How Many Dimensions of Mind Perception Really Are There?

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Abstract

Previous research suggests that people's folk conception of the mind is organized along a few fundamental dimensions; but studies disagree on the exact number of those dimensions. With an expanded item pool of mental capacities, variations of question probes, and numerous judged agents, four studies provide consistent evidence for three dimensions of perceived mind: *Affect (A), Moral and Mental Regulation (M)*, and *Reality Interaction (R)*. The dimensions are not simply bundles of semantically related features but capture psychological functions of the mind—to engage with its own processes, with other minds, and with the social and physical world. Under some conditions, two of the three dimensions further divide: *A* divides into negative and positive (social) affect, and *M* divides into moral cognition and social cognition. We offer a 20-item instrument to measure people's 3- and 5-dimensional representations of human and other minds.

Keywords: anthropomorphism; social cognition; theory of mind; morality; principal component analysis; robots.

Introduction

A significant question for cognitive science is how humans conceptualize agents and their minds. Research in cognitive development has taught us that features such as self-propelled motion, contingent response, and eyes convince infants that they are interacting with a special category of thing: what we call agents (Johnson, 2000; Premack, 1990). Once infants identify agents, they follow their gaze, imitate them, make inferences about their goals, and eventually ascribe complex mental states to them. Over the childhood years, children develop ever more differentiated conceptions of mental states, such that, for example, a goal concept divides into desires and intentions, emotion concepts of good and bad differentiate into a staggering number of different affective terms, and moral dispositions of *mean* and *nice* turn into sophisticated assessments of moral character. In short, we know that humans grow up to have deep-seated expectations about other humans' mental, social, and moral capacities (Hamlin, 2013; Malle, 2005; Tomasello, 2003). But do people treat these capacities as just one long list? Or is there an underlying conceptual organization to uncover? Only empirical studies can answer this question.

Dimensions of Mind

Despite humans' rich representations of mental capacities, previous work indeed suggests that there are fundamental dimensions by which humans organize these capacities. But research diverges on the number of those dimensions.

D'Andrade (1987) considered six categories of mental states: perception, belief, emotions, desires, intentions, and self-control. Interviews suggested that people indeed make distinctions among these classes, but no methods were applied to assess whether the researcher-imposed category number actually captured people's own conceptual structure. Haslam et al. (2008) rearranged d'Andrade's categories, combining intentions and self-control but separating primary from secondary emotions. Through multi-dimensional scaling, they were able to reduce these categories into a two-dimensional space: perception vs. all other categories; thoughts and intentions vs. desires and emotions.

Gray, Gray, and Wegner (2007) offered the simple and elegant proposal that humans distinguish mental states along two dimensions: Experience and Agency. The empirical evidence for this two-dimensional structure was a principal component analysis (PCA) of 18 mental capacities, which people evaluated in 13 different agents. This proposal had seminal impact in research on dehumanization, moral judgment, objectification, and human-robot interaction.

The interpretation of what makes up the two-dimensional space of Experience and Agency is, however, not entirely clear. Even though each dimension in Gray et al.'s study had several items that loaded high on its dimension and low on the other dimension, there were numerous items that loaded high on both dimensions, showing barely distinguishable loadings (see Table 1). Moreover, although the highest-loading Experience items are quite coherent, incorporating physiology and affect, the highest-loading Agency items are more heterogeneous, including planning and self-control as agentic capacities but also emotion recognition, memory, and morality, which are less obviously agentic.

Table 1: Loading matrix for PCA of 18 mental capacities by Gray, Gray, and Wegner (2007).

