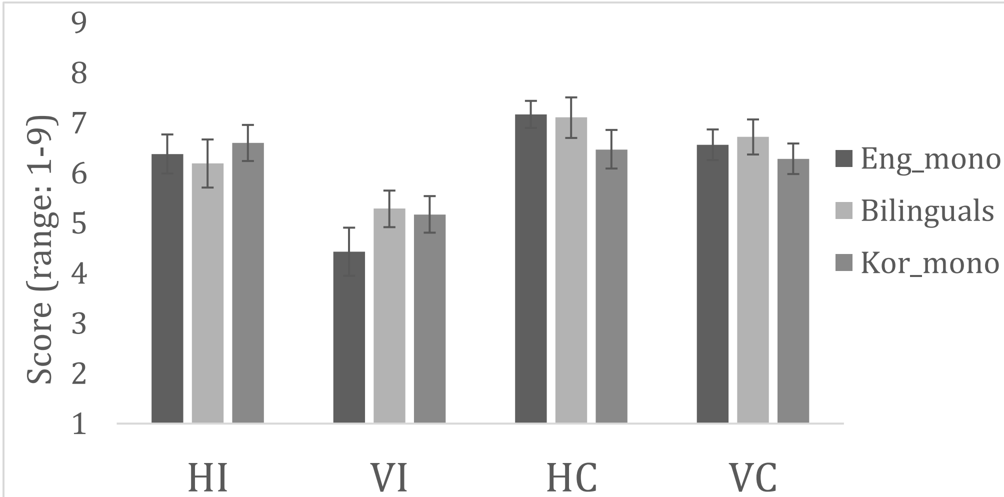

Figure 2. Mean scores in each subscale of the Individualism-Collectivism Scale (INDCOL; HI: Horizontal Individualism, VI: Vertical Individualism, HC: Horizontal Collectivism, and VC: Vertical Collectivism). Error bars represent 95% confidence intervals.

2.2.5 Authoritarian and authoritative parenting attitudes

Missing data precluded measures of authoritative parenting attitudes from three parents (one Caucasian Canadian parent and two Korean parents living in Korea), and measures of authoritarian parenting for one parent (one Korean parent living in Korea). In all cases, parents omitted answers to some questions within each subscale. The reliability statistics (Cronbach's α) for the two subscales of the CRPR are .973 (the authoritative subscale) and .738 (the authoritarian subscale), respectively, indicating high internal consistencies for the both subscales.

Group means and standard deviations of two subscales of the CRPR are presented in Table 2 and Figure 3. There were group differences on both subscales (for the Authoritarian subscale, F (2, 95) = 27.64, $p < .001$, $\eta^2_p = .368$; for the Authoritative subscale, F (2, 93) = 386.47, $p < .001$, $\eta^2_p = .893$). Bonferroni-corrected post-hoc comparisons confirmed that Korean parents, both those living in Canada and those living in Korea, had higher scores on the Authoritarian subscale than Canadian parents (both *p*' s < .001), but did not differ from each other ($p = .413$). As well, Korean parents living

Korea had lower scores on the Authoritative subscale than Korean parents living in Canada and Canadian parents (both *p*' s < .001), who did not differ from each other (*p* = .301).

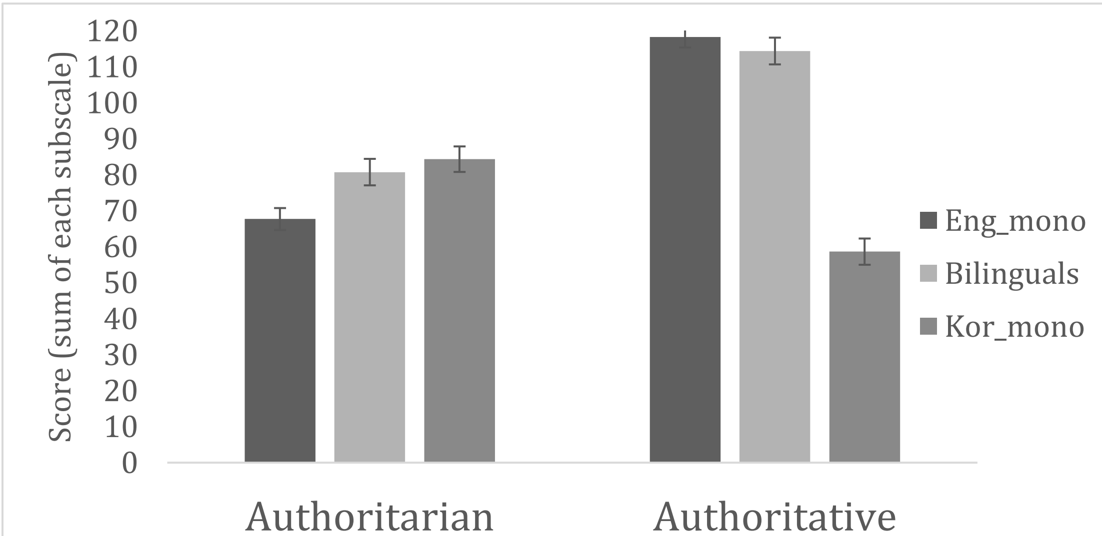

Figure 3. Mean scores in each subscale of the Child-Rearing Practices Report (CRPR). Error bars represent 95% confidence intervals.

2.2.6 Mediation analyses

As a final analysis, we tested whether parental cultural value orientation or child-rearing attitudes mediated the association between country-of-origin and children inhibitory control using a macro developed for SPSS with Model 4 (PROCESS; Hayes, 2013). Neither parenting variable mediated this association (see Figure 4 and 5).

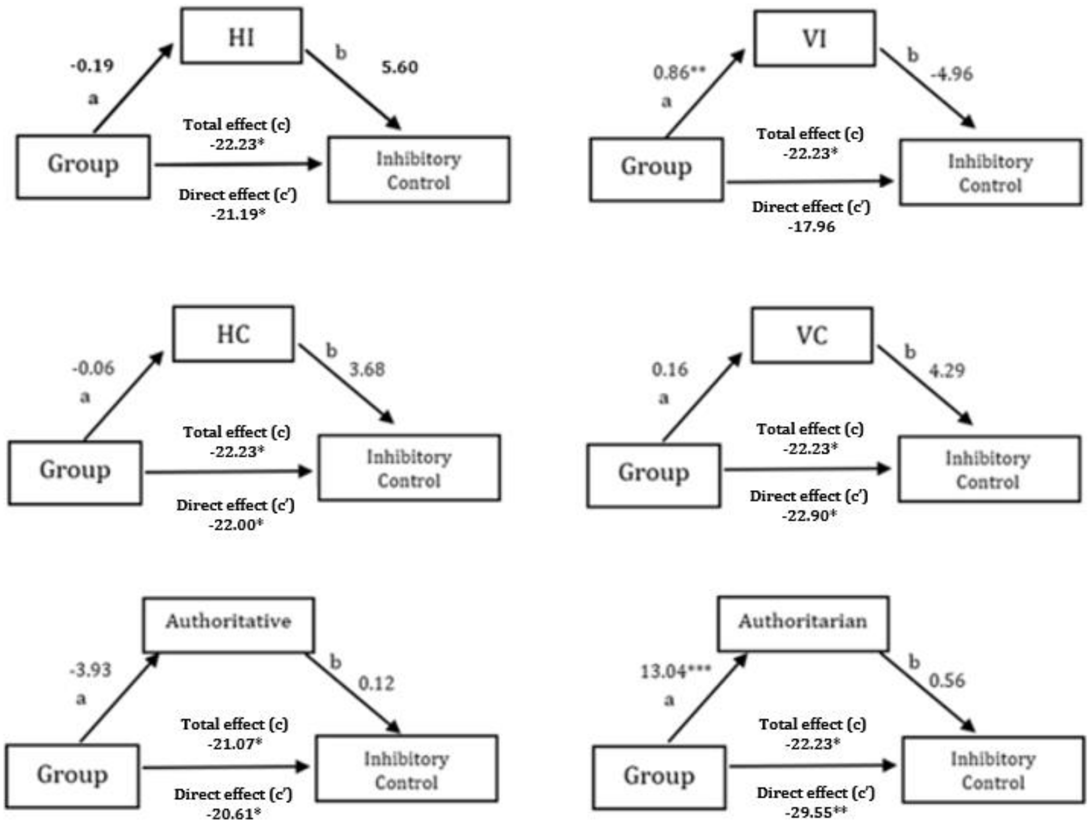

Figure 4. Path diagram of mediation analyses examining four subscales of the Individualism-Collectivism Scale (HI: Horizontal Individualism, VI: Vertical Individualism, HC: Horizontal Collectivism, VC: Vertical Collectivism) and two parenting attitudes (Authoritative and Authoritarian parenting attitudes) as possible mediators of group differences (English monolinguals vs. Korea-English bilinguals) in Inhibitory Control (Interference effect: accuracy on congruent trials minus accuracy on incongruent trials). The figures are coefficients from regression analyses. The analyses indicated that there was no significant mediator of the Group-Inhibitory Control relationship. *p < .05, **p < .01, ***p<.001.

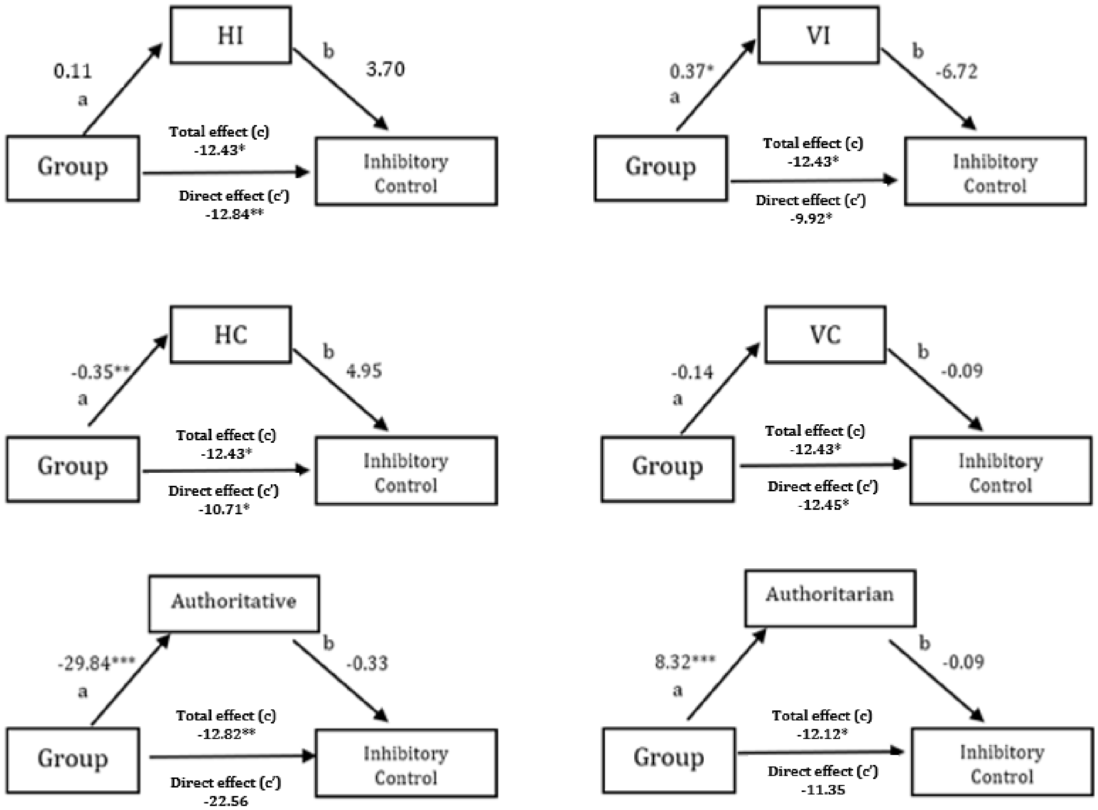

Figure 5. Path diagram of mediation analyses examining four subscales of the Individualism-Collectivism Scale (HI: Horizontal Individualism, VI: Vertical Individualism, HC: Horizontal Collectivism, VC: Vertical Collectivism) and two parenting attitudes (Authoritative and Authoritarian parenting attitudes) as possible mediators of group differences (English monolinguals vs. Korean monolinguals) in Inhibitory Control (Interference effect: accuracy on congruent trials minus accuracy on incongruent trials). The figures are coefficients from regression analyses. The analyses indicated that there was no significant mediator of the Group-Inhibitory Control relationship. *p < .05, **p < .01, ***p<.001.

2.3 Discussion

The current study compared the performance of bilingual and monolingual kindergarteners of varied national original on an age-appropriate response inhibition task. There were several important results.

First, we replicated evidence that bilingual children of East Asian origin (in the present study, children from South Korea) make fewer errors in response inhibition tasks than do monolingual children of North American origin (Bialystok, 1999). This finding may reflect an effect of language status, such that bilingual children are less prone to distraction than monolingual children (Bialystok, 1999). However, a second and equally plausible interpretation is that this finding reflects differences in children′s and their family’s country-of-origin, given that children from East Asia are less prone to distraction in inhibitory control tasks than are children from North America (Oh & Lewis, 2008; Sabbagh et al., 2006).

We tested this possibility and found that Korean monolingual children performed comparably to Korean-English bilingual children but more accurately than Caucasian Canadian monolingual children. Importantly, group differences in the present study were not attributable to differences in performance across all trial types, as all three groups performed comparably on congruent trials. Differences were only evident on incongruent trials that required maintenance of a response rule and inhibition of a prepotent response. Nor were group differences in inhibitory control attributable to differences in age. Although Korean monolingual children were slightly younger than Korean-English bilingual children, statistically controlling these differences had no impact on the results. Taken together then, the findings suggest that previously reported differences between East Asian bilingual and Canadian monolingual children (Bialystok, 1999; Bialystok & Martin, 2004) relate to differences in children’s country-of-origin rather than their language status.

Finally, we explored whether country-of-origin differences in children’s inhibitory control could be explained by differences in either parental cultural values (i.e., collectivist versus individualist; Hofstede, 1984; Lewis et al., 2009) or attitudes (i.e., authoritarian versus authoritative; Chen et al., 1998; Chen, Dong, & Zhou, 1997; Vinden, 2001). Korean and Korean-Canadian parents were generally more authoritarian and less authoritative than Canadian parents, but not more collectivist and less individualist (Clarke-Stewart et al., 2006; Hofstede, 1980). Importantly, neither parenting variable explained country-of-origin differences in children's inhibitory control. Of course, these findings could simply reflect idiosyncrasies of our sample, the nature of our measures, or the fact that individuals from East Asia are not always more collectivist and less individualist than individuals from North America (Oyserman, Coon, & Kemmelmeier, 2002). However, they are certainly at odds with the common assumption that country-of-origin differences in children's inhibitory control can be easily explained by differences in parental collectivist/individualist cultural values (Yang et al., 2011). These issues deserve further research attention.

The critical overarching implication of the present findings though is that previously reported differences between East Asian bilingual children and Canadian monolingual children's inhibitory control (e.g., Bialystok, 1999) were likely not related to differences in children's language status, but to differences in children's and their parents' country-of-origin. Between-group comparisons are difficult to interpret because they often encompass variables beyond those of immediate interest (Morton & Harper, 2007). The current findings suggest that measuring and controlling such variables significantly attenuates the bilingual advantage in children's inhibitory control.

Chapter 3

3 The effects of individual differences in language status and country of origin on Theory of Mind

Theory of mind (ToM), or the ability to understand other people's mental states, is crucial for social adaptation, and shows robust development in preschool-aged children (Wellman et al., 2001). Indeed, during this period, individual differences in ToM become increasingly pronounced as the result of a variety of social factors, such as opportunities for social interaction (Bartsch & Wellman, 1995; Hughes & Dunn, 1998), the presence of siblings (McAlister & Peterson, 2007), and culture (Vinden, 1996).

Several lines of evidence suggest that ToM is related to EF. First, there is evidence suggesting that the developmental timetable of ToM parallels that of EF. Children typically start succeeding on standard false-belief tasks in the preschool period when EF skills are also rapidly developing (Carlson & Moses, 2001; Zelazo et al., 2003). Second, performance in ToM and EF tasks are frequently correlated, even when age, gender, and verbal ability are controlled (Carlson & Moses, 2001; Frye et al., 1995). In addition, evidence suggests that advances in EF lead to advances on ToM and vice versa. For example, early EF predicts later ToM (Carlson, Mandell, & Williams, 2004; Hughes & Ensor, 2007) and early ToM predicts later EF (McAlister & Peterson, 2013). The close relation between ToM and EF can also be found in brain studies. There are common brain regions such as the prefrontal cortex, that activate in association with both ToM and EF tasks (Channon & Crawford, 2000; Frith & Frith, 1999; Funahashi & Andreau, 2013; Koechlin & Summerfield, 2007). These findings suggest that ToM and EF might be based on a common process.

