BEHAVIORAL, STRUCTURAL AND FUNCTIONAL SIGNATURE OF ACTION CONTROL

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INTRODUCTION

School achievement is highly predictive of future success. Thus variables predicting school achievement are of utmost importance. The results of a recent study suggest that volition is an important predictor of achievement in secondary education (Schlueter et al. 2018). Individuals differ in their ability to initiate self- and emotional control mechanism. These differences have been explicity described in Kuhl´s action-control theory (1992). Although interindividual differences in action control make a major contribution to everyday life, their neural foundations remain unknown.

METHODS I

We measured action control (see Tab. 1) in a sample of 264 healthy adults and related interindividual differences in action control to variations in brain structure and resting-state connectivity (see Fig. 1 (a) and (b)).

Table 1. Sample Items From Each of the Action Control Scales (Adapted from Kuhl, 1994)

Scale	Sample question
AOF	When I am told that my work has been completely unsatisfactory: A) **I do not let it bother me for too long.** B) I feel paralyzed.
AOD	When I do not have anything in particular to do, and I am getting bored: A) I have trouble getting up enough energy to do anything at all. B) **I quickly find something to do.**
AOP	When I am watching a really good movie: A) **I get so involved in the film that I do not think of doing anything else.** B) I often want to get something else to do while I am watching the movie.

Note: The three scales assessed (a) Action Orientation Subsequent to Failure Versus Preoccupation (the *AOF* scale), (b) Prospective and Decision-Related Action Orientation Versus Hesitation (the *AOD* scale), and (c) Action Orientation During (Successful) Performance of Activities Versus Volatility (the *AOP* scale). Action-oriented answers are highlighted in bold.

