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Wearing a bike helmet leads to less cognitive control, revealed by lower frontal midline theta power and risk indifference

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Abstract

A recent study claims that participants wearing a bike helmet behave riskier in a computer-based risk task compared to control participants without a bike helmet. We hypothesized that wearing a bike helmet reduces cognitive control over risky behavior. To test our hypothesis, we recorded participants' EEG brain responses while they played a risk game developed in our laboratory. Previously, we found that, in this risk game, anxious participants showed greater levels of cognitive control as revealed by greater frontal midline theta power, which was associated with less risky decisions. Here, we predicted that cognitive control would be reduced in the helmet group, indicated by reduced frontal midline theta power, and that this group would prefer riskier options in the risk game. In line with our hypothesis, we found that participants in the helmet group showed significantly lower frontal midline theta power than participants in the control group, indicating less cognitive control. We did not replicate the finding of generally riskier behavior in the helmet group. Instead, we found that participants chose the riskier option in about half of trials, no matter how risky the other option was. Our results suggest that wearing a bike helmet reduces cognitive control, as revealed by reduced frontal midline theta power, leading to risk indifference when evaluating potential behaviors.

KEYWORDS

cognitive control, EEG, frontal midline theta, helmet, risk behavior

1 | INTRODUCTION

Most people wear helmets during cycling, driving a motor bike, or skiing because they are convinced that such gear reduces the risk of head injuries (Ross, Ross, Rahman, & Cataldo, 2010). For example, a few years ago, a well-known German politician and a world-famous Formula 1 racer suffered head injuries caused by skiing accidents. Although both wore a helmet and survived, a person involved in the ski accident with the politician did not wear a helmet and died immediately. Afterward, the helmet industry in Germany experienced a steep increase in helmet sales (Tödtmann, 2009). These perceived benefits notwithstanding, some research has highlighted an adverse effect of helmet wearing in that people tend to take more risks when wearing a helmet than when not wearing one (for a review, see Adams & Hillman, 2001; Trimpop, 1994; Trimpop & Wilde, 1993). This adverse effect, termed risk compensation (Peltzman, 1975), has been addressed by several related theoretical frameworks including the most popular (Pless, 2016; Trimpop, 1994, 1996) but highly controversial (Evans, 1986; Pless, 2016; Radun, Radun, Esmaeilikia, & Lajunen, 2018) theory, called risk homeostasis (Wilde, 1988, 1998), and an alternative framework called risk allostasis (Lewis-Evans & Rothengatter, 2009). Similar concerns about risk compensation have been discussed for other safety-related tools such as seat belts (Adams, 1982), airbags, safety goggles, or vaccinations (for reviews, see Pless, 2016; Trimpop, 1994; Trimpop & Wilde, 1994).

A recent study (Gamble & Walker, 2016) postulated that risk compensation might also be effective in risk situations where people wear protective devices that have no direct, obvious protective function for the risky action they are engaged in. The authors showed that participants wearing a bike helmet while playing the balloon analogue risk task (BART), a computerized risk game (Lejuez et al., 2002), took greater risks than participants in a control group wearing a baseball cap. To keep participants of both groups blind about the purpose of the study, they were falsely told that the headgear would be used to record their eye movements during the game. Participants of both groups were asked to stepwise inflate a virtual balloon on a computer screen by pressing a button as long as they believed the balloon would not burst. Pumping the balloon could be stopped at any time, and the money earned would be banked for later payout. However, in case of a burst, the collected winnings of the trial were lost. Thus, the level of risk taking was characterized by the number of button presses that inflated the balloon. Even though the helmet had no direct protective function for the computer game, participants wearing the helmet showed greater risk taking and more pumping actions than participants wearing the baseball cap. Furthermore, the helmet wearers also reported higher scores of sensation seeking than the cap wearers. This relatively enhanced risk preparedness and sensation seeking in the helmet wearers was interpreted by Gamble and Walker (2016) as effects of social priming. On this account, they reflect implicit unconscious propensities to generalize protective effects of safety devices beyond their common area of application.