On the other hand, there is evidence suggesting that ToM and EF are distinct processes. For example, children with autism show deficits in false-belief tasks but intact performance in tasks that have similar EF loads but do not involve mental state reasoning, suggesting that ToM and EF can be dissociated (Charman & Baron-Cohen, 1992; Leslie & Thaiss, 1992). Several neuroimaging studies (Saxe & Kanwisher, 2003; Saxe, Schulz, & Jiang, 2006; Saxe & Wexler, 2005) also lend support to the idea that

ToM and EF are distinct processes. For example, the right temporo-parietal junction (rTPJ) shows increased activity to stories that involve reasoning about others' mental states, but not to stories that involve reasoning about nonsocial events or physical aspects of a person (social but non-ToM related stories). These findings suggest that the rTPJ is a ToM-specific brain region.

Thus, it is unclear whether ToM and EF are two facets of the same underlying process or are distinct processes. As part of examining this question, Experiment 2 tested whether the effects of country-of-origin (culture) on EF reported in Experiment 1 extend to ToM. To that end, the identical samples reported in Experiment 1 (the Korean-English (K-E) bilingual, English monolingual, and Korean monolingual kindergarteners) were administered two ToM measurements: (1) the "unexpected-contents" false-belief task where children are shown a container with unexpected content, such as a chocolate box containing a toy car, and are asked what someone who had never opened the box before would think was inside; and (2) a modified version of the standard "change-in-location" false-belief task (Wimmer & Perner, 1983) called the sandbox task. In this task, children are introduced to two characters who know the location of an object. One character then leaves and during the first character's absence, the second character moves the object to another location. When the first character comes back, children are asked to indicate where the first character will look for the object. If children understand that the first character holds a false-belief about the location of the object, they will indicate the original hiding location even though this departs from their own knowledge and reality. The advantage with the sandbox task however is that children's false-belief bias can be continuously measured by calculating the distance between the original hiding location and location of the dot they draw.

The predictions were as follows. If ToM and EF are simply two facets of a domain-general process, then the effects of country-of-origin (culture) on EF reported in Experiment 1 should be observed in ToM. In Experiment 1 (Chapter 3), K-E bilingual and Korean monolingual children outperformed English monolingual children in the Stroop task, suggesting evidence of cultural effect on EF. Thus, if ToM and EF are based on a common process, K-E bilingual and Korean monolingual children should also outperform English monolingual children in ToM tasks. However, if ToM and EF are different processes, then the pattern of results for EF (observed in Experiment 1) relating to language status and country-of-origin and the pattern of results for ToM should be different. To be specific, children of all three groups are predicted to show comparable performance on ToM tasks based on the evidence showing universal development of ToM, irrespective of ToM task types and countries (Avis & Harris, 1991; Lee, Olson, & Torrance, 1999; Sabbagh et al., 2006; Wellman et al., 2001).

Since a null finding is predicted, and conventional Null Hypothesis Significance Testing (NHST) is unable to test null effects, the current study conducted not only NHST but also Bayesian analyses to see which hypothesis (null vs. alternative) can be supported by the data.

3.1 Methods

3.1.1 Participants

The participants were identical to those in the Chapter 2.

3.1.2 Tasks and measures

3.1.2.1 Language status

The language status measures were identical to those in the Chapter 2 (see Appendix B).

3.1.2.2 Socio-economic status

The socio-economic status measures were identical to those in the Chapter 2 (see Appendix B).

3.1.2.3 Theory of Mind

Theory of mind ability was measured using two tasks: (1) the “unexpected-contents” false-belief task and (2) Sandbox task.

First, in the “unexpected-contents” false-belief task (Gopnik & Astington, 1988; Sabbagh et al., 2006) children were shown a chocolate candy box and asked to report what they thought was inside. After responding, children watched as the box was opened to reveal a crayon (i.e., unexpected contents). Children were then asked: (1) what they had thought was inside when they first saw the box before they opened it; (2) what someone else who had not looked inside the box before would think was inside; and (3) what was actually inside the box. Since the first two questions were related to the ability to infer their own belief and another person's belief, children's answers to these two questions were scored to provide a total task score between 0 and 2. In addition to the false-belief task, children were also administered a control task that paralleled the false-belief task but did not involve mental state inference. In the control task, children were asked to open a box containing a toy pig, get the toy pig out of the box, and then put a toy horse inside instead. After doing so, the box was closed, and children were asked: (1) what was inside the box now; and (2) what had been inside the box before they opened it.

Second, the sandbox task (Mahy, Bernstein, Gerrard, & Atance, 2017) is a variant of the standard "change-in-location" false-belief task that continuously measures children's false-belief understanding. In the current study, a paper and pencil version of the sandbox task was used. In this task, a protagonist hid an object in Location 1 (L1; marked with an X). The object was then moved 121mm away to Location 2 (L2; marked with a second X) during the protagonist's absence. The task consisted of two different stories. In one story (false-belief condition), children were asked to mark a dot to indicate where the protagonist thought the object was. In the other story (memory-control condition), children were asked to mark a dot to indicate where the protagonist had hidden the object. Since the correct response to both conditions is L1, children's scores were calculated as the distance between L1 and the dot they marked. Greater accuracy on both stories was, therefore, represented by scores closer to zero, while false-belief or memory biases were reflected by larger, positive scores. Importantly, the two stories differed in terms of their processing demands. The false-belief condition required not only the ability to remember the original location of the object but also the ability to consider the protagonist's false-belief of the location of the object (ToM ability). In contrast, the memory-control condition required only memory of the original location of the object. The dependent variable for this task, false-belief bias, was calculated by subtracting the memory-control condition score from the false-belief condition score. As such, it allowed detection of small intra-individual differences in ToM ability.

3.1.3 Procedure

The procedure was identical to that in Chapter 2.

3.2 Results

3.2.1 Language status

Descriptive statistics for PPVT scores and daily language use are provided in Table 1 in Chapter 2.

3.2.2 Socio-economic status

Socio-economic background is reported in Table 1 in the Chapter 2.

3.2.3 Theory of Mind

3.2.3.1 Unexpected-contents false-belief task

A one-way ANOVA was conducted to compare the effect of group on children's performance in the unexpected-contents false-belief task (Table 3 and Figure 6). There was no effect of group, F (2, 96) = 2.438, p = .093, even after controlling for age, F (2, 95) = 2.634, p = .077. Further, the Bayes Factor (with a default Cauchy prior width of 0.707, JASP Team, 2018) suggested inconclusive evidence on which hypothesis of group (null or the alternative one) was favoured by the data, BF_{01} = 1.536. However, when considering both group and age variables using Bayesian ANCOVA, the Bayes Factor indicated positive and moderate evidence for the null hypothesis, BF_{01} = 4.746, relative to the alternative hypothesis.

Table 3. Participants' means (and standard deviations) of scores for two theory of mind tasks, respectively. Range for scores on false-belief contents task is 0-2, and scores on

sandbox task are calculated by subtracting the memory-control condition score from the false-belief condition score (in millimeter)

	English monolingual	Korean-English bilingual	Korean monolingual
False-belief contents task	0.94 (0.69)	0.59 (0.71)	0.64 (0.70)
Sandbox task (False-belief bias)	47.82 (90.06)	21.25 (76.44)	17.24 (61.12)

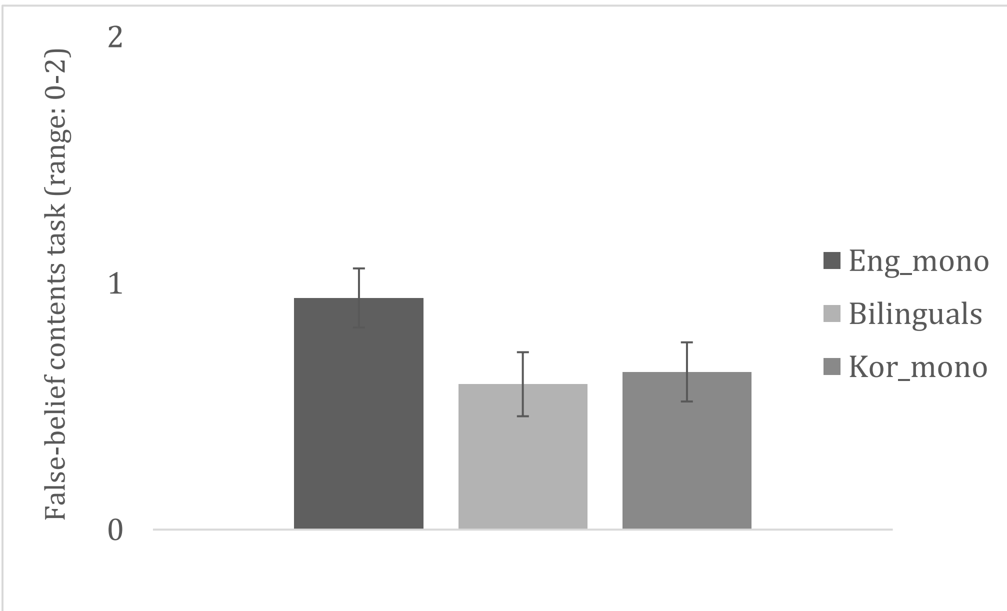

Figure 6. Mean scores in the false-belief contents task. Error bars represent standard errors.

The three groups also performed comparably in the control condition: English monolingual group = 1.68 (0.54), K-E bilingual group = 1.78 (0.49), and Korean monolingual group = 1.70 (0.64). A one-way ANOVA comparing the effect of group on performance revealed no effect of group, F (2, 96) = 0.323, p = .725, even after controlling for age, F (2, 95) = 0.085, p = .918. Further, the Bayes Factor (with a default Cauchy prior width of 0.707, JASP Team, 2018) suggested positive and moderate evidence for null hypothesis of group effect, BF_{01} = 8.352. Even when considering both group and age variables using Bayesian ANCOVA, the Bayes Factor indicated positive and moderate evidence for null hypothesis, $BF_{01} = 3.042$, relative to the alternative hypothesis. Thus, the Bayesian analysis suggested that there was a null effect of group.

3.2.3.2 Sandbox task

Missing data precluded one English monolingual child's false-belief bias score due to experimenter error. A one-way ANOVA revealed that there was no group difference in children's false-belief bias on the Sandbox task (the scores of the false-belief condition minus the scores of the memory-control condition; see Table 3 and Figure 7), $F(2, 95) = 1.540$, $p = .220$, even after controlling for age, $F(2, 94) = 1.709$, $p = .187$. Further, the Bayes Factor (with a default Cauchy prior width of 0.707, JASP Team, 2018) suggested positive and moderate evidence for null hypothesis regarding the group effect, $BF_{01} = 3.127$, relative to the alternative hypothesis of a group effect. Also, when considering both group and age variables using Bayesian ANCOVA, the Bayes Factor indicated positive and moderate evidence for the null hypothesis, $BF_{01} = 6.013$, relative to the alternative hypothesis. Again, the Bayesian analysis suggested a null effect of group.

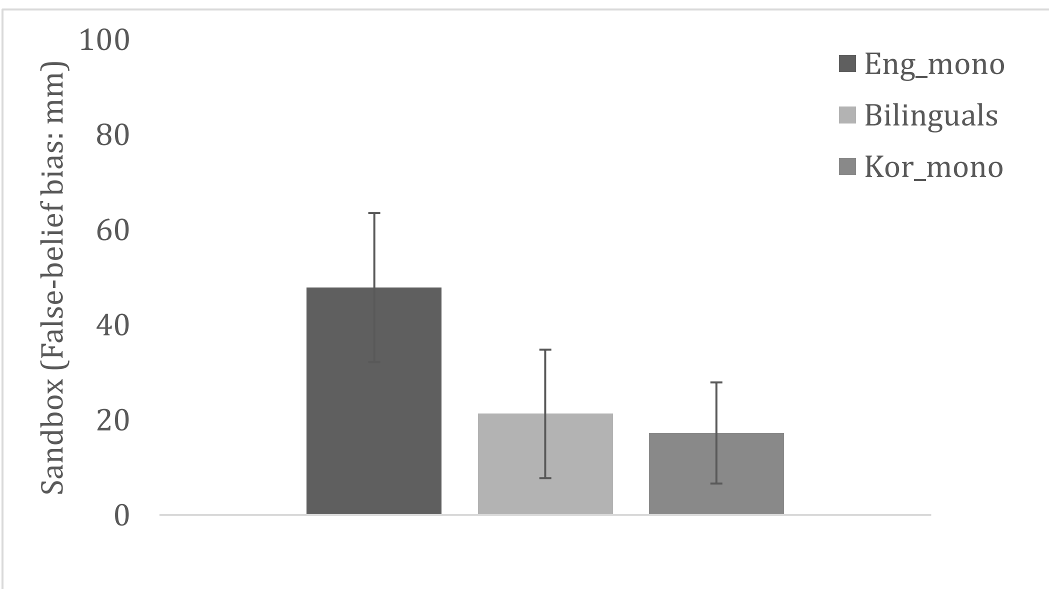

Figure 7. Mean scores in the sandbox task. Error bars represent standard errors.

3.3 Discussion

Experiment 2 investigated whether ToM and EF are based on a common process or they are distinct by examining if the socio-cultural factors that influence EF extend to ToM. To that end, bilingual and monolingual Canadian and Korean kindergarteners were administered ToM tasks, and their performance on the tasks was compared. There were several important results.

First, when three groups with comparable socio-economic backgrounds (K-E bilingual, English monolingual, and Korean monolingual preschool-aged children) were compared, there was no difference among the three groups in two widely used false-belief ToM tasks (i.e., the “unexpected-contents” and “change-in-location” false-belief tasks). Despite attempts to detect subtle differences between the groups using a continuous measurement of “change-in-location” false-belief task (i.e., the sandbox task), there was no difference in children’s ToM performance, implying no evidence of either a bilingual advantage or a cultural difference in ToM.

Lack of group difference in ToM task performance contrasts with the results on EF reported in Experiment 1. In Experiment 1, both K-E bilingual and Korean monolingual children outperformed English monolingual counterparts in the age-appropriate Stroop task, suggesting that country-of-origin (culture) has effect on EF. However, in the current study, all the children showed comparable performance in the ToM tasks regardless of their language status and country-of-origin, implying that neither language status nor country-of-origin (culture) have a comparable effect on ToM. These findings are consistent with the idea that ToM and EF are distinct processes because the effect of country-of-origin on EF reported in the previous chapter did not extend to ToM.

In a view of one of the critical shortcomings in the previous literature on the relation between ToM and EF in early childhood, namely, the possibility of independent co-development of the two abilities, the current study has important implication. In the previous literature (Carlson & Moses, 2001; Frye et al., 1995), a significantly strong correlation between children’s performance on ToM tasks and EF tasks was found even after controlling for other extraneous variables (e.g., age, gender, verbal ability), and the significant correlation was interpreted as evidence showing that these two abilities are strongly associated with each other. Given that both ToM and EF rapidly develop in the same period (i.e., preschool period, Carlson & Moses, 2001; Zelazo et al., 2003), it is possible that the significant correlation simply comes from the independent (but coincident) co-development of the two abilities. The current study has important features in that it proposed a new approach, examining whether the pattern of results for one ability (e.g., EF) due to individual difference in socio-cultural factors is similar to that for the other ability (e.g., ToM), to investigate the relationship between the two abilities while being free from the shortcoming that the previous literature might have.

In contrast with the previous findings on bilingual advantage in ToM (Berguno & Bowler, 2004; Goetz, 2003; Kovács, 2009), K-E bilingual children in the current study did not show any advantage in ToM compared to English or Korean monolingual children. Regarding the discrepancy, one critical difference between the previous literature and the current study is whether or not extraneous variables possibly related to bilingual advantage (i.e., SES and country-of-origin) are controlled for. Though some previous studies attempted to control for these extraneous variables (Goetz, 2003; Nguyen & Astington, 2014), many other studies did not (Berguno & Bowler, 2004; Farhadian et al., 2010; Gordon, 2016; Kovács, 2009; Kyuchukov & de Villiers, 2009). Thus, it is possible that bilingual advantage in ToM reported in the previous literature comes in part from differences in other extraneous variables that have been relating to ToM, such as SES (Cutting & Dunn, 1999; Pears & Moses, 2003) and country-of-origin/culture (Ahn & Miller, 2012; Liu et al., 2008; Naito & Seki, 2009; Wang, Devine, Wong, & Hughes, 2016). The importance of controlling for other relevant variables can also be found in the bilingual advantage in cognitive control. For example, there have been prevailing results showing that bilingual children are advantaged in a variety of cognitive control tasks, including response inhibition tasks (Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok, 2008) and working memory tasks (Blom, Küntay, Messer, Verhagen, & Leseman, 2014; Morales, Calvo, & Bialystok, 2013), compared to monolingual children. However, when attempting to properly control possible differences in extraneous variables relating to bilingual advantage (i.e., ethnicity, SES), the bilingual advantage in cognitive control disappeared (Duñabeitia et al., 2014;

Morton & Harper, 2007). Likewise, no evidence for the bilingual advantage in ToM in the current study might be due to the attempt to measure and control extraneous variables relating to bilingual-monolingual group comparison.

