Frontal Electroencephalogram Alpha Asymmetry Relates to Implicit Achievement Motives: A Pilot Study

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ABSTRACT— The achievement motive is one of the core motives of human behavior and can be divided into two motives: an approach motive (i.e., hope for success [HS]), and an avoidance motive (i.e., fear of failure [FF]). Research has demonstrated that frontal electroencephalogram (EEG) asymmetry in the alpha frequency band is an important marker for differences in motivational processes. The present study investigated the relationship between resting state alpha asymmetry and the achievement motive. Resting state EEG was recorded, and implicit and explicit achievement motives, divided in HS and FF, assessed. Alpha activation asymmetries were calculated by subtracting the average left ln power from the average right ln power at frontal sites and at parietal sites as control position. Our results suggest a positive relationship between stronger left-sided activation and higher implicit HS scores; no other significant correlations where found. Possible explanations for these findings are discussed.

Looking at what drives human behavior, research has among others focused on different motives, such as the power motive, the affiliation, or the achievement motive (e.g., Brunstein & Heckhausen, 2010; Langens, Schmalt, & Sokolowski, 2005; McClelland, 1987; Schmalt, Sokolowski, & Langens, 2000). The achievement motive is thus one of the core motives of human behavior. In the field of educational psychology, it is a central concept (e.g., Elliot, 1999; Pintrich, 2005) that is an important predictor for educational achievement (e.g., Ames, 1992). Typical for achievement-motivated behaviors of an individual is the importance of a standard of excellence. Thus, especially in an educational setting, it seems important to be able to predict and influence the achievement motive to be able to stimulate individuals as well as possible (e.g., Busato, Prins, Elshout, & Hamaker, 2000). Research has shown that greater achievement motivation is associated with greater academic achievement and performance in educational contexts, such as schools and universities (e.g., Martin & Liem, 2010; Meijer & Wittenboer, 2004; Steinmayr & Spinath, 2009). Given this important role, gaining knowledge about the underlying mechanisms and neural correlates can help to optimize learning processes, to support educational procedures, and to evaluate interventions (Goswami, 2006; Lee & Juan, 2013), for example by providing measures that help to clarify training effects as an additional tool to observe behavior, or as a supplemental methodological approach to increase the validity of observational or psychometric measures of motivation. Surprisingly, until now the neural underpinnings of the achievement motives are unknown. Therefore, the present pilot study aims at investigating which neural processes are associated with the achievement motive.

Importantly, the achievement motive can be divided into an approach and an avoidance tendency (e.g., Thrash & Elliot, 2002). On one hand, hope for success (HS) is defined as the tendency to approach a situation in which the individual can pursue or accomplish success in order to experience the feelings of joy or pride when the aspired goal or standard is achieved. On the other hand, fear of failure (FF) is defined as the tendency to avoid such situations and thus not experiencing feelings such as shame or sadness when

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[The copyright line for this article was changed on 03 October 2018 after original online publication on 24 September 2018.]

the aspired goal is not accomplished (Atkinson, 1957; Pang, 2010). The achievement motive can be a powerful predictor of people's behavior in performance contexts (e.g., McClelland, Koestner, & Weinberger, 1989), for example, in team sport competitions (Wegner & Teubel, 2014).

Notably, two different ways to measure human motives have been established: an explicit, self-report measure, and an implicit measure. Explicit measures assume that individuals are able to access their motives and that they can know about the causes of behavior. Implicit measures are proposed to indicate dispositional and stable preferences of the individual for certain affective states, and the behaviors or situations associated with them. They orient, select, and energize behavior and are not accessible to the conscious mind of the individual (McClelland et al., 1989). Whereas explicit measures seem to have higher face validity, implicit measures are less prone to social desirable responses.

