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# Educating parents to enhance children's reasoning abilities: A focus on questioning style

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ABSTRACT

This study investigated whether parents can be educated to alter parent-child interactions and whether this can improve children's reasoning abilities. Parents of four- to eight-year-olds were randomly assigned to a compact psycho-educational program ($N = 34$) or control condition ($N = 36$). Parental questioning style was observed during problem-solving interactions at home and children's scientific and social reasoning were assessed using performance-based tasks. Parents in the educational condition asked significantly more open-ended, observational and explanatory questions at post-test than controls did. Asking relatively more open-ended questions at post-test was associated with improved aspects of scientific reasoning in their children. Asking more observational or explanatory questions was not associated with improved reasoning abilities. Educating parents to adaptively modify their parent-child interactions can positively influence their questioning style, which in turn may benefit their child's reasoning abilities.

Parent-child interactions are an essential part in the cognitive development of children, as they allow for daily opportunities to practice problem-solving skills in a meaningful context, especially when exploration and explanation are encouraged (Busch, Willard, & Legare, 2018; Gauvain, 2001; Legare, Sobel, & Callanan, 2017). By using nondirective instructional techniques, parents can help their child engage in complex problem-solving by scaffolding the task either verbally (e.g., asking questions) or nonverbally (e.g., attention redirection behaviors) (Lewis & Carpendale, 2009). Scaffolding can be defined as the parental input during parent-child interaction promoting independent problem-solving and learning (Dieterich, Assel, Swank, Smith, & Landry, 2006; Mermelshtine, 2017). Parents may become more involved in their children's learning when they are educated about how their child reasons and learns (Gleason & Schauble, 1999). In this sense, parents that are educated in reasoning development and ways to promote development during daily interactions may be better equipped to recognize their child's level of competence and facilitate development by adaptively challenging their child's skills through parent-child interaction. The aim of the current study is to investigate whether parents can be educated to improve the interactions with their child by adaptively scaffolding problem-solving and thereby challenge their child's reasoning abilities through a compact psycho-educational program.

Fluid reasoning abilities reflect the ability to think logically, detect patterns and relations, form concepts, and solve problems in novel situations (Cattell, 1987; Schneider & McGrew, 2012). Cattel (1987) conceptualized reasoning abilities as a scaffold for learning, serving as a foundation to acquire other cognitive skills. These reasoning abilities have repeatedly been shown to be predictive of school performance, especially math achievement (e.g. Floyd, Evans, & McGrew, 2003; Green, Bunge, Briones Chiongbian, Barrow, & Ferrer, 2017; Hale, Fiorello, Kavanagh, Holdnack, & Aloe, 2007; Miller Singley & Bunge, 2014). Reasoning is traditionally considered a relatively stable trait of an individual, and resistant to change through training (e.g. Carroll, 1993). However, more recently this notion has been called into question (Flynn, 2007; Nisbett et al., 2012). Specifically, reasoning abilities have been shown to be influenced by environmental factors and to be improvable (e.g. Mackey, Hill, Stone, & Bunge, 2011; Nisbett et al., 2012). Furthermore, parent-child interaction characterized by a high degree of explanation and exploration has been associated with children's reasoning and learning (For a review, see Legare et al., 2017; Willard et al., 2019). Given that young children spend a substantial amount of time with their parents or other primary caregivers, this raises the question whether parents can be educated to support the early development of reasoning abilities through parent-child interaction.

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A distinction in children's reasoning abilities can be discerned based on the domain of the problem that has to be unraveled, in particular problems with social content versus more logical or scientific problems (Marini & Case, 1994). Even though there is compelling evidence relating parent-child interactions to children's cognitive abilities and school achievement, studies focusing on the association between parent-child interactions and socio-emotional development are scarce (For a review, see Mermelshtine, 2017).

Around the age of four children start developing an increasing awareness of how people obtain knowledge and begin to differentiate between assertions and reality (For reviews, see Kuhn, 2000, 2010). Furthermore, children begin to realize that perceptual information has to be correct and not just present to generate knowledge (Flavell, 2004). For instance, Flavell, Green, Flavell, Watson, and Campione (1986) showed that while three-year-olds are not yet able to make the distinction between the true color of a glass of milk and its appearance when a red filter is wrapped around it, most four-year-olds can correctly distinguish that the milk looks red but really is white. This metacognitive awareness is considered the origin of scientific thinking, as it allows children to see evidence as a source of support for a theory (Bullock, Sodian, & Koerber, 2009; Kuhn, 2010). Before the age of four, children think that mental representations are merely copies of reality, which makes it impossible for them to understand falsifiable theories, central to scientific reasoning. According to the Theory theory (Gopnik & Wellman, 1994, 2012), young children construct naïve theories about the social, psychological and physical world in order to predict and make sense of the world around them. Children begin to consciously revise these theories by the age of four, as they are confronted with evidence that does not match their current naïve theory. More recently, the social context is considered to play a formative role in this conceptual change, as social experiences influence children to revise and improve their theories and conceptions of others, which influences their social experiences in return (Hughes & Leekam, 2004; Miller & Aloise-Young, 2018). For instance, parent-child conversation has been associated with children's developing beliefs about the social world (Chalik & Rhodes, 2014). Insight in how these skills can be practiced in the real-life social context of parent-child interaction may provide opportunities to promote the development of children's early social and scientific understanding.

Kuhn (2010) posited that practicing reasoning abilities in the real-life social context may be especially promising. In order to solve problems using skilled reasoning, children need to learn strategies to achieve their goals. A way to learn new strategies is through social interaction, either by being instructed specifically, by imitating others, or by collaborating (Gauvain, 2001). Caregivers can use verbal scaffolding, such as asking questions, to provide structure during a complex problem-solving task, enabling a child to gain control over his or her cognitive performance and behavior (Lewis & Carpendale, 2009). During verbal scaffolding parents provide their children with age-appropriate contingent responses (i.e. they follow the child's conversational lead), respecting the child's autonomy and stimulating explanation and explorative behavior. Especially prompting explanations seems to be beneficial for children's reasoning (Legare & Lombrozo, 2014), with the highest problem-solving accuracy when the child is explaining to a parent as compared to self-explaining (Rittle-Johnson, Saylor, & Swygert, 2008). A specific verbal scaffolding strategy is the use of open-ended and metacognitive questioning when asking for explanations, such as “Why do you think that?” and “How are you going to figure that out?” (Hmelo-Silver & Barrows, 2006). Prompting explanations enhances problem-solving by uncovering gaps and inconsistencies in children's knowledge, stimulating them to ask questions and to persist in applying knowledge to new contexts (For a review, see Busch et al., 2018). When parents scaffold during problem-solving tasks, metacognitive processes involved in reasoning (e.g. shifting ideas, planning, monitoring) are also externalized and shared with children when they are not yet able to monitor these processes on their own, in line with Vygotsky's (1978) zone of proximal development. Verbal scaffolding has been associated with children's executive functions, neurocognitive functions fundamental to reasoning and problem-solving in general (For a meta-analysis, see Valcan, Davis, & Pino-Pasternak, 2018). Furthermore, an association has been found between parents' tendency to use open-ended over closed-ended questions and to ask more elaborative metacognitive questions and better executive functioning skills in their children (Spruijt, Dekker, Ziermans, & Swaab, 2018).

