Face Cognition: A Set of Distinct Mental Abilities

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Perceiving, learning, and recognizing faces swiftly and accurately is of paramount importance to humans as a social species. Though established functional models of face cognition[1,2] suggest the existence of multiple abilities in face cognition, the number of such abilities and the relationships among them and to other cognitive abilities can only be determined by studying individual differences. Here we investigated individual differences in a broad variety of indicators of face cognition and identified for the first time three component abilities: face perception, face memory, and the speed of face cognition. These component abilities were replicated in an independent study and were found to be robustly separable from established cognitive abilities, specifically immediate and delayed memory, mental speed, general cognitive ability, and object cognition. The analysis of individual differences goes beyond functional and neurological models of face cognition by demonstrating the difference between face perception and face learning, and by making evident the distinction between speed and accuracy of face cognition. Our indicators also provide a means to develop tests and training programs for face cognition that are broader and more precise than those currently available[3,4].

There is ample evidence for several separable yet correlated cognitive abilities in humans[5] such as reasoning and memory. Recent debates suggest that established and validated concepts of human cognitive abilities should be expanded to aspects of performance in social and emotional contexts that can include face cognition[6]. The idea that abilities reflective of face cognition need to be distinguished from established abilities like reasoning and object cognition is supported by evidence from various fields. Clinical studies of brain-damage patients with double dissociations between the perception and memory of faces and objects indicate the partial distinctness of the underlying brain systems[7]. This is supported by evidence from neuroimaging, which endorses the perspective that face cognition is located in dedicated brain regions like the fusiform face area[8].

Based on experimental evidence and studies of brain-damaged patients, functional models of face cognition[1,2] propose an initial stage of structural encoding common to both unfamiliar and familiar faces. The pictorial and structural codes extracted during this stage are maintained for a short period of time. If the face is familiar, so-called face recognition units (FRUs) will be activated. FRUs are representations of invariant facial structures of previously learned and now familiar faces stored in long-term memory. Following FRU activation, domain-general knowledge about the person and names can be retrieved. More recent neuroimaging studies identified the neural substrates of these modular functions[9].

Despite the interest in face cognition in experimental, clinical, and neurophysiological research, it is unclear whether the component processes suggested in models of face cognition reflect separate abilities that can vary more or less independently across individuals. It is also unclear how such abilities in face cognition are related to other cognitive abilities. Information about the number and structure of cognitive abilities can be obtained by analyzing the correlations of measures (indicators) collected from a large number of participants sampled from the application population. Our first goal, therefore, was to create a model that adequately captures hitherto neglected individual differences in the most relevant aspects postulated in functional and neuroanatomical models of face cognition. The second goal was to test the relationships of the component abilities of face cognition to each other and to established abilities like immediate and delayed memory, mental speed, object cognition, and general cognitive ability.

Existing tests of individual differences in face cognition have used highly specific performance indicators from just one task[4]. However, the degree to which a single specific indicator captures a general ability cannot be evaluated on the basis of that one indicator alone. Only through reliance on several indicators is it possible to transcend specificities of single indicators and to measure a general ability such as face cognition. With a broad collection of indicators, confirmatory factor analysis can reveal the number of component abilities of face cognition and the relationships among them[10]. Common variances between indicators are conceptualized as latent factors, which can represent mental abilities that cannot be measured directly. Only by using a measurement model in which latent factors cause the observed individual differences in face cognition is it possible to test the exhaustiveness of a solution and to examine the relationships to established abilities (see Supplementary Information).

Apart from these methodological considerations, it is important that face cognition indicators draw predominantly on face-specific processes. For example, assessing the recognition of famous faces[11] is conceptually problematic because it neglects differential learning opportunities and prior exposure to the face stimuli. In addition, many of the experimental and correlational studies have used portraits that include objects irrelevant for face cognition like other body parts, clothing, hair, or such paraphernalia as glasses[12,13].

Based on functional and neuroanatomical models of face cognition, we expected to find two latent factors: one related to face perception, and the other related to face memory. Both factors were assessed with both speed as well as accuracy indicators. Though the importance of distinguishing speed and accuracy of behaviour has been demonstrated[14], it has been hitherto neglected in face cognition studies.