Interestingly, frontal cortical activation asymmetry—that is, the relative difference between activity recorded from the left frontal scalp locations and the corresponding right locations as assessed by means of electroencephalogram (EEG) alpha power (8–13 Hz)—has been related to differences in affective style, motivational processes, and the motivational direction of emotions (Buss et al., 2003; Davidson & Fox, 1982; Field, Pickens, Fox, & Nawrocki, 1995; Fox et al., 1995; Fox, Schmidt, Calkins, Rubin, & Coplan, 1996; Harmon-Jones, 2003; Harmon-Jones, Gable, & Peterson, 2010; Harmon-Jones, Vaughn-Scott, Mohr, Sigelman, & Harmon-Jones, 2004; Jackson et al., 2003; Jones, Field, Davalos, & Hart, 2004; Koslov, Mendes, Pajtas, & Pizzagalli, 2011; McGregor, Nash, & Inzlicht, 2009; Shankman et al., 2005; Smith & Bell, 2010; Sutton & Davidson, 1997; Tomarken, Davidson, & Henriques, 1990). Thereby, greater right relative to left frontal activity has been linked to withdrawal-oriented emotions, to an avoidance motivation, and to the experience of negative affect (e.g., Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Fox, 1991; Fox, Henderson, Rubin, Calkins, & Schmidt, 2001; Harmon-Jones, Gable, & Peterson, 2010; Jones & Fox, 1992; Saby & Marshall, 2012; Shankman et al., 2003, 2005; Sutton & Davidson, 1997). Furthermore, greater relative left frontal activity has been associated with approach-oriented emotions, to an approach motivation, and the experience of positive affect (e.g., Davidson & Fox, 1982; Fox, 1991; Fox et al., 2001; Harmon-Jones et al., 2010; Licata, Paulus, Kühn-Popp, Meinhardt, & Sodian, 2015; Paulus, Kühn-Popp, Licata, Sodian, & Meinhardt, 2013; Pizzagalli, Sherwood, Henriques, & Davidson, 2005; Shankman et al., 2003, 2005; Sutton & Davidson, 1997; Tomarken & Keener, 1998). For example, video clips that evoke fear or disgust resulted in greater relative right frontal brain activity (Davidson et al., 1990; Jones & Fox, 1992), while 10-month-old infants displayed increased left frontal activation after watching film clips of a woman with a happy facial expression as compared with a sad expression (Davidson & Fox, 1982). Furthermore, trait and experimentally manipulated approach-motivated anger also has been found to relate to relatively greater left frontal activity than relatively greater right frontal activity (Harmon-Jones, 2003, 2004, 2007; Harmon-Jones & Allen, 1998).

More recent studies focused on the relationship of asymmetrical frontal activity to the motivation-related variables or constructs, especially those involved in decisional processes or choices of behavior (Harmon-Jones, Harmon-Jones, Fearn, Sigelman, & Johnson, 2008; Harmon-Jones, Harmon-Jones, Serra, & Gable, 2011). As EEG alpha power is related to approach and avoidance motivation, it is not surprising that correlations with the personality traits of the behavioral activation system (BAS) and the behavioral inhibition system (BIS) could be demonstrated (e.g., Coan & Allen, 2003; Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997). Whereas people with higher levels of trait BAS are assumed to actively seek out positive and negative reinforcement (Gray, 1994), and thus show a stronger approach tendency, people with high levels of trait BIS are assumed to be more sensitive to signals of punishment and nonrewards, and thus show a stronger avoidance tendency (Gray, 1994). For example, greater trait BAS is linked to more spreading of alternatives, and to an increase in relative left frontal alpha activity after a difficult decision is made (Harmon-Jones et al., 2008, 2011).

