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The neurobiological basis of nonverbal intelligence and mathematical abilities

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The relationship between different cognitive abilities is an everstanding question in psychophysiolog of individual differences. In is known that individual differences in mathematical abilities are correlated with intelligence on the behavioral level. Additionally, the genetic correlations between the general cognitive ability and mathematical ability is high (0.83), which may suggest common neurobiological basis [3]. However, studies also demonstrate that mathematical and general cognitive abilities have different time-courses of development [2]. Considering this, whether those abilities can be dissociated on the behavioural and psychophysiological level remains unknown.

Recent studies demonstrate that mathematical and general cognitive abilities are both associated with intrinsic brain connectivity [1, 6]. However, there is already strong evidence that the numerical abilities of the human brain rest in part on specialized cerebral processes [4]. Accordingly, we aimed to estimate the variance of individual differences in intrinsic brain connectivity that is explained by mathematical abilities only.

Methods

The participants were recruited via announcement in social networks (N = 165). They participated voluntarily without any monetary incentive. The exclusion criteria were any recorded history of psychiatric or neurological disorders and head trauma. Participants' age ranged from 17 to 34 (M = 21.7, SD = 3.36, 30% identified as female). The majority of the participants were students or had a bachelor degree.

Mathematical abilities were measured with 2 tasks. Problem Verification Task aims to measure the effectiveness with which the subject can evaluate simple arithmetic solution [7]. The Number Series task measures cognitive ability to process quantitative information [8]. Nonverbal intelligence was estimated with Raven's Standard Progressive Matrices.

During resting state EEG acquisition all participants were instructed to sit still, think of nothing in particular and not to fall asleep for 10 min. Every 2 min the participants were asked to open or close their eyes with verbal instructions: "Now open your eyes" "Now close your eyes." Only the closed eyes condition data was used for analysis in the present study. To assess synchronization between pair of signals we used wPLI measure [5]. Graph measures were calculated with igraph package (http://igraph.org/) for R (R Core Team, 2018).

Results

We have found that nonverbal cognitive abilities and mathematical abilities was significantly associated with graph metrics (beta coefficient b=18.78 and b=16.54, $p<0.001$ respectfully). However, when both nonverbal cognitive and mathematical abilities were accounted for in one model, only nonverbal intelligence remained significant predictor.

Discussion

The shared variance between mathematical abilities, nonverbal intelligence and capacities of brain functional connectivity suggest that, on the one hand, the association between connectivity and mathematical abilities may be mediated by intelligence. In that case, functional wiring in the brain may be integral to general intellectual abilities while domain-specific abilities are supported by different neuronal basis. However, it is also possible that it is the functional

wiring properties that mediate the relation between different abilities as they co-develop in ontogenesis. It is stays unclear whether the domain-specific abilities are supported by specific neuronal processes or the common neuronal processes support the common variance in all cognitive tasks.

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