What is Theory of Mind?

A Psychometric Study of Theory of Mind and Intelligence

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Abstract

Theory of mind (ToM) is an essential ability for social competence and communication, and it is necessary for understanding behaviors that differ from our own (Premack and Woodruff, 1978). Recent research suggests that tasks designed to measure the ToM construct might not adequately capture ToM ability (Warnell & Redcay, 2019; Quesque & Rosetti, 2020). This hinders the interpretation of experimental findings and puts into question the validity of the ToM construct. This study examines the structure of ToM, crystallized intelligence (Gc), and fluid intelligence (Gf) to (a) understand whether ToM should be considered a monolithic ability and (b) to explore whether tasks of ToM present adequate construct validity. For this, confirmatory factor analyses (CFAs), exploratory factor analysis (EFA), and exploratory network analysis (NMA) were conducted. The results of the models largely point to the same conclusion: ToM tasks are not purely assessing a single construct. Importantly, these findings align with recent theoretical accounts proposing that ToM should not be considered a monolithic construct (Quesque & Rosetti, 2020; Schaafsma et al., 2015; Devaine et al., 2014), and should instead be explored and measured as multiple sub-components.

Keywords: social cognition, theory of mind, psychometric measurement, intelligence.

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How do humans understand what other people feel and believe? Psychologists and philosophers have long asked this basic question. Theory of mind (ToM) is understood as the ability to understand the beliefs, knowledge, and intentions of others based on their behavior. The term was first coined by Premack and Woodruff (1978) to refer to chimpanzees' ability to infer human goals, and it was quickly adopted by psychologists to study humans' ability to infer and predict the behavior of others. This was followed by a vast number of studies on the topic. A simple search of the term "theory of mind" on PsycInfo reveals over 7000 articles and 1000 books on Theory of Mind. This is not surprising given that ToM has been found to be necessary for numerous complex cognitive tasks, including communicating (e.g., Grice, 1989; Sperber & Wilson, 1995), understanding criticism (Cutting & Dunn, 2002), deception (Sodian, 1991), joking, lying (Hughes & Leekam, 2004; Leekam & Prior, 1994), and irony (Happé, 1994), and it is related to pragmatic language competence (Eisenmajer & Prior, 1991), and problem solving (Greenberg, Bellana, & Bialystok, 2013). In addition, ToM has been observed across cultures and countries (Avis & Harris, 2016; Lee, Olson, & Torrance, 1999; Naito, Komatsu, & Fuke, 1994; Tardif & Wellman, 2000) and impaired ToM has been linked to psychiatric and developmental disorders, such as schizophrenia and autism spectrum disorder in both children and adults (Baron-Cohen, Leslie, & Frith, 1985, 1986; Frith, 2004; Hughes & Russell, 1993).

However, despite the numerous findings related to ToM (for a review see Schaafsma et al., 2015), it is still unclear what cognitive processes underly ToM ability. This might be partly due to the variability with which researchers operationalize the construct of ToM. For example, behavioral and neuroimaging research usually distinguishes between language-independent

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implicit ToM (i.e., fast, automatic ToM) and culture and language-dependent explicit ToM (i.e., slower, deliberative ToM) (Apperly & Butterfill, 2009; van Overwalle & Vandekerckhove, 2013). Other researchers instead distinguish between ToM as an emergent property based on experience and context, and a latent ability that is expressed as the result of its interaction with general cognitive processes, such as working memory and executive function (Gopnik & Wellman, 1994, 2012; Leslie & Polizzi, 1998; Leslie, 1994). There are also differences between cognitive compared to affective ToM (Abu-Akel & Shamay-Tsoory, 2011; Poletti et al., 2012) and empathic ToM compared to representing the mental states of others (Preston & de Waal, 2002; Bernhardt, & Singer, 2012; van Veluw & Chance, 2014). Because of this variability, researchers have proposed that the overarching concept of ToM as it is used by researchers in several fields likely entails a number of different processes that represent different dimensions of a ToM ability (Schaafsma et al., 2005; Quesque & Rossetti, 2020).

The conceptual variability around ToM research is also reflected in the variety of tests and tasks used to assess ToM ability. The variation in terminology has contributed to the prolific creation of ToM measurements that however seem to present poor psychometric properties. Recent research shows that several measures commonly used to assess ToM likely test different cognitive processes (Warnell & Redcay, 2019), and it is unclear whether all these processes really tap into an overarching ToM ability, whether they tap different lower-level processes (Quesque & Rossetti, 2020), or whether they tap different processes altogether. In fact, there has been strong criticism of the way ToM is investigated and conceptually defined for several years (Bloom & German, 2000; Frith & Happé, 1994), yet the problem persists. Thus, one of the main goals of the field should be to address the psychometric properties of ToM measures to better understand ToM processes and mechanisms.

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In particular, due to inconsistent terminology and measurement, many studies have examined diverse subconstructs or dimensions of ToM that might not completely represent ToM ability and therefore do not provide solid evidence for theoretical accounts of ToM. Schaafsma et al. (2015) suggested that one solution to this issue is to avoid treating ToM as a “monolithic” ability. Instead, researchers should consider the flexible nature of the construct when proposing theories that account for the processes that likely engage ToM, such as considering individual differences in ToM.

ToM Measurement

The first task designed to assess ToM was the false-belief task (Wimmer & Perner, 1983). This was quickly followed by the development of multiple tasks and tests that assess different aspects of ToM. Some of the processes that these tasks measure include false belief understanding (Berstein, Thornton, & Sommerville, 2010; Wimmer & Perner, 1983), accounting for others’ perspectives (Dumontheil, Apperly, & Blakemore, 2010), the ability to infer mental states from the expression of people’s eyes (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Baron-Cohen, Wheelwright, Spong, Scahill, & Lawson, 2001), detection of faux pas (e.g., Baron-Cohen, O’Riordan, Stone, Jones, & Plaisted, 1999), deceptive intentions (e.g., Sebanz & Shiffrar, 2009), understanding others’ thoughts (Keysar, 1994), and the difference between Level 1 perspective-taking and Level 2 perspective-taking (Piaget & Inhelder, 1956; Samson, Apperly, Braithwaite, Andrews, & Bodley Scott, 2010), among numerous others.

Despite the fast proliferation of ToM tasks, psychometric assessments of the validity of existing ToM measures have only recently been conducted, with results suggesting concerns about the underlying structure being measured by these tasks. Specifically, Warnell and Redcay (2019) examined the relationship among different ToM measures (including the false belief task,

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the Reading the Mind in the Eyes test, and pragmatic language comprehension, among others) in children and adults. The researchers found that an exploratory factor analysis did not support a clear structure underlying a ToM factor for the adult group. In addition, even though factor analysis was not possible due to low sample size for the children sample, correlations among the tasks administered to children also revealed poor to no correlations. These findings suggest that the measures used to assess ToM might not adequately tap into a single reliable construct. These findings are consistent with recent theoretical accounts proposing that ToM is not likely a single construct, but that instead it might be a composite of both social and cognitive abilities (e.g., Apperly, 2012; Gerrans & Stone, 2008; Schaafsma et al., 2015). Thus, it is critical to clarify whether this view of ToM is more consistent with the findings of ToM measures.