Lastly, the lack of difference among the three groups in the current study seems to correspond with existing literature showing universal development of ToM. For example, when comparing children from Western culture and from non-Western countries (i.e., China, Cameroon), their performance on a variety of ToM tasks was not different, showing no cross-cultural difference in ToM development (Avis & Harris, 1991; Lee et al., 1999; Sabbagh et al., 2006). In addition, preschool-aged children show their consistent and robust development of false-belief understanding, irrespective of task types and countries of origin (Wellman et al., 2001). The lack of difference in performance on ToM tasks between Canadian and Korean children in the current finding can be seen as evidence adding weight to the universal development of ToM.

The critical implication of the present findings is that the current study is consistent with previous findings suggesting that ToM and EF seem to be distinct processes (Charman & Baron-Cohen, 1992; Leslie & Thaiss, 1992; Lough, Gregory, & Hodges, 2001; van der Meer, Groenewold, Nolen, Pijnenborg, & Aleman, 2011). When seeking whether socio-cultural factors influencing EF (i.e., language status and country-of-origin) have comparable effects on ToM, the current findings suggest that the previously reported close relationship between ToM and EF (Carlson & Moses, 2001; Frye et al., 1995) seems to be overestimated due to similar developmental timetables between the two abilities.

Chapter 4

4 The relationship between Theory of Mind and Executive Function: Results from experiments 1 and 2

Experiment 1 examined whether socio-cultural factors (i.e., language status and country-of-origin) are associated with differences in preschool-aged children's EF. To that end, bilingual and monolingual preschool-aged children of varied national origin were compared on an age-appropriate inhibitory control task. The results showed that Korean children, regardless of their language status, made fewer errors in the task compared to Caucasian English monolingual children from Canada, indicating that country-of-origin, not language status, is related to differences in young children's EF.

Experiment 2 compared the performance of the children studied in Experiment 1 on two widely used false-belief understanding tasks. The results showed that there was no group difference in ToM task performance.

In order to see whether the effects of groups on ToM and EF performance, respectively, are different, one-way MANOVA was conducted with groups as independent variables (3 levels: English monolinguals, Korean monolinguals, and Korean-English bilinguals groups) and with interference effect in the Stroop task (calculated by subtracting accuracy on the incongruent trials from accuracy on the congruent trials and then transformed into Z scores) and false-belief bias in the Sandbox task (calculated by subtracting the memory-control condition score from the false-belief condition score and then transformed into Z scores) as dependent variables. There was a statistically significant difference in ToM and EF performance based on groups, F (4, 188) = 2.645, p = .035, Wilk's Λ = 0.896, partial $\eta2$ = .053, and which remained significant even when controlling for group difference in age, F (4, 186) = 2.735, p = .030, Wilk's Λ = 0.892, partial $\eta2$ = .056. To be specific, groups have a statistically significant effect on the interference effect in the Stroop task, F (2, 95) = 4.267, p = .017, partial $\eta2$ = .082, but not on the false-belief bias in the Sandbox task, F (2, 95) = 1.540, p = .220. Tukey HSD post-hoc revealed that K-E bilinguals and Korean monolinguals significantly outperformed English monolinguals on a Stroop task (*p*s = .054 and .024, respectively) but they were indistinguishable (*p* = .950).

The results indicate that the effects of groups on EF demonstrated in Experiment 1 are different from the effects of groups on ToM shown in Experiment 2. Thus, it suggest that a group factor did not show analogous patterns of differences in ToM and EF, and which adds weight to the possibility that ToM and EF are distinct processes.

Chapter 5 [3]

5 Introduction

The ability to imagine what other people are thinking, including thoughts that differ from one's own, is known as theory of mind (ToM). Converging evidence suggests ToM ability declines with age (Maylor, Moulson, Muncer, & Taylor, 2002). However, given that ToM ability depends on at least ToM-specific processes (including inferring mental states from observed behavior; binding agent representations, propositional attitudes, and propositional content; and decoupling mental state representations from primary representations, among other processes) and executive function (EF), it is unclear what leads to the age-related deterioration of ToM ability. Does it come from the decline of ToM-specific competence, EF, or both? Here we explore the underlying causes of age-related decline in ToM ability.

EF is associated with the development of ToM across the lifespan. For example, aspects of EF including inhibitory control and working memory have been shown to be correlated with false-belief reasoning in early development (Carlson & Moses, 2001). It is also well established that EF deteriorates with age (Salthouse, Atkinson, & Berish, 2003), and although this alone does not establish that it is responsible for changes in ToM among the elderly, it has been also found that the age-related decline of ToM is related to the deterioration of EF (Bailey & Henry, 2008; Charlton et al., 2009; German & Hehman, 2006; Phillips et al., 2011; Rakoczy, Harder-Kasten, & Sturm, 2012). For example, EF is significantly correlated with performance on ToM tasks (German & Hehman, 2006) and even statistically mediates age-related decline of ToM (Bailey & Henry, 2008; Charlton et al., 2009; Phillips et al., 2011; Rakoczy et al., 2012). While suggestive, these results are unable to establish whether older adults' difficulty in ToM is caused by reduced EF or by decline in ToM competence.

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[3] This chapter was accepted for publication (citation information: Cho I, Cohen AS (2019) Explaining age-related decline in theory of mind: Evidence for intact competence but compromised executive function. PLoS ONE 14(9): e0222890. https://doi.org/10.1371/journal.pone.0222890). The current version is slightly modified for formatting required for dissertation.

ToM ability in the elderly has been primarily assessed with elicited-response (or explicit) tasks (Bailey & Henry, 2008; Charlton et al., 2009; German & Hehman, 2006; Phillips et al., 2011; Rakoczy et al., 2012). In a common variant, participants observe an object moved in the presence or absence of an agent and then are prompted to provide a verbal response indicating where the agent thinks the object is located. Task analyses suggest these conditions impose high EF load (e.g., inhibiting a prepotent response, Baillargeon, Scott, & He, 2011).

One previous meta-analysis (Henry, Phillips, Ruffman, & Bailey, 2013) reviewed existing studies on aging and ToM to see whether there is age-related decline of ToM in a variety of ToM tasks by categorizing tasks according to domain (i.e., cognitive, affective, or mixed ToM) and modality of presentation (i.e., dynamic-visual, static-visual, or verbal). The results showed that older adults performed more poorly than younger adults across all types of ToM tasks, and it was concluded that ToM decline with age is due to the elderly's real deterioration of ToM competence, not due to performance factors. However, the meta-analysis does not answer whether changes in underlying ToM competence, EF, or both cause age-related decline of ToM. Critically, since the tasks entered into the meta-analysis were elicited-response ToM tasks, which impose high executive demands, it leaves the possibility open that the high performance demands of those tasks masked an intact, underlying mindreading capacity in the elderly.

In contrast to the elicited-response tasks, spontaneous-response (or implicit) tasks reduce response-selection and response-inhibition (Scott, 2017). For example, spontaneous-response tasks (e.g., looking behavior, spontaneous helping behavior) do not require participants to explicitly generate their responses, needing less non-ToM processing compared to the elicited-response ToM tasks. During the tasks, participants' spontaneous response (e.g., looking behavior) is measured. In the current study, we use a spontaneous-response ToM task to explore whether the elderly show improved ToM ability when performance demands are reduced.

An EF-decline account, in which decline in underlying EF is responsible for reduced ToM ability in the elderly, produces two logically connected predictions. First, individuals with compromised EF, such as the elderly, should have difficulty on ToM tasks that put high demands on EF. The first prediction is supported by many previous studies (Bailey & Henry, 2008; Charlton et al., 2009; German & Hehman, 2006; Phillips et al., 2011; Rakoczy et al., 2012). These studies all relied on explicit elicited-response tasks which impose high performance demands, including EF load. These increased demands appear to overwhelm the limited EF in the elderly, producing age-related deterioration in ToM ability. Second, individuals with compromised EF should show improved performance on ToM tasks that reduce load on EF. While these low demand tasks have been used extensively with infants and children (Onishi & Baillargeon, 2005; Southgate, Senju, & Csibra, 2007; Surian, Caldi, & Sperber, 2007), they have not to be widely used with older adults. The current investigation tests the second prediction. If the EF-decline account is correct, it is predicted that the elderly in the current study would show comparable performance to younger adults on a spontaneous-response task which involves low EF demand.

In contrast, a competence-decline account, in which decline in ToM competence is responsible for reduced ToM ability in the elderly, predicts worse performance on ToM tasks in the elderly compared to younger adults for both elicited-response and spontaneous-response tasks. Reduced demands should be of no benefit if the elderly lack the concepts and mechanisms to represent and compute mental states.

This sets up a critical test: If ToM competence in the elderly is intact as the EF-decline account claims, then reducing EF demands should improve ToM performance, but if ToM competence is not intact as the competence-decline account claims, then reducing EF demands should not improve ToM performance. To adjudicate between the accounts, we explored what happens in a low-demand task.

A recent study found that both older and younger adults performed similarly on a spontaneous-response ToM task, consistent with the EF-decline account that older adults have preserved false-belief tracking (Grainger, Henry, Naughtin, Comino, & Dux, 2018). The current study differed in three critical respects: 1) the research was preregistered, supporting valid null hypothesis significance testing by controlling long-run error rates,

2) Bayesian analysis was used to quantify evidence for a null hypothesis of no difference in belief tracking between older and younger adults relative to an alternative hypothesis that there was a difference, and 3) EF differences between older and younger adults were measured, not inferred. A brief introduction is suggested here.

5.1 Materials and methods

We preregistered hypotheses described above, an a priori power analysis, and data analysis plans. Preregistration, stimuli, and data analyses are available on the Open Science Framework: [https://osf.io/y7xrq/?view_only=e0fe507f7d9d4420a98b2152d91c2481]. Raw data were not institutionally approved to be shared on a repository but are available upon request.

5.1.1 Participants

Sixty-seven younger adults and 68 older adults participated in the study. Thirty-seven younger adults were recruited through a university research participation pool and received course credit for their participation, and the rest were recruited via poster on campus and were paid for their participation[4]. The older adults were recruited from the local community and were paid for their participation. Prior to collecting data, we conducted an a priori power analysis using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007). Based on an a priori power analysis with 80% power, a medium effect size, and an alpha value of .05, we needed 98 participants (49 participants per each age group).

Out of 135 participants, 37 (18 younger and 19 older adults) were excluded for further analysis due to failure to look at both object and empty locations in at least one condition (n = 12, 4 younger and 8 older adults), having a current diagnosis or history of major psychiatric and neurological illnesses (n = 13, 5 younger and 9 older adults), self-reporting as English as a second language (3 younger adults), failing to complete several

[4] This study was approved by Human Research Ethics board at Western University (see Appendix F).

measures (1 younger adult), or demonstrating signs of depression (n = 7, 5 younger and 2 older adults) measured on the short Geriatric Depression Scale (sGDS; Sheikh & Yesavage, 1986). For two younger adults, data was obtained from only the first half of the ToM task (see Procedure section), but their data was included as it met our pre-registered inclusion criteria. As a result, the final sample consisted of 49 (34 females) healthy younger adults (M = 20.37, SD = 3.25, 25 from the Participation Pool) and 49 (37 females) healthy older adults between 60 to 87 years of age (M = 69.37, SD = 7.58). Older adults reported more years of education than the younger adults (older: M = 16.03, SD = 3.24; younger: M = 14.08, SD = 2.48, t(96) = 3.34, p = .001). Also, older adults showed higher scores in verbal subtest of Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 2011) compared to the younger adults (older: M = 41.69, SD = 7.65; younger: M = 37.47, SD = 6.48, t(96) = 2.95, p = .004). The two age groups were not significantly different in the Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975), t(59.815) = 1.886, p = .064. Regarding sGDS, older adults showed lower scores than the younger adults (older: M = 0.59, SD = 0.96; younger: M = 1.96, SD = 1.56, t(77.730) = 5.20, p < .001).

5.1.2 Tasks and materials

5.1.2.1 General cognitive assessment tasks

To ensure that all participants had normal mental functioning, participants were asked to complete a simple questionnaire to obtain their demographic data, the MMSE for screening dementia, verbal subtest of the WASI for obtaining an estimate of their crystalized IQ, and the sGDS for screening any symptoms of depression.

5.1.2.2 Theory of Mind (ToM) eye tracking task

Forty animations (20 true-belief and 20 false-belief trials) varying in child identity, animal identity, initial animal location, and room identity, were used. For half of the 40 animations, a child stood behind the box where s/he believed the animal was located at the end of a trial, whereas for the other half of the animations, the child stood behind the box where s/he did not believe the animal was located. Therefore, where the child stood was unrelated to his/her belief about the location of the animal.

There were four phases in each trial: Animation phase, Anticipation phase, Fixation phase, and Response phase. During the animation phase (11 seconds), a child (protagonist) put an animal in one of two boxes and left the room. At this time, on false-belief trials, the animal moved out of the box and into the other box during the child's absence, whereas, on true-belief trials, the child returned the room first and then the animal moved out of the box and into the other box. When the child returned to the room on both types of trials, s/he walked forward, toward the boxes, but stayed in the middle. During the anticipation phase (4 seconds), the child stood still in the middle. During the fixation phase (1 second), a white fixation cross appeared on a grey screen. Lastly, during the response phase, the child stood behind one of the two boxes. At this time, participants were asked to press one of the buttons (left arrow key or right arrow key) to indicate whether the child stood behind either the left or right box.

To measure participants' eye movements, a corneal reflection eye tracker (Tobii x120, Tobii Technology, Stockholm, Sweden) was used with E-prime software (version 2.0.8.90; Psychology Software Tools Inc., Pittsburgh, PA, USA) and E-prime Extensions for Tobii (version 2.0.1.26). Specifically, the amount of time participants looked at each of the two boxes during a five-second-analysis window (including the anticipation phase and the fixation phase), from after the child returned to the room to before she/he was about to approach one of the boxes, was measured and used to compute a preferential looking score ranging from 0 (looking only to the animal box) to 1 (looking only to the empty box). Since the child believed the animal was in the empty box on false-belief trials and in the animal box on true belief trials, if participants spontaneously track those beliefs and make anticipatory eye movements to the location where they expect the child to search given those same beliefs, they should look more to the empty box on false-belief trials, than on true-belief trials.

5.1.2.3 Executive function (EF) tasks

Since executive function (EF) refers to a set of multiple cognitive processes for goal-directed behavior (Baddeley, 1996; Miyake et al., 2000), using a variety of EF tasks is crucial to measure EF. One of the widely used models proposes that EF consists of three subcomponents including inhibition, updating, and shifting (Miyake & Friedman, 2012;

Miyake et al., 2000). Based on this model, we measured each of the three subcomponents of EF with two or more standard tasks in case one task did not fully measure a specific subcomponent. For inhibition, we used Stroop and Go/No-go tasks; for updating, we used forward and backward digit span tasks; for shifting, we used Digit Symbol Substitution Test (DSST, Patel & Kurdi, 2015), Trail Making Test (TMT, Reitan, 1958), and Wisconsin Card Sorting Test (WCST, Piper et al., 2012). In the Stroop task, participants were asked to respond to color of a word, not to the name of the word, as quickly and accurately as possible. There were 180 trials (60 congruent trials, 60 incongruent trials, and 60 neutral trials). The reaction time and accuracy for each trial were recorded. In the Go/No-go task, participants were asked to press the Enter key when the Go condition was met (i.e., whenever the letter ‘W’ appears on a monitor) and not to press anything when the Go condition was not met (No-Go condition). There were 300 trials in total, and 45 trials out of them were the No-Go condition. Accuracy was recorded, and the false-alarm rate was analyzed. In the DSST, participants were asked to attend to the symbol associated with each of nine different digits and then to draw the corresponding symbols under each digit as quickly as possible in 90 seconds. The number of correct answers was recorded. Also, in the Digit Span tasks (forward and backward) measuring working memory, participants heard a series of numbers and they were asked to recall the numbers in sequence (or in reverse of the presented order). There were three trials in each section (e.g., in section 2, two numbers were presented, and three numbers were presented in section 3). If they correctly recalled one of the three trials within the same section, the task went on. If they gave wrong numbers on all the trials within the same section, the task was stopped. The number of correct answers was analyzed. In the TMT, there were two parts to the test: in Part A, participants were required to connect letters in alphabetical order as quickly as possible and in Part B, they had to connect letters and numbers alternatingly in alphabetical (letters) and ascending (numbers) order, respectively (e.g., A1B2C3). Since Part B has been considered an EF measurement, the total time to complete Part B was measured. Lastly, for the WCST, the Psychology Experiment Building Language tests (PEBL)’s version of the WSCT (Piper et al., 2012) was used. Accuracy was analyzed.