Taken together, there is evidence that resting state frontal alpha asymmetry is an important marker for differences in motivational orientation (Buss et al., 2003; Davidson & Fox, 1982; Field et al., 1995; Fox et al., 1995, 1996; Harmon-Jones, 2003; Harmon-Jones et al., 2010; Harmon-Jones, Vaughn-Scott, Mohr, Sigelman, & Harmon-Jones, 2004; Jackson et al., 2003; Jones et al., 2004; Koslov et al., 2011; McGregor et al., 2009; Shankman et al., 2005; Smith & Bell, 2010; Sutton & Davidson, 1997; Tomarken et al., 1990). We have therefore good reasons to assume that it might be related to individual differences in people's achievement motivation. To investigate this possibility, the current pilot study was designed to explore the relation between frontal asymmetrical cortical activity and people's approach and withdrawal motivational tendencies. In particular, we assessed both the implicit and explicit achievement motives. Achievement motive was further divided into the HS as tendency to approach, and the FF as tendency to avoidance.

Resting state EEG was assessed in healthy adults, and alpha asymmetry scores were calculated for frontal sites and parietal sites as control condition. Subsequently, implicit and explicit measures of achievement motive were assessed, and correlated with the asymmetry scores. We predicted that greater *implicit* HS relative to FF should be linked to greater relative left than right frontal activity. For explicit

HS and explicit FF, our predictions are less straight forward given that explicit self-reports are prone to distortion and social desirability effects: on one hand, based on earlier research which found no relationship between lateral activation scores and *explicit* motives of power and affiliation (Kuhl & Kazen, 2008), a relationship between frontal EEG asymmetry and explicit HS and explicit FF seems unlikely. On the other side, correlations between frontal EEG asymmetry and explicit motivational orientations and personality traits (e.g., Coan & Allen, 2003; Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997) were demonstrated in other research areas, making a possible relationship in the current study more likely.

METHOD

Participants

Twenty-nine volunteers (17 female; mean age = 24.1 years, *SD* = 5.2) participated in the study for course credit points if needed. Because handedness influences hemispheric specialization (e.g., Brookshire & Casanto, 2012; Harmon-Jones, 2006), only right-handed participants were recruited. They were native German speakers with no history of psychiatric or neurological disorders. All participants gave written consent after being informed about the procedure.

Materials and Procedure

Upon arrival in the lab, participants were told that first resting state EEG is assessed, and that they afterward had to fill in some questionnaires assessing personal characteristics. After the experimenter explained that all data were assessed anonymously and participants could ask questions about the method, participants gave written consent. The EEG session took place in an electrically shielded, sound-attenuated chamber with a 19-inch computer monitor placed 100 cm in front of the participants. Participants were seated in a comfortable arm chair and EEG electrodes were attached. Eight 45 s resting baseline periods with eyes-open (O) or eyes-closed (C) were presented. For the closed eyes condition, participants were told to sit comfortably with their eyes closed; for the eyes open condition, participants were instructed to look at a blue fixation cross presented against a black monitor background. The instructions were presented via sound files at 65 dB sound pressure level (SPL). These two conditions were presented in alternating order beginning with the eyes-open condition (O, C, O, C, O, C, O, C). Between each trial, there was a short break of 7 s. Stimulus presentation was controlled via the Presentation software package (Neurobehavioral Systems, Berkeley, CA).

The questionnaires were completed in a separate room after the EEG recording to prevent activation of implicit motives. The multi-motive-grid (MMG; Schmalt et al., 2000) was used to assess the implicit motives (achievement, power, and affiliation). The MMG consists of 14 different line drawings paired with 4 to 10 statements. The three implicit motives achievement, power, and affiliation are assessed with 12 statements for each motive. Participants were presented with the drawings one by one, and had to indicate whether each statement depicted by the drawings applied to them or not (yes/no response alternatives). In sum, the MMG consists of 94 items (drawing-statement combinations): 22 filler items and 72 test items. As the focus of the study was on the correlation between resting state EEG and achievement motive, the power motive and the affiliation motive were not further analyzed. The scores for the achievement motive were divided into HS and FF.