	Experience	Agency	*Difference*
Hunger	0.98	0.15	*0.83*
Fear	0.93	0.31	*0.62*
Pain	0.89	0.42	*0.48*
Pleasure	0.85	0.51	*0.34*
Rage	0.78	0.59	*0.20*
Desire	0.76	0.64	*0.12*
Joy	0.68	0.61	*0.07*
Personality	0.72	0.68	*0.04*
Consciousness	0.71	0.69	*0.03*
Pride	0.71	0.69	*0.03*
Embarrassment	0.70	0.65	*0.05*
Thought	0.68	0.73	*0.05*
Communication	0.66	0.74	*0.08*
Planning	0.55	0.82	*0.27*
Emotion recognition	0.54	0.83	*0.29*
Morality	0.36	0.93	*0.57*
Memory	0.33	0.91	*0.58*
Self-control	0.18	0.97	*0.79*

Note: Clearly and highly loading items on each dimension are color-marked. Items in the middle show almost no difference in their loadings on the two dimensions.

Replications by Takahashi, Ban, and Asada (2016) and Weisman, Dweck, and Markman (2017) confirmed the Experience dimension with its familiar marker items but continued to find several middling items (in particular, personality, consciousness, pride, and embarrassment) as well as considerable heterogeneity on the Agency dimension.

Other studies suggest that people may conceptualize the mind in three rather than two dimensions. Kozak, Marsh, & Wegner (2006) applied a PCA to 10 items similar to those in Gray et al. (2007) and identified three dimensions, labeled Emotion (feelings, pain, emotion, pleasure; hence similar to Experience), Intention (doing things on purpose, planning, goals; hence similar to Agency), and Cognition (conscious, memory, thought). Using a larger item pool of 40 mental capacities, Weisman et al. (2017) found three major dimensions, which they labeled Body (related to Experience), Heart (primarily covering emotions), and Mind (perceptions, cognition). Thus, Agency did not emerge in this structure.

The Present Investigation

How do people represent and conceptualize capacities of the mind, and what number of fundamental dimensions underlie this representation? To answer this question, we need a comprehensive item pool. As noted by several authors (Haslam et al., 2008; Weisman et al., 2017), the original 18 capacities used by Gray et al. had limitations (e.g., perception items were missing, some categories were represented by single items). Only an expanded item pool and replications across different pools can reveal the dimensions of mind perception. Across four studies, we therefore analyzed varied item pools that represent capacities of perception, cognition, emotion, agentic control, learning, communication, and social-cognitive and social-moral capacities, all represented by multiple items. For consistency, one constraint was to include items about which one could explicitly ask, "Is the agent capable of X?" This question disfavors highly specific states (e.g., feeling disrespected) and abstract words such as "personality." Across studies we experimented with different items and formulations in order to gain confidence in the clusters of capacities that best represent the dimensions of mind perception. In analogy to cognitive theories of concepts, we conceive of such dimensions as bundles of capacities typically represented together; if similar dimensions of mind reappear across variations in items and samples, we can be more confident in the underlying dimension in question.

The conceptual structure of mental capacities is difficult to study when asking participants to indicate how much of each capacity human adults have, as the ratings will tend to be at ceiling. Following other authors, we increased judgment variance by including nonhuman agents, which arguably lack some of the capacities. Particularly useful targets are robot agents, as the reality of their minds is a wide open question. Robots are like a projection screen for people's general conceptions of mind, so these conceptions may emerge particularly well when people judge robots' minds.

In the present project, we thus investigated how many dimensions may be fundamental in people's representations of various agents' minds. We report on a first study in detail to lay out our methodological approach and major results, then summarize the results of three additional studies that varied the pool of capacities and tested different question probes and judged agents. We then report on a final study that relied on an integrated item pool derived from multiple previous data sets so as to represent the full conceptual range of people's perceptions of mind. Based on these results, we offer a parsimonious multi-dimensional measurement scale of mental capacities applicable to humans and other agents.

For instructions, item formulations, and detailed results tables, please see the Supplementary Materials (SM), which can be found at http://bit.ly/SA_MindCapacities.