Our first study established a confirmatory measurement model for individual differences in face cognition (see Methods). We collected, adapted, and developed 21 computerized indicators of face cognition, drawn primarily from popular experimental face cognition tasks. We ensured the psychometric quality of each indicator (see Supplementary Information) and tested a family of measurement models, ranging from one that postulated a single latent factor of face cognition to models that distinguished between processes (perception and memory) and dependent variables (speed and accuracy). We obtained three main results. First, comparisons of these models revealed among the accuracy indicators two related yet separable factors of face perception and face memory. Second, the face speed indicators required no further distinction between perceptual and memory processes. Third, indicators of face cognition speed were clearly separated from the two latent factors of face cognition accuracy. Figure 1 presents the final measurement model from Study 1 (see Supplementary Information for descriptions of indicators).

Our second study aimed to replicate the measurement model, which had been derived in part from the data, and to enhance it by distinguishing the factors of face cognition from established ability factors. We selected 14 of the 21 face cognition indicators for Study 2 based on psychometric quality, practical considerations of test efficiency, and theoretical assumptions confirmed and partly modified in Study 1 (see Methods). In order to distinguish factors of face cognition from established abilities, the study included indicators for established abilities that might be related to or causal for individual differences in face cognition. These indicators assessed immediate and delayed memory, general cognitive ability, mental speed, and object cognition. We successfully replicated the critical distinctions obtained for the measurement model of Study 1. The fit of this model for face cognition was good (χ^2 = 118, df = 71, RMSEA = .06, CFI = .965). The correlation between the memory and perception factors was higher than in Study 1 (.75 vs. .50). However, both factors were still sufficiently independent from one another that they can be considered separate abilities.

As expected, a measurement model of established abilities distinguished between factors representing immediate and delayed memory, mental speed, object cognition, and general cognitive ability (see Figure 2) (see Supplementary Information for descriptions of indicators). The fit of this model was good. The measurement models for face cognition and for established abilities were integrated into a structural model that critically tested the relative independence of factors of face cognition from other factors. Figure 3 shows the structural model of Study 2. The fit of this model was also good and unequivocally indicated that none of the three latent factors of face cognition can be essentially reduced to established abilities. It is important to stress that the proportion of explained variance in the latent factors of face cognition did not exceed 60% of the total variance. This provides very strong evidence for the relative independence of individual differences in face cognition from such other cognitive abilities as object cognition. In the structural model, the relation between face perception and face memory drops from .75 to .57 once we control for other cognitive abilities. This indicates that, after statistically controlling relevant criteria, specificity between face perception and face memory remains significant.

We show here for the first time that individual differences in face cognition constitute separable abilities that belong alongside other cognitive abilities. Face perception expresses the ability to perceive facial stimuli and to extract from them such relevant aspects as facial features and their configuration. Face memory represents the ability to encode and transform facial stimuli, and to store them in and retrieve them from long-term memory. The speed of face cognition captures the ability to process facial stimuli swiftly.

These results are consistent with experimental, clinical, and neuroimaging evidence[1,9]. However, they go considerably beyond these findings by (a) encompassing face learning as an integral part of face memory and (b) by demonstrating that speed and accuracy of face cognition draw on different aspects of the mind. Furthermore, we provide evidence that abilities of face cognition are dissociated from one another and from established abilities. Face cognition represents a set of distinct mental abilities in their own right. In the long-standing controversy about whether faces are just another instance of object cognition[15,16], our research gives substantial support to the view that faces are indeed special. Abilities of face cognition might represent a facet of social and emotional intelligence. The methods developed here provide a dependable measurement tool to assess face cognition abilities that can be applied, for example, in clinical settings or for personnel selection in jobs demanding swift and accurate recognition of faces.

Methods

The first study included 153 and the second study 209 neurologically unimpaired participants broadly varying in their demographic background (age ranges 18-35 years). All participants gave informed consent. Up to 9 participants were tested simultaneously in four and five hour sessions, respectively, with 10 minute-breaks about every 50 minutes of testing.

In both studies, face perception was measured by tasks requiring perceptual comparisons of face stimuli without any reliance on memory processes. Face memory was assessed by tasks that required the learning and recognition of face stimuli. Performance in the indicators from these two factors was expressed by proportion of correct responses. Face cognition speed was measured by tasks that required swift responses for perceptual comparisons and recognitions of faces. Performance in these tasks was expressed by inverted reaction times of correct responses. The metric of the resulting scores is the number of correct trials per second. Accuracy in all these measures was at ceiling. In Study 2, all participants also completed tasks that measured general cognitive ability, mental speed, object cognition, and immediate and delayed memory. The tasks for object cognition were the same as the corresponding tasks for face cognition, but used houses instead of faces as stimuli.