Despite the early emergence of the metacognitive precursors of reasoning abilities, the developmental trajectory of these abilities is prolonged and requires adequate support and practice (Morris, Croker, Masnick, & Zimmerman, 2012). Even in typically developing children, considerable inter-individual differences in social understanding occurs (Repacholi and Slaughter, 2004) and differences in scientific reasoning abilities already appear during primary school (Bullock et al., 2009). When children reach primary school age, they become more active participants in interactions, which leads to parents systematically increasing their contingent instructions during parent-child interaction (Conner & Cross, 2003). However, even though adults intuitively alter the manner in which they talk to children to support their science learning, these well-intended alterations may actually be disadvantageous to learning, for instance by adding more unnecessary information (Vlach & Noll, 2016). This suggests that parent-child interactions may benefit from external guidance. Furthermore, the influence of reasoning abilities on later achievement is considered to be the strongest between ages five and ten (Ferrer & McArdle, 2004), suggesting this is an optimal age-range to promote the development of reasoning abilities through parent-child interaction. Interventions that include social interactive components aimed at supporting the development of social understanding such as theory of mind (For a meta-analysis, see Hofmann et al., 2016) or the development of scientific reasoning abilities (For a meta-analysis, see Engelmann, Neuhaus, & Fischer, 2016) have proven to be successful. Butler and Markman (2014) showed that four-year-olds were more likely to display deeper categorization reasoning abilities when an adult was deliberately scaffolding the task, in comparison to an accidental demonstration of the task. Parents may be a valuable asset in supporting the early development of reasoning abilities through parent-child interaction. For instance, parents who ask their children questions during problem-solving help them to structure the task; a strategy which is often spontaneously imitated by children (For a review, see Morris et al., 2012).

Educating parents in supporting the development of early reasoning abilities during daily interactions may be a promising approach to promote learning, and parent-child interaction has already been associated with reasoning abilities in kindergartners (Stright, Herr, & Neitzel, 2009) and ten- and eleven-year-old children (Chng, Wild, Hollmann, & Otterpohl, 2014). Furthermore, parent training has been shown to be successful in improving parents' beliefs about scaffolding and the promotion of learning (Gartner, Vetter, Schaferling, Reuner, & Hertel, 2018). Parents show individual differences in the extent to which they encourage explanatory behavior in their children (e.g. by asking questions), which may influence their children's reasoning and learning development (Clegg & Legare, 2017). Providing parents with explicit guidance instructions has been shown to successfully alter parent-child interaction in informal settings (Vandermaas-Peeler, Massey, & Kendall, 2016; Willard et al., 2019). Furthermore, these altered interactions were associated with enhanced exploration and reasoning in their children. Educating parents about the development of reasoning and its underlying neurocognitive functions, and practicing ways to promote this development during daily interactions might be a fruitful way to improve parents' scaffolding skills to enhance their child's reasoning abilities.

The Curious Minds parent educational program focuses on educating parents on how to support and scaffold the development of cognitive, social-emotional and self-regulatory skills necessary for adaptive behavior and learning. A major objective of this study is to examine whether the Curious Minds parent educational program is able to improve verbal scaffolding by zooming in on parental questioning style in a low-risk sample of four- to eight-year-olds, and whether this can positively impact their child's social and scientific reasoning abilities. We hypothesized that due to the educational program, parents would have a preference for open-ended over closed-ended questions and would ask more elaborative questions compared to parents in the control condition. Additionally, we hypothesized that parental questioning style would mediate the association between educational program condition and children's reasoning abilities.

## Method

### Participants

The current study is embedded within the Curious Minds program: a longitudinal program investigating the development of cognitive, social-emotional and self-regulatory skills necessary for adaptive behavior and learning in primary school-aged children in the Netherlands, and evaluating the effects of an educational program (approved by the Ethical Board of the department of Education and Child Studies at Leiden University (ECPW-2010016)).

Parents of 138 4- to 8-year-old children ($M$ = 6.26 years, $SD$ = 1.19, 55.1% male) from the lowest four grades of two Dutch primary schools (pre-school to second grade in USA school system), from towns that are part of the Rotterdam-The Hague metropolitan area took part in the Curious Minds longitudinal program and signed an informed consent letter. Children were randomly assigned to either the four-session parent educational program condition ($N$ = 69) or the control condition ($N$ = 69) by drawing participant numbers from a jar. Participants were included in the analyses when their parents agreed to a home visit at pre and posttest, when parents attended at least two of the first three sessions (educational program condition only), and when complete pre- and post-test data were available. Parents of 99 out of the 138 eligible children agreed to both home visits (response = 71.7%). To check for potential attrition bias participants whose parents agreed to the home visits were compared to those who did not agree to a home visit on background variables. These groups did not significantly differ on: age, sex, school, grade, or prevalence of referral to mental health care in the past year, nor did their parents significantly differ on single parenthood status or parental education (all $p > .05$). Participants in the educational program condition who missed all ($N$ = 18) or three out of four ($N$ = 5) sessions were excluded from analyses and also did not significantly differ from those who remained in the educational program condition on any of the background variables (all $p > .05$). Participants who were included in the analyses attended either two of the first three sessions ($N$ = 5); three out of four sessions ($N$ = 10) or all four sessions ($N$ = 19). The final sample size for analysis ($N$ = 70) consisted of 34 children in the educational condition and 36 in the control condition. For detailed sample characteristics, see Table 1.