Study 1

Methods

To generate a broad item pool we took Gray et al.'s item pool as a starting point and classified them into four rough groups: physiological (hunger, pain), affective (joy, pride, desire, pleasure, rage, fear, emotion recognition), cognitive (remember, planning, thinking), and agentic (self-control, communicate). Taking Sytsma and Machery (2010), Haslam et al., (2008), and d'Andrade (1987) as inspiration, we added two items to the agentic group (choosing freely, imitating others) and two to the physiological group (sleep, thirst) to make them four each. We retained six of the affective items (reformulating emotion recognition into empathy); decomposed "thinking" into more concrete cognitive capacities (believing, knowing, deliberating, reasoning) to make the total of cognitive items six as well. We added four perceptual items (perceive, see or hear, taste or smell, vividly imagine) and differentiated morality into four items (moral obligations, having values, deserving praise or blame, deserving punishment). We omitted the two most abstract items of personality and consciousness, as well as embarrassment, all of which were undifferentiated in Gray et al. (see Table 1).

Participants were 160 undergraduate students from a private university in the Northeast United States; no demographic information was collected. In a one-page survey, each participant rated one of 16 agents (e.g., human adult, robot, rabbit, chimpanzee, similar to Gray et al.'s agents, but also group agents, such as a city council and a large company). Twelve participants were excluded, two how provided illegible ratings, ten who had a rating range of 0 or 1 on the 8-point scale, leaving 148 participants for analysis. Fewer than 1% of individual item ratings were mising and were replaced by their respective sample means.

On the top of the survey page, the agent was introduced, and each statement repeated the agent description (e.g., "The most advanced robot in 2050 can feel joy," "…can have values," "can perceive things.") The 28 statements were listed in random order with rating scales next to each statement. The column header for the ratings contained the question, "Is this true?", and the anchors for the ratings scales were "Definitely NOT true" (0) and "Definitely true" (7).

We used Principal Component Analysis (PCA) to analyze the correlation matrix resulting from the 148 (participants) × 28 (capacities) raw data, ignoring agent type, which served as a source of meaningful judgment variability. One challenge of PCA is that multiple criteria are available to decide how many components one should extract. Common heuristics include Kaiser's (1960) rule ("K1"; retain components with eigenvalue $\lambda > 1$) and Cattell' (1966) scree test (on the scree plot, draw a linear fit line from the smallest components upward and retain those that lie above the line). However, with larger variable sets, K1 extracts too many factors, and the scree test can suffer from ambiguity. Zwick and Velicer (1986) compared these and more sophisticated criteria and concluded that Parallel Analysis (PA) represents the best approach. This procedure (Buja & Eyuboglu, 1992) recognizes that even for a population of perfectly uncorrelated variables, any sample from it will contain correlations among variables that a PCA would pick up and turn into spurious components with $\lambda > 1$. By assessing hundreds of random permutations of the actual data matrix, PA estimates what number and size of spurious components one can expect if the original data were in reality uncorrelated (i.e., all λs = 1). The recommendation is then to retain those components from the actual PCA whose eigenvalues are at or above the corresponding spurious ones.

Results

The K1 and scree criteria suggested 4 components, but the fourth was very weak, $\lambda = 1.04$. PA suggested 3 components. The three-component solution accounted for 67.3% of the total variance and was interpretable after rotation (see Table 2). The first component had 25.1% explained variance (EV) and grouped 11 items with loadings $l \geq .60$, both social-moral capacities (shame, values, obligations, praise) and cognitive control capacities (believing, deliberating, choosing). We label this component *Moral and Mental Regulation* (*M*). The second component (22.7% EV) grouped 8 physiological and affective items together (e.g., hunger, pain, taste, anger, joy); we label this component *Affect* (*A*). The third component (15.6% EV) grouped perceptual, cognitive, and some interaction items (perceive, remember, know, communicate), which we label *Reality Interaction* (*R*).

To illustrate in a heuristic way how much a loading matrix approximates *simple structure* (D'Agostino & Russell, 2014) we counted items with "errand loadings"—defined as $l > .316$ (i.e., > 10% of variance) on components that are not the item's primary component (where it loads most highly). Of all possible 84 loadings, 15 (18%) were errand in this way. To examine the possibility of component correlations we applied oblique rotation to all 28 items, which reduced errand loadings to 11% (which is expected for oblique rotations). This solution showed small correlations between *A* and *M* (r = .21) and between *A* and *R* (r = .18) and a more notable one between *M* and *R* (r = .42). Thus, Agency from Gray et al.'s (2007) two-dimensional model broke into two dimensions that may, however, not be entirely independent.