See supplementary information for more details.

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Supplementary information is linked to the online version of the paper at www.nature.com/nature

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Figure legends

Figure 1. Final measurement model for Face cognition tasks in Study 1

χ^2 = 103, df = 71, RMSEA = .055, CFI = .963, N = 151

Coefficients that did not reach the significance level α = .05 were italicized. Some indicators in Study 1 and 2 contained two different conditions. The difference between two conditions (i.e. accuracy in upright versus inverted faces is expected to reflect a highly specific process of face cognition. Therefore, the common variance between two such conditions from a task is not expected to be captured completely by a latent factor. Therefore error variables for indicators from one task were allowed to correlate with each other. This covariance reflects task specificity that is of no substantive interest.

Figure 2. Final measurement model of established abilities in Study 2

χ^2 = 152, df = 100, RMSEA = .05, CFI = .956

Abbreviations: I & D Memory – immediate and delayed memory

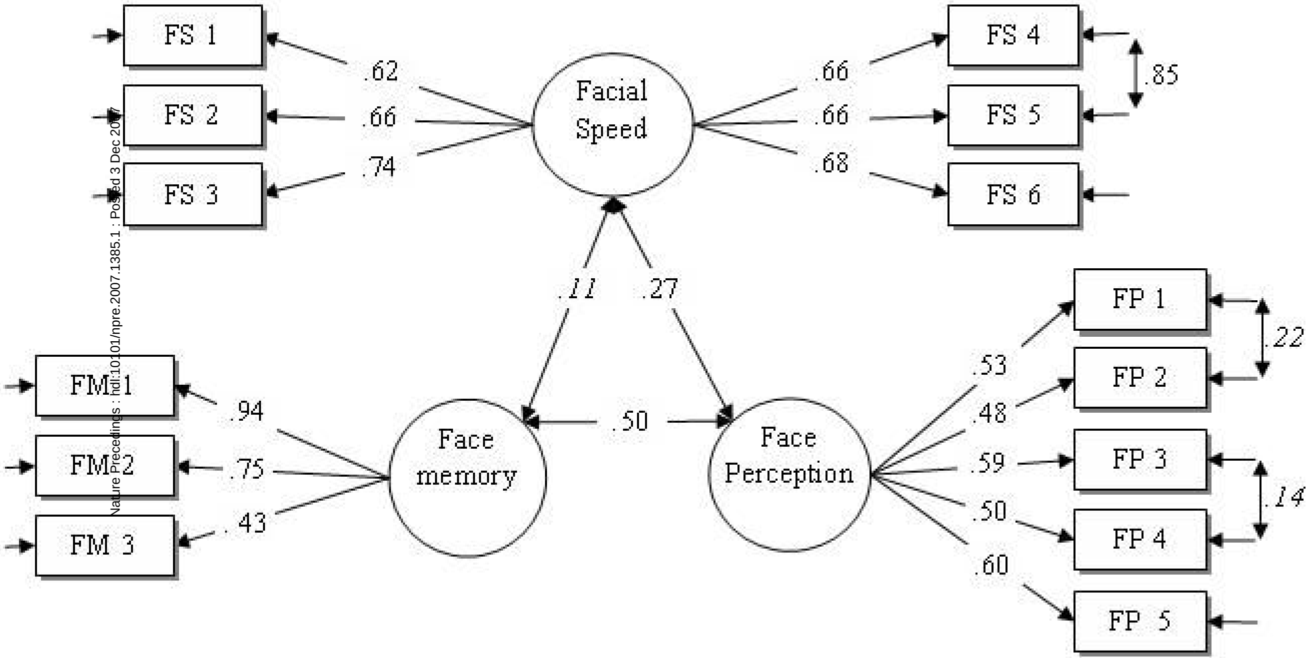
Coefficients that did not reach statistical significance at α = .05 were italicized.