The Achievement-Motive-Scale-Revised (AMS-R; Lang & Fries, 2006) was used to assess the explicit achievement motive. The AMS-R consists of 10 items, 5 for HS (e.g., "I am attracted to situations in which I can test my abilities") and 5 for FF (e.g., "If I do not understand a problem immediately, I become anxious"). Participants could indicate on a 4-point Likert scale whether an item applied to them or not (1 = *totally not applicable* to 4 = *totally applicable*).[1] Subsequently, sociodemographic variables were assessed (age, gender, mother tongue, handedness, and study or profession). After completion of the questionnaires, participants were thanked and debriefed.

EEG Recording and Processing

The EEG was acquired using BrainAmp amplifiers (Brain Products, Gilching, Germany) with 64 active electrodes (ActiCap System, Brain Products, Gilching, Germany) placed on standard positions according to the extended International 10–20 System. To be able to compare results with earlier research, all electrodes were referenced to position Cz. Electrodes below and above the right eye (Veog Lower, Fp2) were used to monitor the vertical eye movements and blinks. Electrodes near the external outer canthi of the left and right eyes (F9, F10) were used to monitor the horizontal eye movements. The ground electrode was positioned at AFz. Impedances of all electrodes were kept below 10 kΩ. Signals were recorded with a band-pass filter of 0.016–100 Hz and were continuously sampled to a hard disk at a rate of 500 Hz.

EEG data were examined and analyzed using Brain Vision Analyzer (Brain Products, Gilching, Germany). Offline, EEG data were digitally band pass filtered with 1–35 Hz (−24 dB/oct). Subsequently, the data were segmented into epochs of 2 s with 50% overlap. By means of semiautomatic artifact rejection and visual inspection, segmented epochs were identified as artifacts and excluded if EEG amplitude of any channel exceeded 100 µV or if they contained eye movements, blinks, or (motor) artifacts. 16.65% of all epochs were

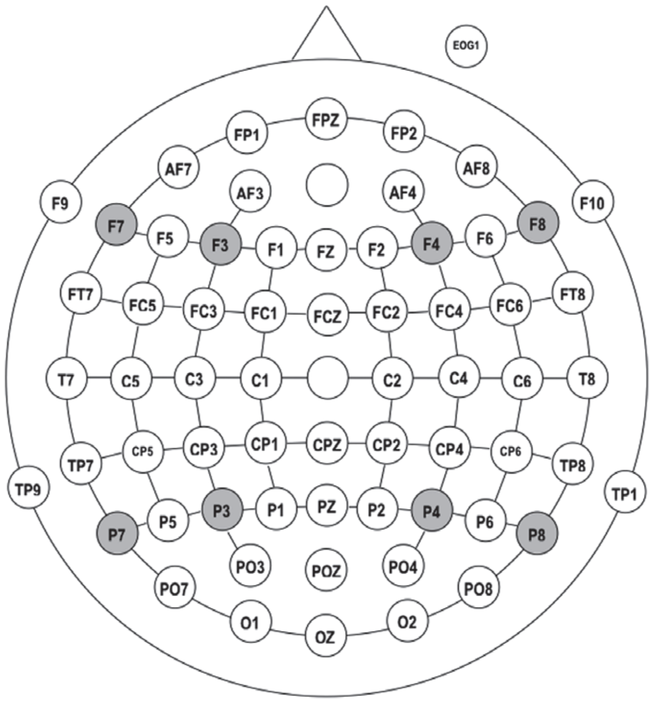

Fig. 1. Frontal alpha asymmetry cluster (F87, F43) and parietal asymmetry cluster (P87, P43).

Table 1
Mean Values (M) and Standard Deviations (*SD*) for Frontal and Parietal Alpha Asymmetry Scores

Alpha asymmetry	M	SD
Frontal	−0.05	0.20
Parietal	0.16	0.31

Note. N = 29.