Discussion

Study 1 recovered the Experience dimension from previous studies (here, labeled *Affect*), but by expanding the item pool to represent domains of perception, cognition, and morality we uncovered a third dimension of mind perception. Specifically, the Agency dimension (arguably multi-faceted to begin with) broke into two distinct dimensions. The original Gray et al. items of morality, empathy, and planning became part of a *Moral and Mental Regulation* dimension, whereas items of perception, cognition, and communication constituted a *Reality Interaction* dimension. These two dimensions can be treated as orthogonal, but in an oblique rotation they show a cleaner simple structure with a nontrivial correlation.

Importantly, the items that define each dimension hang together not simply due to semantic similarity (e.g., moral and mental regulation are semantically distinct). The items constitute their components in psychologically meaningful ways. For example, *R* refers to a progression of information processing from perceiving to knowing to remembering to communicating. Likewise, *M*'s cognitive facet forms a sequential process: we believe things, then deliberate, then choose and plan; and *M*'s moral facet refers to empathy, obligations, and values as action regulation and also includes responses to one's moral (or immoral) behavior in the form of pride or shame on the inside, praise or blame from the outside. Thus, moral and mental regulation occurs in a dynamic mental and social context and is the culmination of a complex and nuanced picture of the social-moral mind.

Table 2. Loading matrix of PCA on 28 items in Study 1.

	Moral & Mental Regulation	Affect	Reality Interaction
can feel shame or pride	0.79	0.35	0.20
can have values	0.76	0.10	0.26
may deserve praise or blame	0.76	0.18	0.04
may deserve punishment	0.74	0.12	-0.06
has moral obligations	0.71	0.02	0.28
can have empathy for others	0.68	0.23	0.21
can believe certain things	0.64	0.22	0.37
can deliberate	0.64	-0.01	0.49
can vividly imagine things	0.63	0.39	0.30
can plan for the future	0.63	-0.19	0.41
can choose freely	0.61	0.29	0.31
can feel thirsty	0.12	0.91	-0.04
can be in physical pain	0.09	0.88	-0.01
has a need for sleep	0.08	0.86	0.01
can feel hunger	0.08	0.82	0.05
can taste or smell things	-0.07	0.80	0.32
can experience pleasure	0.34	0.75	0.18
can be angry	0.45	0.64	0.08
can feel joy	0.46	0.62	0.18
can see or hear things	-0.08	0.60	0.59
can want certain things	0.42	0.51	0.28
can communicate with others	0.10	0.30	0.73
can remember things	0.11	0.09	0.67
can perceive things	0.37	0.12	0.66
can reason logically	0.50	-0.18	0.64
can know certain things	0.52	-0.02	0.63
can exercise self-control	0.35	0.20	0.61
can imitate others	0.46	0.03	0.47

Study 2

Encouraged by the effects of enlarging the item pool of mental capacities we further expanded the pool by rewriting several items for clarity and adding 30 new ones, for a total of 54, to represent (with several items each) physiology, affect, moral competence, social cognition, thinking and cognitive control, perception, learning, and communication. We thus allowed for the possibility of components from Study 1 breaking apart even further (thus pointing to more dimensions) or else clustering reliably around the same three dimensions, despite new item content.

We probed mental capacity ascriptions to an average adult, a two-year-old child, a cat, and a home care robot. Any given participant made judgments for only one agent. Of 459 participants recruited online via Amazon Mechanical Turk, 17 provided fewer than a quarter of ratings and 27 had a rating range of 0 or 1 (on an 8-point scale), leaving 415 participants for analysis. Of these, 45.3% identified as female, 53.5% as male. They ranged in age from 18 to 74 (M = 35.5, SD = 11.8), and 52% of them had completed a bachelor's degree or higher. In the principal component analysis (PCA), the K1 and scree criteria suggested five components, but PA suggested three. We considered a 4-component solution, but the fourth component accounted for less than 5% of the variance and had only three items with $l > .50$ and almost as high cross-loadings on other components. The 3-component solution (see Table SM3) explained 65.2% of the variance.