These findings of Gamble and Walker (2016) run counter to commonly held beliefs about the effects of helmet wearing and as such have drawn considerable public attention while being received controversially by the scientific community (e.g., Radun & Lajunen, 2018). We therefore attempted to extend and replicate their observations. Another point is that the Gamble and Walker study did not experimentally assess participants' concepts about implicit unconscious beliefs and social priming. Since such concepts are difficult to disentangle experimentally, we instead tested whether the concept of cognitive control and its neuronal foundations could provide insight into the behavior of the helmet wearers.

To be specific, we hypothesized that wearing a bike helmet might ameliorate participants' implicit concerns about risk when engaged in risky decision making, which would be reflected in reduced cognitive control during task performance. Cognitive control describes the ability to use internal goals to guide thought and behavior (Egner, 2017). This includes the process of monitoring ongoing actions and performance outcomes (Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004), which is necessary for adaptive goal-directed behavior (Koechlin, Ody, & Kouneiher, 2003). In the context of risky behavior, cognitive control comes into play when participants have to decide between riskier and less risky alternatives, where high risk is characterized by an unknown probability distribution of the option outcome (De Groot & Thurik, 2018). We hypothesized that wearing a bike helmet would induce a sense of security in participants, which in turn would diminish cognitive control over risky behavior even in task domains that are entirely unrelated to traffic such as computer-based risk games.

Cognitive control is subserved by a network of brain structures including the prefrontal cortex, the orbitofrontal cortex, and the anterior cingulate cortex, as revealed by lesion studies (Gläscher et al., 2012), functional neuroimaging, and animal neurophysiology studies (Egner, 2017). Notably, the control function of anterior cingulate cortex appears to be reflected in frontal midline theta EEG oscillations (Cavanagh & Frank, 2014; Holroyd & Umemoto, 2016). For example, frontal midline theta power is enhanced after participants committed a cognitive or behavioral error, when participants received negative feedback about the output of a targeted action, or when there is a high amount of conflict between potential cognitive and/or behavioral alternatives (Cavanagh, Zambrano-Vazquez, & Allen, 2012). Frontal midline theta power is also associated with effort and attentional processes associated with anterior cingulate cortex function (Holroyd & Umemoto, 2016).

In the context of risky decision making, less risky behavior might be mirrored in reduced frontal midline theta power (Schmidt, Kanis, Holroyd, Miltner, & Hewig, 2018). In a recent study, we showed by use of mediation analysis that anxiety was associated with greater frontal midline theta power during the decision time, which in turn predicted less risky choices afterward (Schmidt et al., 2018). We argued that participants showing greater frontal midline theta power when making risky decisions exerted more cognitive control, which in turn led to more conservative behavior. Due to these findings, we hypothesize that wearing a bike helmet reduces cognitive control, which would be reflected in lower frontal midline theta power. Wearing a bike helmet might induce the feeling of security accompanied by reduced cognitive control. Riskier behavior should in turn be associated with lower cognitive control and reduced midfrontal theta power (Aron, 2007; Schmidt et al., 2018).

To test this hypothesis, we aimed to replicate the study by Gamble and Walker (2016) while recording the EEG from participants playing a risk game. Since the BART (Lejuez et al., 2002) used by Gamble and Walker has problematic features for its use in EEG experiments (see Discussion), we used an alternate risk game developed in our lab where expected values of each response option are equal on each trial (Schmidt et al., 2017, 2018, 2019; Schmidt & Hewig, 2015; Schmidt, Mussel & Hewig, 2013). In each trial of this game, participants decide between playing a very risky gamble of winning either 11 or 0 cents with a probability of 50%, or playing a less risky gamble like winning either 5 or 6 cents with a probability of 50%. The expected values are thus equal for both alternative gambling options, and participants know the probability distribution governing the outcomes. This task design is characteristic of a risk game as opposed to an uncertainty game (De Groot & Thurik, 2018).