A first attempt to create a taxonomy of ToM tasks and the ToM dimensions they assess was performed by Quesque and Rossetti (2020). The researchers assessed the face validity of over 20 measures of ToM used by researchers from a variety of areas, including developmental, clinical, cognitive, and cognitive neuroscience and concluded that there were apparent differences in the underlying cognitive mechanisms that each of the tasks seemed to measure, including perspective-taking, eye tracking, and inference making. This conclusion indicates that research should focus on identifying and classifying the different subprocesses or dimensions that form ToM, including lower-order cognitive processes, such as kinematic processing (Obhi, 2012), social attention (Heyes, 2014) or emotion recognition (Oakley et al., 2016) and higher-order processes, such as inhibiting one's perspective, creating models of alternative emotional responses, and updating one's own knowledge. Thus, Quesque and Rossetti (2020) argued that numerous tasks created and implemented to date do not meet the criteria required to measure a single ToM construct.

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Despite the apparent lack of construct validity across tasks, many studies have used ToM tasks to examine the relationship between ToM and other cognitive abilities. Specifically, research has shown that ToM is related to verbal ability, executive function, and IQ (e.g., German & Hehman, 2006; Milligan, Astington, & Dack, 2007). In fact, many of the ToM tasks used in the literature have components that, at face value, share processes with constructs commonly studied in the cognitive abilities research literature, such as crystallized and fluid intelligence. To better understand the components of ToM, the relationship among ToM tasks and other cognitive constructs should be examined. This would help elucidate the tasks that measure specific ToM processes, and the tasks that measure other related, but different, cognitive abilities.

More specifically, there is little research examining the relationship between ToM and general intelligence (Spearman, 1904, 1927). General intelligence or *g* is thought to be the result of the positive manifold, that is, the largely replicated finding that cognitive abilities are consistently positively correlated. General intelligence research is related to various specific cognitive abilities. Specifically, one of the earliest models of intelligence was the fluid/crystallized (*Gf/Gc*) theory (Cattell, 1963, 1971; Horn, 1994). The *Gf/Gc* model proposed that general intelligence was the result of two specific and exclusive abilities: *Gf* or fluid intelligence and *Gc* or crystallized intelligence. *Gf* is the ability to solve problems in novel situations, regardless of previous knowledge and *Gc* is the ability to solve problems using previously acquired skills, largely related to the amount of formal schooling one has been exposed to (Kan, Kievit, Dolan, & van der Maas, 2011). These two abilities have been expanded and incorporated into more recent models of intelligence, including the Cattell–Horn–Carroll (CHC) model (McGrew, 2009), which combines the *Gf/Gc* model with other specific abilities, such as visual-spatial (*Gv*), processing speed (*Gr*)

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and memory retrieval (Gr). Importantly, Gf and Gc remain two of the strongest factors in models of intelligence and have been replicated consistently across the literature and across neuroscientific and developmental studies.

Research has found that ToM is related broadly to IQ, usually measured as school achievement (Baker et al., 2014; Coyle, Elpers, Gonzalez, Freeman, and Baggio, 2018; Dodell-Feder et al., 2013; Navarro, Goring, & Conway, 2021), nevertheless, ToM has not been psychometrically examined together with Gf and Gc. Gf and Gc represent two correlated, but different dimensions of intelligence and several reliable tasks are used to measure each construct. It is important to understand the correlation between ToM and these intelligence constructs to better explain the processes measured by ToM tasks. In other words, by examining these constructs, we could begin to understand the extent to which ToM should be considered a group of multiple subcomponents (Schaafsma et al., 2015), rather than a monolithic entity.

The Current Study

The goal of this study was to examine the validity of ToM tasks by comparing performance on the tasks to measures of fluid intelligence (Gf) and crystallized intelligence (Gc) (Cattell, 1963) and to explore the claims made by theoretical accounts that propose that ToM should not be considered a monolithic construct (Apperly & Butterfill, 2009; Devaine et al., 2014; Schaafsma et al., 2015). Examining the differences between these constructs would allow us to explore whether the processes tapped by ToM tasks represent a unique ToM construct, or whether they instead measure multiple subconstructs. For this purpose, participants completed a battery of ToM, Gc, and Gf tasks. Confirmatory factor analyses were used to examine the structure of the data. We hypothesized that if ToM tasks represent a monolithic cognitive ability, then a three-factor model should best fit the data.

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In addition, a psychometric network modeling analysis was conducted to examine the relationship among ToM, Gc, and Gf tasks. Psychometric network modeling conceptualizes cognitive abilities as interconnected networks composed of interactive processes (see Epskamp & Fried, 2018). This approach has many benefits. Specifically, psychometric networks are a powerful visualization tool to explore anticipated or unknown relationships amongst variables in a dataset and, unlike latent variable modeling, they are not constrained by the principle of local independence (i.e., the assumption that a latent factor causes any and all covariation among measures of the same construct). In addition, network modeling can account for the one-to-one relationships amongst tasks belonging to the same construct while at the same time estimating individual relationships between tasks belonging to different constructs.

Method

Design and Participants

An online sample of 208 participants was recruited using Amazon's Mechanical Turk (MTurk). The number of participants is based on the minimum sample size required for a three-factor Confirmatory Factor Analysis (CFA; Wolf, Harrington, Clark, & Miller, 2013). All participants were located in the US and were over 18 years of age. Participants' ages ranged from 18 to 69 years old ($M = 39.89$; $SD = 9.34$, Median = 39). 116 participants identified as female. In terms of ethnicity, 148 participants identified as Caucasian, 13 identified as Black/African American, 9 identified as Asian, 3 identified as Hispanic/Latino, and 7 identified as mixed ethnicity. None reported being color blind. In addition, all participants reported having correct-to-normal vision and were fluent in English. The final sample size after multivariate outliers were removed was $N = 203$.

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The design of the study was a correlational approach using two different psychometric modeling techniques. To conduct factor analyses, it is recommended that each latent construct includes at least three tasks. In this study, participants completed 9 tasks in total: 3 tasks of ToM, 3 tasks of Gf, and 3 tasks of Gc. Participants were randomly assigned to complete the tasks in one of three different orders. In order 1 (n = 74), participants first completed the Gf tasks, followed by the Gc and by the ToM tasks. In order 2 (n = 58), participants first completed the ToM tasks followed by the Gf and Gc tasks. In order 3 (n = 76), participants first completed the Gc tasks followed by the ToM and Gf tasks¹.

Measures

Theory of Mind Tasks

Reliability for all tasks was calculated using Cronbach's alpha. The ToM measures that were used in the study involve (a) taking the perspective of another person (i.e., Director task), (b) inferring mental states from people's eyes (i.e., Reading the Mind in the Eyes), and (c) interpreting socially inappropriate situations (Short Stories Questionnaire). The tasks lasted approximately 15 minutes.