Table 3. Loading matrix of Orthogonal PCA on 38 selected items in Study 1

	Affect	Moral & Mental Regulation	Reality Interaction
Being hungry	0.91	-0.17	0.11
Feeling pain	0.91	-0.16	0.10
Feeling pleasure	0.91	-0.04	0.14
Feeling panic	0.90	-0.02	0.16
Feeling happy	0.90	-0.01	0.12
Having emotions	0.88	0.06	0.13
Getting angry	0.88	-0.02	0.19
Loving specific people	0.87	0.00	0.21
Having intense urges	0.86	0.00	0.17
Smelling and tasting things	0.83	-0.11	0.25
Having desires	0.83	0.09	0.18
Feeling stress	0.82	0.13	0.10
Disliking people	0.80	0.09	0.23
Feeling gratitude	0.72	0.39	0.04
Feeling compassion	0.72	0.38	-0.06
Vividly imagining things	0.65	0.33	0.11
Feeling sexual arousal	0.63	0.28	-0.03
Providing reasons for their actions	-0.18	0.87	0.04
Planning for the future	-0.02	0.86	0.09
Upholding moral values	0.25	0.85	-0.07
Understanding a person's goals	0.13	0.85	-0.03
Explaining their decisions to others	-0.22	0.84	0.03
Setting goals	-0.05	0.83	0.05
Praising moral actions	0.18	0.81	-0.07
Disapproving of immoral actions	0.29	0.79	-0.07
Reasoning logically	-0.21	0.78	0.24
Understanding others' minds	0.26	0.77	-0.03
Taking a person's visual point of view	0.02	0.74	0.02
Inferring what a person is thinking	0.12	0.74	0.09
Deliberating before acting	0.03	0.73	0.30
Exercising self-control	0.17	0.72	0.08
Following norms	0.11	0.70	0.10
Communicating verbally	-0.20	0.64	0.26
Moving on their own	0.20	0.07	0.78
Seeing and hearing the world around them	0.31	-0.03	0.74
Learning by imitation	0.12	0.27	0.63
Communicating nonverbally	0.31	0.18	0.63
Feeling temperature, touch, etc.	0.49	-0.01	0.62

The first component had 21 strongly loading items ($l \geq .60$), dominated by affective states (pain, hunger, stress), emotions (angry, compassion, gratitude), and social relations (loving people, relationships). We see here again the *Affect* dimension from Study 1, supplemented by social facets. The second component had 17 strongly loading items, capturing moral capacities (e.g., upholding values, praising moral actions), social cognition (e.g., understanding others' minds, their goals, and thinking), and cognitive control (e.g., setting goals, providing reasons for one's actions). We see here the *Moral and Mental Regulation* dimension, with enhanced social-cognitive facets. The third component included 7 strongly loading items, featuring seeing, learning, moving, and communicating, confirming the *Reality Interaction* dimensions of Study 1. The remaining items loaded more weakly or on multiple components, producing the bulk of the 15% errand loadings. Removing weaker and cross-loading items led to a set of 38 items that had only 2% errand loadings, yielding a clean three-dimensional structure (see Table 3). Oblique rotation on all items also reduced errand loadings (12%) and showed modest correlations (the highest between M and R at .30). Removing 12 weak items reduced errand loadings to 6% and the $M*R$ correlation to .26 (see Table SM4).

In sum, we replicated a three-dimensional structure of mind perception. The previously labeled Experience factor is well represented by the *Affect* dimension, which includes social emotions and relations. The previously labeled *Agency* dimension again separated into one of *Social-Moral and Mental Regulation* and the dynamic dimension of *Reality Interaction* (perception, learning, to action).