**Table 1**
Participant characteristics and descriptive statistics (M (SD)) variables of interest at pretest.

| | EPC | CC | p |
|---|---|---|---|
| | (n = 34) | (n = 36) | |
| Age in months at T1 | 76.56 (14.89) | 75.97 (14.32) | .87 |
| Sex (% male) | 47.06 | 63.88 | .16 |
| Parental educational level[a] | | | .91 |
| High (%) | 43.75 | 45.71 | |
| Medium (%) | 50.00 | 45.71 | |
| Low (%) | 6.25 | 8.57 | |
| Single parenthood (%) | 6.25 | 2.86 | .60 |
| Referral to mental health care past year (%) | 6.25 | 8.57 | .72 |
| Number of questions per minute T1[b] | | | |
| Total questions | 4.24 (1.69) | 4.06 (1.87) | .68 |
| Ratio open/closed questions | -0.11 (1.10) | -0.41 (1.05) | .24 |
| Observational leading questions | 0.67 (0.46) | 0.56 (0.51) | .37 |
| Procedural questions | 0.18 (0.18) | 0.12 (0.18) | .17 |
| Explanatory questions | 0.18 (0.20) | 0.15 (0.18) | .52 |
| Social reasoning ability T1 | | | |
| Social reasoning proficiency | 32.35 (12.96) | 31.97 (15.44) | .91 |
| Scientific reasoning ability T1 | | | |
| Conservation proficiency: Quantity task | 35.50 (12.35) | 36.44 (13.60) | .76 |
| Proportional proficiency: Balance scale predictions[b] | 4.76 (1.26) | 4.42 (1.25) | .25 |
| Proportional complexity: Balance scale explanations[b] | 1.40 (0.35) | 1.28 (0.45) | .21 |

[a] Background information was missing for N = 3 children due to non-response on parent questionnaire.
[b] Original values before standardization. EPC = Educational program condition; CC = Control condition.

### Procedure

This study uses observational data of parents' interactive behavior with their child collected during problem-solving interactions during home visits, and child paper-and-pencil and hands-on tests to assess level of social and scientific reasoning abilities. Pre-test baseline data were collected in the period between November 2013 and February 2014 (school 1) and between May and June 2014 (school 2). The parent educational program took place at their children's school and was initiated after all baseline assessments with participating parents and children were completed. The caregiver of each child who also participated in the home visits was asked to attend the sessions. Post-test data were collected in the period between June and July 2014 (school 1) and between January and February 2015 (school 2). Paper-and-pencil and hands-on performance tasks were administered in a separate room at the child's school, during two individual test sessions of approximately 60 min. Tests were administered by two trained junior investigators or by one of the senior investigators (AMS, MCD). All home visits were conducted by two trained junior investigators. Children were rewarded with a small token of appreciation for participation after the test session.

### Curious Minds parent educational program

The content of the parent educational program was inspired by the Vygotskian principles of the Tools of the Mind curriculum for preschool children (Bodrova & Leong, 2007; Diamond, Barnett, Thomas, & Munro, 2007), which focuses on supporting and scaffolding the development of cognitive, social-emotional and self-regulatory skills necessary for adaptive behavior and learning by using a familiar adult in a real-life setting as a change agent.

The educational program was provided by a skilled clinical neuropsychologist specialized in child and adolescent neurodevelopment, and consisted of four, monthly group sessions of approximately two hours each. During each session, the focus was on a specific (neuro) cognitive mechanism, for which parents first received basic information on typical developmental aspects. Information about the brain-behavior developmental course at specific ages was illustrated using everyday examples of parent-child interactions. Parents also received a workbook summarizing information about the development of cognitive, social-emotional and self-regulatory skills, as well as matching home assignments to practice the interactions with their child following each session, to enhance the learning experience of parents. Parents were encouraged to ask open-ended questions and to characterize the interactions with their child by a high degree of explanation and exploration. Examples of the type of questions parents could ask during home assignments were provided in the workbook as a recurring element for each session. Furthermore, parents were made aware of their questioning style by written reminders in the workbook such as: “What type of questions did you ask during this assignment? How did your child respond?”. These home assignments were discussed during the following session along

**Table 2**
Description of the discussed topics and home assignments per session of the Curious Minds educational program.

| Session | Main theme | Home assignments |
|---|---|---|
| Session 1 | How children learn and process new information, and how parents can help their child to explore topics in more depth by encouraging (explanatory) reasoning through asking questions. | e.g.: - Do science experiments with soap bubbles (e.g. What do you think will happen if two bubbles touch each other? Why?)<br>- Think outside the box by imagining as many different uses for a paperclip as possible.<br>- Play sensory games, such as touching and tasting different types of food while blindfolded (e.g. What do you taste while holding your nose? And without holding your nose? Why do you think it was easier the second try?) |
| Session 2 | Teaching parents how to stimulate specific aspects of Attentional Control and Executive Functioning while interacting with their child. Discussion of home assignments session 1. | e.g.: - Tell two different stories to your child simultaneously, while your child focuses on one of the stories, and ask questions afterwards about its content (targeting attention).<br>- Play the game Yes and no are forbidden: trick your child into answering questions with 'yes' or 'no (targeting inhibition).<br>- Play the Going on a trip game: alternately add an item to the sentence 'I am going on a trip and I am going to pack…', after recalling all items that have been mentioned (targeting working memory).<br>- Let your child come up with alternative plans when a playdate is suddenly cancelled, and observe whether your child is able to flexibly change plans (targeting cognitive flexibility). |
| Session 3 | Teaching parents how to stimulate emotion regulation, social cognition and social reasoning while interacting with their child. Discussion of home assignments session 2. | e.g.: - Practice and discuss a range of facial emotion expressions in front of the mirror.<br>- Observe and address your child's emotional reactions during daily interaction and describe the reactions.<br>- Discuss several short, illustrated stories (e.g. How does Billy feel when he's not allowed to play with the other kids? How do you know?)<br>- In a naturally occurring situation, explain why it is important to place yourself in someone else's shoes (i.e. perspective taking), using questions (e.g. How would you feel if this happened to you? What would you do?) |
| Session 4 | Recap of sessions 1 through 3; parents were free to discuss what they had learned and ask additional questions. Discussion of home assignments session 3. | There were no home assignments following session 4. |

with a short recap of the previous topic, allowing parents to learn from the trainer's feedback and each other's day-to-day experiences. For a more detailed description per session, see Table 2.