Director Task (Dumontheil, Apperly, and Blakemore, 2010; Legg, E. W., Olivier, L., Samuel, S., Lurz, R., & Clayton, N. S., 2017). The task was proposed by Keysar, Lin, and Barr (2003) and automated by Dumontheil, Apperly, & Blakemore (2010). The current version was an automated version adapted from Legg et al. (2017). The task includes two conditions (Director, No Director) and 2 trial types (Experimental, Control). The stimuli are set up in a 4x4 shelf

¹ No significant differences were found in any of the dependent variables based on order of administration.

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containing eight different objects arranged in different positions. In the Director Condition, an avatar called the Director stands behind the shelf. Some of the compartments in the shelf are occluded from the Director's view so that only the participant can see those objects. The participant is asked to attend to the instructions that the Director gives them via a speech box. On each trial, the Director asks the participant to select one of the objects in the shelf (e.g., "the yellow sock", "the small cup"). The participant responds by clicking on the correct object within the shelf. Participants were asked to consider the perspective of the Director when responding to instructions. This condition is thought to assess theory of mind because the participant has to remember that the perspective of the Director is not the same as theirs. In the *No Director* condition, participants are shown the same shelf, but the Director is not behind it anymore. Instead, participants are told to ignore all objects placed in the slots with red backgrounds. This condition does not require theory of mind and instead requires the participant to inhibit prepotent information while keeping in mind a rule, therefore just requiring general executive function. The No Director condition is used as a control condition. Both conditions present two types of trials. *Experimental trials* are trials where the shelf contains a target and a competing distractor that can be the most appropriate response but only from the perspective of the participant. In *Control trials*, the target object has a competitor but is always the best response from both perspectives and no competing object is included in an occluded compartments. *Filler trials* that have no competitor and are visible to both Director and participant. Control and experimental trials appear in a pseudorandom intermixed order throughout the task and the order of presentation of the stimuli is counterbalanced across participants. Participants respond to a total of 16 control trials, 16 experimental trials and 64 filler trials in each condition. Participants also

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complete a practice trial before the Director condition. Participants have 5 seconds to respond to each instruction. Average accuracy and reaction times for all trials was recorded.

Reading the Eyes in the Mind (RMET; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). The RMET task was programmed on a computer. In the task, participants are presented with a series of 36 black and white photographs of the eye region of the face of females and males of different ages. One photograph is presented at a time and participants have no time limit to respond. Four words describing the potential emotion conveyed by the eyes are presented together with the photograph. Participants must select the word that best describes what the person in the photograph is feeling (e.g., sad, happy, scared, depressed). The test is thought to assess how well a person can understand other people's mental states. RMET scores range from 0 to 36 in a discrete fashion. Accuracy is recorded. The task lasts approximately 10 minutes.

Short Stories Questionnaire (SSQ; Dodell-Feder, Lincoln, Coulson, & Hooker, 2013; Lawson, Baron-Cohen, & Wheelwright, 2004). SSQ was implemented on Qualtrics. The test contains 10 short stories, each divided into three sections. The stories involve utterances made by a character that could upset another character in the story. In this task, participants must infer the mental states of the characters (i.e., how they felt, what they thought). There are a total of 30 sections with at least four utterances in each section. 10 sections contained *blatant* target utterances (e.g., incorrectly estimating a middle-aged woman's age), 10 contained *subtle* target utterances (e.g., lying about remembering someone's name) and 10 contained *filler* control utterances (e.g., discussing the weather). Each section contained a question asking the participant whether something said in the story could have upset someone and to indicate what part of the text corresponded to the upsetting utterance. Each of the 10 stories included a filler question. The order of presentation of the stories was randomized. Participants were scored based on the

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number of targets correctly identified. Scores range from 0 to 20 in a discrete fashion. The task lasts approximately 15 minutes.

Fluid Intelligence Tasks

The tasks are thought to measure the ability to follow rules and solve novel problems.

Letter Series (Ekstrom, French, Harman, & Dermen, 1976). In the task, ten sets of four letters are presented. All sets present 5 series of letters that followed a certain pattern except for one set. To respond correctly, participants must select the letter set that does not follow the pattern. Accuracy is measured in this task. Participants were given three practice trials before completing the task. The task automatically ends after 5 minutes.

Number Series (Thurstone, 1938). In the task, ten trials are presented showing a series of numbers of varying lengths in it. Each series of numbers is organized following a specific rule or pattern. Participants are asked to select the number that would be consistent with the series from five given choices. Participants were given three practice trials before completing the task. Accuracy is measured in this task. The task automatically ends after 5 minutes.

Raven's Progressive Matrices (Raven, 1938). A short version of Raven's figural inductive reasoning task was used in this study. Participants completed a total of 18 items per task from the Raven's Progressive Matrices Set II (Hamel & Schmittmann, 2006). Participants were randomly assigned to one of two task orders (odd trials or even trials). In this task, each item is part of a pattern of eight black and white figures arranged in a 3x3 matrix in which the last bottom-right figure is missing. At the bottom of the matrix is a list of eight possible figures to choose from. Only one of those figures is the correct answer that best completes the pattern of the missing piece in the matrix. Each item follows a series of rules that the participant needs to find and keep in mind to find the right answer. Participants were given three practice trials before

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completing the task. A standardized score of accurate responses is calculated. The task ends automatically after 15 minutes.

Crystallized Intelligence tasks

All tasks are thought to measure previously acquired knowledge.

Synonyms. The synonyms test presented participants with 10 words shown one at a time each with a list of possible answer choices. Participants had to choose the word whose meaning was the same as the initial word displayed on the screen. Accuracy is measured in this task.

Participants had 5 minutes to answer all 10 questions.

Antonyms. The antonyms test is identical to the Synonyms test, with the exception that participants have to choose from a list of options the word that represents the opposite meaning to the word displayed. Accuracy is measured in this task. Participants have 5 minutes to answer all 10 questions.

General Knowledge. The test consisted of 10 questions regarding general knowledge (e.g., “What planet is furthest from the sun?”). Participants have to type out their answers to respond and are asked to enter “I don’t know” if they do not know the answer. Accuracy is measured in this task. Participants have 5 minutes to answer all questions.

Procedure

All tasks were administered via Qualtrics and participants accessed the study from Amazon’s MTurk. Participants were assigned to one of three counterbalanced orders as indicated above. Tasks within each construct were presented always in the same order. Participants were allowed breaks in between tasks. Completing the battery of tasks took approximately 90 minutes. Participants were compensated with \$15.