Studies 3a and 3b

Now we report on two samples that we collected in continuation of a related project in which we focused on mental capacities people *would like to* see in robots, thus a slightly different question from the one in Studies 1 and 2. However, these studies had a considerable impact on our last stage of item selection and so we describe them briefly.

Though the rating means may differ between inferred capacities of various agents and desired capacities of robots in particular, the dimensional structure should still be similar. We presented participants in Study 3a (N = 100) with 60 mental capacity items largely the same as in Study 2, and participants in Study 3b (N = 99) with a selection of 41 items. The two samples were recruited online from Amazon Mechanical Turk and had highly similar demographics as those in Study 2. We invited people to indicate which capacities they would want or not want in "the most advanced home robot" they could imagine, defined as an autonomous robot that takes care of older adults or children and does household chores.

In Study 3a, K1 and scree criteria suggested 6 to 13 components, but PA suggested 3 to 4, so we examined both solutions. Each one yielded R (perception, cognition, learning) and A (but solely negative affective states). In the 4-component solution, the third and fourth component both contained social emotions, relations, and hints of morality, and it was difficult to find a distinction between the two components. Indeed, in the 3-component solution the two combined into a dimension similar to *M* (but populated more with positive social emotions and relations than we saw in Studies 1 and 2), and errand loadings decreased from 14% to 11%. Oblique rotation reduced errand loadings to 6%, with the highest correlation between *M* and *R* at $r = .39$. Overall, the three-dimensional structure from Studies 1 and 2 was replicated even when probing people's desired capacities for robots. However, *A* became negative and *M* took on positive social emotions that had loaded on *A* in Studies 1 and 2. We will return to this trend in Study 4.

For Study 3b, we reduced the number of items to 41, omitting eight items with very low loadings in Study 3a, five that were semantically redundant with other items in the set, and two that plainly do not apply to robots (physiology, hunger). Four items were omitted due to a clerical error. K1 and scree criteria suggested 5 to 8 components, but PA suggested only 2 to 3. The 2-component solution dispersed familiar *M* items across both other item sets, making the solution difficult to interpret, even from an Experience-Agency perspective (see Table SM6). The 3-component solution showed three strong components after rotation (15.3% to 23.1% EV), replicating *A* (solely negative affective states), *M* (social emotions, relations, and moral capacities), *R* (perception, decision making, communication, and some stray social cognition), with 20% errand loadings. Oblique rotation improved the errand rate to 10%, with *M* and *R* correlating at .48, and at .40 after removal of very weak items.

Taken together, the two studies on desired mental capacities of robots largely supported a three-dimensional structure of mind perception. However, Study 3a raised the possibility of a split of *Affect* into a positive and negative facet, which we decided to explore further in Study 4. However, the primary purpose of Study 4 is explained next.

Integrative Item Selection

After we completed this first set of studies, Weisman et al. (2017) published a series of studies that suggested three dimensions of mind comparable to our three, thus providing further confidence in a three-dimensional model of mind perception. However, their components (to which we will refer as W1 to W3) differed somewhat from ours in item composition and in the authors' interpretation. W1 was labeled "Body," highlighting its physiological items, but almost half of its high-loading items refer to basic emotions (calm, angry, fear, safe). W2 was labeled "Heart," also highlighting emotion items (embarrassed, pride, love), but these emotions are social, and other items in this component also hinted at moral capacities (telling right from wrong, guilt) and cognitive control (thoughts, intentions, self-restraint), casting doubt on the labeling of "Heart." W3 was nonspecifically labeled "Mind," but it encompassed perception, memory, reason, and communication.