Taken together, the aim of our present study was to replicate the Gamble and Walker study and extend its observations by additionally investigating the neuronal mechanism associated with risk behavior when participants wear a bike helmet during the computer-based risk task. We predicted that wearing a bike helmet would reduce cognitive control about the task performance and that this would be revealed by decreased frontal midline theta power. Apart from the inclusion of EEG brain responses and the change of the behavioral task, we followed the methods described in the study by Gamble and Walker (2016).

2 | METHOD

2.1 | Participants

We tested 40 participants separated into two groups of 20 participants. We recruited participants via Facebook posts in groups including people who are willing to participate in experiments, which were not only university students. We also sent an email invitation via the distribution list of the psychology department of the University of Jena. Participants of the helmet group wore a bike helmet during the experiment, whereas participants of the control group did not. The study was single-blinded, as the participants did not know that there were two groups in our experiment that differed concerning their headwear. In each group were 10 male and 10 female participants. The average age of participants in the helmet group was 22.4 years (*SD* = 3.2, range 18–29 years) and that of the control group was 23.3 years (*SD* = 2.9, range 19–30 years). Payment depended on the outcomes in the risk game. On average, participants won 13.16 Euros (*SD* = 0.26) during the game. In addition, participants received 6 Euros per hour for participation or course credit. The whole experimental session lasted about 90 min. The ethics committee of the Faculty of Social and Behavioral Sciences of the Friedrich Schiller University of Jena approved the study, and the study is in line with the Declaration of Helsinki. To implement the ethical requirement to debrief participants after the experiment while also guarding against participants telling anyone else about it, after debriefing we asked them not to tell others about the real purpose of the helmet.

2.2 | Procedure

Prior to the experiment, participants read written instructions and signed an informed consent. Afterward, they filled in the State-Trait Anxiety Inventory (STAI) to assess trait and state components of anxiety (Spielberger, Gorsuch, & Lushene, 1970; German version by Laux, Glanzmann, Schaffner, & Spielberger, 1981). Trait anxiety implies a behavioral propensity to assess environmental conditions more likely as threatening. State anxiety is characterized by subjective feelings of apprehension and tension (Spielberger, 1966). State and trait components of anxiety are assessed by 20 questions each. These items are scored from 1 (*not at all*) to 4 (*very much*). Therefore, scores of both scales vary between 20 and 80. Then, an electrode cap (Easycap, Wörthsee-Etterschlag) for recording the EEG was mounted on participants' heads. Participants sat in a dimly lit room on a comfortable chair in front of a computer monitor that was positioned approximately 100 cm apart from the participants. Participants in the helmet group wore a plastic shower cap and a bike helmet in addition to the electrode cap (Figure 1). The shower cap was required to keep the electrode gel from the bike helmet. The helmet was big enough that it did not put much pressure on the electrodes, which prevented artifact contamination of the EEG.

At the front of the bike helmet an eye tracker (SMI, Teltow) was fixed as in the study of Gamble and Walker (2016). This eye tracker served as a cover story for the participants. In the following, we describe our efforts to make the cover story as

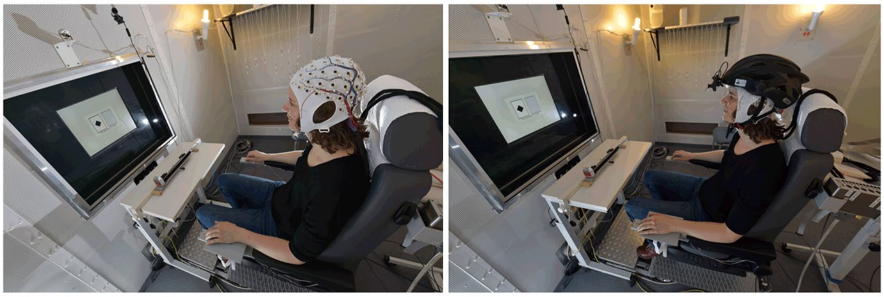

FIGURE 1 Participant with electrode cap (left, control group) and participant with electrode cap, shower cap, and bike helmet (right, helmet group)