Results

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Descriptive statistics for each measure and reliability estimates are presented in Table 1. Cronbach's alpha was used to measure the internal consistency of the tasks in this study. All measures demonstrated adequate reliability (i.e., $\alpha \geq .60$) for each of the given constructs they measure. Bivariate correlations between measures are reported in Table 2. Gf and Gc tasks were moderately or strongly correlated. Gc and Gf measures were also correlated with each other as it was expected based on models of intelligence. The ToM measures presented less consistent correlations. As previous research has shown (e.g., Coyle et al., 2018; Warnell & Redcay, 2019), correlations among ToM tasks were poor. In addition, all tasks appeared to correlate with measures of Gf. For example, the director task and SSQ presented low but significant correlations with all tasks, not just with ToM tasks, and the RMET seemed strongly related to the Gf measures in particular. We further explored these relationships using confirmatory factor analyses. Data cleaning procedures can be found at: <https://osf.io/tpnj9/>

Confirmatory Factor Analysis

Confirmatory factor analysis is a technique used to test and estimate relationships among observed and unobserved variables to construct a measurement model. The measurement model can be used to examine whether tests that assess a construct are consistent with the theoretical definition of the construct of interest. To decide whether a model fits the data, multiple fit indices are observed. Fit indices consider the fit of the model relative to the saturated model (where all relations are specified) or the null model (where no relations are specified). According to Kline (2015), adequate models should have a chi-square to degrees of freedom ratio lower than 2, a Comparative Fit Index (CFI) greater or equal to .90, a Standardized Root Mean Square Residual (SRMR) lower or equal to .08, and a Root mean square error of approximation (RMSEA)

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between .05 and .10 (Kline, 2015). In addition, factor loadings should also be observed; cognitive tests tend to present loading values between .30 and .60. When several models are being compared, model comparison indicates whether the models are significantly different, indicating that one of the models represents the data more adequately.

In this study, CFA was used to assess the construct validity of the tasks by comparing model fit and path loadings. CFA requires the use of an estimation algorithm to compare iterated sets of values with the goal of minimizing the difference between the observed and the implied correlation matrix. Robust maximum likelihood (Gibson & Ninness, 2005) is an adequate estimator for data that present multivariate non-normality (as was the case in these data) and was used in this study. Data from $N = 203$ participants were used.

Three models were specified. The first model, Model 1, was a one-factor model where all manifest variables were predicted by a single general construct. Model fit indices are in Table 3. Generally, Model 1 presented poor fit based on Kline's fit indices, with no indices within standard ranges. While the fit indices presented a poor model, the standardized factor loadings were overall adequate, and only Raven's Progressive Matrices presented loadings under .30 (see Figure 1). This indicates that, as expected, a model with a single factor does not adequately represent the ability that the measures are thought to assess.

Model 2 was conducted next to examine whether the ToM tasks would be better represented by a Gf factor compared to a separate factor. Model 2 was a two-factor model where Gf and Gc were the latent factors. The tasks corresponding to the traditional ToM and Gf constructs were combined in this model based on their bivariate correlations. The reasoning behind this was to understand whether ToM tasks represent an independent construct or if they share processes with tasks of fluid reasoning. Model 2 originally presented a Heywood case,

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indicating a misestimation of the model. To avoid this issue and understand whether the ToM tasks adequately loaded into the latent factor, a model with only Gf and Gc (i.e., the classical two-factor model) was estimated and the estimates for each variable were used to constrain the Gf and Gc variables in Model 2. This avoided the emergence of a Heywood case and provided a more adequate representation of the ToM measures. Fit indices for Model 2 are in Table 3.

Overall, Model 2 did not present an excellent fit based on Kline's fit indices, and no indices were within standard ranges, however some of the indices were close to excellent fit. Compared to Model 1, Model 2 presented better CFI, RMSEA, and chi-square to degrees of freedom ratio. Standardized factor loadings in Model 2 were adequate for the Gc and Gf factors, despite the fact that the ToM measures were loaded into the Gf factor. The correlation between Gf and Gc was strong (see Figure 1). These findings seem to indicate that although a two-factor solution was not a perfect fit for the data, nevertheless Model 2 seemed overall better than Model 1 and was not a complete misrepresentation of the data.

Finally, Model 3 was conducted to examine whether a theoretically-driven three-factor model provided a more adequate representation of the data. Model 3 was a three-factor model where each set of tasks was grouped under the psychological construct they represent theoretically. Just like for Model 2, Gf and Gc tasks were constrained to the estimates reported in the model with only Gf and Gc to avoid a Heywood case. Contrary to what was expected, Model 3 presented overestimated correlations between latent factors and fit indices indicated that the model did not adequately fit the data. One reason why the model presented poor fit might be due to the weak correlations among ToM tasks. Unlike the Gc and Gf tasks, the ToM tasks all presented poor loading paths and the correlations between the ToM factor and both the Gc and Gf factors showed correlations above 1, suggesting that perhaps the tasks in the ToM factor

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might have overlapping variance with some of the tasks in the other factors. This could also explain the occurrence of the Heywood case. To further understand this, modification indices were used to re-examine Model 3. Modification indices are estimates of the amount by which the chi-square value of a given model would be reduced, and therefore fit increased, if a specific parameter were modified in the model. That is, modification indices allow researchers to understand the ways in which the model fit could improve based on a data-driven approach. Because of this, it is not advisable to use modification indices to specify a model a priori, but rather to examine potential issues in the existing model a posteriori. To better understand the reasons behind the misfit of Model 3, modification indices were examined. Modification indices for Model 3 (see Figure 1) suggested that the fit of the model would improve if the RMET were predicted by both Gf and ToM. This modification considerably improved the fit of the model (see Table 3) and the manifest variables loadings of the ToM latent factor, suggesting that the RMET is contributing variance to both constructs and therefore that the task assesses shared processes across these two constructs.

In general, none of the models presented excellent fit according to the fit indices. Overall, the two-factor model presented the most adequate indices, however there was no difference with the other models. After modifications, Model 3 had slightly better fit indices than the two-factor model.

Exploratory factor analysis

Given the lack of fit of the CFAs, we decided to conduct an exploratory factor analysis (EFA) to understand whether the data were indeed a good representation of the measurement model constructed in the CFAs. A parallel analysis was conducted to determine the number of factors that should be retained from the data. Parallel analysis is a method to determine the

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number of factors that the data form when conducting EFA. The analysis creates a random dataset with the same number of observations and variables as the original data and eigenvalues are computed for the randomly created dataset. Then, the randomly generated eigenvalues are compared to the observed eigenvalues. Because the random eigenvalues mostly represent random noise, only those factors that fall outside the random eigenvalues are considered real and are retained. The parallel analysis indicated that 2 factors should be retained (see Figure 2), rather than 3. This indicates that the third factor is likely so small that it is little more than random noise. However, to obtain a more interpretable EFA, we decided to follow the theoretical framework and extract three factors from the data, corresponding to the three psychological constructs. Because the data were not normal, the chosen estimator was weighted least squares and the rotation estimator was Oblimin², given the correlations among the variables. We specified 3 factors in a factor analysis on all 9 measures. The results of the EFA are in Table 4. All variables with loadings greater than .30 were considered to load on a given factor. The results showed that all measures of Gc loaded adequately under the same factor. However, the Director task and RMET loaded under the Gf factor with the rest of the Gf measures, whereas the SSQ was almost entirely loading on the third factor by itself. These results suggest that in this sample, the ToM measures share processes with another construct, and the tasks seem to be measuring abilities closer to fluid reasoning, rather than a single ToM construct. We next conducted an exploratory network model to better understand the relationships among individual measures.