Aside from interpretational ambiguities, some of the discrepancies between Weisman et al.'s and our three-dimensional model can be explained by item selection, so to address this possibility, we collated the 62 items used at least twice across Gray et al., Weisman et al., Malle and Thapa Magar (2017), and our data reported so far. We tracked each item's loadings within the corresponding components across data sets. This correspondence was straightforward for our three components and Weisman et al.'s. (*A* ~ W1, *M* ~ W2, *R* ~ W3). Gray et al.'s first component clearly corresponds to *A* and all but one of the other reused items fit under *M*. We reanalyzed the data from Malle and Thapa Magar (2017) with the same criteria as we had applied in the present studies and found better support for a three-dimensional structure (rather than the originally reported four-dimensional structure), and the three dimensions were very similar to the present *A-M-R* structure. (See the resulting compilation matrix in Table SM8.)

We identified candidate items by using two inclusion heuristics: (a) A *differential loading* index was the averaged loading in a given component minus the averaged loadings on the other two components; we aimed for this difference to be at least .30. (b) An item's *number of replications* on the same component with a loading $l > .50$; we aimed for two or more such replications. We also used two exclusion heuristics: (c) content was already covered by another item; (d) item had substantial loadings on two components. We made specific attempts to retain enough items in the content domains of agency, perception, social emotions, and social cognition. The resulting item pool included 12 items targeting *A* (physiology, basic emotions and motivation), 20 targeting *M* (perhaps the most diverse dimension with social emotions, moral competence, social cognition, and cognitive control), and 10 targeting *R* (perception, learning, communication, action).

Study 4

In light of possible differences between the dimensional structure of inferred and desired capacities, which had arisen in Studies 3a and 3b, we asked one group of participants to *infer* the capacities of either an average adult, a two-year-old child, or one of two kinds of robots—a home robot or a military robot; and we asked a second group to indicate the capacities they *would like* a home or military robot to have. Of 495 participants recruited from Amazon Mechanical Turk, 11 entered no ratings, 2 entered fewer than half, and 19 had a rating range of 1 or 0 on an 8-point scale, leaving an *N* of 463, again with very similar demographics as those in Study 2.

We applied PCA to each question condition separately. In the inferred capacity group ($N = 304$), K1 and scree suggested three to four components, while parallel analysis suggested three, which were easily interpretable as the *A-M-R* structure (71.1% EV, 19% errand loadings). After removing only four items with $l < .60$, errand loadings decreased to 10% (73.1% EV). An oblique rotation yielded virtually not change, with *M* and *R* showing a small correlation of .32.

In the desired-capacity condition ($N = 159$), K1 suggested eight components, the scree plot suggested six and especially showed a fourth and fifth component distinctly separating from the lower ones. Parallel analysis suggested three, but this solution (EV = 51.7%) was not interpretable as it intermixed items that in other studies consistently loaded in the familiar *A, M,* and *R* dimensions. When allowing a fourth component, the Affect items split into a negative set (e.g., anger, stress, pain) and a positive set (e.g., happy, gratitude, friendships), the moral items formed their own component, but *M* and *R* items remained intermixed. When allowing a fifth component, finally, rotation produced five evenly strong components (EVs = 10.6% to 13.2%), with *M* and *R* cleanly separating and errand loadings down to 11% (Table SM10). Under oblique rotation, correlations were moderate, with the highest between the social and moral component at .37.

Instrument development

The final step was to create a measurement instrument of people's perceptions of mind that accommodates both inferred and desired capacities and is also suitable for other applications. We aimed for five subscales representing the components of the desired-capacity set whereby the items of the negative and positive-social affect subscales would combine into an overall Affect scale and the items of the moral and social-cognitive subscales would combine into an overall Social-Moral scale, thus representing the three-dimensional structure of inferred capacities. Of the 42 items in the two analyses (inferred, desired) of Study 4, we removed 10 that had $l < .50$ or strong cross-loadings in at least one analysis, and 2 items that fell under distinct components in the two analyses. Then we selected the four highest-loading items in each of the five components, yielding a 20-item measure with sufficient internal consistency on each of the five subscales (see Fig. 1), and errand loadings of 5-7%. With only two items more than Gray et al. used, we can now measure three to five dimensions of mind perception.