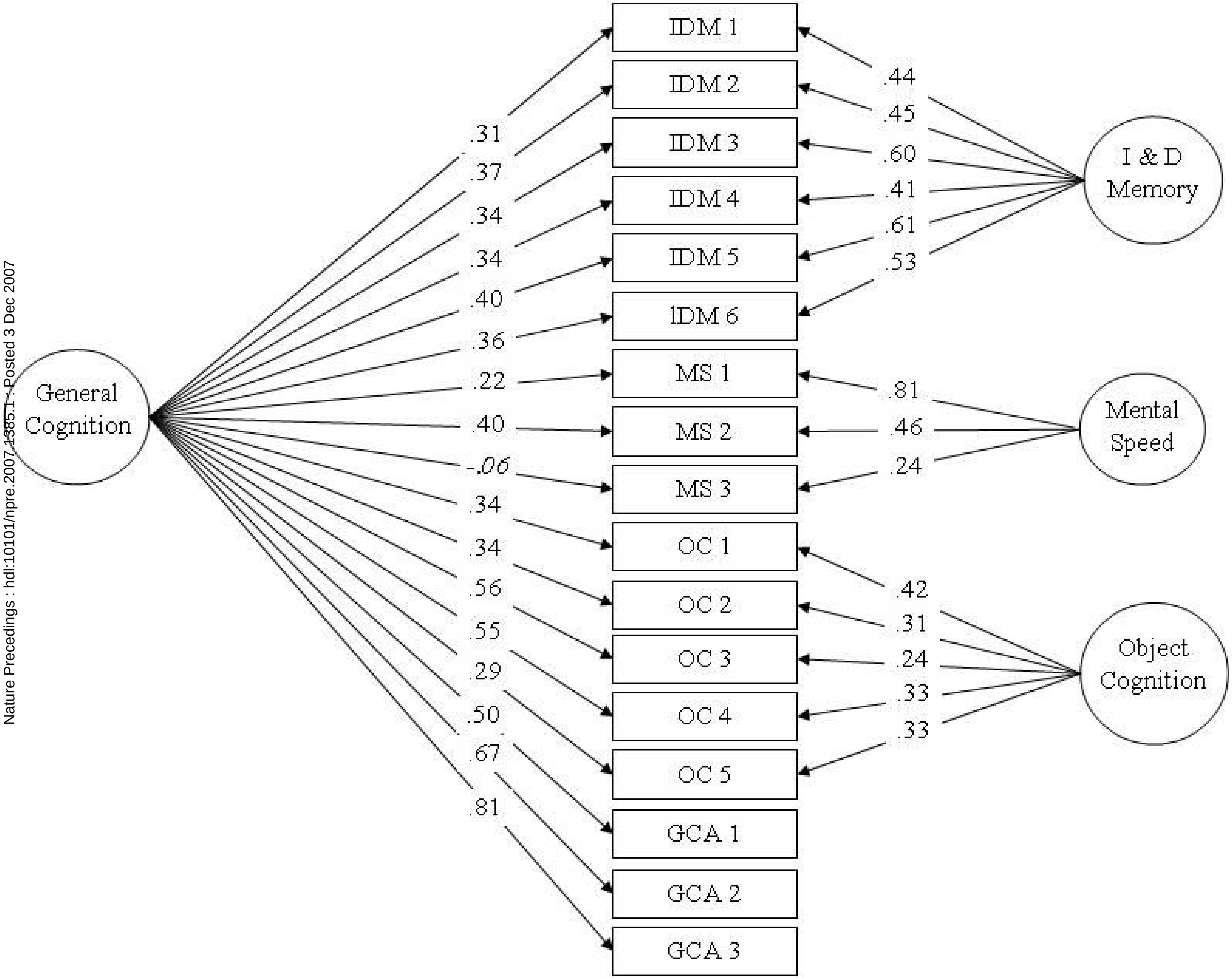
Effects of different experimental conditions of one task were captured by correlated error terms for these indicators.

Figure 3. Schematic diagram for the structural model in Study 2

χ^2 = 576, df = 403, RMSEA = .045, CFI = .938

Abbreviations: I & D Memory – immediate and delayed memory, R^2 – amount of explained variance.


FS 1
FS 2
FS 3
FS 4
FS 5
FS 6
.62
.66
.74
.66
.66
.68
.85
Facial Speed
.11
.27
FP 1
FP 2
FP 3
FP 4
FP 5
.22
.14
.53
.48
.59
.50
.60
FM 1
FM 2
FM 3
.94
.75
.43
Face memory
.50
Face Perception