### Measures

#### Demographic characteristics

Parents filled out a complementary background information questionnaire, using the online survey software Qualtrics (http://www.qualtrics.com/). The highest completed level of education by the parent who participated in the home visit was used as an indicator of educational attainment according to the Dutch Standard Classification of Education (SOI) which is based on UNESCO's International Standard Classification of Education (ISCED) ("SOI, 2003 (Issue 2006/'07),"): 1. primary education (SOI level 1 to 3; at most vocational training); 2. secondary education (level 4 of SOI); and 3. higher education (level 5 to 7 of SOI; bachelor's degree or higher). Single parenthood status was established for the parent who participated in the home visit, and was defined by not having the child's other parent or a new caregiver living in the same household. Mental health care referral was assessed by asking parents whether their child had been referred, examined or treated for emotional and behavioral problems in the past year.

#### Parental questioning style

The parent's interactive behavior with the child was videotaped at pre- and post-test home visits during two joint activity problem-solving tasks. These problem-solving tasks consisted of a combining task and a sorting task of approximately five to ten minutes each, both based on tasks designed by Utrecht University (Corvers, Feijs, Munk, & Uittenbogaard, 2012). Parent-child dyads were alternately assigned to either task version A ($N = 32$, 46%) or task version B of each joint activity task ($N = 38$, 54%) at pre-test, which were reversed at post-test to avoid test-retest learning effects. Version A consisted of combining four different eyes and four different mouths to form 16 unique smiley faces and sorting different types of toy animals, and version B consisted of combining four different flower petals with four different disks to form 16 unique flowers and sorting different types of toy food. Parent-child dyads were free to sort and combine the items according to their own strategy, as long as all combinations in the combining task were different. Parents were instructed to support their child as they would normally do. The combining tasks consisted of more flower petals/disks and eyes/mouths than possible unique combinations, challenging parent-child dyads to reason about a strategy to form only unique combinations. The sorting tasks did not have a best solution, challenging parents to provide their child with age-appropriate contingent responses when they came up with a sorting rule. The videotapes were coded afterwards for parental questioning style.

The form and category of questions parents asked their children during the two joint activity problem-solving tasks were used as a measure of parental questioning style. All questions were coded from video-recordings using transcribed verbatim reports. Each question was first coded as being either (a) open-ended (e.g., "How do you want to start?"), (b) multiple choice (e.g., "Does a kangaroo live in the zoo or in the ocean?"), or (c) closed-ended (e.g., "Is a cow a farm animal?"). Next, questions were coded in the following categories: (a) observational leading questions (e.g., "What's the color of this food?", inquiring about observable aspects during the task), (b) procedural questions (e.g., "How are you going to sort the animals?", inquiring about an action plan), and (c) explanatory questions (e.g., "Why can the toad not be in the ocean group?", inquiring about the child's reasoning behind decisions). The form and category of each question were coded for both joint activity problem-solving tasks by three coders who were blind to other data concerning the child or the parent. All coders completed extensive training consisting of several practice and feedback sessions supervised by one of the investigators (AMS). Interrater reliability (Cohen's kappa) was large, with .84 on average for the sorting task ($N_{questions} = 122$) and .87 on average for the combining task ($N_{questions} = 115$). For each question form and category within each task, the number of questions per minute was calculated. Although parent–child dyads were randomly assigned to either joint Task Battery A or B, each task battery may have elicited a somewhat different interaction frequency between parent and child. Therefore, we

**Table 3**
Coding scheme for the complexity level of proportional reasoning.

| Code | Level of complexity | Content of explanation | Example |
|---|---|---|---|
| 4 | Representational system level | All relevant parts of the explaining mechanism and the relationships between these parts | "There is a balance because the distance on the side with one card is twice as long as the distance on the side with two cards" |
| 3 | Representational mapping level | Two or more parts of the explaining mechanism | "Because there are two cards and here only one, and because the cards are not at the same spot" |
| 2 | Single representational level | One part of the explaining mechanism | "Because they have the same weight" |
| 1 | Sensorimotor system level | Relation between action and result or an observation of the situation | "Because the card was put there" |
| 0 | Not specified | Indicates not to know an explanation | "I don't know" |

standardized the number of questions per minute within each task (sorting or combining) for each task version (A or B), followed by averaging these z-scores over the joint activity tasks.

Due to very low occurrence of multiple-choice questions (2.4%), this form was excluded from further analyses. The difference score between the standardized amounts of open- and closed-ended questions was calculated as a relative measure of question format preference during the tasks (question format preference score), which has previously been associated with improved executive functioning skills (Spruijt et al., 2018). A higher ratio score indicates that the parent asked more open-ended than closed-ended questions relative to the other parents. Total number of questions per minute, question format preference (ratio score), and question categories (observational leading, procedural and explanatory) were considered in the analyses.

*Reasoning abilities*

*Scientific reasoning.* Aspects of scientific reasoning ability, conservation and proportional reasoning, were measured with *(i)* the subtest Quantity of the Revised-Amsterdam Intelligence Test for children ages 4 to 11 (Bleichroth, Drenth, Zaal, & Resing, 1987), a paper-and-pencil task to study conservation reasoning, and *(ii)* the balance scale task, a seminal task to study proportional reasoning.

*Conservation reasoning.* Conservation reasoning proficiency was assessed using the Quantity paper-and-pencil task that consists of 65 items (40 for four-year-olds) on relative length, weight, volume, amount, relative distance, surface area, and odds (e.g. which glass contains the most lemonade?; which rope is the longest?; which necklace has the most beads?; which cow has the most grass to eat?). Out of four pictures, children were asked to point to the picture with the right answer. The test-retest reliability ($r$ = .76) and internal consistency (Cronbach's alpha = .91) of this subtask are considered sufficient (Bleichroth et al., 1987). The total number of correct answers was used in analyses as a measure of conservation reasoning proficiency.