Table 2
Mean Values and Standard Deviations for the Difference Scores (HS – FF) of Implicit and Explicit Pearson Correlations Between the Frontal and Parietal Asymmetry Scores (AsymF, AsymP) and the Difference Score of the Implicit Achievement Motives on the MMG, and the Difference Score of the Explicit Achievement Motives on the AMS-R Achievement Motives

Difference Scores	M	SD
Implicit Achievement motives	3,31	2,49
Explicit Achievement motives	4.75	3.66

Note. N = 29 (implicit), *N* = 28 (explicit).

eliminated from subsequent analyses, resulting on average in 280.07 ($SD = 57.41$) epochs per person. Artifact-free epochs were extracted through a Hamming window and power spectra were calculated via fast Fourier transform (FFT) and expressed as mean square microvolts (μV^2). For all participants, the 8–13 Hz frequency band was computed.

Statistical Analysis

To normalize the distribution, EEG alpha power was natural logarithm transformed (Gasser, Bacher, & Mocks, 1982). EEG asymmetry scores were calculated as the difference between natural logarithm of EEG alpha power at the right recording site and the left recording site (e.g., Allen, Urry, Hitt, & Coan, 2004; Coan, Allen, & Harmon-Jones, 2001; Harmon-Jones, 2007; Stewart, Coan, Towers, & Allen, 2011). A frontal alpha asymmetry cluster (AsymF) was formed from the frontal electrodes F3/F4 and F7/F8. Similarly, a parietal alpha asymmetry cluster (AsymP) has been calculated consisting of the electrodes P3/P4 and P8/P7 (AsymP) as control condition to be able to clarify that only processes of frontal areas are involved. The asymmetry score for the frontal sites and parietal sites was computed by subtracting the average ln left power from the average ln right power, and calculating the mean over both asymmetry indices (Figure 1; see Harmon-Jones, 2007, for a similar procedure). EEG alpha power is interpreted as an indication of less cortical activity in the underlying regions (e.g., Allen et al., 2004); thus a higher difference score means stronger left than right cortical activity.

For the MMG, sum scores were calculated for each *yes* answer on the test items for the achievement motive subscale (Cronbach's $alpha_{HS} = .586$, Guttman $split\text{-}half_{HS} = .618$; Cronbach's $alpha_{FF} = .776$, Guttman $split\text{-}half_{FF} = .645$). A difference score was calculated by subtracting FF from HS. Thus, the higher the score, the stronger participants' HS was compared to their FF (Brunstein & Heckhausen, 2010). As the focus of the study was on the correlation between resting state EEG and achievement motive, the power motive and the affiliation motive were not further analyzed. The scorings form of the MMG was used to decide which drawing-statement combination belonged to which subscale. For the AMS-R, a sum score was calculated for both explicit HS (Cronbach's $alpha_{HS} = .382$, Guttman $split\text{-}half_{HS} = .573$) and explicit FF (Cronbach's $alpha_{FF} = .532$, Guttman $split\text{-}half_{FF} = .406$). A difference score was calculated by subtracting FF from HS. Thus, the higher the score, the stronger participants' HS was compared to their FF. Research showed that although internal consistency is normally low for implicit motives, stable overall scores can be obtained (e.g., Schultheiss, Liening, & Schad, 2008). Therefore, we proceeded despite the rather low reliability coefficients.

RESULTS

Table 1 presents the mean values and standard deviations for frontal and parietal alpha asymmetry scores. Table 2

Table 3
Pearson Correlations Between the Frontal and Parietal Asymmetry Scores (AsymF, AsymP) and the Difference Score of the Implicit Achievement Motives on the Multi-Motive-Grid (MMG), and the Difference Score of the Explicit Achievement Motives on the Achievement-Motive-Scale-Revised (AMS-R)

	AsymF	*AsymP*
Implicit difference score	.402*	.233
Explicit difference score	.264	.081

Note. $N = 29$. Asymmetry score = ln right − ln left.
*$p < .05$, two-tailed.