² Extraction techniques produce factors that are orthogonal and atheoretical. Rotation allows the transformation of the factor loadings, so they become more interpretable. Oblimin is an oblique (as opposed to orthogonal) extraction technique, therefore it allows the factors to be correlated (which is often the case in psychological studies).

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Network Model Analysis

Exploratory Network Model Analysis (NMA) is an alternative analysis that conceptualizes cognitive abilities as interconnected networks composed of interactive processes (see Epskamp & Fried, 2018). In this technique, observed manifest variables are represented by *nodes* and estimated partial correlations amongst them are modeled via connections called *edges*. Therefore, this technique does not need the assumption of a superordinate unobservable factor. NMA can be used in conjunction or as an alternative to latent variable modeling and it presents a number of benefits. For example, because of its exploratory nature, NMA can be used as a powerful visualization tool to explore anticipated or unknown relationships amongst variables in a dataset. NMA is also not constrained by the principle of local independence, unlike traditional latent modeling. The principle of local independence assumes that a latent factor causes any and all covariation among measures of the same construct, and therefore CFA does not allow to observe the variance that manifest variables potentially have in common. Instead, NMA estimates associations between observed variables without assuming that a latent cause is responsible for any and all covariation among measures of the same construct. For this reason, NMA can account for one-to-one relationships among nodes belonging to the same construct while at the same time estimating individual relationships between nodes belonging to different constructs. Finally, NMA estimates associations between all observed variables, therefore it is ideal for modeling cognitive theories that propose overlapping processes among processes within the same construct. In addition, since NMA is an exploratory technique, it can be used on the same data as the CFA.

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In this study, NMA was used to examine tasks that assess ToM, Gf, and Gc and the extent to which they are related among them. NMA was conducted on the correlation matrix extracted from the same 203 participants.

The model was conducted and visualized using the *qgraph* package in R. The method and techniques used in this study are consistent with recommendations from the network modeling tutorial written by Epskamp and Fried (2018). To conduct an NMA, two parameters must be set. Gamma is a hyperparameter that determines whether the model favors a more simple or complex structure per the number of estimated edges. Lambda is a tuning parameter that determines the rigorousness of removal of identified spurious edges that occur due to sample error. The NMA was generated using the graphical least absolute shrinkage and selector operator (gLASSO) regularization method to determine the level of network sparsity. Specifically, the extended BIC method was utilized, which produces simpler models, as gamma is automatically set to its most conservative setting (= .50). Consistent with Epskamp, Lunansky, Tio, and Borsboom (2018), lambda was set to remove spurious (false-positive) edges while at the same time maintaining as many true edges as possible (i.e., .01). The settings used for the network model are designed to facilitate high-specificity during the estimation process, and high-sensitivity regarding network edge-pruning.

Figure 3 shows the results of the network model. First, both Gf and Gc measures show strong partial correlations and form two closely related but independent constructs. One of the tasks, Raven's, seems to have an especially central position in regards to the correlations among all three psychological constructs. While the Gf and Gc tasks cluster together, the ToM tasks do not seem to represent a strong unified cluster. Similar to the findings observed in the CFA, in the NMA the ToM tasks are visually less related to each other than the tasks that form the other

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constructs. In fact, they seem more related to other non-ToM tasks. Specifically, SSQ is slightly more related (.17) to Raven's Progressive Matrices than it is to either of the other ToM tasks (.1 and .06, respectively). In addition, the Director task and the RMET do not share any significant edges with each other, despite loading on the same latent factor in the EFA, suggesting that the relationship between the two measures that were observed in the EFA might be due to their relationship to Raven's. In addition, RMET seems to be more closely related to all the Gf tasks than to any other task, clustering with the Gf construct, rather than with the ToM construct, following the findings of the EFA. Overall, the ToM tasks do not seem to form a uniform construct, and rather seem to share processes with the tasks belonging to the other two constructs.

The results of the NMA show that the three ToM tasks measured in this study are not as strongly related to each other as previously thought, thus questioning the monolithic view of ToM as an overarching construct. In addition, these findings replicate recent research suggesting that there is little coherence among ToM tasks (Warnell & Redcay, 2019). Although the ToM tasks used in this study might be tapping on to *some* dimension of a ToM construct, the findings above suggest that there are clear differences in the processes the tasks are assessing and that they are possibly also measuring other cognitive abilities (such as Gf), in addition to solely ToM. This indicates that more psychometric research is necessary to understand what tasks should be used to assess ToM in adults, but also to understand whether ToM should be interpreted as an independent monolithic construct, rather than a number of sub-constructs.

Discussion

The goal this study was to explore the psychometric properties of ToM tasks compared to fluid intelligence (Gf) and crystallized intelligence (Gc) (Cattell, 1963), as well as to contribute

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to novel theoretical approaches to ToM that view it as a fluid multidimensional construct, rather than as a sole monolithic ability (e.g., Apperly & Butterfill, 2009; Devaine et al., 2014; Schaafsma et al., 2015). As previous research has indicated, the ToM measures were poorly correlated (Warnell & Redcay, 2019), but presented adequate reliability, indicating that although they are reliable, they might not measure entirely the same processes. The CFA showed that none of the measurement models presented excellent fit. Specifically, Model 2 (the two-factor model with a Gf-ToM latent factor and a Gc latent factor) presented similar indices and path loadings to Model 3 (the model with Gf, Gc, and ToM). In addition, Model 3 had to be modified a posteriori based on modification indices due to the model being over specified. These findings suggest that the tasks used to measure ToM were more related to tasks of Gf than previously thought. In fact, the modified CFA model showed that the RMET shares processes with Gf and that a model where RMET was predicted by the ToM and Gf latent factors improved model fit. This was further confirmed by the exploratory factor analysis (EFA) in which the RMET and the Director task loaded under the Gf factor, whereas the SSQ loaded separately, indicating that the ToM tasks tested here do not represent a unified construct. Finally, the NMA presented a description of the individual tasks. Specifically, the network model showed that measures of the well-established Gc and Gf constructs presented strong edges among the corresponding tasks and overall clustered together. However, the edges of the ToM measures were weak, and the nodes were spatially closer to the Gf tasks (especially Raven's), than to each other. Specifically, the RMET seemed related to all Gf tasks but only presented a weak edge with the SSQ, and no edges with the director task. Similarly, the director task shared weak edges with measures of Gc and with the SSQ but not with the RMET, whereas SSQ presented weak edges with both ToM tasks

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and with Raven's. Overall, these findings suggest that at least in samples of neurotypical adults, some of the most common measures of ToM do not adequately represent a single construct.