*Proportional reasoning.* Proportional reasoning proficiency and reasoning complexity level were assessed using a balance scale task (utilizing a beam centered on a fixed balance point with ten hanging points on both sides, and a set of 30 weights of 10 g each). The ten hanging positions were marked with different stickers (e.g. red star, yellow smiley), similar on each side. Two parallel versions of this task were used (version A and B), each consisting of eight similar situations of increasing difficulty. A standard set of two explanatory questions was asked for the eight different test situations, resulting in a total of 16 explanations. The children were first asked to predict the end position of the balance scale before it was manipulated (i.e. before a card was placed) and to explain why. After the balance scale had been manipulated, they were asked to explain why the balance scale was in a certain position. The first four test situations focused on weight, the fifth on distance and the last three test situations on both weight and distance. The children did not receive feedback or extra assistance during the task, other than additional questions such as "what do you mean?" and "could you tell me more about that?" to reach the optimal complexity level of explanation. Administration of the balance scale task took approximately 15 min.

Balance scale problem tasks have repeatedly been used to assess scientific reasoning in primary school children (e.g. Halford, Andrews, Dalton, Boag, & Zielinski, 2002; Jansen & van der Maas, 2002; Meindertsma, Van Dijk, Steenbeek, & Van Geert, 2012; Philips & Tolmie, 2007). The administration of the Balance scale task was recorded on video and coded by junior investigators who received extensive training, resulting in a large inter-coder reliability of .86 (ranging from .81 to .90). Predictions of the eight end positions were coded as either correct (1) or incorrect (0). The overall proficiency on proportional reasoning was calculated by summing the eight predictions, standardized within each task version (A/B). The explanations of the participants were coded using the coding scheme of Meindertsma et al. (2012), which is based on the dynamic skill theory of cognitive development by Fischer (1980) and Fischer and Bidell (2007). The coding of the complexity level of proportional reasoning can be found in Table 3. The overall complexity level of proportional reasoning was calculated by averaging the sixteen explanations. Mean complexity level was standardized within each task version (A/B) and was considered as such in the analyses.

*Social reasoning.* Proficiency on a social reasoning task was measured with two parallel versions (A or B) of the short form of the Social Cognitive Skill Test (SCST) (Van Manen, 2007). The SCST is a semi-structured interview, based on the structural developmental approach of social cognition as proposed by Selman and Byrne (1974). Participants completed either version A or B at pre-test, corresponding to their randomly assigned A or B condition during the home visit, which were reversed at post-test. Both versions consisted of three short stories with accompanying pictures depicting different social situations in which a child is confronted with a social problem. Administration time was approximately 20 min. Eight questions regarding emotion recognition and perspective taking, increasing in difficulty, were asked per story, which were afterwards coded to yield either: (i) 3 points; when the answer was correct straightaway; (ii) 1 point; when the answer was not completely correct, but after a supplementary question became correct; (iii) 0 points; when the answer was incorrect from the start or still not completely correct after a supplementary question. The correlation between version A and B has been shown to be .84 with test-retest reliability ranging from .77 for version A to .78 for version B (Van Manen, 2007). Summed total scores were used in the analyses.

*Verbal ability*

To assess whether associations between parental questioning style and children's reasoning ability were independent of differences in children's language skills, children's verbal ability was controlled for using the Concepts and Following Directions task of the Clinical Evaluation of Language Fundamentals (CELF-4$^{NL}$) (Semel, Wiig, & Secord, 2010). This task gives an indication of the child's ability to interpret and act upon spoken directions of increasing length and complexity (i.e. receptive semantic skills). Children are instructed to identify in correct order a set of images that were verbally presented using categorical (e.g. small, green) and time ordered prepositions (e.g. first, after). Administration took approximately 20 min. The task contains 49 items of increasing length and complexity. Administered items were afterwards coded to yield either 0 points for an incorrect answer or 1 point for a correct answer. Summed raw scores were used as a covariate in the analyses. The test-retest reliability ($r$ = .76) of this subtask is considered sufficient (Semel et al., 2010).

*Data analyses*

Data were analyzed using IBM SPSS version 23. Demographic characteristics for both schools and educational program and control conditions were compared with chi-square tests, independent $t$-tests and Fisher's exact tests. The educational effect on parental questioning style was assessed using ANCOVA controlling for corresponding pre-test values, verbal ability and age. The educational effect on reasoning through mediation by parental questioning style was assessed using bootstrapping, a nonparametric resampling procedure (Hayes, 2009). Bootstrapping analysis with 5000 resamples was done to test for significant indirect effects using the SPSS macro developed by Hayes (2012). In this analysis, mediation is significant if the 95% bias corrected confidence interval for the indirect effect does not include zero. Only parental questioning style variables with a significant educational program effect were included in the mediation analyses. Unstandardized residual scores were used for parental questioning style variables in the mediation analyses, in order to control for pre-test values. Verbal ability and age were centered and controlled for in all analyses. For all significant effects, partial $\eta^2$ addressed effect size (0.04 = small effect; 0.25 = moderate effect; 0.64 = strong effect (Ferguson, 2009). Alpha for significant effects was set at $p < .05$.

## Results

Sample characteristics and descriptive statistics for the variables of interest are displayed in Table 1. Children in the educational program condition did not significantly differ from those in the control condition for age, sex, school, grade, single parenthood status, parental educational level or prevalence of referral to mental health care in the past year, nor did they differ on any of the scientific and social reasoning measures at pre-test (all $p > .05$).

*Curious Minds parent educational program effect*

*Parental questioning style*

Parents in the educational program condition had at post-test a significantly higher question format preference ratio (i.e. ratio open- versus closed-ended questions) score ($\eta_p^2$ = .10), and asked significantly more observational leading questions ($\eta_p^2$ = .07) and more explanatory questions ($\eta_p^2$ = .13) than parents in the control condition, while controlling for corresponding pre-test questioning style, verbal ability and age (see Table 4). Parents in the educational program condition did not ask more questions in total than parents in the control condition, nor did they ask more procedural questions at post-test.

*Mediation analyses: scientific reasoning*

Bias-corrected bootstrapping analyses were conducted to test for an indirect effect of educational program condition on aspects of scientific reasoning. Detailed results of the bootstrapping analyses with questioning style as a mediator in the relation between educational program condition and scientific reasoning are provided in Table 5.

*Conservation reasoning proficiency: quantity task*

There was a significant mediation effect for educational program condition on conservation reasoning via ratio questions ($b$ = 1.56, $SE$ = 1.03, 95% CI [0.12, 4.32]). This indicates that for parents in the educational program condition, asking relatively more open- than closed-ended questions at post-test was associated with enhanced performance on the quantity task in their children (see Fig. 1). Standardized indirect effects via observational questions ($b$ = 0.12, $SE$ = 0.67, 95% CI [-0.82, 1.99]) and explanatory questions ($b$ = 0.37, $SE$ = 0.99, 95% CI [-1.35, 2.84]) were non-significant.