believable as possible in order to prevent participants from becoming suspicious about the real purpose of the helmet. They were told that the bike helmet holds a camera that tracks their eye movements (see Figure 1). In the control group, participants were told that their eye movements are tracked by an eye tracker installed on a table in front of them. However, no eye-tracking data were recorded in this study. To make the cover story even more valid, we carefully adjusted the eye tracker on the helmet and simulated the calibration procedure of the eye tracker in both groups. During the calibration procedure, participants gazed at a dot that moved at different locations of the screen in front of them.

After calibration of the eye tracker, participants filled in the Sensation-Seeking Scale Form V (SSS-V, Zuckerman, Eysenck, & Eysenck, 1978). This scale measures four dimensions (10 self-report items each) of sensation-seeking behavior: thrill and adventure seeking, disinhibition, experience seeking, and boredom susceptibility. Scores on the SSS-V range from 0 to 40, with higher scores indicating more sensation seeking. After that, participants played the risk game as described below to assess their risk behavior. After the risk game, participants filled in the STAI-State questionnaire again. Then, the helmet and the electrode cap were removed, and participants were offered a shower to wash their hair. When they returned, they filled in the STAI-State questionnaire a third time. At the end of the experiment, they filled in a final questionnaire. One question asked how secure they felt during the experiment using a Likert scale ranging from 1 (*very insecure*) to 10 (*very secure*). Bicycling frequency was also assessed using a Likert scale ranging from 1 (*never*) to 6 (*five times a week or more*) as described in Gamble and Walker (2016). If participants selected anything other than *never* on this instrument, helmet-wearing frequency was assessed using a Likert scale ranging from 1 (*never*) to 6 (*always*) as described in Gamble and Walker. Finally, participants indicated whether they believed that the helmet affected their behavior during the experiment and if so, how. Afterward, participants were debriefed about the cover story.

The risk game was presented using Presentation software (Neurobehavioral Systems, Inc., Berkeley, CA; www.neurobs.com). Statistical analyses were performed with R (R Development Core Team, 2019). For between-group *t* tests, we used the Welch unequal variances *t* test implemented in R that corrects the degrees of freedom in case of unequal variances. We used Cohen's *d* to quantify effect sizes for *t* tests. Sizes of ANOVA effects were estimated by omega-squared.

2.3 | Risk game

Participants played the same risk game as described in earlier studies of our group (Schmidt et al., 2013, 2017, 2018; Schmidt & Hewig, 2015). Participants played two blocks of the risk game, each consisting of 120 trials. The two blocks were separated by short breaks in which participants rated the response options according to their perceived valence, arousal, and riskiness. Valence and arousal were measured using the Self-Assessment Manikin (Bradley & Lang, 1994). The rating scales ranged from 1 to 9 with higher scores indicating more positive, more arousing, and riskier evaluations. One block of the risk game lasted about 20 min.

At the beginning of each trial, a fixation cross was shown for a random interval of 1,000 to 2,000 ms (Figure 2). Then, two options were presented that differed in their associated risks. Both of these options consisted of two monetary rewards. The expected value of both options was always 5.5 cents, and the degree of riskiness differed between the