	Desired Capacities		*Inferred Capacities*	
Feeling happy	0.84	**Positive Social Affect**	0.96	**Affect**
Loving specific people	0.80		0.91	
Feeling pleasure	0.79	*16.2% EV*	0.94	*36.7% EV*
Experiencing gratitude	0.77	α = 0.88	0.80	α = 0.98
Feeling pain	0.86	**Negative Affect**	0.97	
Feeling stress	0.81		0.87	
Experiencing fear	0.78	*15.3% EV*	0.94	
Feeling tired	0.77	α = 0.86	0.95	
Disapproving of immoral actions	0.80	**Moral Cognition**	0.83	**Moral & Social Cognition**
Telling right from wrong	0.77		0.73	
Upholding moral values	0.76	*13.5% EV*	0.84	
Praising moral actions	0.66	α = 0.84	0.81	*29.4% EV*
Inferring a person's thinking	0.78	**Social Cognition**	0.80	α = 0.94
Planning for the future	0.75		0.82	
Understanding others' minds	0.67	*12.6% EV*	0.84	
Setting goals	0.61	0.78	0.83	
Communicating verbally	0.81	**Reality Interaction**	0.67	**Reality Interaction**
Seeing and hearing the world	0.70		0.68	
Learning from instruction	0.69	*12.5% EV*	0.72	*11.2% EV*
Moving on their own	0.68	α = 0.79	0.76	α = 0.71

Figure 1: Individual item loadings from PCAs on desired mental capacities of robots (5 components, left) and inferred capacities of humans or robots (3 components, right).

General Discussion

What are the dimensions of mind? Our results suggest that people's ascriptions of mental capacities follow at least three major axes. A three-dimensional structure is consistent with previous work (Kozak et al., 2006; Weisman et al., 2017), but the specific dimensions we identified, and successfully replicated over five different samples, offer new insights into their psychological meaning and interrelationships.

First, each dimension shows multiple facets that previously have been overlooked. Dimension *A* unites aspects of physiological and positive as well as negative emotional capacities that are largely unintentional. *M* encompasses aspects of both moral cognition and social cognition, which itself includes the simulation of one's own mind (e.g., planning) and others' minds (e.g., inferring their thoughts); its appropriate label may thus be *Moral & Social Cognition.* These processes are largely under the agent's intentional control and enable understanding and regulation of one's own and others' behavior, thus carving out a specific meaning of agency. *R* illustrates the dynamic transition from perception and cognition through learning to communication and action—a second more specific meaning of agency.

It is noteworthy that none of the dimensions are made up simply of bundles of semantically related words. The use of PCA in personality psychology has sometimes been criticized as merely recovering dictionary relations between trait adjectives (e.g., Extraversion = outgoing, sociable, gregarious, friendly, etc; *cf.* D'Andrade, 2017). The items that are clustering together in the *A-M-R* structure are only midly semantically related, but more so they point to fundamental psychological functions of the mind—to engage with its own processes, with other minds, and with the social and physical environment.

We also found that, under some conditions, two of the three dimensions bifurcate: *A* divides into negative and positive-social affect; *M* divides into moral cognition and social cognition. We have so far identified only instance in which a full five-dimensional structure emerges: when people consider the desired capacities of a robot. Other instances may emerge as a function of one's attitude toward the agent (e.g., friend or foe), or the functional role of the capacity ascriptions (e.g., for interaction vs. evaluation).

Finally, we have offered a short, reliable measure of the three- to five-dimensional structure of mind perception, thus opening the door to many new investigations. These include developmental and cross-cultural studies of mind perception, as well as studies into how mind perceptions change over time—such as when interacting with a robot. The scale also invites a more refined assessment of anthropomorphism, sometimes cast as a relatively indiscriminate human tendency that may, in reality, be more selective. Finally, questions of dehumanization can be posed anew, as denying "mind" is unlikely to occur in a simple on/off way (Rai, Valdesolo, & Graham, 2017); rather, its impact on social and moral behavior may be differentiated depending on what aspect of mind—out of three to five—is denied.

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