presents the mean values and standard deviations for the difference scores (HS − FF) of implicit and explicit achievement motives. The present study aimed at investigating the relationship between frontal (AsymF), and parietal (AsymP) activation asymmetries and implicit and explicit achievement motives. To this end, Pearson product correlations (two-tailed) were calculated between the asymmetry scores (AsymF, AsymP) and the difference scores on the MMG as well as the difference scores on the AMS-R (Table 3). Important to mention, explicit and implicit achievement motive difference scores did not correlate significantly with each other, $r(29) = .232$ $p = .236$. Results show that there was a significant positive correlation between frontal alpha asymmetry score and the implicit difference score, $r(29) = .402$ $p = .031$ (see Figure 2). The higher people scored on HS (or less to FF), the greater relative left than right frontal activity. However, no significant correlation between frontal alpha asymmetry scores and the explicit achievement motive difference score were found ($p = .174$). The two correlations did not significantly differ from each other ($p = .534$). The control analyses between parietal asymmetry scores and both implicit and explicit measures showed no significant correlation ($p_{\text{implicit}} = .233$; $p_{\text{explicit}} = .081$; see Table 3).

General Discussion

The aim of the current study was to explore the relationship between the asymmetrical cortical activity in the frontal cortex associated with approach and withdrawal motivational tendencies, and the implicit and explicit achievement motives. We predicted that greater implicit HS relative to FF should be linked to greater relative left than right frontal activity, while for explicit measures, no clear predictions were formulated. Our results confirmed that the implicit achievement motive showed the predicted relation, that is, greater HS relative to FF is related to greater relative left than right frontal activity. Yet, no significant correlations were found between the frontal EEG asymmetry and the explicit achievement motives. The control analyses with parietal EEG asymmetry and implicit and explicit achievement motives showed no significant relationships.

Our findings are in line with previous research demonstrating the relationship between approach-oriented emotions, approach motivation, and approach-related constructs with increased left frontal cortical activity (e.g., Davidson & Fox, 1982; Fox, 1991; Fox et al., 2001; Harmon-Jones et al., 2010; Licata et al., 2015; Pizzagalli

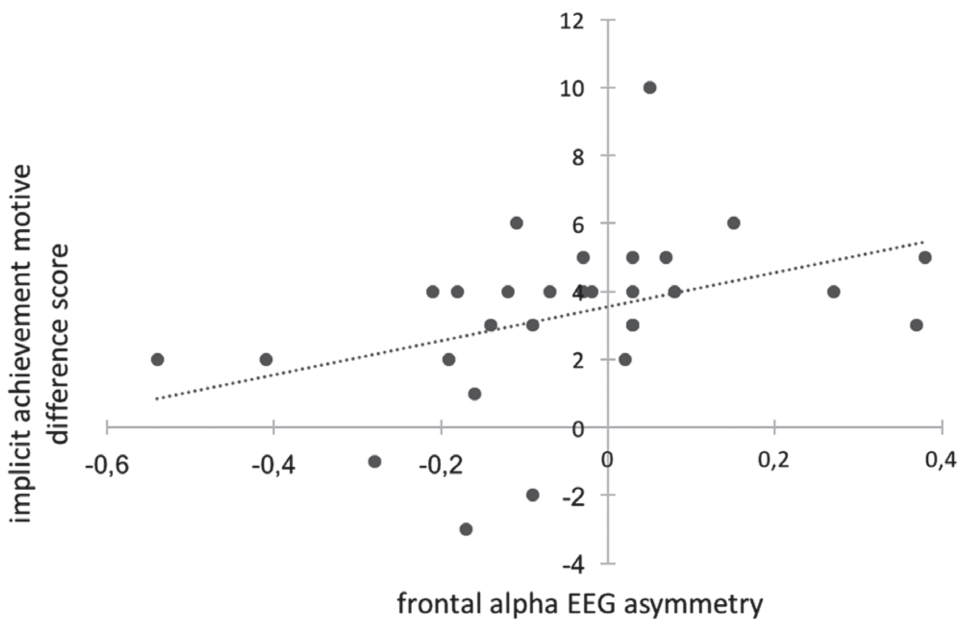

Fig. 2. Scatter plot of the frontal electroencephalogram (EEG) alpha asymmetry cluster (RH − LH) and the implicit achievement motive different scores (HS − FF).