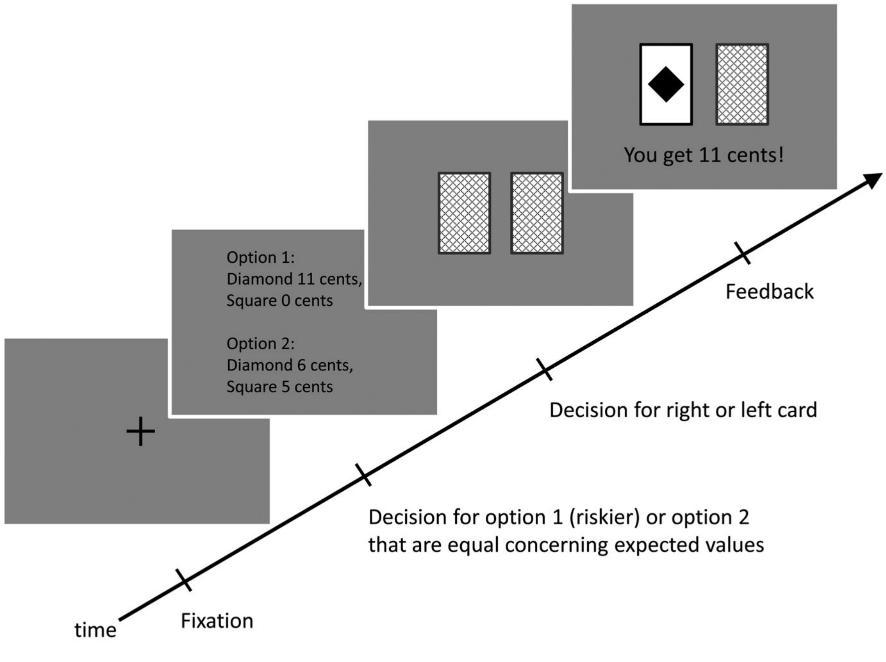

FIGURE 2 Time course of one trial in the risk game

options, from 11 cents versus 0 cents as the riskiest option and 6 cents versus 5 cents as the safest option. Participants always chose between the riskiest option (11 cents vs. 0 cents) and one of the other options. All option pairs were presented in random order and at random locations on the monitor screen. Participants were required to choose an option by pressing one of two buttons. After another random interval of 500 to 1,000 ms, two cards were shown face down (Figure 2). Then, participants had to choose one of the cards by pressing one of two buttons with their right hand. After another random interval of 500 to 1,000 ms, the back of the selected card was shown, displaying either a diamond that indicated the higher monetary reward (positive feedback) or a square indicating the lower monetary reward (negative feedback), together with the statement "You get XX cents!" for 1,500 ms. Unbeknownst to the participants, on 50% of the trials the monetary feedback was positive and on the other 50% the monetary feedback was negative, delivered at random independently of their choices. All stimuli in the risk game occupied about 10° of visual angle horizontally and 5° vertically. At the end of the game, the total accumulated reward was presented to the participants. Participants were paid the corresponding amount.

2.4 | EEG recording and ERP quantification

The EEG was recorded using BrainAmp amplifiers (Brain Products GmbH, Gilching, Germany) from 64 Ag/AgCl electrodes mounted on participants' heads including one electrode under the left eye. All electrodes were referenced to the electrode FCz. Impedances of all electrodes were kept below 10 kΩ. Data were band-pass filtered online from 0.016 Hz to 250 Hz. For offline data processing, EEGLAB (Delorme & Makeig, 2004) running under the MATLAB environment (The MathWorks, Inc.) was used.

For offline analysis, EEG sampling rate was reduced to 250 Hz. For eye artifact correction, independent component analysis (ICA) was applied as proposed by Debener, Thorne, Schneider, and Viola (2010). Eye-related artifact components were removed by back-projection of all remaining components. The artifact-corrected data were then rereferenced to the mean of electrodes TP9 and TP10. For ERP analysis, the data were filtered with a low-pass filter of 20 Hz. For frontal midline theta analysis, EEG data were segmented into epochs around the presentation of risk options −2,500 ms to 2,500 ms. Residual artifacts were identified by statistical criteria (joint probability and kurtosis) and removed from all further analysis.