5.1.3 Procedure

The study proceeded in the following order: General cognitive assessment tasks, calibration phase for the eye tracking task, ToM eye tracking task (the first session; 20 trials), half of the EF tasks, 10-minute break, ToM eye tracking task (the second session; 20 trials), a questionnaire to ensure whether they understood the eye tracking task's instructions, and the remaining half of the EF tasks. Half of the participants were given the Stroop task, Trial making task, and Digit span task as the first half of the EF tasks, whereas the other half of the participants were given Go/No-go task, Digit symbol substitution task, and Wisconsin card sorting task as the first half of the EF tasks.

5.2 Results

For the ToM eye tracking task, the ratio of the participants' looking time to the empty box on the false-belief trials (or the true-belief trials) to the total looking time to both the empty and object box on the false-belief trials (or the true-belief trials) was calculated, producing a looking preference score to the empty box for both conditions (Figure 8).

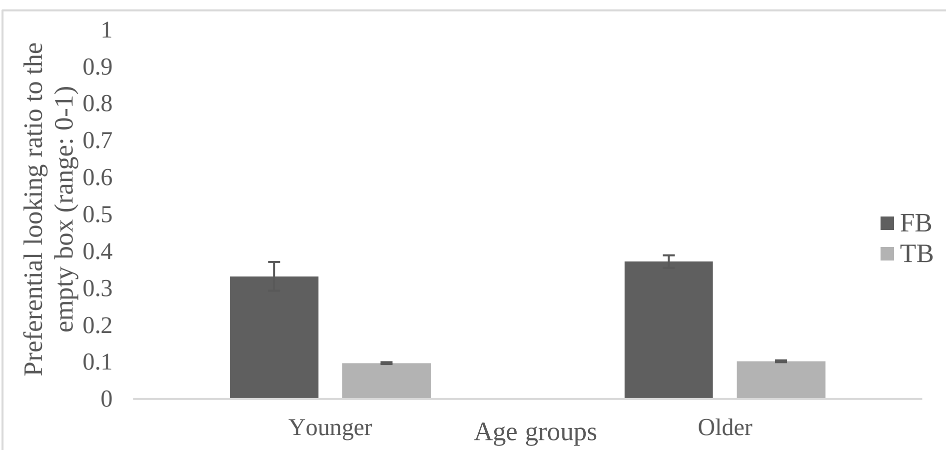

Figure 8. Preferential looking ratios, with a score of 0 meaning looking only to the animal box, a score of 1 meaning looking only to the empty box. Error bars represent standard errors.

5.2.1 Age differences in spontaneous belief-reasoning

As a confirmatory analysis, age effects on preferential looking ratio to the empty box were investigated using a 2 (age group: younger vs. older adults) X 2 (belief type: true-belief vs. false-belief) mixed design ANOVA. There was a significant main effect of belief type, $F(1, 96) = 63.61$, $p < .001$, $\eta_p^2 = .399$, showing that looking preference to the empty box was larger in false-belief trials (M = 0.35, SD = 0.29) than in true-belief trials (M = 0.10, SD = 0.14). This indicates that participants processed the child's belief about the location of the animal. No main effect of age group, $F(1, 96) = 0.47$, $p = .493$, and no interaction effect between age group and belief type, $F(1, 96) = 0.28$, $p = .598$, were found. Further, the Bayes Factor (with a default Cauchy prior width of 0.707, JASP, 2018) suggested positive evidence for null hypotheses about the age effect, BF_{01}=4.999, and the interaction effect, BF_{01}=3.95 relative to the alternative hypotheses of age effect and interaction effect, respectively.

5.2.2 Age differences in the EF tasks

As a confirmatory analysis, descriptive information on each age group's performance on each EF task (raw scores) and the statistical differences for each comparison is shown in Table 4. For the analysis, dependent measures from all the EF tasks were standardized. The younger adults significantly outperformed the older adults on all the EF tasks except the Go-Nogo task and the Digit Span task (both forward and backward).

Table 4. Descriptive information and t-test analyses of age-related differences on EF tasks.

	Younger		Older		Group difference			
	M	SD	M	SD	*t*	*df*	*P*	*Cohen's d*
Inhibition								
Stroop effect[a] (s)	0.10	0.10	0.22	0.19	-3.64	66.813	.001	-0.89
Go/No-go[b] (%)	4.14	2.38	3.53	2.32	1.27	94	.206	0.26
Updating								
Digit Span: Forward[c]	18.80	2.90	18.60	3.72	0.28	95	.777	0.06
Digit Span: Backward[c]	12.10	3.20	11.15	3.57	1.39	95	.168	0.29

Shifting								
Digit Symbol Substitution[c]	50.76	12.14	34.25	7.65	7.88	75.004	<.001	1.82
TMT_B[d] (s)	57.22	21.35	79.09	31.55	-4.02	96	<.001	-0.82
WCST[c] (%)	76.40	11.48	69.92	12.94	2.60	94	.011	0.54

[a] median reaction time (RT) for neutral condition - the median RT for incongruent condition
[b] false alarm rate
[c] the number of correct answers (cf. Digit Symbol Substitution: within 90 seconds)
[d] the total time to complete the part

5.2.3 Spontaneous belief-reasoning and EF

As an exploratory analysis, correlation analyses between EF and the looking scores in the false belief condition were explored (we thank a reviewer for this recommendation). There was no significant correlation between the looking scores in the false belief condition and EF (all ps > .10). In addition, the Bayes Factor suggested positive evidence for null hypotheses concerning the correlation relative to the alternative: Go-Nogo (BF_{01} = 6.231), Stroop (BF_{01}= 4.740), the updating composite score (BF_{01}= 3.593), and the shifting composite score (BF_{01}= 7.583), suggesting no significant association between EF measurements and false-belief reasoning.

When correlations between the looking scores in the false belief condition and EF were broken down by age group, in the older group, there was no significant correlation between the looking scores in the false belief condition and EF (ps > .090) except for the updating composite score (r = 0.30, p = .041). In the younger age group, there was no significant correlation between the looking scores in the false belief condition and EF (all ps >.50).

However, this analysis should be interpreted with caution for several reasons. First, ToM and EF could still be related if other unmeasured variables weaken the relationship or even pull the relationship in the other direction, washing out the correlation. Second, while a weak or lack of a correlation is consistent with reduced executive demands in the spontaneous-response task, a strong correlation would still be consistent with lowered executive demands because the claim is not that spontaneous-response tasks eliminate executive demands, just that they sufficiently reduce them to reveal underlying competence better than their elicited-response task counterparts.

5.3 Discussion

The current study examined whether older adults, known to show age-related decline in ToM ability when given tasks that impose high performance demands (Bailey & Henry, 2008; Charlton et al., 2009; German & Hehman, 2006; Phillips et al., 2011; Rakoczy et al., 2012), would track belief when using a spontaneous-response task that reduced non-ToM processing. The present finding suggests that older adults track belief when EF demands are sufficiently lowered, revealing intact underlying ToM competence in the elderly. Although recent work appears to show a similar result (Grainger et al., 2018), lack of preregistration and use of $p > .05$ to argue for no differences in belief tracking between younger and older adults limit the validity of those results. The current study was preregistered and used Bayesian model comparison to support valid inference.

This work has several implications. It addresses competence and performance factors in ToM processing and aging. The elderly's intact mentalizing ability in the current study implies that the age-related deterioration of ToM that the previous studies have shown comes from the elderly's difficulty in expressing their ToM competence, not from decline of ToM competence. This study suggests that EF seems to be the underlying sources of age-related deterioration of ToM that the previous literature have shown.

Several limitations should be considered. First, the older adults in this study had relatively higher years of education and WASI scores compared to the younger counterparts, so it is possible that their relatively high functioning allowed them to compensate for an otherwise reduced ToM capacity in the spontaneous-response ToM task (e.g., by using non-mentalistic strategy to predict others' behavior). Closer matching of participants in future research would address this concern. Second, even though numerous studies have shown age-related decline of ToM with various elicited-response ToM tasks, directly comparing older adults' performance on elicited-response ToM tasks and closely matched spontaneous-response ToM tasks would be necessary to strongly claim the existing ToM tasks have heavy EF demands for future studies (cf. Grainger et al., 2018). Third, not all agree on how to interpret performance in spontaneous-response tasks. This study assumes they tap a conceptual ToM system rather than a "belief-like" or non-mentalistic capacity (Apperly & Butterfill, 2009; Perner & Ruffman, 2005), and although recent work casts doubt on these alternative accounts (e.g., Hyde, Simon, Ting, & Nikolaeva, 2018; Király, Oláh, Csibra, & Kovács, 2018), this assumption is still being debated and tested. Lastly, although the current study suggests that some aspects of core ToM mechanisms are intact in the elderly, ToM involves multiple sub-systems each with multiple processes and concepts (Apperly, 2012; Apperly & Butterfill, 2009; Leslie, Friedman, & German, 2004; Schaafsma, Pfaff, Spunt, & Adolphs, 2015; Warnell & Redcay, 2019) and it is possible that concepts, processes, or sub-systems not engaged by the specific task used here are in fact compromised in the elderly.

This study helps illuminate age-related development of ToM, providing evidence that the deterioration of ToM ability with age is caused by changes in EF, not in ToM competence. While the competence-performance distinction has long played a role in explaining the acquisition of abilities in early development (e.g., Chomsky, 1964), the current work shows the distinction can be put to work to explain changes in late development as well.

Chapter 6

6 Discussion

From the standpoint of phylogenetic timescales, there has been an abrupt co-emergence of several higher-order cognitive functions. Modern humans and their closest evolutionary cousin, the chimpanzee, are thought to share a common evolutionary ancestor that existed 5 million and 7 million years ago. In the intervening period, humans evolved a suite of higher-order cognitive functions, including language, EF, ToM, and symbolizing abilities. Understanding whether one of these functions evolved first and served as a foundation for others, or whether different functions developed separately but in parallel, is extremely challenging because intermediate phenotypes, such as those of Homo erectus and Homo neanderthalensis, no longer exist and cannot easily be reconstructed from the archeological record.

Much the same problem is observed when the emergence of these functions is studied on ontogenetic timescales. Across the lifespan, higher-order cognitive functions show similar developmental timetables. For example, both ToM and EF rapidly develop within the early stage of one's life, the preschool period (Carlson & Moses, 2001; Carlson et al., 2002; Frye et al., 1995; Hughes & Ensor, 2005), and decline in late-adulthood (German & Hehman, 2006; McDowd & Craik, 1988; Phillips et al., 2011; Salthouse & Babcock, 1991; Verhaeghen et al., 2003). Thus, the analogous developmental trajectories between ToM and EF, especially the rapid development of the two abilities in a short period, bring challenges to testing the nature of the relationship between the two abilities.

Three experiments in the current work explored the relationship between ToM and EF given challenges to testing the relationship. There were several important findings and implications that will be briefly reviewed.

6.1 Summary of findings

One empirical challenge to testing the nature of the relationship between ToM and EF is that the development timetables of ToM and EF are very similar making it difficult to know whether the relationship between the two is causal or merely statistical. To address this challenge, the first two experiments (Experiments 1 and 2) explored whether socio-cultural influences on EF have comparable effects on ToM. First, given that language status (Bialystok & Martin, 2004; Bialystok & Senman, 2004) and country-of-origin (Oh & Lewis, 2008; Sabbagh et al., 2006) influence children's EF, Experiment 1 investigated whether the two socio-cultural factors impact preschool-aged children's EF. To that end, Korean-English (K-E) bilingual, Korean monolingual, and English monolingual preschool-aged children were compared on an age-appropriate response inhibition task. The results demonstrated that both K-E bilinguals and Korean monolinguals outperformed English monolinguals in the task, implying that country-of-origin, but not language status, affects young children's inhibitory control.

Experiment 2 explored whether the effects reported in Experiment 1 extended to ToM. To that end, the performance of identical samples reported in Experiment 1 on two typically used false-belief tasks was compared. The results showed that there was no difference among the three groups in their performance on the ToM tasks, suggesting that neither country-of-origin nor language status influences preschool-aged children's ToM. In other words, the effect of country-of-origin observed in Experiment 1 (EF) was not found in Experiment 2 (ToM).

Another empirical challenge to testing the relationship between ToM and EF is that the strong relationship between the two abilities might actually come from methodological artifacts. For example, high cognitive loads that ToM tasks typically impose to perform might make the two abilities appear to be strongly correlated. To address this issue, Experiment 3 examined whether older adults, believed to have age-related decline of ToM due to their deficits in EF with age (Bailey & Henry, 2008; Charlton et al., 2009; German & Hehman, 2006; Phillips et al., 2011), show difficulty in tracking others' beliefs even when using a ToM task with a reduced cognitive load. To that end, young adults and older adults were compared on a spontaneous-response ToM task (which requires low cognitive load to perform) and a variety of EF measurements. The results exhibited that older adults tracked belief to same extent as young adults when cognitive demands in a ToM task were reduced, in spite of their deficits in EF. It suggests that correlations between ToM and EF performance might be artificially increased due to the high cognitive demands that most of ToM tasks impose.

6.2 Implications on the relationship between Theory of Mind and Executive Function

Regarding the relationship between ToM and EF, two possibilities have been proposed: (1) ToM and EF are two facets of the same process; (2) ToM and EF are distinct (but coincidently developed) processes. In regard to the first possibility, ToM (specifically, false-belief understanding) has been suggested to be merely one form of EF using higher-order rules (e.g., Cognitive Complexity and Control theory; Frye et al., 1998). According to this idea, it may be possible that a common domain-general process is involved in both the response inhibition task used in Experiment 1 and the false-belief tasks used in Experiment 2. For example, to successfully perform the false-belief tasks, the ability to switch judgments using if-if-then rules (e.g., *if* a character in the tasks saw that an object was located in A, *if* he/she did not see the change of the object's location (from location A to location B), *then* location A; *if* he/she saw that an object was located in A, *if* he/she saw the change of the object's location to B, *then* location B) might be involved. Likewise, the identical reasoning ability to switch judgments might be necessary for successfully performing the response inhibition task (e.g., *if* it is an incongruent condition, *if* a computer says "red", *then* pressing a blue circle; *if* it is a congruent condition, *if* a computer says "red", *then* pressing a red circle). If ToM and EF are based on the same cognitive process (e.g., using if-if-then rules), advance in one ability (e.g., EF) should lead to advance in the other ability (e.g., ToM). The results from Experiments 1 and 2, however, challenge the first possibility in that differences in response inhibition associated with country-of-origin did not extend to differences in performance on ToM tasks.

The results from Experiments 1 and 2 seem to support the second possibility in that the analogous effects of sociocultural factors (i.e., country-of-origin and language status) on EF (reported in Experiment 1) did not extend to ToM. In addition, previous findings (Sabbagh et al., 2006; Wang et al., 2016) add weight to this possibility. For example, Chinese preschoolers outperformed U.S. counterparts on a variety of EF measurements, but were indistinguishable from U.S. children on several ToM tasks, suggesting that differences in EF possibly associated with country-of-origin do not extend to differences in ToM (Sabbagh et al., 2006).

If the second possibility is correct, however, it is still complicated to explain the myriad of evidence showing the strong correlation between ToM and EF (e.g., Carlson & Moses, 2001; Frye et al., 1995; Hughes & Ensor, 2007; McAlister & Peterson, 2013). If ToM and EF are distinct processes, why are EF and ToM measures frequently correlated? The results of Experiment 3 offer one possibility.

In Experiment 3, older adults with their age-related deterioration of EF showed intact belief-tracking ability when using a low-demand ToM. Given that (1) the age-related decline of ToM is attributable to the age-related deterioration of EF (Bailey & Henry, 2008; Charlton et al., 2009; German & Hehman, 2006; Phillips et al., 2011) and (2) ToM tasks typically require high cognitive demands to perform (i.e., elicited-response tasks), the results suggest that high cognitive load that the elicited-response tasks impose might be the underlying sources of age-related decline of ToM that previous literature has reported. Thus, the results from Experiment 3 support the possibility that methodological artifacts lead to a seemingly interdependent but, in truth, independent relationship between ToM and EF.