Recently, the director task has been the subject of intense debate. Specifically, researchers have questioned whether it measures a specific dimension of ToM or rather some other cognitive processes, such as mental rotation or selective attention (Rubio-Fernandez, 2017). In this study, the director task was poorly related to the other ToM constructs but moderately correlated to the Gf and Gc tasks. It is unclear from this study whether the director task constitutes an adequate measure of ToM. It is possible that the director task represents a perspective-taking (cognitive), rather than social-cognitive or social-perceptual dimension of ToM, thus correlating more strongly with fluid reasoning. For example, the SSQ is thought to be a social-cognitive measure whereas the RMET is thought to better capture social-perceptual ability (lower-order perceptual responses). Following this, it is possible that the director task represents yet another aspect of ToM. Another possibility is that the director task does not necessarily measure a ToM-related ability but a different cognitive process. For example, Rubio-Fernandez (2017) has proposed that perhaps the director task could instead be measuring selective attention rather than solely ToM. Specifically, she proposes that the egocentric eye fixations often observed when participants see the critical items in the director task might not necessarily represent participants' egocentric fixations, but rather the use of selective attention to discard the inappropriate item that hinders the listener's ability to carry out an action. This question is still unclear and requires further experimental research, however the findings in this research open the possibility for the director task to be capturing some dimension of ToM while also requiring a degree of attention (largely related to fluid intelligence).

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In general, these findings indicate that there are systematic issues around the conceptualization of ToM. Shaafsma et al. (2015) have pointed out that the use of ToM has been “vague and inconsistent” across the literature and that this provokes deep inconsistencies in the research, both related to the validity of the measures and the claims made via the use of these measures in experimental designs. As discussed in the introduction, there are a number of different levels in which ToM is conceptualized and described, and different terminology is used to refer to the same construct, including cognitive development, social cognition, self-understanding, perception of others, mentalizing, understanding logical inferences, emotion and/or empathy. However, it is unlikely that all these different aspects of cognition correspond to the same umbrella term. More specifically, neurological research has found that there are computational features (i.e., domain-general) as well as content-specific features (i.e., domain-specific) that relate to people’s ability to understand desires, intentions, and beliefs (e.g., Hampton et al, 2008; Behrens et al., 2009; Gallagher & Frith, 2003; Yoshida et al., 2008). Currently, a large part of the field of ToM does not consider these processes when assessing ToM. As an example, in intelligence research, it is often thought that general intelligence encompasses a number of specialized sub-abilities whose positive correlations (i.e., positive manifold) represent a general intelligence construct. For each of these sub-abilities, a number of reliable and valid tests (ideally at least three) are necessary to measure each sub-construct’s validity and reliability. It is possible that ToM follows a similar structure, whereby multiple related but separate sub-abilities form theory of mind. Quesque and Rossetti (2020) first proposed that there are likely several separate mechanisms under the term ToM. For example, the RMET might assess “Facial Expression Categorization”, the SSQ could be a task of “Mental States Ascription”, and so on. To understand whether ToM is the result of multiple sub-abilities, it is

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necessary that multiple ToM measures reflect both general and specific computational processes used when one interprets desires, intentions, and beliefs in social contexts.

This study shows that the current monolithic view of ToM is not supported by the processes measured by ToM tasks. To further explore the multiplicity of sub-abilities that could form ToM, researchers should consider theoretical accounts of ToM that consider the dynamic nature of this ability and employ reliable and valid tests of *each* proposed sub-ability to more adequately capture ToM ability. Conducting this important psychometric work would allow researchers to reconcile developmental, clinical, cognitive and neurological research on ToM.

References

- Abu-Akel, A., & Shamay-Tsoory, S. (2011). Neuroanatomical and neurochemical bases of theory of mind. *Neuropsychologia*, 49(11), 2971-2984.
- 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. (2009). Do Humans Have Two Systems to Track Beliefs and Belief-Like States? *Psychological Review*, 116(4), 953–970.
- Avis, J., & Harris, P. L. (2016). Belief-Desire Reasoning among Baka Children : Evidence for a Universal Conception of Mind. *Society for Research in Child Development*, 62(3), 460–467.
- Baker, C. A., Peterson, E., Pulos, S., & Kirkland, R. A. (2014). Eyes and IQ: A meta-analysis of the relationship between intelligence and “Reading the Mind in the Eyes.” *Intelligence*, 44(1), 78–92. <https://doi.org/10.1016/j.intell.2014.03.001>
- Baron-cohen, S., Leslie, A., & Frith, U. (1985). Does the autistic child have a “theory of mind”? *Cognition*, 21, 37–46.
- Baron-Cohen, S., O’Riordan, M., Jones, R., Stone, V., & Plaisted, K. (1999). A new test of social sensitivity: Detection of faux pas in normal children and children with Asperger syndrome. *Journal of Autism and Developmental Disorders*, 29(5), 407-418.
- Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The “Reading the Mind in the Eyes” Test revised version: A study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychology and*

WHAT IS THEORY OF MIND?

Psychiatry and Allied Disciplines, 42(2), 241–251.

<https://doi.org/10.1017/S0021963001006643>

Behrens, T. E., Hunt, L. T., & Rushworth, M. F. (2009). The computation of social behavior. *science*, 324(5931), 1160-1164.

Bernhardt, B. C., & Singer, T. (2012). The neural basis of empathy. *Annual Review of Neuroscience*, 35, 1-23.

Cattell, R. B. (1963). Theory of fluid and crystallized intelligence: A critical experiment. *Journal of Educational Psychology*, 54(1), 1-22.

Cattell, R. B. (1971). *Abilities: Their structure, growth, and action*. Houghton Mifflin.

Coyle, T. R., Elpers, K. E., Gonzalez, M. C., Freeman, J., & Baggio, J. A. (2018). General intelligence (g), ACT scores, and theory of mind:(ACT) g predicts limited variance among theory of mind tests. *Intelligence*, 71, 85-91.

Cutting, A. L., & Dunn, J. (2002). The cost of understanding other people: Social cognition predicts young children's sensitivity to criticism. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 43(7), 849–860. <https://doi.org/10.1111/1469-7610.t01-1-00047>

Dodell-Feder, D., Lincoln, S. H., Coulson, J. P., & Hooker, C. I. (2013). Using fiction to assess mental state understanding: a new task for assessing theory of mind in adults. *PloS one*, 8(11).

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>

WHAT IS THEORY OF MIND?

Eisenmajer, R., & Prior, M. (1991). Cognitive linguistic correlates of ‘theory of mind’ ability in autistic children. *British Journal of Developmental Psychology*, 9(2), 351–364.

<https://doi.org/10.1111/j.2044-835x.1991.tb00882.x>

Ekstrom, R. B., Dermen, D., & Harman, H. H. (1976). Manual for kit of factor-referenced cognitive tests (Vol. 102). Princeton, NJ: Educational testing service.

Epskamp, S., & Fried, E. I. (2018). A tutorial on regularized partial correlation networks. *Psychological methods*, 23(4), 617.

Epskamp, S., Lunansky, G., Tio, P., & Borsboom, D. (2018). Recent developments on the performance of graphical LASSO networks [Blog post].

Frith, C. D. (2004). Schizophrenia and theory of mind. *Psychological Medicine*, 34(3), 385–389. <https://doi.org/10.1017/S0033291703001326>

Frith, U., & Happé, F. (1994). Language and communication in autistic disorders. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, 346(1315), 97-104.

Gallagher, H. L., & Frith, C. D. (2003). Functional imaging of ‘theory of mind’. *Trends in cognitive sciences*, 7(2), 77-83.