*Proportional reasoning proficiency: balance scale predictions*

There were no mediation effects for educational program condition on proportional reasoning proficiency via parental questioning style. The standardized indirect effect via ratio questions ($b$ = 0.02, $SE$ = 0.06, 95% CI [-0.09, 0.16]) was non-significant. Nor were standardized indirect effects via observational questions ($b$ = -0.01, $SE$ = 0.05, 95% CI [-0.17, 0.05]) and explanatory questions ($b$ = 0.06, $SE$ = 0.06, 95% CI [-0.03, 0.22]).

*Proportional reasoning complexity: balance scale explanations*

There was a significant mediation effect for educational program condition on proportional reasoning complexity via ratio questions ($b$ = 0.09, $SE$ = 0.06, 95% CI [0.01, 0.24]). This indicates that for parents in the educational program condition, asking relatively more open- than closed-ended questions at post-test was associated with more complex explanations by their children (See Fig. 2). Standardized indirect effects via observational questions ($b$ = 0.04, $SE$ = 0.04, 95% CI [-0.01, 0.17]) and explanatory questions ($b$ = -0.06, $SE$ = 0.06, 95% CI [-0.22, 0.03]) were non-significant.

*Mediation analyses: social reasoning*

Bias-corrected bootstrapping analyses were conducted to test for an indirect effect of educational program condition on social reasoning. Detailed results of the bootstrapping analyses with questioning style as a mediator in the relation between educational program condition and social reasoning are provided in Table 6.

There was no mediation effect for educational program condition on social reasoning proficiency via parental questioning style. The standardized indirect effect via ratio questions ($b$ = 0.15, $SE$ = 1.06, 95% CI [-1.36, 2.93]) was non-significant. Nor were standardized indirect effects via observational questions ($b$ = 0.54, $SE$ = 0.65, 95% CI [-0.19, 2.57]) and explanatory questions ($b$ = 0.72, $SE$ = 0.89, 95% CI [-0.57, 3.18]).

## Discussion

Parent-child interactions allow for daily opportunities to practice problem-solving skills in meaningful social context, especially when exploration and explanation are encouraged (Busch et al., 2018; Gauvain, 2001; Legare et al., 2017). When children reach primary school age, they become more active participants in parent-child interactions, which leads to parent systematically increasing their contingent instructions to adaptively challenge their child's skills (Conner & Cross, 2003). However, parents show individual differences in the extent to which they encourage explanatory behavior in their children (e.g. by asking questions), which may influence their children's reasoning and learning development (Clegg & Legare, 2017). Educating parents about the early development of reasoning skills and ways to promote development during daily interactions can better equip them to recognize their child's level of competence and to adjust their questioning style to optimize the learning environment. The aim of the current study was to examine whether the Curious Minds parent educational program was able to alter parental questioning style in a low-risk sample of four- to eight-year-olds, which may positively impact their child's social and scientific reasoning abilities. This study has provided unique evidence for the feasibility of implementing a compact psycho-educational parent program with home-assignments that can achieve modest gains in parental verbal scaffolding through asking

**Table 4**
Analysis of covariance (ANCOVA) results comparing educational and control condition on parental questioning style at posttest, controlling for corresponding pre-test score, age and verbal ability.

| | EPC M (SE) | CC M (SE) | F (df) | $\eta_p^2$ | p |
|---|---|---|---|---|---|
| Parental questioning style | | | | | |
| Total questions | 0.12 (0.14) | 0.05 (0.13) | 0.15 (65) | < .01 | .70 |
| Ratio open/closed questions | 0.35 (0.16) | -0.25 (0.15) | 7.35 (65) | .10 | < .01 |
| Observational leading questions | 0.11 (0.12) | -0.27 (0.12) | 4.82 (65) | .07 | .03 |
| Procedural questions | 0.17 (0.13) | -0.05 (0.13) | 1.41 (65) | .02 | .23 |
| Explanatory questions | 0.34 (0.12) | -0.19 (0.12) | 9.93 (65) | .13 | < .01 |

Note. M: Marginal means. EPC = Educational program condition; CC = Control condition.

more open and elaborative questions. Our findings extend previous reports of successful improvements in parents' beliefs about scaffolding and the promotion of learning (Gartner et al., 2018) and successfully altered parent-child interactions after providing explicit guidance instructions (Vandermaas-Peeler et al., 2016; Willard et al., 2019). Asking more open- than closed-ended questions mediated the association between educational program condition and aspects of scientific reasoning.

Our findings indicate that the enhanced scientific reasoning abilities of children with parents in the educational condition may be attributed to the altered questioning style by their parents. This suggests that children's reasoning can be positively influenced by altered parent-child interactions (Vandermaas-Peeler et al., 2016). This is also in line with the study by Butler and Markman (2014), who showed that four-year-olds were more likely to display deeper categorization reasoning abilities when an adult was scaffolding the task. However, where children in these studies showed improved reasoning ability while being scaffolded concurrently, the present study demonstrated that children's reasoning ability was enhanced on tasks without the parent present. This may suggest that changes in the parental questioning style may have also increased the child's ability to better monitor its own reasoning, while working on reasoning tasks (Wertsch, 1998). Likewise, it has previously been shown that children are more likely to persist on a new challenging solo task after they are encouraged to generate explanations through parental questioning on a collaborative task (Wilson et al., 2019).

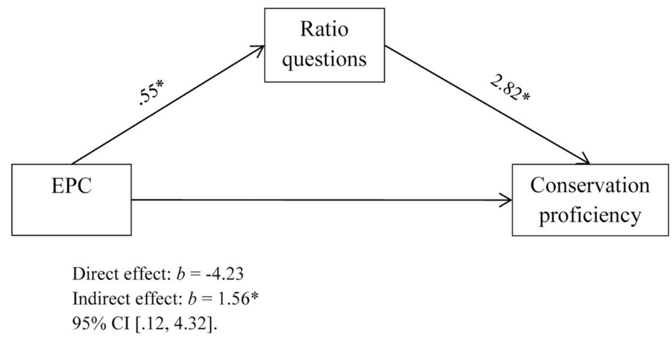


**Fig. 1.** Unstandardized regression coefficients for the mediated association between educational condition and conservational reasoning proficiency level (Quantity task).