To quantify frontal midline theta power, we performed a wavelet analysis as described in HajiHosseini and Holroyd (2013) and Schmidt et al. (2018). We used complex Morlet wavelets to compute power values for frequencies between 1 and 20 Hz for every trial and averaged the trials for each participant. The time-frequency resolution was 1 Hz. Then, we computed a baseline between −500 ms to −200 ms before the presentation of options and performed a baseline correction for every participant. Finally, we extracted power values for the theta range (4–8 Hz) within a time window between 100 ms and 360 ms at electrode FCz to get frontal midline theta power values for every participant and condition. It is the same time window as in our previous study (Schmidt et al., 2018) and is in line with observations reported in reviews of frontal midline theta by Cavanagh and Shackman (2015). For plotting, we averaged power values over participants after baseline correction and performed a logarithm transformation to plot data as dB change from baseline.

3 | RESULTS

3.1 | Anxiety scores, sensation seeking, and frequency of bicycling

Trait anxiety scores measured via the STAI trait did not differ between groups ($p > .3$, $M_{\text{helmet}} = 38.7$, $M_{\text{control}} = 36.3$). The minimum score in both STAI parts is 20, and the maximum score is 80, with higher scores indicating more anxiety. Also, sensation-seeking scores measured with the SSS-V did not differ between groups ($p > .7$, $M_{\text{helmet}} = 22.5$, $M_{\text{control}} = 22.1$). Recall that, as stated in the Method, scores on the SSS-V range from 0 to 40 with higher scores indicating more sensation seeking. The two groups also did not differ concerning any of the four subscales of the SSS-V. According to the questionnaire that was delivered at the end of the experiment, participants in the two groups did not differ concerning their experienced security during the experiment ($p > .4$, $M_{\text{helmet}} = 8.7$, $M_{\text{control}} = 9.0$). This scale ranges from 1 to 10, with high scores indicating more security. Also, both groups reported equivalent frequencies of bicycling ($p > .6$, $M_{\text{helmet}} = 4.1$, $M_{\text{control}} = 3.8$). This scale ranges from 1 (*never*) to 6 (*more than five times a week*). The participants in the helmet group indicated that they wore a bike helmet more often than did the participants in the control group, $t(16.7) = 2.4$, $p = .03$, $M_{\text{helmet}} = 1.9$, $M_{\text{control}} = 1.1$. On this scale, 1 indicates *never* and 6 indicates *always*. During the debriefing, one person in the helmet group spontaneously reported that the helmet affected her behavior because it restricted her movements. This participant explicitly said that the feeling of being restricted only referred to head movements, and that she had no idea concerning the real purpose of the helmet. We therefore did not exclude the data of this participant from further analysis.

To test the effects of the helmet on participants' state anxiety, we applied an analysis of variance (ANOVA) on STAI state scores with the between-subjects factor group (helmet, control) and the within-factor time (before putting on electrode cap and helmet, after the risk game, after removing electrode cap and helmet). The only significant effect in this analysis was the main effect of time, $F(2, 76) = 7.7$, $p < .001$, $\omega^2 = .04$. State anxiety ratings decreased during the experiment from the time before participants put on the electrode cap and helmet ($M = 35.7$) to the time after the risk game ($M = 34.3$) to the time after removing the electrode cap and helmet ($M = 32.6$). The main effect of group was not significant ($p > .2$).