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>

Gerrans, P., & Stone, V. E. (2008). Generous or parsimonious cognitive architecture? *Cognitive neuroscience and theory of mind. British Journal for the Philosophy of Science*, 59(2), 121–141. <https://doi.org/10.1093/bjps/axm038>

WHAT IS THEORY OF MIND?

- Gibson, S., & Ninness, B. (2005). Robust maximum-likelihood estimation of multivariable dynamic systems. *Automatica*, 41(10), 1667-1682.
- Gopnik, A., & Wellman, H. (1994). The 'theory' theory. In L. C. John Tooby, Alan M. Leslie, Dan Sperber, Alfonso Caramazza, Argye E. Hillis, Elwyn C. Leek, Michele Miozzo (Ed.), *Mapping the Mind: Domain Specificity in Cognition and Culture*. Cambridge: Press, Cambridge University.
- Gopnik, A., Meltzoff, A., & Kuhl, P. (2000). The scientist in the crib: What early learning tells us about the mind. William Morrow Paperbacks.
- Gottfredson, L. S. (1997). Why g matters: The complexity of everyday life. *Intelligence*, 24(1), 79-132.
- Greenberg, A., Bellana, B., & Bialystok, E. (2013). Perspective-taking ability in bilingual children: Extending advantages in executive control to spatial reasoning. *Cognitive Development*, 28(1), 41–50. <https://doi.org/10.1016/j.cogdev.2012.10.002>
- Grice, H. (1989). *Studies in the Way of Words*. Harvard University Press.
- Hampton, A. N., Bossaerts, P., & O'Doherty, J. P. (2008). Neural correlates of mentalizing-related computations during strategic interactions in humans. *Proceedings of the National Academy of Sciences*, 105(18), 6741-6746.
- Happé, F. G. E. (1994). An advanced test of theory of mind: Understanding of story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. *Journal of Autism and Developmental Disorders*, 24(2), 129–154. <https://doi.org/10.1007/BF02172093>

WHAT IS THEORY OF MIND?

Happé, F., & Frith, U. (1996). Theory of mind and social impairment in children with conduct disorder. *British Journal of Developmental Psychology*, 14(4), 385–398.

<https://doi.org/10.1111/j.2044-835x.1996.tb00713.x>

Heyes, C. (2014). Submentalizing: I am not really reading your mind. *Perspectives on Psychological Science*, 9, 131–143.

Hughes, C., & Leekam, S. (2004). What are the links between theory of mind and social relations? Review, reflections and new directions for studies of typical and atypical development. *Social Development*, 13(4), 590–619. <https://doi.org/10.1111/j.1467-9507.2004.00285.x>

Hughes, C., & Russell, J. (1993). Autistic children's difficulty with mental disengagement from an object: Its implications for theories of autism. *Developmental Psychology*. <https://doi.org/10.1037//0012-1649.29.3.498>

Kan, K. J., Kievit, R. A., Dolan, C., & van der Maas, H. (2011). On the interpretation of the CHC factor Gc. *Intelligence*, 39(5), 292-302.

Keysar, B. (1994). The illusory transparency of intention: Linguistic perspective taking in text. *Cognitive psychology*, 26, 165-165.

Keysar, B., Lin, S., & Barr, D. J. (2003). Limits on theory of mind use in adults. *Cognition*, 89(1), 25–41. [https://doi.org/10.1016/S0010-0277\(03\)00064-7](https://doi.org/10.1016/S0010-0277(03)00064-7)

Kline, R. B. (2015). *Principles and practice of structural equation modeling*. Guilford publications.

Kovacs, K., & Conway, A. R. (2016). Process overlap theory: A unified account of the general factor of intelligence. *Psychological Inquiry*, 27(3), 151-177.

WHAT IS THEORY OF MIND?

- Lawson, J., Baron-Cohen S., and Wheelwright, S., (2004). Empathising and systemising in adults with and without Asperger Syndrome. *Journal of Autism and Developmental Disorders*, 34, 301-310
- 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), 1–21.
<https://doi.org/10.1017/S0305000998003626>
- Leekam, S. R., & Prior, M. (1994). Can Autistic Children Distinguish Lies from Jokes? A Second Look at Second - order Belief Attribution. *Journal of Child Psychology and Psychiatry*, 35(5), 901-915. <https://doi.org/10.1111/j.1469-7610.1994.tb02301.x>
- Legg, E. W., Olivier, L., Samuel, S., Lurz, R., & Clayton, N. S. (2017). Error rate on the director's task is influenced by the need to take another's perspective but not the type of perspective. *Royal Society Open Science*, 4(8), 170284.
- Leslie, A. (1994). ToMM, ToBy, and Agency: Core architecture and domain specificity. In L. C. John Tooby, Alan M. Leslie, Dan Sperber, Alfonso Caramazza, Argye E. Hillis, Elwyn C. Leek, Michele Miozzo (Ed.), *Mapping the Mind: Domain Specificity in Cognition and Culture* (119–148).
- Leslie, A. M., & Polizzi, P. (1998). Inhibitory processing in the false belief task: Two conjectures. *Developmental Science*, 1(2), 247–253. <https://doi.org/10.1111/1467-7687.00038>
- McGrew, K. S. (2009). CHC theory and the human cognitive abilities project: Standing on the shoulders of the giants of psychometric intelligence research. *Intelligence*. 37(1), 1-10.

WHAT IS THEORY OF MIND?

- Milligan, K., Astington, J. W., & Dack, L. A. (2007). Language and theory of mind: Meta-analysis of the relation between language ability and false-belief understanding. *Child Development*, 78(2), 622–646. <https://doi.org/10.1111/j.1467-8624.2007.01018.x>
- Naito, M., Komatsu, S., & Fuke, T. (1994). Normal and autistic children's understanding of their own and others' false belief: A study from Japan. *British Journal of Developmental Psychology*, 12(3), 403–416. <https://doi.org/10.1111/j.2044-835x.1994.tb00643.x>
- Navarro, E., Goring, S. A., & Conway, A. R. (2021). The relationship between theory of mind and intelligence: A formative g approach. *Journal of Intelligence*, 9(1), 11.
- Oakley, B. F., Brewer, R., Bird, G., & Catmur, C. (2016). Theory of mind is not theory of emotion: A cautionary note on the Reading the Mind in the Eyes Test. *Journal of Abnormal Psychology*, 125, 818–823. doi:10.1037/abn0000182
- Obhi, S. (2012). The amazing capacity to read intentions from movement kinematics. *Frontiers in Human Neuroscience*, 6, Article 162. doi:10.3389/fnhum.2012.00162
- Piaget, J., & Inhelder, B. (1956). *The child's concept of space*. Routledge & Paul.
- Poletti, M. et al. (2012) Cognitive and affective Theory of Mind in neurodegenerative diseases: neuropsychological, neuroanatomical and neurochemical levels. *Neurosci. Biobehav. Rev.* 36, 2147–2164
- Premack, D., & Woodruff, G. (1978). Chimpanzee theory of mind. *Behavioral and Brain Sciences*, 4(1978), 515–526.
- Preston, S. D., & De Waal, F. B. (2002). Empathy: Its ultimate and proximate bases. *Behavioral And Brain Sciences*, 25(1), 1-20.