Contrary to our hypotheses, parents asking more observational or explanatory questions did not result in enhanced reasoning performance in their children. This may be explained by the findings of Legare and Lombrozo (2014), who concluded that not necessarily the manner in which explanations were prompted (i.e. to be asked to describe or explain a mechanical toy) but rather that the content of

**Table 5**
Bootstrapping analyses results with parental questioning as a mediator in the relation between educational condition and scientific reasoning ability.

| | | Scientific reasoning ability (N = 70) | | |
|---|---|---|---|---|
| | | Conservation proficiency: Quantity task | Proportional proficiency: Balance scale predictions | Proportional complexity: Balance scale explanations |
| | Direct effect | | | |
| Mediator | Program – Q | b (SE) | b (SE) | b (SE) |
| Total effect educational program | | -2.39 (2.15) | 0.31 (0.18) | 0.34 (0.14)* |
| Covariate age | | 0.35 (0.11)* | 0.02 (0.01)* | 0.01 (0.01) |
| Covariate verbal ability | | 0.14 (0.39) | 0.04 (0.03) | -0.01 (0.03) |
| Covariate T1 Reasoning[a] | | 0.50 (0.13)* | 0.11 (0.13) | 0.55 (0.11)* |
| Ratio questions (Ratio) | 0.55 (0.21)* | | | |
| Direct effect program – Reasoning | | -4.23 (2.23) | 0.29 (0.19) | 0.24 (0.14) |
| Direct effect Ratio – Reasoning | | 2.82 (1.22)* | 0.04 (0.10) | 0.16 (0.07)* |
| Indirect effect (mediation) | | 1.56 (1.03)* | 0.02 (0.06) | 0.09 (0.06)* |
| Observational questions (Obs) | 0.30 (0.17) | | | |
| Direct effect program – Reasoning | | -2.54 (2.24) | 0.33 (0.18) | 0.29 (0.14)* |
| Direct effect Obs – Reasoning | | 0.41 (1.57) | -0.05 (0.13) | 0.14 (0.10) |
| Indirect effect (mediation) | | 0.12 (0.67) | -0.01 (0.05) | 0.04 (0.04) |
| Explanatory questions (Exp) | 0.48 (0.17)* | | | |
| Direct effect program – Reasoning | | -2.81 (2.33) | 0.24 (0.19) | 0.40 (0.15)* |
| Direct effect Exp – Reasoning | | 0.77 (1.60) | 0.12 (0.14) | −.12 (0.10) |
| Indirect effect (mediation) | | 0.37 (0.99) | 0.06 (0.06) | -0.06 (0.06) |

Note. Results based on 5000 bootstrapped samples. [a] Covariate T1 reasoning refers to corresponding pretest scientific reasoning ability. B = Unstandardized regression coefficients. SE = Standard error. * $p < .05$.

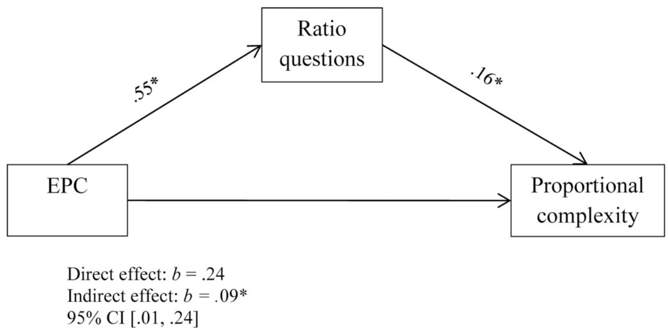


**Fig. 2.** Unstandardized regression coefficients for the mediated association between educational condition and proportional reasoning complexity level (Balance Scale).

children's response to such a prompt influenced their performance. More specifically, both ‘describe the toy’ and ‘explain the toy’ prompts were equally successful in generating explanations in children, while prompts to observe the toy were not effective. This may indicate that asking children more open-ended questions during a problem-solving task may already effectively induce explanations, regardless if these questions are explicitly prompting an explanation. This would be in line with our finding that parents having a higher preference for open- over closed-ended questions resulted in improved scientific reasoning in their children. In our study, however, we did not assess the content of children's responses to their parents' questions, which may have differentially influenced their reasoning performance and would be an interesting direction for future research.

Not all aspects of children's reasoning performance were associated with parents' improved questioning style after the educational program. More specifically, only children's reasoning complexity level on the balance scale task and children's proficiency on the quantity task were influenced by their parents' altered questioning style. This may be explained by the nature of the proficiency tasks; while the balance scale task included predicting how the beam would react after changing the weights to obtain a higher score, the quantity task consisted of solving a range of conservation problems, of which the latter may have tapped more into conceptual understanding than mere predictions. False belief tasks have shown similar effects, in which young children were unable to correctly predict where a figure would search for a toy, but were capable of adequately explaining why the figure would search in the wrong place (For a review, see Wellman, 2011). This is also in line with the study of Vandermaas-Peeler et al. (2016), which showed that children gave more correct responses on a conservation reasoning task when their parents asked for explanations rather than predictions.

In addition to reasoning proficiency, reasoning complexity level was also taken into account in this study. Research focusing on mathematical problem solving skills in preschoolers has shown that even though counting proficiency is necessary for problem solving success, especially the conceptual understanding of the counting process was predictive of math performance (Muldoon, Lewis, & Freeman, 2003). Perhaps children's reasoning complexity level reflects their conceptual understanding of reasoning, which might be more predictive of their school achievement than mere proficiency on a reasoning task. Furthermore, Wilkenfeld and Lombrozo (2015) stated that explanations do not have to be accurate to promote learning, but rather that the process of generating explanations in itself is a tool for learning. In this study, only social reasoning proficiency and not complexity was taken into account. As scientific reasoning complexity was coded regardless of the correctness of the explanation, this may explain why no effects on social reasoning were found. Given our findings on scientific reasoning complexity level, future studies are recommended to include complexity level when assessing the development of children's reasoning ability and relating it to school achievement and social development.