Regarding how EF relates to ToM (i.e., emergence[5] and expression accounts), the results from experiments 1 and 2 do not seem to support the expression account whereas the result from experiment 3 does. Under the expression account, it is predicted that (1) an advance in EF (in other words, an advance in the ability to express one's mentalizing ability) should lead to an advance in ToM task performance and (2) lowering EF demands of a ToM task should lead to increased or intact ToM ability in the elderly. Although the results from the experiment 3 seems to be consistent with this prediction,

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[5] Since the current work did not involve a longitudinal design or training effect, it is not possible to conclude anything about a causal relationship between ToM and EF (i.e., whether EF is necessary for ToM) from the current work.

the results from experiments 1 and 2 do not seem to favour this account in that it showed that Korean children's earlier development of EF did not extend to parallel advantage in ToM compared to Canadian children. The inconsistent findings on the expression account might come from the limitations of the current work, which will be addressed in the following section.

6.3 Limitations and future directions

The purpose of the current work is to examine whether ToM and EF stem from one process or are distinct processes, but there are limitations in addressing this question.

One limitation is that it was not possible to directly test whether socio-cultural variables (i.e., language status and country-of-origin) are differently related to ToM than EF through Experiments 1 and 2. In both experiments, there was a lack of bilingual samples from individualistic cultures (e.g., French-English bilingual children in Canada). As such, these incomplete 2 (language status: bilinguals vs. monolinguals) x 2 (country-of-origin: collectivistic vs. individualistic) factorial designs did not allow us to disentangle the effects of the two socio-cultural variables on ToM and EF respectively, and to see whether there is the possible interaction of language status and country-of-origin on ToM and EF.

Future studies are, therefore, necessary to elucidate the impact of socio-cultural variables on ToM and EF, both independently and collectively. Specifically, future work should aim to collect an equal amount of data from individualistic and collectivist countries, allowing for a complete 2 x 2 factorial design in one analysis/study. This will enable researchers to directly compare the magnitude of the socio-cultural effects on ToM and EF. In addition, a longitudinal study with complete 2 x 2 factorial designs potentially allows us to test not only whether the possible interaction exists but also whether individual differences in one ability (e.g., EF) associated with socio-cultural variables are related to individual differences in the other ability (e.g., ToM) later in development.

Interestingly, the results from experiments 1 and 2 suggest that sociocultural factor (i.e., country-of-origin) influences EF but not ToM, which may seem counterintuitive. For example, ToM involves one's understanding of how others think so that it is highly likely to be influenced by socialization and cultures, but which is not true in the current results. The present work attempted to clarify the nature of the sociocultural factor (i.e., country-of-origin) by using questionnaires on parental cultural values and parenting styles, but it is still unclear. For future studies, it would be interesting to investigate what factor leads to the observed sociocultural effect on EF but not on ToM by encompassing a variety of sociocultural measurements.

Although the present work proposes methodological artifacts as a possible basis underlying the seemingly correlated relationship between ToM and EF, it is difficult to say that the results from Experiment 3 can be direct evidence of supporting this possibility. Experiment 3 was lacking in direct comparisons of performance between closely matched ToM tasks with higher cognitive demands and ToM tasks with lower cognitive demands. As such, it was not directly tested whether the relationship between ToM and EF is dependent on the extent of cognitive demand that a ToM task imposes to perform. To that end, a more direct comparison would enable us to draw better conclusions about whether or not a highly interrelated relationship between ToM and EF comes from the incidental EF loads that ToM tasks require to perform. This should be further addressed in future studies.

One limitation relating to the false-belief eye-tracking task used in Experiment 3 is that there have been controversies on whether spontaneous-response behaviour (i.e., eye movement) can be interpreted as indicative of false-belief understanding. On one hand, it has been proposed that spontaneous-response behaviour can be regarded as evidence showing the innateness or early onset of ToM competence (Leslie et al., 2004; Onishi & Baillargeon, 2005). On the other hand, it is suggested that spontaneous-response behaviour can be explained by behavioural rules (e.g., people are more likely to search for an object where they last saw it; Perner & Ruffman, 2005) or actor-object-location associations (Perner & Ruffman, 2005; Ruffman & Perner, 2005). Thus, this issue should be explored further by future work.

Conceptual issues relating to the definitions of ToM and EF should also be considered. For example, ToM has been proposed to encompass a variety of domains (i.e., cognitive vs. affective ToM; Kalbe et al., 2010; Shamay-Tsoory & Aharon-Peretz, 2007 or implicit vs. explicit ToM; Schuwerk, Vuori, & Sodian, 2015; Wiesmann, Friederici, Singer, & Steinbeis, 2017) and levels (i.e., first-order or second-order false-belief reasoning; Apperly, Samson, Carroll, Hussain, & Humphreys, 2006; Lecce, Bianco, Demicheli, & Cavallini, 2014) of ToM. In regard to EF, it is difficult to define because (1) EF is an umbrella term to include a variety of cognitive processes (i.e., inhibitory control, working memory updating, set-shifting) for goal-directed behaviour and (2) there is no consensus on the definition EF (Barkley, 2001, 2012). Therefore, it is possible that the relationship between ToM and EF might be dependent on the definitions or types of ToM and EF. For example, other subcomponents of EF (i.e., set-shifting and working memory updating) might have a bidirectional relationship with ToM, whereas inhibitory control might not have any bidirectionality with ToM (Austin et al., 2014). The relationship between ToM and EF should be explored further by future studies, which focus on encompassing diverse domains and types of ToM and EF.

Neuroscience methods may provide deeper insight into the relationship between ToM and EF given the limitations of behavioural evidence (e.g., mixed results even with sophisticated study designs; Wade et al., 2018). Based on a few existing neuroscience findings (Saxe et al., 2006; Scholz, Triantafyllou, Whitfield-Gabrieli, Brown, & Saxe, 2009; van der Meer et al., 2011), the proposal of a completely overlapping relationship between ToM and EF can be ruled out (Wade et al., 2018) because separable neural mechanisms underlying ToM and EF (but with some shared brain areas involving both ToM and EF) have been found. The current work seems to be consistent with the neuroscience findings in that the results from Experiments 1 and 2 do not support the possibility of one common process underlying both ToM and EF. Even with existing neuroscience findings, however, it is still uncertain whether ToM and EF are distinct processes and whether the shared neural mechanisms are attributable to incidental cognitive (or domain-general) demands that both ToM and EF tasks impose. Further neuroscience works may explore this possibility with various approaches (e.g., functional connectivity between ToM and EF) in the future.

6.4 Conclusion

The current work tested hypotheses concerning the relationship between ToM and EF by conducting three interrelated experiments. The results suggest that: (1) ToM and EF are distinct processes; and (2) methodological overlap between ToM and EF tasks might inflate apparent correlations between ToM and EF abilities. Given that the similar developmental trajectories between ToM and EF are one of the key empirical challenges to elucidate the nature of relationship, the current work provides meaningful contributions in that it suggests a new framework to investigate the relationship, examining whether the effects of individual differences in socio-cultural factors on EF extend to ToM. The current work provides not only important contributions to understanding the nature of the relationship between ToM and EF, but insight into our understanding of higher cognitive functions in terms of evolutionary perspectives.

References

Ahn, S., & Miller, S. A. (2012). Theory of mind and self-concept: A comparison of Korean and American children. *Journal of Cross-Cultural Psychology*, *43*(5), 671–686. https://doi.org/10.1177/0022022112441247

Apperly, I. A. (2012). What is "theory of mind"? Concepts, cognitive processes and individual differences. *Quarterly Journal of Experimental Psychology*, *65*(5), 825–839. https://doi.org/10.1080/17470218.2012.676055

Apperly, I. A., & Butterfill, S. A. (2009). Do humans have two systems to track beliefs and belief-like states? *Psychological Review*, *116*(4), 953–970. https://doi.org/10.1037/a0016923

Apperly, I. A., Samson, D., Carroll, N., Hussain, S., & Humphreys, G. (2006). Intact first- and second-order false belief reasoning in a patient with severely impaired grammar. *Social Neuroscience*, *1*(3–4), 334–348. https://doi.org/10.1080/17470910601038693

Austin, G., Groppe, K., & Elsner, B. (2014). The reciprocal relationship between executive function and theory of mind in middle childhood: A 1-year longitudinal perspective. *Frontiers in Psychology*, *5*, 1–11. https://doi.org/10.3389/fpsyg.2014.00655

Avis, J., & Harris, P. L. (1991). Belief-desire reasoning among Baka children : Evidence for a universal conception of mind. *Child Development*, *62*(3), 460–467.

Baddeley, A. (1996). Exploring the central executive. *Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology*, *49*(1), 5–28. https://doi.org/10.1080/713755608

Bailey, P. E., & Henry, J. D. (2008). Growing less empathic with age: Disinhibition of the self-perspective. *Journals of Gerontology - Series B Psychological Sciences and Social Sciences*, *63*(4), 219–226. https://doi.org/10.1093/geronb/63.4.P219

Baillargeon, R., Scott, R. M., & He, Z. (2011). False-belief understanding in infants. *Trends in Cognitive Sciences*, *14*(3), 110–118. https://doi.org/10.1016/j.tics.2009.12.006.False-belief

Barkley, R. A. (2001). The executive functions and self-regulation: An evolutionary neuropsychological perspective. *Neuropsychology Review*, *11*(1), 1–29. https://doi.org/10.1023/A:1009085417776

Barkley, R. A. (2012). *Executive functions: What they are, how they work, and why they evolved*. New York: Guilford Press.

Bartsch, K., & Wellman, H. M. (1995). *Children talk about the mind*. New York: Oxford University Press.

Berguno, G., & Bowler, D. M. (2004). Communicative interactions, knowledge of a second language, and theory of mind in young children. *Journal of Genetic Psychology*, *165*(3), 293–309. https://doi.org/10.3200/GNTP.165.3.293-309

Bialystok, E. (1999). Cognitive complexity and attentional control in the bilingual mind. *Child Development*, *70*(3), 636–644.

Bialystok, E. (2010). Global-local and trail-making tasks by monolingual and bilingual children: beyond inhibition. *Developmental Psychology*, *46*(1), 93–105. https://doi.org/10.1037/a0015466

Bialystok, E., Klein, R., Craik, F. I. M., & Viswanathan, M. (2004). Bilingualism, aging, and cognitive control: Evidence from the Simon task. *Psychology and Aging*, *19*(2), 290–303. https://doi.org/10.1037/0882-7974.19.2.290

Bialystok, E., & Martin, M. M. (2004). Attention and inhibition in bilingual children: Evidence from the dimensional change card sort task. *Developmental Science*, *7*(3), 325–339. https://doi.org/10.1111/j.1467-7687.2004.00351.x

Bialystok, E., & Senman, L. (2004). Executive processes in appearance-reality tasks: The role of inhibition of attention and symbolic representation. *Child Development*, *75*(2), 562–579. https://doi.org/10.1111/j.1467-8624.2004.00693.x

Blakemore, S. (2012). Development of the social brain in adolescence. *Journal of the Royal Society of Medicine*, *105*(3), 111–116. https://doi.org/10.1258/jrsm.2011.110221

Block, J. H. (1981). *The Child-Rearing Practices Report (CRPR): A set of Q items for the description of parental socialization attitudes and values*. Berkeley, CA: University of California, Institute of Human Development.

Blom, E., Küntay, A. C., Messer, M., Verhagen, J., & Leseman, P. (2014). The benefits of being bilingual: Working memory in bilingual Turkish-Dutch children. *Journal of Experimental Child Psychology*, *128*, 105–119. https://doi.org/10.1016/j.jecp.2014.06.007

Buchsbaum, D., Bridgers, S., Weisberg, D. S., & Gopnik, A. (2012). The power of possibility: Causal learning, counterfactual reasoning, and pretend play. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*, 2202–2212. https://doi.org/10.1098/rstb.2012.0122

Burzynska, A. Z., Nagel, I. E., Preuschhof, C., Gluth, S., Bäckman, L., Li, S. C., … Heekeren, H. R. (2012). Cortical thickness is linked to executive functioning in adulthood and aging. *Human Brain Mapping*, *33*(7), 1607–1620. https://doi.org/10.1002/hbm.21311

Cabeza, R., Anderson, N. D., Locantore, J. K., & McIntosh, A. R. (2002). Aging gracefully: Compensatory brain activity in high-performing older adults. *NeuroImage*, *17*, 1394–1402. https://doi.org/10.1006/nimg.2002.1280

Carlson, S. M. (2005). Developmentally sensitive measures of executive function in preschool children. *Developmental Neuropsychology*, *28*(2), 595–616. https://doi.org/10.1207/s15326942dn2802

Carlson, S. M., Mandell, D. J., & Williams, L. (2004). Executive function and theory of mind: Stability and prediction from ages 2 to 3. *Developmental Psychology*, *40*(6), 1105–1122. https://doi.org/10.1037/0012-1649.40.6.1105

Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science*, *11*(2), 282–298. https://doi.org/10.1111/j.1467-7687.2008.00675.x

Carlson, S. M., & Moses, L. J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development*, *72*, 1032–1053.

Carlson, S. M., Moses, L. J., & Breton, C. (2002). How specific is the relation between executive function and theory of mind? Contributions of inhibitory control and working memory. *Infant and Child Development*, *11*, 73–92. https://doi.org/10.1002/icd

Carlson, S. M., Moses, L. J., & Hix, H. R. (1998a). The role of inhibitory processes in young children's difficulties with deception and false belief. *Child Development*, *69*(3), 672–691. https://doi.org/10.1111/j.1467-8624.1998.00672.x

Carlson, S. M., Moses, L. J., & Hix, H. R. (1998b). The role of inhibitory processes in young children's difficulties with deception and false belief. *Child Development*, *69*(3), 672–691. https://doi.org/10.1111/j.1467-8624.1998.00672.x

Case, R. (1992). The role of the frontal lobes in the regulation of cognitive development. *Brain and Cognition*, *20*(1), 51–73. https://doi.org/10.1016/0278-2626(92)90061-P

Cepeda, N. J., Kramer, A. F., & Gonzalez de Sather, J. C. M. (2001). Changes in executive control across the life span: Examination of task-switching performance. *Developmental Psychology*, *37*(5), 715–730.

Channon, S., & Crawford, S. (2000). The effects of anterior lesions on performance on a story comprehension test: Left anterior impairment on a theory of mind-type task. *Neuropsychologia*, *38*, 1006–1017. https://doi.org/10.1016/S0028-3932(99)00154-2

Chao, L. L., & Knight, R. T. (1997). Prefrontal deficits in attention and inhibitory control with aging. *Cerebral Cortex*, *7*, 63–69. https://doi.org/10.1093/cercor/7.1.63

Charlton, R. A., Barrick, T. R., Markus, H. S., & Morris, R. G. (2009). Theory of mind associations with other cognitive functions and brain imaging in normal aging. *Psychology and Aging*, *24*(2), 338–348. https://doi.org/10.1037/a0015225

Charman, T., & Baron-Cohen, S. (1992). Understanding drawings and beliefs: a further test of the metarepresentation theory of autism: a research note. *Journal of Child Psychology and Psychiatry*, *33*(6), 1105–1112. https://doi.org/10.1111/j.1469-7610.1992.tb00929.x

Chen, X., Hastings, P. D., Rubin, K. H., Chen, H., Cen, G., & Stewart, S. L. (1998). Child-rearing attitudes and behavioral inhibition in Chinese and Canadian toddlers: A cross-cultural study. *Developmental Psychology*, *34*(4), 677–686. https://doi.org/10.1037/0012-1649.34.4.677

Chen, Xinyin, Dong, Q., & Zhou, H. (1997). Authoritative and authoritarian parenting practices and social and school performance in Chinese children. *International Journal of Behavioral Development*, *21*(4), 855–873.

Chiappe, D., & MacDonald, K. (2005). The evolution of domain-general mechanisms in intelligence and learning. *Journal of General Psychology*, *132*(1), 5–40.

https://doi.org/10.3200/GENP.132.1.5-40

Chomsky, N. (1964). *Aspects of the theory of syntax*. Cambridge, MA: MIT Press.

Clarke-Stewart, K. A., Lee, Y., Allhusen, V. D., Kim, M. S., & McDowell, D. J. (2006). Observed differences between early childhood programs in the U.S. and Korea: Reflections of “developmentally appropriate practices” in two cultural contexts. *Journal of Applied Developmental Psychology*, *27*(5), 427–443. https://doi.org/10.1016/j.appdev.2006.06.006

Cosmides, L. (1989). The logic of social exchange: Has natural selection shaped how humans reason? Studies with the Wason selection task. *Cognition*, *31*(3), 187–276.