General Cognition
I & D Memory
Mental Speed
Object Cognition
IDM 1
IDM 2
IDM 3
IDM 4
IDM 5
IDM 6
MS 1
MS 2
MS 3
OC 1
OC 2
OC 3
OC 4
OC 5
GCA 1
GCA 2
GCA 3
.31
.37
.34
.34
.40
.36
.22
.40
-.06
.34
.34
.56
.55
.29
.50
.67
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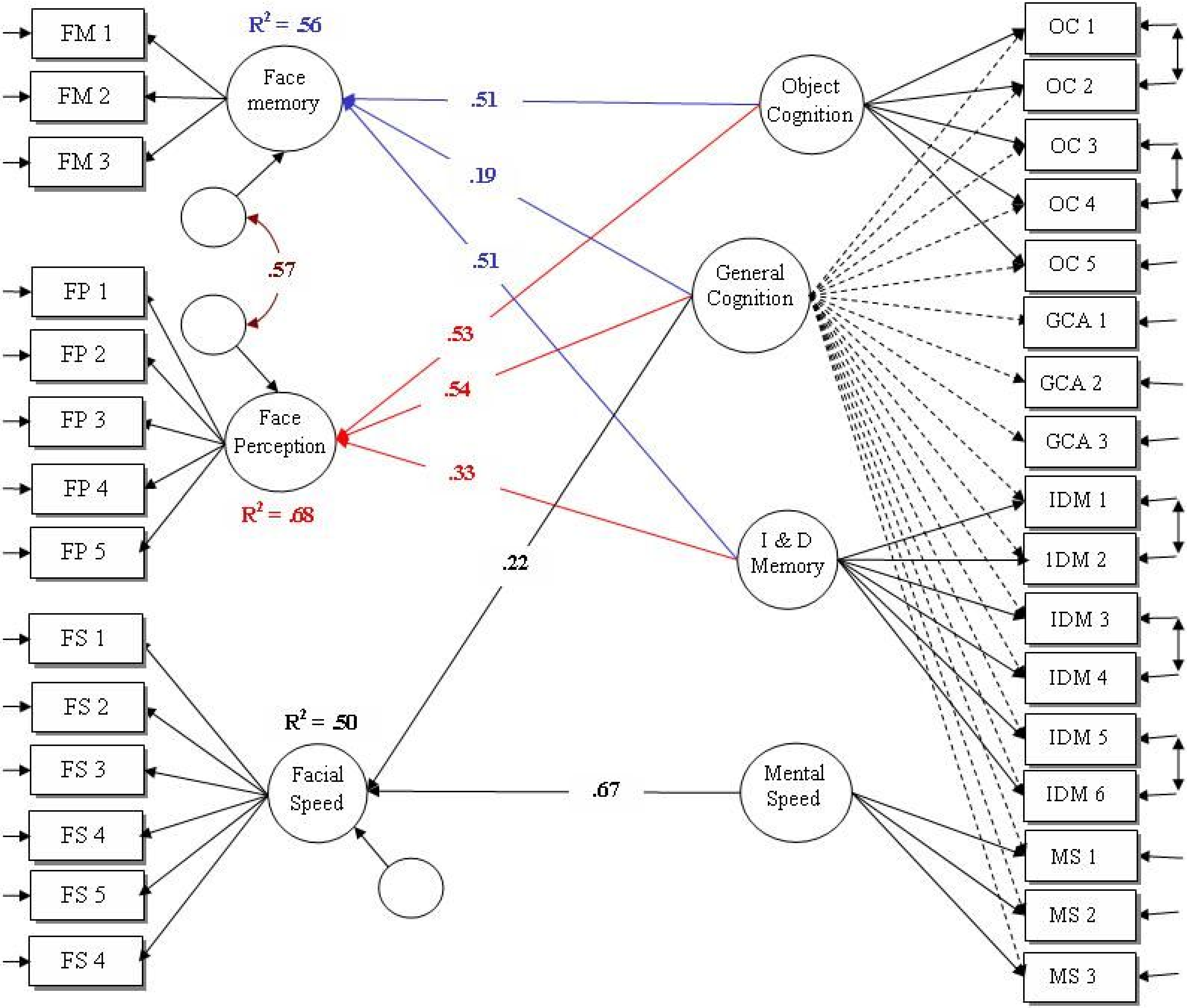
.31
.24
.33
.33



FM 1
FM 2
FM 3
Face memory
$R^2 = .56$
.51
.19
.51
.57
FP 1
FP 2
FP 3
FP 4
FP 5
Face Perception
$R^2 = .68$
.53
.54
.33
.22
FS 1
FS 2
FS 3
FS 4
FS 5
FS 4
Facial Speed
$R^2 = .50$
.67
Object Cognition
General Cognition
I & D Memory
Mental Speed
OC 1
OC 2
OC 3
OC 4
OC 5
GCA 1
GCA 2
GCA 3
IDM 1
1DM 2
IDM 3
IDM 4
IDM 5
IDM 6
MS 1
MS 2
MS 3