As expected, educating parents to modify their daily parent-child interactions and having them practice questioning styles that encourage exploration and explanations in daily interactions with their child, altered their questioning style and seems to have positively influenced some reasoning abilities of their child. This finding supports the notion that practicing reasoning abilities in the real-life social context using scaffolding techniques is a promising approach to stimulate the development of early reasoning abilities (Kuhn, 2010). Our findings are in line with previous successful interventions that included social interactive components to stimulate the development of scientific reasoning abilities (For a meta-analysis, see Engelmann et al., 2016), and extends research focusing on altering parent-child interactions using explicit guidance instructions (Vandermaas-Peeler et al., 2016; Willard et al., 2019) Potential benefits of this compact parental group program in comparison to for instance home visiting programs targeting school

**Table 6**
Bootstrapping analyses results with parental questioning as a mediator in the relation between educational condition and social reasoning proficiency.

| | | Social reasoning proficiency (N = 69) |
|---|---|---|
| | Direct effect | |
| Mediator | Program - Questioning | b (SE) |
| Total effect program | | 1.16 (2.25) |
| Covariate age | | 0.52 (0.10)* |
| Covariate verbal ability | | 0.37 (0.39) |
| Covariate T1 Reasoning[a] | | 0.30 (0.11)* |
| Ratio questions (Ratio) | 0.49 (0.21)* | |
| Direct effect program-Reasoning | | 1.00 (2.37) |
| Direct effect Ratio - Reasoning | | 0.31 (1.35) |
| Indirect effect (mediation) | | 0.15 (1.06) |
| Observational questions (Obs) | 0.26 (0.17) | |
| Direct effect program-Reasoning | | 0.52 (2.30) |
| Direct effect Obs - Reasoning | | 2.10 (1.66) |
| Indirect effect (mediation) | | 0.54 (0.65) |
| Explanatory questions (Exp) | 0.46 (0.18)* | |
| Direct effect program-Reasoning | | 0.38 (2.40) |
| Direct effect Exp - Reasoning | | 1.58 (1.66) |
| Indirect effect (mediation) | | 0.72 (0.89) |

Note. Results based on 5000 bootstrapped samples. [a] Covariate T1 reasoning refers to corresponding pretest social reasoning ability. B = Unstandardized regression coefficients. SE = Standard error. * $p < .05$.

readiness (For a review, see Welsh et al., 2014), include its wide employability and low cost.

Several limitations of the current study need to be acknowledged. Not all parents who were assigned to the educational condition participated in the program or completed all sessions, which may have biased our results due to selective drop-out. However, parents who were excluded from analyses did not significantly differ from those who remained in the educational program condition on parental education or single parenthood status, suggesting no attrition bias for these variables. Second, a no-contact control group was used, suggesting motivational issues may have arisen for parents in the control condition. However, parents in the control condition were invited to attend an informative workshop covering the topics discussed during the program after all the post-test assessments with participating parents and children were completed, possibly reducing motivational concerns. Third, during the Curious Minds program, the home assignments were not individually checked or monitored. Unfortunately, we do not have detailed information on the amount and quality of practice for each parent. Nonetheless, home assignments were discussed freely in each following session, possibly generating cohesiveness and social pressure to complete the assignments.

This study is among the first few to examine manners in which parents can be educated to facilitate the early development of social and scientific reasoning ability in their children through questioning style by using a compact educational program. Strengths of this study include the objective coding with high interrater reliability of observed parental questioning style and the assessment of both reasoning proficiency and complexity level of scientific reasoning. Furthermore, parents were randomized to the educational program conditions within schools and within classes rather than assigning schools or total classes to different conditions, which would limit classroom and school effects.

In sum, the current study showed that the Curious Minds educational parent program had a modest, but positive impact on parental questioning style, which may have enhanced aspects of reasoning complexity and proficiency in their children. Our findings are in line with the notion that the social environment can be an important asset in promoting early reasoning abilities (e.g. Mackey et al., 2011; Nisbett et al., 2012). Nevertheless, our results await further replication and future studies are encouraged to examine the effect of variations in educational program responsiveness and assessing these relations over time. Furthermore, including reasoning complexity level when assessing long-term effects on school achievement are topics for further consideration in future studies.

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**Declaration of Competing Interest**

None.

## Appendix

Table A1
Partial correlations among observed parenting behaviors and child reasoning ability at pretest, controlled for verbal ability and age.

| | Parental questioning style | | | | |
|---|---|---|---|---|---|
| | Total | Ratio | Observational | Procedural | Explanatory |
| Scientific reasoning | | | | | |
| 1. Conservation proficiency | −.22[†] | −.09 | −.09 | −.06 | .11 |
| 2. Proportional proficiency | −.12 | −.01 | −.11 | −.08 | −.06 |
| 3. Proportional complexity | −.03 | .23[†] | .04 | −.03 | −.09 |
| Social reasoning | | | | | |
| 4. Total proficiency | .15 | .01 | .09 | .20 | −.13 |

[†]$p < .10$; $^{**}p < .05$;$^{**}p < .01$.

Table B1
Mean and standard deviations of observed parenting behaviors and child reasoning ability at pretest and posttest.

| Parental questioning style *(M (SD))* | | | | | | |
|---|---|---|---|---|---|---|
| | | Total Questions[a] | Ratio Questions[a] | Observational Questions[a] | Procedural Questions[a] | Explanatory Questions[a] |
| EPC | T1 | .01 (.89) | .16 (.82) | .07 (.78) | .08 (.58) | .13 (.79) |
| | T2 | .13 (.86) | .37 (1.05) | .11 (.76) | .19 (.76) | .35 (87) |
| CC | T1 | −.04 (1.03) | −.05 (.97) | −.14 (.87) | .01 (.91) | −.04 (.79) |
| | T2 | .04 (.95) | −.26 (.81) | −.26 (.78) | −.07 (.79) | −.19 (.65) |

| Child reasoning abilities *(M (SD))* | | | | | |
|---|---|---|---|---|---|
| | | Social reasoning proficiency | Conservation proficiency: Quantity task | Proportional proficiency: Balance scale predictions[a] | Proportional complexity: Balance scale explanations[a] |
| EPC | T1 | 32.35 (12.95) | 35.50 (12.35) | .26 (.87) | .33 (.75) |
| | T2 | 40.79 (13.74) | 40.74 (15.37) | .35 (.73) | .56 (63) |
| CC | T1 | 31.97 (15.44) | 36.44 (13.60) | .07 (.86) | .09 (.95) |
| | T2 | 38.46 (15.23) | 43.17 (12.38) | −.02 (.93) | .09 (.85) |

[a] Mean value after standardization.

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