Cosmides, L., & Tooby, J. (1997). Evolutionary psychology: A primer. *Evolutionary Psychology*, *1*, 1–27. https://doi.org/10.1016/0162-3095(89)90012-5

Crone, E. A., Donohue, S. E., Honomichl, R., Wendelken, C., & Bunge, S. A. (2006). Brain regions mediating flexible rule use during development. *Journal of Neuroscience*, *26*(43), 11239–11247. https://doi.org/10.1523/JNEUROSCI.2165-06.2006

Cutting, A. L., & Dunn, J. (1999). Theory of Mind, emotion understanding, language, and family background: Individual differences and interrelations. *Child Development*, *70*(4), 853–865. https://doi.org/10.1111/1467-8624.00061

Devine, R. T., & Hughes, C. (2018). Family correlates of false belief understanding in early childhood: A meta-analysis. *Child Development*, *89*(3), 971–987. https://doi.org/10.1111/cdev.12682

Devine, R. T., White, N., Ensor, R., & Hughes, C. (2016). Theory of mind in middle childhood: Longitudinal associations with executive function and social competence. *Developmental Psychology*, *52*(5), 758–771. https://doi.org/10.1017/CBO9781107415324.004

Diamond, A. (2002). Normal development of prefrontal cortex from birth to young adulthood: Cognitive functions, anatomy, and biochemistry. In D. T. Stuss & R. T. Knight (Eds.), Principles of frontal lobe function (pp. 466–503). Oxford: Oxford University Press. *Principles of Frontal Lobe Function*, 466–503.

Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: Development of the abilities to remember what I said and to “do as I say, not as I do.” *Developmental Psychobiology*, *29*(4), 315–334. https://doi.org/10.1002/(SICI)1098-2302(199605)29:4<315::AID-DEV2>3.0.CO;2-T

Dick, A. S., Garcia, N. L., Pruden, S. M., Thompson, W. K., Hawes, S. W., Sutherland, M., … Gonzalez, R. (2018). *No bilingual advantage for executive function: Evidence from a large sample of children in the Adolescent Brain and Cognitive Development (ABCD) Study*. *17*, 1–14. https://doi.org/10.31234/OSF.IO/GJH95

Dumontheil, I., Apperly, I. A., & Blakemore, S. J. (2010). Online usage of theory of mind continues to develop in late adolescence. *Developmental Science*, *13*(2), 331–338. https://doi.org/10.1111/j.1467-7687.2009.00888.x

Duñabeitia, J. A., Hernández, J. A., Antón, E., Macizo, P., Estévez, A., Fuentes, L. J., & Carreiras, M. (2014). The inhibitory advantage in bilingual children revisited: Myth or reality? *Experimental Psychology*, *61*(3), 234–251. https://doi.org/10.1027/1618-3169/a000243

Dunn, L. M., & Dunn, D. M. (2007). *PPVT-4: Peabody picture vocabulary test*. Bloomington, MN: NCS Pearson, Inc.

Farhadian, M., Abdullah, R., Mansor, M., Redzuan, M., Kumar, V., & Gazanizadand, N. (2010). Theory of mind in bilingual and monolingual preschool children. *Journal of Psychology*, *1*(1), 39–46. https://doi.org/10.1080/09764224.2010.11885444

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). A Calorimetric investigation of the liquid bi-ni alloys. *Behavior Research Methods*, *39*(2), 175–191.

Flavell, J. H., Green, F. L., & Flavell, E. R. (2000). Development of children's awareness of their own thoughts. *Journal of Cognition and Development*, *1*(1), 97–112. https://doi.org/10.1207/S15327647JCD0101N

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-mental state": a practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, *12*, 189–198. https://doi.org/10.3744/snak.2003.40.2.021

Frith, C. D., & Frith, U. (1999). Interacting minds - A biological basis. *Science*, *286*, 1692–1695. https://doi.org/10.1126/science.286.5445.1692

Frye, D., Zelazo, P. D., & Burack, J. A. (1998). Cognitive complexity and control: I. Theory of mind in typical and atypical development. *Current Directions in Psychological Science*, *7*(4), 116–121.

Frye, D., Zelazo, P. D., & Palfai, T. (1995). Theory of mind and rule-based reasoning. *Cognitive Development*, *10*, 483–527. https://doi.org/10.1016/0885-2014(95)90024-1

Funahashi, S., & Andreau, J. M. (2013). Prefrontal cortex and neural mechanisms of executive function. *Journal of Physiology - Paris*, *107*, 471–482. https://doi.org/10.1016/j.jphysparis.2013.05.001

German, T. P., & Hehman, J. A. (2006). Representational and executive selection resources in "theory of mind": Evidence from compromised belief-desire reasoning in old age. *Cognition*, *101*(1), 129–152. https://doi.org/10.1016/j.cognition.2005.05.007

Gerstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: performance of children 3 1/2–7 years old on a Stroop-like day-night test. *Cognition*, *53*, 129–153.

Goetz, P. J. (2003). The effects of bilingualism on theory of mind development. *Bilingualism: Language and Cognition*, *6*(1), 1–15. https://doi.org/10.1017/s1366728903001007

Gopnik, A., & Astington, J. W. (1988). Children's understanding of representational change and its relation to the understanding of false belief and the appearance-reality distinction. *Child Development*, *59*(1), 26–37.

Gopnik, A., & Slaughter, V. (1991). Young children's understanding of changes in their mental states. *Child Development*, *62*(1), 98–110.

Gordon, K. R. (2016). High proficiency across two languages is related to better mental state reasoning for bilingual children. *Journal of Child Language*, *43*, 407–424. https://doi.org/10.1017/S0305000915000276

Grainger, S. A., Henry, J. D., Naughtin, C. K., Comino, M. S., & Dux, P. E. (2018). Implicit false belief tracking is preserved in late adulthood. *Quarterly Journal of Experimental Psychology*, *71*(9), 1980–1987. https://doi.org/10.1177/1747021817734690

Grant, D. A., & Berg, E. (1948). A behavioral analysis of degree of reinforcement and ease of shifting to new responses in a Weigl-type card-sorting problem. *Journal of Experimental Psychology*, *38*(4), 404–411.

Happé, F. G., Winner, E., & Brownell, H. (1998). The getting of wisdom: Theory of mind in old age. *Developmental Psychology*, *34*(2), 358–362. https://doi.org/10.1037/0012-1649.34.2.358

Hartanto, A., & Yang, H. (2019). Does early active bilingualism enhance inhibitory control and monitoring? A propensity-matching analysis. *Journal of Experimental Psychology: Learning Memory and Cognition*, *45*(2), 360–378. https://doi.org/10.1037/xlm0000581

Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. New York, NY: Guilford Publications.

Henry, J. D., Phillips, L. H., Ruffman, T., & Bailey, P. E. (2013). A meta-analytic review of age differences in theory of mind. *Psychology and Aging*, *28*(3), 826–839. https://doi.org/10.1037/a0030677

Heyes, C. (2012). New thinking: The evolution of human cognition. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*, 2091–2096. https://doi.org/10.1098/rstb.2012.0111

Hofstede, G. (1980). *Culture's consequences: International differences in work-related values*. Beverly Hills, CA: Sage.

Hughes, C. (1998). Finding your marbles: Does preschoolers' strategic behavior predict later understanding of mind? *Developmental Psychology*, *34*(6), 1326–1339.

Hughes, C., & Dunn, J. (1998). Understanding mind and emotion: longitudinal associations with mental-state talk between young friends. *Developmental Psychology*, *34*(5), 1026–1037. https://doi.org/10.1037/0012-1649.34.5.1026

Hughes, C., & Ensor, R. (2005). The development of executive function in young children : Contributions to the emergence of self-regulation. *Developmental Neuropsychology*, *28*(2), 645–668. https://doi.org/10.1207/s15326942dn2802

Hughes, C., & Ensor, R. (2007). Executive function and theory of mind: Predictive relations from ages 2 to 4. *Developmental Psychology*, *43*(6), 1447–1459.

Huizinga, M., Dolan, C. V., & van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia*, *44*(11), 2017–2036. https://doi.org/10.1016/j.neuropsychologia.2006.01.010

Huttenlocher, P. R., & Dabholkar, A. S. (1997). Regional differences in synaptogenesis in human cerebral cortex. *Journal of Comparative Neurology*, *387*, 167–178. https://doi.org/10.1002/(SICI)1096-9861(19971020)387:2<167::AID-CNE1>3.0.CO;2-Z

Hyde, D. C., Simon, C. E., Ting, F., & Nikolaeva, J. I. (2018). Functional organization of the temporal–parietal junction for theory of mind in preverbal infants: A near-infrared spectroscopy study. *Journal of Neuroscience, 38*(18), 4264–4274. https://doi.org/10.1523/JNEUROSCI.0264-17.2018

JASP Team. (2018). *JASP. Version 0.9*. Retrieved from http://jasp-stats.org/

Jensen, A. R., & Rohwer Jr., W. D. (1966). The stroop color-word test: A review. *Acta Psychologica*, *25*, 36–93.

Kalbe, E., Schlegel, M., Sack, A. T., Nowak, D. A., Dafotakis, M., Bangard, C., … Kessler, J. (2010). Dissociating cognitive from affective theory of mind: A TMS study. *Cortex*, *46*, 769–780. https://doi.org/10.1016/j.cortex.2009.07.010

Kim, Y. T., Chang, H. S., Yim, S. S., & Beak, H. J. (1995). *Peabody Picture Vocabulary Test-Revised Korean version*. Seoul: Seoul Community Rehabilitation Centre Press.

Király, I., Oláh, K., Csibra, G., & Kovács, Á. M. (2018). Retrospective attribution of false beliefs in 3-year-old children. *Proceedings of the National Academy of Sciences*, *115*(45), 11477–11482. https://doi.org/10.1073/pnas.1803505115

Kirkham, N. Z., Cruess, L., & Diamond, A. (2003). Helping children apply their knowledge to their behavior on a dimension-switching task. *Developmental Science*, *6*(5), 449–476. Retrieved from http://www.devcogneuro.com/Publications/kirkhametalcardsorting2003.pdf

Kleibeuker, S. W., De Dreu, C. K. W., & Crone, E. A. (2013). The development of creative cognition across adolescence: Distinct trajectories for insight and divergent thinking. *Developmental Science*, *16*(1), 2–12. https://doi.org/10.1111/j.1467-7687.2012.01176.x

Kleibeuker, S. W., Koolschijn, P. C. M. P., Jolles, D. D., Schel, M. A., De Dreu, C. K. W., & Crone, E. A. (2013). Prefrontal cortex involvement in creative problem solving in middle adolescence and adulthood. *Developmental Cognitive Neuroscience*, *5*, 197–206. https://doi.org/10.1016/j.dcn.2013.03.003

Kochanska, G., Kuczynski, L., & Radke-yarrow, M. (1989). *Correspondence between mothers' self-reported and observed child-rearing practices*. *60*(1), 56–63.

Koechlin, E., & Summerfield, C. (2007). An information theoretical approach to prefrontal executive function. *Trends in Cognitive Sciences*, *11*(6), 229–235. https://doi.org/10.1016/j.tics.2007.04.005

Kovács, Á. M. (2009). Early bilingualism enhances mechanisms of false-belief reasoning. *Developmental Science*, *12*(1), 48–54. https://doi.org/10.1111/j.1467-

7687.2008.00742.x

Kyuchukov, H., & de Villiers, J. (2009). Theory of mind and evidentiality in Romani-Bulgarian bilingual children. *Psychology of Language and Communication*, *13*(2), 21–34. https://doi.org/10.2478/v10057-009-0007-4

Lecce, S., Bianco, F., Demicheli, P., & Cavallini, E. (2014). Training preschoolers on first-order false belief understanding: Transfer on advanced ToM skills and metamemory. *Child Development*, *85*(6), 2404–2418. https://doi.org/10.1111/cdev.12267

Lee, K., Olson, D. R., & Torrance, N. (1999). Chinese children's understanding of false beliefs: The role of language. *Journal of Child Language*, *26*, 1–21. https://doi.org/10.1017/S0305000998003626

Leslie, A. M., Friedman, O., & German, T. P. (2004). Core mechanisms in "theory of mind." *Trends in Cognitive Sciences*, *8*(12), 528–533. https://doi.org/10.1016/j.tics.2004.10.001

Leslie, A. M., & Thaiss, L. (1992). Domain specificity in conceptual development: evidence from autism. *Cognition*, *43*, 225–251. https://doi.org/0010-0277/92/

Lewis, C., Koyasu, M., Oh, S., Ogawa, A., Short, B., & Huang, Z. (2009). Culture, executive function, and social understanding. *New Directions in Child and Adolescent Development*, *123*, 69–85. https://doi.org/10.1002/cd

Liu, D., Wellman, H. M., Tardif, T., & Sabbagh, M. A. (2008). Theory of mind development in Chinese children: A meta-analysis of false-belief understanding across cultures and languages. *Developmental Psychology*, *44*(2), 523–531. https://doi.org/10.1037/0012-1649.44.2.523

Lough, S., Gregory, C., & Hodges, J. R. (2001). Dissociation of social cognition and executive function in frontal variant frontotemporal dementia. *Neurocase*, *7*(2), 123–130. https://doi.org/10.1093/neucas/7.2.123

Luria, A. R., Pribram, K. H., & Homskaya, E. D. (1964). An experimental analysis of the behavioral disturbance produced by a left frontal arachnoidal endothelioma (meningioma). *Neuropsychologia*, *2*, 257–280.

MacLeod, C. M. (1991). Half a century of reseach on the stroop effect: An integrative review. *Psychological Bulletin*, *109*(2), 163–203. https://doi.org/10.1037/0033-2909.109.2.163

MacPherson, S. E., Phillips, L. H., & Della Sala, S. (2002). Age, executive function, and social decision making: A dorsolateral prefrontal theory of cognitive aging. *Psychology and Aging*, *17*(4), 598–609. https://doi.org/10.1037/0882-7974.17.4.598

Mahy, C. E. V., Bernstein, D. M., Gerrard, L. D., & Atance, C. M. (2017). Testing the validity of a continuous false belief task in 3- to 7-year-old children. *Journal of Experimental Child Psychology*, *160*, 50–66. https://doi.org/10.1016/j.jecp.2017.03.010

Martin-Rhee, M. M., & Bialystok, E. (2008). The development of two types of inhibitory control in monolingual and bilingual children. *Bilingualism: Language and*

Cognition, *11*(1), 81–93.

Maylor, E. A., Moulson, J. M., Muncer, A. M., & Taylor, L. A. (2002). Does performance on theory of mind tasks decline in old age? *British Journal of Psychology*, *93*(4), 465–485. https://doi.org/10.1348/000712602761381358

McAlister, A., & Peterson, C. (2007). A longitudinal study of child siblings and theory of mind development. *Cognitive Development*, *22*(2), 258–270. https://doi.org/10.1016/j.cogdev.2006.10.009

McAlister, A. R., & Peterson, C. C. (2013). Siblings, theory of mind, and executive functioning in children aged 3-6 years: New longitudinal evidence. *Child Development*, *84*(4), 1442–1458. https://doi.org/10.1111/cdev.12043

McDowd, J. M., & Craik, F. I. M. (1988). Effects of aging and task difficulty on divided attention performance. *Journal of Experimental Psychology: Human Perception and Performance*, *14*(2), 267–280. https://doi.org/10.1037/0096-1523.14.2.267

McDowd, J. M., & Shaw, R. J. (2000). *Attention and aging: A functional perspective. In F. I. M. Craik & T. A. Salthouse (Eds.), The handbook of aging and cognition (2nd ed., pp. 221–292). Mahwah, NJ: Erlbaum*.