et al., 2005; Shankman et al., 2003, 2005; Sutton & Davidson, 1997; Tomarken & Keener, 1998). In addition, a personality trait related to a stronger approach tendency, the BAS (Gray, 1994), is linked to an increase in relative left frontal alpha activity after a difficult decision is made (Harmon-Jones et al., 2008; Harmon-Jones et al., 2011). Thus, not surprisingly, implicit HS relative to FF positively correlated with frontal EEG asymmetry scores, given that it is defined as the tendency to approach a situation in which the individual can pursue or accomplish success in order to experience the feelings joy or pride when the aspired goal or standard is achieved. Overall, our findings support theoretical views according to which greater left than right frontal cortical activity is associated with both positive and negative approach motivation (Harmon-Jones et al., 2010).

It is important to note that significant correlations between EEG asymmetry scores and implicit achievement motive scores were only found for frontal areas. Our control analysis using electrodes above parietal areas did not relate significantly to neither implicit nor explicit achievement motives. This finding supports the notion that frontal activation asymmetries play a special role in prediction individual differences in motivation-related variables (e.g., Harmon-Jones et al., 2008; Harmon-Jones et al., 2011).

In the current study, explicit HS and FF did not relate significantly to frontal EEG asymmetry scores. However, based on the nonsignificant correlations between frontal EEG asymmetry scores and explicit motives, we cannot conclude that a relationship does not exist, and this study should be seen as a pilot study. Importantly to note is that our sample is rather small, raising a power problem when interpreting null effects. Moreover, internal consistency was rather low. Therefore, it is not possible to conclusively conclude that a relationship exists or not, and we suggest future research with a larger sample to further investigate this question. In addition, as implicit and explicit measures often correlate weakly, it will be of great interest whether or not both measures have indeed different neural correlates.

Due to the exploratory nature of our study, several limitations need to be addressed. Importantly, in the current study, we only tested healthy adults in a very specific setting, that is, at the university, which might be seen as related to academic achievement. Thus, future research is necessary to validate the current findings in a different, less achievement-related setting. Furthermore, as frontal EEG asymmetry is stable in children (e.g., Fox, Bell, & Jones, 1992; Müller, Kühn-Popp, Meinhardt, Sodian, & Paulus, 2015), it would be interesting to explore the relationship between both concepts in younger children, to understand more about the ontogenetic origins and the predictive value. For future research, it would also be worthwhile to investigate which other factors relate to both the approach-avoidance system and implicit achievement motive. For example, research has shown that children of depressed mothers show an altered frontal EEG asymmetry (e.g., Jones, Field, & Davalos, 2000). Given that our results suggest a relation between frontal EEG asymmetry and the implicit achievement motive, it would be interesting to examine whether these children also show differences in their implicit achievement motive.

In summary, we extended the current literature by investigating the relationship between the implicit and explicit achievement motives and frontal EEG asymmetry. The present study is, to the best of our knowledge, the first showing a positive relationship between the implicit achievement motive and frontal EEG asymmetry. In an educational setting, it seems important to be able to predict and influence the achievement motive to be able to stimulate individuals as good as possible. To be able to do so, future research is necessary to explore whether and under which circumstances frontal EEG asymmetry is also predictive for explicitly assessed achievement motives.

NOTE

1 One participant did not complete the explicit achievement motive measure. Thus, only the data of the implicit measure of this participant is included in the analyses.

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