WHAT IS THEORY OF MIND?

- Quesque, F., & Rossetti, Y. (2020). What do theory-of-mind tasks actually measure? Theory and practice. *Perspectives on Psychological Science*, 15(2), 384-396.
- Raven, J. C. (1938). *Progressive Matrices: Sets A, B, C, D, and E*. University Press, published by HK Lewis.
- Rubio-Fernández, P., & Glucksberg, S. (2012). Reasoning about other people's beliefs: Bilinguals have an advantage. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 38(1), 211.
- Samson, D., Apperly, I. A., Braithwaite, J. J., Andrews, B. J., & Bodley Scott, S. E. (2010). Seeing it their way: evidence for rapid and involuntary computation of what other people see. *Journal of Experimental Psychology: Human Perception and Performance*, 36(5), 1255.
- 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>
- Sebanz, N., & Shiffrar, M. (2009). Detecting deception in a bluffing body: The role of expertise. *Psychonomic Bulletin & Review*, 16(1), 170-175.
- Sodian, B. (1991). The development of deception in young children. *British Journal of Developmental Psychology*, 9(1), 173–188. <https://doi.org/10.1111/j.2044-835x.1991.tb00869.x>
- Spearman, C. (1904). General Intelligence, Objectively Determined and Measured. *American Journal of Psychology*, 15, 201-93.
- Spearman, C. E. (1927). *The abilities of man* (Vol. 89). New York: Macmillan.

WHAT IS THEORY OF MIND?

- Sperber, D., & Wilson, D. (1995). *Relevance: Communication and cognition*. Cambridge, MA: Harvard University Press.
- Tardif, T., & Wellman, H. M. (2000). Acquisition of mental state language in Mandarin- and Cantonese-speaking children. *Developmental Psychology*, 36(1), 25–43.
- Thurstone, L. L. (1938). *Primary mental abilities* (Vol. 119). Chicago: University of Chicago Press.
- Van Overwalle, F., & Baetens, K. (2009). Understanding others' actions and goals by mirror and mentalizing systems: a meta-analysis. *Neuroimage*, 48(3), 564-584.
- van Veluw, S. J., & Chance, S. A. (2014). Differentiating between self and others: an ALE meta-analysis of fMRI studies of self-recognition and theory of mind. *Brain imaging and behavior*, 8(1), 24-38.
- Warnell, K. R., & Redcay, E. (2019). Minimal coherence among varied theory of mind measures in childhood and adulthood. *Cognition*, 191, 103997.
- 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.
- Wolf, E. J., Harrington, K. M., Clark, S. L., & Miller, M. W. (2013). Sample size requirements for structural equation models: An evaluation of power, bias, and solution propriety. *Educational and Psychological Measurement*, 73(6), 913-934.
- Yoshida, W., Dolan, R. J., & Friston, K. J. (2008). Game theory of mind. *PLoS computational biology*, 4(12), e1000254.

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Table 1 - *Descriptive Statistics.*

Variables		Latent Construct	<i>N</i>	<i>M</i>	<i>SD</i>	Skew	Kurtosis	Range	<i>α</i>
1. Ravens Progressive Matrices	RV	Fluid Reasoning (Gf)	203	9.28	3.84	-.89	-.78	0-18	.81
2. Letter Series	LS		203	6.77	2.59	.05	-.40	0-10	.77
3. Number Series	NS		203	9.40	3.07	-.26	-.61	0-15	.85
4. General Knowledge	GK	Crystallized intelligence (Gc)	203	7.09	2.26	-.99	.34	0-10	.79
5. Synonyms Task	SYN		203	5.99	2.52	-.63	-.33	0-10	.86
6. Antonyms Task	ANT		203	6.16	2.15	-.48	-.68	0-10	.85
7. Director Task	DT	Theory of Mind (ToM)	203	.59	.39	-.48	-1.61	0-1	.66
8. Reading the Eyes in the Mind	RME		203	30.14	4.02	-.92	1.12	0-36	.72
9. Short Stories Questionnaire	SSQ		203	10.15	3.33	-.20	-.24	0-20	.72

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Table 2. *Correlations among variables.*

Variable	1	2	3	4	5	6	7	8
1. General Knowledge	-							
2. Synonyms	.50	-						
3. Antonyms	.43	.66	-					
4. Letter Series	.17	.19	.18	-				
5. Ravens	.52	.38	.44	.36	-			
6. Number series	.39	.33	.34	.49	.56	-		
7. SSQ	.18	.15	.15	.16	.33	.14	-	
8. RMET	.33	.32	.32	.30	.41	.39	.24	-
9. Director task	.16	.16	.16	.18	.32	.27	.18	.17

Note. All correlations were significant at $p = <.05$

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Table 3. *Model Fit Indices for All CFA Models.*

Fit Indices	χ^2	df	χ^2/df	CFI (TLI)	RMSEA	SRMR
Recommended fit (Kline, 2015)			≤ 2	$\geq .90$	$\leq .08$	.05 - .10
Model 1: One predictor	164.19	28	5.86	.73 (.65)	.16	.149
Model 2: GF + TOM	95.51	32	2.98	.88 (.86)	.09	.157
Modified Model 3: GF + GC + TOM	92.86	31	2.99	.87 (.85)	.09	.161
Network model	21.46	11	1.95	.98(.92)	.068	.033

Note. It is common that the Network model presents excellent fit, nevertheless, because the network model is an exploratory analysis, it is not possible to directly compare it to the CFAs.

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Table 4. *Exploratory Factor Analysis Loadings for 3 factors. Tasks that loaded at >.30 were considered to load onto the same factor.*

Tasks	Factor 1 - Gc	Factor 2 - Gf	Factor 3 - ToM
1. Letter Series		.60	
2. Ravens		.55	
3. Number Series		.87	
4. Synonyms	.82		
5. Antonyms	.81		
6. General Knowledge	.49		
7. Director Task		.31	
8. SSQ			.84
9. RMET		.31	

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Figure 1. Model 1 (top left): One-factor model. Model 2: Two-factor model (top right). Model 3: Three-factor model with modifications (bottom). Standardized factor loadings are presented. All loadings were within adequate range ($>.30$) with the exception of Raven's. ANT = Antonyms, SYN = Synonyms, GEN = General Knowledge, DT = Director task, SSQ = Short stories questionnaire, RME = Reading the eyes in the mind test, NUM = Number series, LET = Letter series, RAV = Raven's progressive matrices.

Figure 2. Parallel analysis. The black line represents the number of factors extracted from the dataset based on eigenvalues. The blue line represents the number of random factors retained from the random eigenvalues. The overlap of the blue and black line at factor 3 suggests that only factor 1 and 2 should be retained (Adjusted Eigenvalue 1 = 2.74, Adjusted Eigenvalue 2 = .29).

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Psychometric Network Analysis

Figure 3. Network model. Nodes represent the tasks measured in the study. Edges represent the partial correlations among measures. Colors represent the theoretical construct they assess.

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