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science*, *21*(1), 8–14. https://doi.org/10.1177/0963721411429458

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology*, *41*, 49–100. https://doi.org/10.1006/cogp.1999.0734

Morales, J., Calvo, A., & Bialystok, E. (2013). Working memory development in monolingual and bilingual children. *Journal of Experimental Child Psychology*, *114*, 187–202. https://doi.org/10.1016/j.jecp.2012.09.002

Moriguchi, Y., & Hiraki, K. (2013). Prefrontal cortex and executive function in young children: A review of NIRS studies. *Frontiers in Human Neuroscience*, *7*, 1–9. https://doi.org/10.3389/fnhum.2013.00867

Morton, J. B., Bosma, R., & Ansari, D. (2009). Age-related changes in brain activation associated with dimensional shifts of attention: An fMRI study. *NeuroImage*, *46*, 249–256. https://doi.org/10.1016/j.neuroimage.2009.01.037

Morton, J. B., & Harper, S. N. (2007). What did Simon say? Revisiting the bilingual advantage. *Developmental Science*, *10*(6), 719–726. https://doi.org/10.1111/j.1467-7687.2007.00623.x

Morton, J. B., & Harper, S. N. (2009). Bilinguals show an advantage in cognitive control - The question is why. *Developmental Science*, *12*(4), 502–503. https://doi.org/10.1111/j.1467-7687.2009.00867.x

Morton, J. B., & Munakata, Y. (2002). Active versus latent representations: A neural network model of perseveration, dissociation, and decalage. *Developmental Psychobiology: The Journal of the International Society for Developmental*

Psychobiology, *40*(3), 255–265. https://doi.org/10.1002/dev.10033

Moses, L. J. (2001). Executive accounts of theory-of-mind development. *Child Development*, *72*(3), 688–690. https://doi.org/10.1111/1467-8624.00306

Naito, M., & Seki, Y. (2009). The relationship between second-order false belief and display rules reasoning: The integration of cognitive and affective social understanding. *Developmental Science*, *12*(1), 150–164. https://doi.org/10.1111/j.1467-7687.2008.00748.x

Nguyen, T. K., & Astington, J. W. (2014). Reassessing the bilingual advantage in theory of mind and its cognitive underpinnings. *Bilingualism*, *17*(2), 396–409. https://doi.org/10.1017/S1366728913000394

Oh, S., & Lewis, C. (2008). Korean preschoolers' advanced inhibitory control and its relation to other executive skills and mental state understanding. *Child Development*, *79*(1), 80–99.

Onishi, K. H., & Baillargeon, R. (2005). Do 15-month-old infants understand false beliefs? *Science*, *308*, 255–258. https://doi.org/10.1126/science.1107621

Oyserman, D., Coon, H. M., & Kemmelmeier, M. (2002). Rethinking individualism and collectivism: Evaluation of theoretical assumptions and meta-analyses. *Psychological Bulletin*, *128*(1), 3–72. https://doi.org/10.1037//0033-2909.128.1.3

Ozonoff, S., & McEvoy, R. E. (1994). A longitudinal study of executive function and theory of mind development in autism. *Development and Psychopathology*, *6*(3), 415–431.

Ozonoff, S., Pennington, B. F., & Rogers, S. J. (1991). Executive function deficits in high-functioning autistic individuals: Relationship to theory of mind. *Journal of Child Psychology and Psychiatry, 32*(7), 1081–1105. https://doi.org/10.1111/j.1469-7610.1991.tb00351.x

Patel, T., & Kurdi, M. S. (2015). A comparative study between oral melatonin and oral midazolam on preoperative anxiety, cognitive, and psychomotor functions. *Journal of Anaesthesiology, Clinical Pharmacology*, *31*(1), 37–43.

Pears, K. C., & Moses, L. J. (2003). Demographics, parenting, and theory of mind in preschool children. *Social Development*, *12*(1), 1–20. https://doi.org/10.1111/1467-9507.00219

Peirce, J. W. (2009). Generating stimuli for neuroscience using PsychoPy. *Frontiers in Neuroinformatics*, *2*(10), 1–8.

Perner, J., & Ruffman, T. (2005). Infants' insight into the mind: How deep? *Science*, *308*, 214–216. https://doi.org/10.1126/science.1111656

Peters, S., Van Duijvenvoorde, A. C. K., Koolschijn, P. C. M. P., & Crone, E. A. (2016). Longitudinal development of frontoparietal activity during feedback learning: Contributions of age, performance, working memory and cortical thickness. *Developmental Cognitive Neuroscience*, *19*, 211–222. https://doi.org/10.1016/j.dcn.2016.04.004

Phillips, L. H., Bull, R., Allen, R., Insch, P., Burr, K., & Ogg, W. (2011). Lifespan aging and belief reasoning: Influences of executive function and social cue decoding. *Cognition*, *120*, 236–247. https://doi.org/10.1016/j.cognition.2011.05.003

Piper, B. J., Li, V., Eiwaz, M. A., Kobel, Y. V., Benice, T. S., Chu, A. M., … Mueller, S. T. (2012). Executive function on the psychology experiment building language tests. *Behavior Research Methods*, *44*, 110–123. https://doi.org/10.3758/s13428-011-0096-6

Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences*, *1*(4), 515–526.

Rakoczy, H., Harder-Kasten, A., & Sturm, L. (2012). The decline of theory of mind in old age is (partly) mediated by developmental changes in domain-general abilities. *British Journal of Psychology*, *103*, 58–72. https://doi.org/10.1111/j.2044-8295.2011.02040.x

Randall, W. L. (2013). Aging, irony, and wisdom: On the narrative psychology of later life. *Theory & Psychology*, *23*(2), 164–183. https://doi.org/10.1177/0959354312470754

Reitan, R. M. (1958). Validity of the trail making test as an indicator of organic brain damage. *Perceptual and Motor Skills*, *8*, 271–276.

Rosen, A. C., Prull, M. W., O'Hara, R., Race, E. A., Desmond, J. E., Glover, G. H., … Gabrieli, J. D. E. (2002). Variable effects of aging on frontal lobe contributions to memory. *Neuroreport*, *13*(18), 2425–2428. https://doi.org/10.1097/01.wnr.0000048001.96487

Rosselli, M., & Ardila, A. (1993). Developmental norms for the Wisconsin Card Sorting Test in 5-to 12-year-old children. *Clinical Neuropsychologist*, *7*(2), 145–154.

Ruffman, T., & Perner, J. (2005). Do infants really understand false belief? *Trends in Cognitive Sciences*, *9*(10), 459–462. https://doi.org/10.1016/j.tics.2005.08.002

Rumsey, J. M., & Hamburger, S. D. (1990). Neuropsychological divergence of high-level autism and severe dyslexia. *Journal of Autism and Developmental Disorders*, *20*(2), 155–168. https://doi.org/10.1007/BF02284715

Rypma, B., & D'Esposito, M. (2000). Isolating the neural mechanisms of age-related changes in human working memory. *Nature Neuroscience*, *3*(5), 509–515. https://doi.org/10.1038/74889

Sabbagh, M. A., Xu, F., Carlson, S. M., Moses, L. J., & Lee, K. (2006). The development of executive functioning and theory of mind: A comparison of Chinese and US preschoolers. *Psychological Science*, *17*(1), 74–81. https://doi.org/10.1111/j.1467-9280.2005.01667.x.The

Salthouse, T. A., Atkinson, T. M., & Berish, D. E. (2003). Executive functioning as a potential mediator of age-related cognitive decline in normal adults. *Journal of Experimental Psychology: General*, *132*(4), 566–594. https://doi.org/10.1037/0096-3445.132.4.566

Salthouse, T. A., & Babcock, R. L. (1991). Decomposing adult age differences in working memory. *Developmental Psychology*, *27*(5), 763–776. https://doi.org/10.1037/0012-1649.27.5.763

Saltzman, J., Strauss, E., Hunter, M., & Archibald, S. (2000). Theory of mind and executive functions in normal human aging and Parkinson's disease. *Journal of the International Neuropsychological Society*, *6*, 781–788. https://doi.org/10.1017/S1355617700677056

Saxe, R., & Kanwisher, N. (2003). People thinking about thinking people: The role of the temporo-parietal junction in "theory of mind." *NeuroImage*, *19*, 1935–1842. https://doi.org/10.1016/S1053-8119(03)00230-1

Saxe, R., Schulz, L. E., & Jiang, Y. V. (2006). Reading minds versus following rules: Dissociating theory of mind and executive control in the brain. *Social Neuroscience*, *1*(3–4), 284–298. https://doi.org/10.1080/17470910601000446

Saxe, R., & Wexler, A. (2005). Making sense of another mind: The role of the right temporo-parietal junction. *Neuropsychologia*, *43*, 1391–1399. https://doi.org/10.1016/j.neuropsychologia.2005.02.013

Schaafsma, S. M., Pfaff, D. W., Spunt, R. P., & Adolphs, R. (2015). Deconstructing and reconstructing theory of mind. *Trends in Cognitive Sciences*, *19*(2), 65–72. https://doi.org/10.1016/j.tics.2014.11.007

Scholz, J., Triantafyllou, C., Whitfield-Gabrieli, S., Brown, E. N., & Saxe, R. (2009). Distinct regions of right temporo-parietal junction are selective for theory of mind and exogenous attention. *PLoS ONE*, *4*(3), e4869. https://doi.org/10.1371/journal.pone.0004869

Schuwerk, T., Vuori, M., & Sodian, B. (2015). Implicit and explicit theory of mind reasoning in autism spectrum disorders: The impact of experience. *Autism*, *19*(4), 459–468. https://doi.org/10.1177/1362361314526004

Scott, R. M. (2017). The developmental origins of false-belief understanding. *Current Directions in Psychological Science*, *26*(1), 68–74. https://doi.org/10.1177/0963721416673174

Shamay-Tsoory, S. G., & Aharon-Peretz, J. (2007). Dissociable prefrontal networks for cognitive and affective theory of mind: A lesion study. *Neuropsychologia*, *45*(13), 3054–3067. https://doi.org/10.1016/j.neuropsychologia.2007.05.021

Sheikh, J. I., & Yesavage, J. A. (1986). Geriatric Depression Scale (GDS): Recent evidence and development of a shorter version. *Clinical Gerontologist: The Journal of Aging and Mental Health*, *5*(1–2), 165–173.

Siegel, L. S. (1994). Working memory and reading: A life-span perspective. *International Journal of Behavioral Development*, *17*(1), 109–124.

Southgate, V., Senju, A., & Csibra, G. (2007). Action anticipation through attribution of false belief by 2-year-olds. *Psychological Science*, *18*(7), 587–592. https://doi.org/10.1111/j.1467-9280.2007.01944.x

Surian, L., Caldi, S., & Sperber, D. (2007). Attribution of beliefs by 13-month-old infants. *Psychological Science*, *18*(7), 580–586. https://doi.org/10.1111/j.1467-

9280.2007.01943.x

Tentori, K., Osherson, D., Hasher, L., & May, C. (2001). Wisdom and aging: Irrational preferences in college students but not older adults. *Cognition*, *81*(3), B87–B96. https://doi.org/10.1016/S0010-0277(01)00137-8

Triandis, H. C., & Gelfand, M. J. (1998). Converging measurement of horizontal and vertical individualism and collectivism. *Journal of Personality and Social Psychology*, *74*(1), 118–128.

Trivers, R. L. (1971). The evolution of reciprocal altruism. *Quaterly Review of Biology*, *46*(1), 35–57.

van der Meer, L., Groenewold, N. A., Nolen, W. A., Pijnenborg, M., & Aleman, A. (2011). Inhibit yourself and understand the other: Neural basis of distinct processes underlying theory of mind. *NeuroImage*, *56*(4), 2364–2374. https://doi.org/10.1016/j.neuroimage.2011.03.053

Verhaeghen, P., Steitz, D. W., Sliwinski, M. J., & Cerella, J. (2003). Aging and dual-task performance: A meta-analysis. *Psychology and Aging*, *18*(3), 443–460. https://doi.org/10.1037/0882-7974.18.3.443

Vinden, P. G. (1996). Junin Quechua children's understanding of mind. *Child Development*, *67*, 1707–1716.

Vinden, P. G. (2001). Parenting attitudes and children's understanding of mind: a comparison of Korean American and Anglo-American families. *Cognitive Development*, *16*(3), 793–809. https://doi.org/10.1016/S0885-2014(01)00059-4

Wade, M., Prime, H., Jenkins, J. M., Yeates, K. O., Williams, T., & Lee, K. (2018). On the relation between theory of mind and executive functioning: A developmental cognitive neuroscience perspective. *Psychonomic Bulletin and Review*, *25*, 2119–2140. https://doi.org/10.3758/s13423-018-1459-0

Wang, Z., Devine, R. T., Wong, K. K., & Hughes, C. (2016). Theory of mind and executive function during middle childhood across cultures. *Journal of Experimental Child Psychology*, *149*, 6–22. https://doi.org/10.1016/j.jecp.2015.09.028

Warnell, K. R., & Redcay, E. (2019). Minimal coherence among varied theory of mind measures in childhood and adulthood. *Cognition*, *191*, 103997. https://doi.org/10.1016/j.cognition.2019.06.009

Wechsler, D. (2011). *Wechsler Abbreviated Scale of Intelligence, Second Edition (WASI-II)*. San Antonio, TX: NCS Pearson, Inc.

Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory-of-mind development : The truth about false belief. *Child Development*, *72*(3), 655–684.

West, R. (2004). The effects of aging on controlled attention and conflict processing in the stroop task. *Journal of Cognitive Neuroscience*, *16*(1), 103–113. https://doi.org/10.1162/089892904322755593

West, R. L. (1996). An application of prefrontal cortex function theory to cognitive aging. *Psychological Bulletin*, *120*(2), 272–292. https://doi.org/10.1037/0033-

2909.120.2.272

Wiesmann, C. G., Friederici, A. D., Singer, T., & Steinbeis, N. (2017). Implicit and explicit false belief development in preschool children. *Developmental Science*, *20*(5), 1–15. https://doi.org/10.1111/desc.12445

Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition*, *13*, 103–128. https://doi.org/10.1016/0010-0277(83)90004-5

Yang, S., Yang, H., & Lust, B. (2011). Early childhood bilingualism leads to advances in executive attention: Dissociating culture and language. *Bilingualism*, *14*(3), 412–422. https://doi.org/10.1017/S1366728910000611

Zelazo, P. D. (2006). The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nature Protocols*, *1*(1), 297–301. https://doi.org/10.1038/nprot.2006.46

Zelazo, P. D., Frye, D., & Rapus, T. (1996). An age-related dissociation between knowing rules and using them. *Cognitive Development*, *1*(1), 37–63. https://doi.org/10.1016/S0885-2014(96)90027-1

Zelazo, P. D., Müller, U., Frye, D., Marcovitch, S., Argitis, G., Boseovski, J., … Carlson, S. M. (2003). The development of executive function in early childhood. *Monographs of the Society for Research in Child Development*, *68*(3), 1–137. https://doi.org/10.4135/9781412952644.n420

Appendices

Appendix A. Documentation of ethics approval for experiments 1 and 2

Western Research

Date: 5 February 2019

To: Prof. J Bruce Morton

Project ID: 110562

Study Title: The effects on bilingual language status and collectivistic/individualistic cultural values on children's Theory of Mind and Executive Function

Application Type: Continuing Ethics Review (CER) Form

Review Type: Delegated

Meeting Date: 26/Feb/2019

Date Approval Issued: 05/Feb/2019

REB Approval Expiry Date: 26/Feb/2020

Dear Prof. J Bruce Morton,

The Western University Non-Medical Research Ethics Board has reviewed this application. This study, including all currently approved documents, has been re-approved until the expiry date noted above.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario. Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Daniel Wyzynski, Research Ethics Coordinator, on behalf of Prof. Randal Graham, NMREB Chair

Appendix B. Language status and demographics survey used in experiments 1 and 2

Language status and Demographics Survey

Participant's number: ___________________
The date: ___________________________

The questions below will be about **YOUR CHILD**.

1. The date of your child's birth
   Month:_______________________ Day:_____________________ Year:______________________

2. Your child's gender
   (1) Female
   (2) Male

3. What is your child's first language (i.e., the language your child find easiest to speak, read, and write)?
   (1) English
   (2) French
   (3) Korean
   (4) Chinese
   (5) Spanish
   (6) Other: (specify:_____________________________________)

4. Does your child speak, read, or write other languages?
   (1) Yes
   (2) No

5. Which one(s)?
   (1) English
   (2) French
   (3) Korean
   (4) Chinese
   (5) Spanish
   (6) Other: (specify:____________________________________)

6. What language does your child use when s/he is:

6a. With his/her family (i.e., parents, siblings, grandparents, etc.)?

   (1) Only his/her first language
   (2) Mostly his/her first language
   (3) Both his/her first language and other languages

(4) Mostly his/her other language(s)
(5) Only his/her other language(s)

6b. With his/her friends?

(1) Only his/her first language
(2) Mostly his/her first language
(3) Both his/her first language and other languages
(4) Mostly his/her other language(s)
(5) Only his/her other language(s)

6c. At preschool or day-care?

(1) Only his/her first language
(2) Mostly his/her first language
(3) Both his/her first language and other languages
(4) Mostly his/her other language(s)
(5) Only his/her other language(s)

6d. Watching TV/movies?

(1) Only his/her first language
(2) Mostly his/her first language
(3) Both his/her first language and other languages
(4) Mostly his/her other language(s)
(5) Only his/her other language(s)

6e. Counting or doing math in his/her mind?

(1) Only his/her first language
(2) Mostly his/her first language
(3) Both his/her first language and other languages
(4) Mostly his/her other language(s)
(5) Only his/her other language(s)

7. How many languages does your child speak?
(1) One
(2) Two
(3) More than two

8. (only if you say "yes" to Question 3) Out of the day, the proportion of your child's using his/her first language is approximately (%) and the proportion of using his/her other language(s) is approximately (%). *The total two proportions should be 100%.