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METHODS II

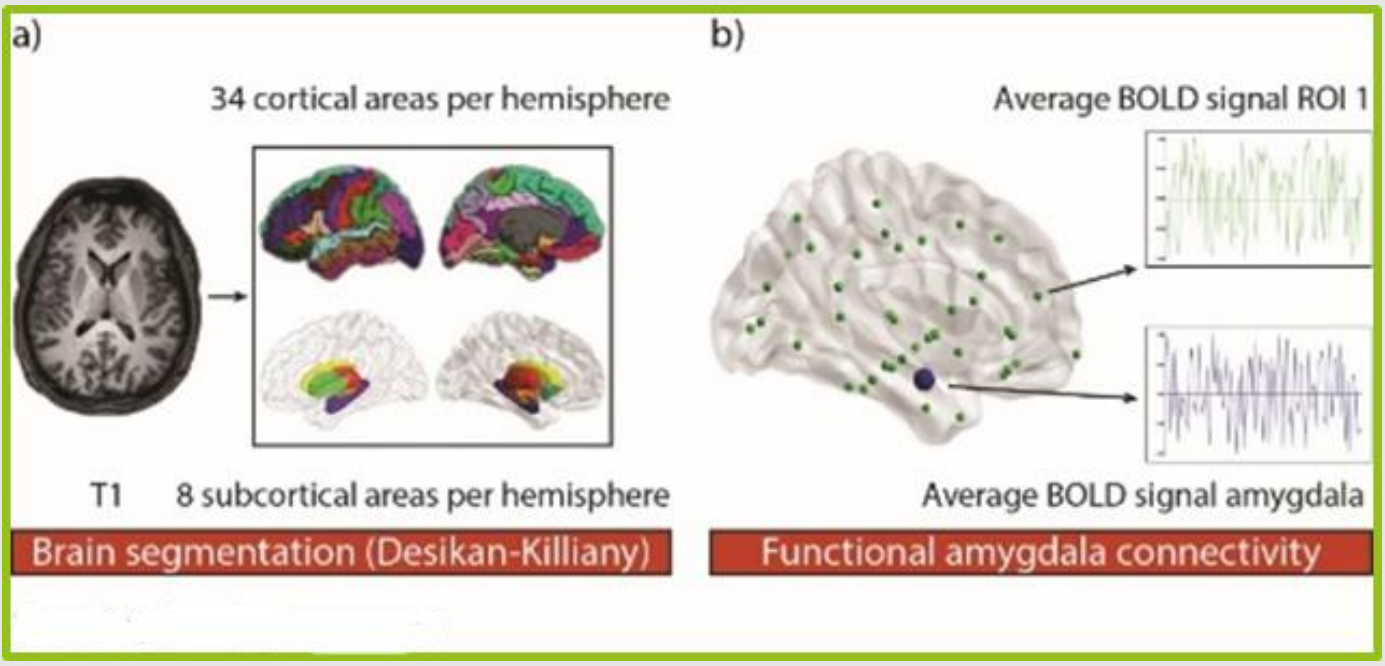

Fig. 1. Methodological sequence for the parcellation of the brain and the analysis of amygdala resting-state connectivity. First (a), T1-weighted images were segmented into 34 cortical and 8 subcortical brain regions per hemisphere according to the Desikan-Killiany atlas. For each of these brain regions, gray-matter and white-matter volume were computed. Second, brain regions were linearly transformed into the native space of the resting-state images. Third (b), the functional connectivity between the amygdala and every other brain region of interest (ROI) was investigated. Thus, we obtained the correlation between the subcortical and cortical regions of both hemispheres and the left or right amygdala, respectively. All correlation coefficients were transformed using Fisher's r-to-z' transformation. These z-transformed connectivity values were averaged to determine the mean correlation of the amygdala and each cortical and subcortical region. BOLD = blood oxygen level dependent.

RESULTS

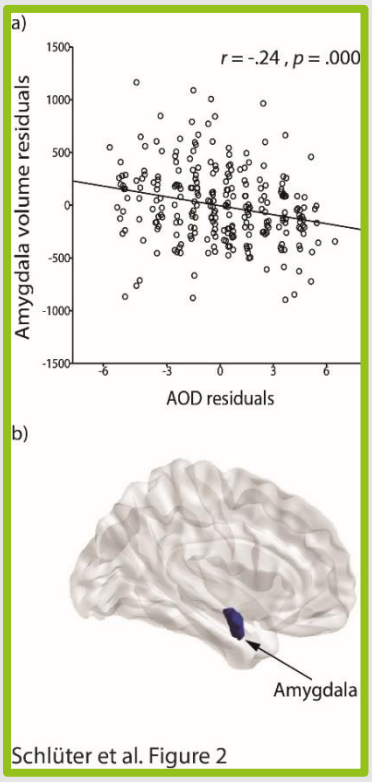

Fig. 2. Results of the correlation analysis between amygdala volume and score on the Prospective and Decision-Related Action Orientation Versus Hesitation (AOD) scale of the Action Control Scale (Kuhl, 1994). The scatterplot (a; with best-fitting regression line) illustrates the statistically significant relationship (N = 264, p < .001) between AOD scores and gray-matter volume of the amygdala. The brain image (b) shows the location of the amygdala within the cortex.

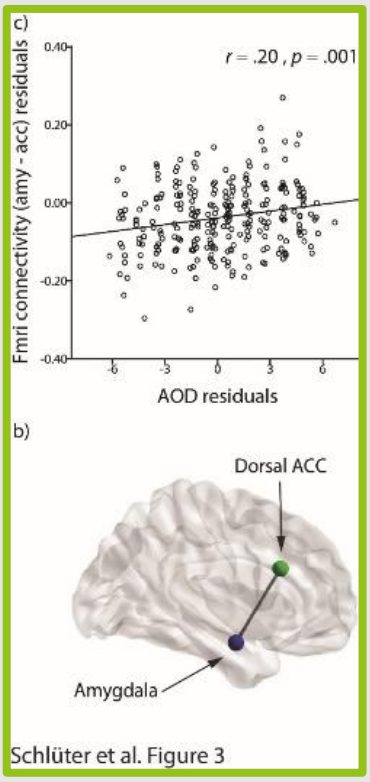

Fig. 3. Results of the correlation analysis between functional MRI (fMRI) amygdala connectivity and score on the Prospective and Decision-Related Action Orientation Versus Hesitation (AOD) scale of the Action Control Scale (Kuhl, 1994). The scatterplot (a; with best-fitting regression line) illustrates the statistically significant relationship (N = 264, p = .001) between AOD scores and resting-state connectivity between the amygdala and the dorsal anterior cingulate cortex (dACC). The brain image (b) shows the location of the amygdala and dACC.

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DISCUSSION

The current study is the first to investigate the neural basis of interindividual differences in action control, which is the ability to ochestrate self- and emotion-control mechanisms. Our results showed that individuals with lower amygdala volume tend to be more action orientated in decision related contexts than individuals with greater amygdala volume. Thus, people with higher volume appear to be more state oriented and therefore tend to hesitate to initiate an intention and tend to delay the beginning of tasks without any good reasons (Blunt & Pychyl, 1998).

Regarding the functional resting-state connectivity showed that interindividual differences in the functional connectivity of the amygdala and the dorso anterior cingulate cortex (dACC) was significantly associated with more action-orientated behavior. The synergy between between the dACC and the amygdala is assumed to play a significant role in purposive behavior (Feng et al., 2014) and self control mechanisms.

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