9. How many brothers and sisters does your child have?
   (1) None   (5) Four
   (2) One   (6) Five
   (3) Two   (7) more than 5
   (4) Three
   If your child has siblings, please specify (i.e., s/he has one younger sister and one older brother):
   ____
   ____

The questions below will be about **<u>You and Your Spouse (child's parents)</u>**.

10. Do you and your spouse (your child's parents) live together or are you separated?
    (1) Live together
    (2) Separated

11. Do you and your spouse work?
    (1) Yes, both work
    (2) No, only 1 parent works
    (3) No, neither of us work

12. What do you and your spouse do for a living?

You: Business owner, Business manager, Office administrator, Engineer/Architect, Artist/Designer, Entertainer, Media/Communications, Computers/Programmer, Agricultural/Fisheries (farmer, fisher, etc), Cleaning/Maintenance services, Scientist, Civilian military officer, Soldier & Veterans, Medical practitioner/technician, Medical support, Community/Social services, Law enforcement/Security (e.g., firefighter, police officer), Legal services, Educator, Transportation services, Personal care/services (e.g., hairstylist), Salesperson, Professor, Food services, Manufacturing/Factory employee, Construction, Homemaker, Government

If your occupation is not included in these categories, please specify your occupation:

____.

Your spouse: Business owner, Business manager, Office administrator, Engineer/Architect, Artist/Designer, Entertainer, Media/Communications, Computers/Programmer, Agricultural/Fisheries (farmer, fisher, etc), Cleaning/Maintenance services, Scientist, Civilian military officer, Soldier & Veterans, Medical practitioner/technician, Medical support, Community/Social services, Law enforcement/Security (e.g., firefighter, police officer), Legal services, Educator, Transportation services, Personal care/services (e.g., hairstylist), Salesperson, Professor, Food services, Manufacturing/Factory employee, Construction, Homemaker, Government

If your spouse's occupation is not included in these categories, please specify his/her occupation:

____.

13. Compared to other families in the country you live in, how much money does your family have?

(1) Not very much
(2) Less than average, but we are not poor
(3) About the same as an average family
(4) More than the average family
(5) My family is very wealthy

14. What is the highest form of education you and your spouse received?

You: No education; Elementary school; High school; College; University (Undergraduate); University (Medicine); University (Graduate)

Your spouse: No education; Elementary school; High school; College/Professional School; University (Undergraduate); University (Medicine); University (Graduate)

Appendix C. Individualism-Collectivism survey used in experiments 1 and 2

INDCOL Scale

Participant's number :____________________
Date :______________________________

Please read the instructions carefully and answer the questions as spontaneously as possible using a 9-point. There are no right or wrong answers; we simply ask that you be completely honest in your responses.

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Never or definitely No								Always or definitely Yes

←——————————————————————————→

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
I'd rather depend on myself than others.									
It is important that I do my job better than others.									
If a coworker gets a prize, I would feel proud.									
Parents and children must stay together as much as possible.									
I rely on myself most of the time; I rarely rely on others.									
Winning is everything.									
The well-being of my coworkers is important to me.									
It is my duty to take care of my family, even when I have to sacrifice what I want.									
I often do my own thing.									
Competition is the law of nature.									
To me, pleasure is spending time with others.									
Family members should stick together, no matter what sacrifices are required.									
My personal identity, independent of others, is very important to me.									
Some people emphasize winning; I am not one of them.									
I feel good when I cooperate with others.									
It is important to me that I respect the decisions made by my groups.									

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Being a unique individual is important to me.									
When another person does better than I do, I get tense and aroused.									
If a relative were in financial difficulty, I would help within my means.									
Children should be taught to place duty before pleasure.									
I enjoy working in situations involving competition.									
It is important to me to maintain harmony in my group.									
I usually sacrifice my self-interest for the benefit of my group.									
Without competition, it is not possible to have a good society.									
I like sharing little things with my neighbors.									
It annoys me when other people perform better than I do.									
My happiness depends very much on the happiness of those around me.									

1 Never or definitely No — **2** — **3** — **4** — **5** — **6** — **7** — **8** — **9** Always or definitely Yes

Thank you for your time!

Appendix D. Authoritative and authoritarian parenting attitudes survey used in experiments 1 and 2

Child Rearing Practices

Participant's number:_________________

Date:_______________________________

In trying to gain more understanding of children, we would like to know what is important to you as a parent and what kinds of methods you use in raising your child. Please read the statements below and put a check on the line that indicates how you agree or disagree with them. There are no right or wrong answers; we simply ask that you be completely honest in your responses.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. I respect my child's opinions and encourage him/her to express them.	_____	_____	_____	_____	_____
2. I encourage my child always to do his/her best.	_____	_____	_____	_____	_____
3. I help my child when he/she is being teased by his friends.	_____	_____	_____	_____	_____
4. I often feel angry with my child.	_____	_____	_____	_____	_____
5. If my child gets into trouble, I expect him/her to handle the problem mostly by himself/herself.	_____	_____	_____	_____	_____
6. I punish my child by putting him/her off somewhere by himself/herself alone.	_____	_____	_____	_____	_____
7. I feel a child should be given comfort and understanding when he/she is scared or upset.	_____	_____	_____	_____	_____
8. I try to keep my child away from children or families who have different ideas or values from our own.	_____	_____	_____	_____	_____
9. I try to stop my child from playing rough games or doing things where he/she might get hurt.	_____	_____	_____	_____	_____
10. I believe physical discipline to be the best way of disciplining.	_____	_____	_____	_____	_____
11. I believe that a child should be seen and not heard.	_____	_____	_____	_____	_____

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
12. I sometimes forget the promises I have made to my child.	_____	_____	_____	_____	_____
13. I think it is a good practice for the child to perform in front of others.	_____	_____	_____	_____	_____
14. I express affection by hugging, kissing, and holding my child.	_____	_____	_____	_____	_____
15. I find some of my greatest satisfactions in my child.	_____	_____	_____	_____	_____
16. I prefer that my child not try things if there is a chance he/she will fail.	_____	_____	_____	_____	_____
17. I encourage my child to wonder and to think about life.	_____	_____	_____	_____	_____
18. I usually take into account my child's preferences in making plans for the family.	_____	_____	_____	_____	_____
19. I feel a child should have time to think, daydream, and even loaf sometimes.	_____	_____	_____	_____	_____
20. I find it difficult to punish my child.	_____	_____	_____	_____	_____
21. I let my child make many decisions for himself.	_____	_____	_____	_____	_____
22. I do not allow my child to say bad things about his/her teachers.	_____	_____	_____	_____	_____
23. I worry about the bad and sad things that can happen to a child as he/she grows up.	_____	_____	_____	_____	_____
24. I teach my child that in one way or another punishment will find him/her when he/she is bad.	_____	_____	_____	_____	_____
25. I do not blame my child for whatever happens if others ask for trouble.	_____	_____	_____	_____	_____
26. I do not allow my child to get angry with me.	_____	_____	_____	_____	_____

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
27. I feel my child is a bit of a disappointment to me.	_____	_____	_____	_____	_____
28. I expect a great deal of my child.	_____	_____	_____	_____	_____
29. I am easy going and relaxed with my child.	_____	_____	_____	_____	_____
30. I tend to spoil my child.	_____	_____	_____	_____	_____
31. I talk it over and reason with my child when he/she misbehaves.	_____	_____	_____	_____	_____
32. I trust my child to behave as he/she should, even when I am not with him/her.	_____	_____	_____	_____	_____
33 I joke and play with my child.	_____	_____	_____	_____	_____
34. I give my child a good many duties and family responsibilities.	_____	_____	_____	_____	_____
35. My child and I have warm, intimate times together.	_____	_____	_____	_____	_____
36. I have strict, well-established rules for my child.	_____	_____	_____	_____	_____
37. I think one has to let the child take many chances as he/she grows up and tries new things.	_____	_____	_____	_____	_____
38. I encourage my child to be curious, to explore and question things.	_____	_____	_____	_____	_____
39. I sometimes feel that I am too involved with my child.	_____	_____	_____	_____	_____
40.I threaten punishment more often than I actually give it.	_____	_____	_____	_____	_____
41. I believe in praising a child when he/she is good and think it gets better results than punishing him/her when he/she is bad.	_____	_____	_____	_____	_____
42. I encourage my child to talk about his/her troubles.	_____	_____	_____	_____	_____

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
43. I teach my child to keep control of his/her feelings at all times.	_____	_____	_____	_____	_____
44. I try to keep my child from fighting.	_____	_____	_____	_____	_____
45. When I am angry with my child, I let him/her know it.	_____	_____	_____	_____	_____
46. I think a child should be encouraged to do things better than others.	_____	_____	_____	_____	_____
47. I punish my child by taking away a privilege he/she otherwise would have had.	_____	_____	_____	_____	_____
48. I give my child extra privileges when he/she behaves well.	_____	_____	_____	_____	_____
49. I enjoy having the house full of children.	_____	_____	_____	_____	_____
50. I believe that too much affection and tenderness can harm or weaken a child.	_____	_____	_____	_____	_____
51. I believe that scolding and criticism makes my child improve.	_____	_____	_____	_____	_____
52. I sometimes tease and make fun of my child.	_____	_____	_____	_____	_____
53. I teach my child that he/she is responsible for what happens to him/her.	_____	_____	_____	_____	_____
54. I worry about the health of my child.	_____	_____	_____	_____	_____
55. There is a good deal of conflict between my child and me.	_____	_____	_____	_____	_____
56. I do not allow my child to question my decisions.	_____	_____	_____	_____	_____
57. I feel that it is good for the child to play competitive games.	_____	_____	_____	_____	_____

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
58. I like to have some time for myself, away from my child.	_____	_____	_____	_____	_____
59. I let my child know how ashamed and disappointed I am when he/she misbehaves.	_____	_____	_____	_____	_____
60. I want my child to make a good impression on others.	_____	_____	_____	_____	_____
61. I encourage my child to be independent of me.	_____	_____	_____	_____	_____
62. I make sure I know where my child is and what he/she is doing.	_____	_____	_____	_____	_____
63. I find it interesting and educational to be with my child for long periods.	_____	_____	_____	_____	_____
64. I think jealousy and quarrelling between brothers and sisters should be punished.	_____	_____	_____	_____	_____
65. I think children must learn early not to cry.	_____	_____	_____	_____	_____
66. I control my child by warning him/her about the bad things that can happen to him/her.	_____	_____	_____	_____	_____
67. I don't allow my child to tease or play tricks on others.	_____	_____	_____	_____	_____
68. I believe it is unwise to let children play a lot by themselves without supervision from grown-ups.	_____	_____	_____	_____	_____

Thank you for your time.

Appendix E. A letter on permission to use copyrighted material for experiment 3

Dear Ms. Cho,

Thank you for your message. PLOS ONE publishes all of the content in the articles under an open access license called "CC-BY." This license allows you to download, reuse, reprint, modify, distribute, and/or copy articles or images in PLOS journals, so long as the original creators are credited (e.g., including the article's citation and/or the image credit). Additional permissions are not required. You can read about our open access license here: http://journals.plos.org/plosone/s/licenses-and-copyright

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Kind regards,

Sue Laborda
Staff EO
PLOS ONE

Case Number: 06434016
ref:_00DU0Ifis._5004PzJNqc:ref

To whom it may concern,

My name is Isu Cho, a University of Western Ontario graduate student. I am completing my Doctoral thesis entitled "The relationship between theory of mind and executive function," but I am wondering if you could allow me to include a recently published article entitled "Explaining age-related decline in theory of mind: Evidence for intact competence but compromised executive function" in my thesis. My thesis will be available in full-text on the internet for reference, study copy. Except in situations where a thesis is under embargo or restriction, the electronic version will be accessible through the Western Libraries web pages, the Library's web , and also through web search engines. I will also be granting Library and Archives Canada and ProQuest/UMI a non-exclusive license to reproduce, loan, distribute, or sell single copies of my thesis by any means and in any form or format. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you.

I would like permission to allow inclusion of the following material in my thesis: Cho I, Cohen AS (2019) Explaining age-related decline in theory of mind: Evidence for intact competence but compromised executive function. PLoS ONE 14(9): e0222890.

The material will be attributed through a citation.

I would appreciate it if you give me the permission and if you could confirm in writing or by email that these arrangements meet with your approval.

Warm wishes,

Isu

Appendix F. Documentation of ethics approval for experiment 3

Western Research

Research Ethics

Western University Non-Medical Research Ethics Board
NMREB Annual Continuing Ethics Approval Notice
*****REVISED*****

Date: October 12, 2016
Principal Investigator: Dr. Adam Cohen
Department & Institution: Social Science\Psychology,

NMREB File Number: 107251
Study Title: The development of social cognition across the lifespan

NMREB Renewal Due Date & NMREB Expiry Date:
Renewal Due -2017/11/30
Expiry Date -2017/12/15

The Western University Non-Medical Research Ethics Board (NMREB) has reviewed the Continuing Ethics Review (CER) form and is re-issuing approval for the above noted study.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), Part 4 of the Natural Health Product Regulations, the Ontario Freedom of Information and Protection of Privacy Act (FIPPA, 1990), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario.

Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Curriculum Vitae

Name:	Isu Cho
Post-secondary Education and Degrees:	The University f Western Ontario London, Ontario, Canada 2015- present Ph.D. Yonsei University Seoul, South Korea 2012-2014 M.A. Yonsei University Seoul, South Korea 2007-2012 B.A.
Scholarship, Honours and Awards:	Western Graduate Research Scholarship 2015-2019 National Scholarship for the Humanities and Social Science Research Korean Students Aid Foundation 2013 Brain Korea (BK) 21 Participation Scholarship The Korean Ministry of Education, Science, and Technology 2012 Merited Based Scholarship Yonsei University 2009, 2010, 2011 Academic Highest Honours Yonsei University 2009, 2010 Academic Honours Yonsei University 2007
Related Work Experience	Instructor (Psychol 3440F: Developmental Cognitive Neuroscience) The University of Western Ontario 2019

Teaching Assistant
The University of Western Ontario
2015-2019

Research supervisor
The University of Western Ontario
2015-2019

Teaching Assistant
Yonsei University
2012

Research supervisor
Yonsei University
2013-2014

Publications:

Cho, I. & Cohen, A. S. (2019). Explaining age-related decline in theory of mind: Evidence for intact competence but compromised executive function. *PloS one, 14*(9), e0222890.

Cho, I. & Song, H. (2013). Korean children's comprehension of postpositional particles: ‘Man’ and ‘Do’. *Korean Journal of Language Sciences, 20*(1), 185-203.

Posters and Presentations:

Lee, Y., **Cho, I.** & Song, H. (2018, June-July). Six-month-olds' ability to use cues selectively to recognize actions as goal-directed. Poster presentation at the International Conference on Infant Studies, Philadelphia, the United States.

Cho, I. & Cohen, A. (2017, October). Implicit Theory of Mind in Older Adults: Are There Two systems for Mindreading? Poster presentation at the Cognitive Development Society, Portland, Oregon, the United States.

Cho, I., Lee, Y., & Song, H. (2016, May). The development of infants’ ability to use linguistic and gazing cues when understanding others’ pointing actions as goal-directed. Poster presentation at the International Conference on Infant Studies, New Orleans, Louisiana, the United States.

Cho, I., & Song, H. (2014, August). Young and Older Adults’ Understanding of Others’ Intentionality in Fairness Consideration. Oral presentation at the annual convention of Korean Psychological Association, Seoul, Korea.

Cho, I., & Song, H. (2014, July). The development of infants' ability to use linguistic information when understanding the goal of others' pointing actions. Poster presentation at the International Conference on Infant Studies, Berlin, Germany.

Jin, K., **Cho, I**., Fisher, C., & Song, H. (2014, July). Finding the missing nouns: Korean children exploit discourse continuity to learn verb transitivity. Oral presentation at the International Conference on Infant Studies, Berlin, Germany.

Cho, I., & Song, H. (2013, November). Theory of Mind in Young Adults and Old Adults: The Role of Cognitive Ability and Social Experience. Poster presentation at the Symposium of Korean society for Developmental Psychology, Seoul, Korea.

Cho, I., & Song, H. (2012, November). Korean Children's comprehension of postpositional particles: 'Man' and 'Do'. Poster presentation at the Symposium of Korean society for Developmental Psychology, Seoul, Korea.

Kim, S., Kim, J., **Cho, I.**, & Han, S. (2010, August). The influence of Discourse Structure on the comprehension of sentences with omitted arguments. Poster presentation at the annual convention of Korean Psychological Association, Seoul, Korea.