3.2 | Risk behavior

Participants chose one of the presented risk options after on average 1.4 s ($SD = 0.4$ s). In order to visualize the participants' risk behavior, we computed the percentage of risky decisions for every participant by dividing the number of trials in the risk game where the participant chose the riskier option by the number of all trials (see Figure 3). We performed separate regressions of risk behavior on the alternative option for the helmet and the control group. The slope of the helmet group regression line was 0.0, centering around the 50% line, whereas the slope of the control group regression line was 10.3. To test if the difference between the two slopes was significant, we performed a model test. We compared a regression model that included only main effects of group (helmet, control) and option (6:5 cents, 7:4 cents, 8:3 cents, 9:2 cents, 10:1 cents; Model 1) with a regression model that included main effects of group and option as well as the interaction between group and option (Model 2). Model 2 including the interaction of group and option fitted the data significantly better than Model 1 without this interaction, $G^2 = 6.62$, $p = .01$. This indicates that in the helmet group participants chose the riskier option in about half of the trials independent of the alternative option (zero regression slope), in contrast to the control group, where participants' choices clearly depended on the alternative option (nonzero regression slope). Post hoc *t* tests revealed that participants wearing a bike helmet chose the riskier option more often ($M = 49\%$) than did participants in the control group ($M = 26\%$) when the difference in these options was most extreme, that is, when they chose between the riskiest option (11 or 0 cents) and the safest option (6 or 5 cents), $t(36) = 2.6$, $p = .01$ (Figure 3).

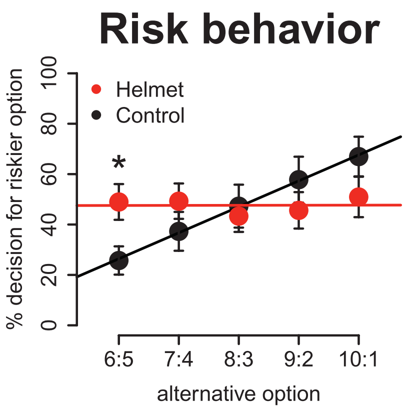

FIGURE 3 Risk behavior in the helmet group and in the control group, dependent on the alternative option that was presented other than the risky option 11 cents or 0 cents. Error bars are standard errors of the mean. The lines are based on regressions of risk behavior on the alternative options, separately for both groups

3.3 | Option ratings

We performed separate ANOVAs on the valence, arousal, and riskiness ratings of the risk options, with group as a between-subjects factor (helmet, control) and risk option as a within-subject factor (6:5 cents, 7:4 cents, 8:3 cents, 9:2 cents, 10:1 cents, 11:0 cents), revealing main effects of risk option for all ratings (valence, $F(5, 190) = 2.6$, $p = .03$, $\omega^2 = .03$; arousal, $F(5, 190) = 54.7$, $p < .001$, $\omega^2 = .31$; riskiness, $F(5, 190) = 176.0$, $p < .001$, $\omega^2 = .65$). Visual inspection of the data indicates lower valence, higher arousal, and higher perceived riskiness with increasing riskiness of the options (Figure 4). The only significant difference between the helmet and the control group emerged for valence ratings of the safest option. Participants in the control group rated the safest option (6:5 cents) as more positive than participants in the helmet group, $t(38) = 2.2$, $p = .03$.

3.4 | Frontal midline theta analysis

We analyzed frontal midline theta power measured at electrode FCz (Figure 5). A mixed two-factor ANOVA on frontal midline theta power, with group as the between-subjects factor (helmet, control) and risk option as within-subject factor (6:5 cents, 7:4 cents, 8:3 cents, 9:2 cents, 10:1 cents, 11:0 cents) revealed a significant main effect of group, $F(1, 38) = 4.3$, $p = .04$, $\omega^2 = .08$, $d = .7$. Frontal midline theta power was lower in the helmet group ($M = 1.26\ \mu V^2$, $SD = 0.2\ \mu V^2$) compared to the control group ($M = 1.41\ \mu V^2$, $SD = 0.3\ \mu V^2$; Figure 5). All other effects did not reach significance.

To test if frontal midline theta power is associated with the percentage of risky choices in the risk game, we computed their correlation based on the values of both variables for all 40 participants. The correlation was not significant ($p = .96$).

4 | DISCUSSION

In the present study, we investigated a neuronal mechanism accounting for the surprising and controversial effect of riskier behavior in participants wearing a bike helmet, as reported by Gamble and Walker (2016). We predicted that frontal midline theta power, a neural indicator of cognitive control (Cavanagh & Shackman, 2015; Holroyd & Umemoto, 2016;

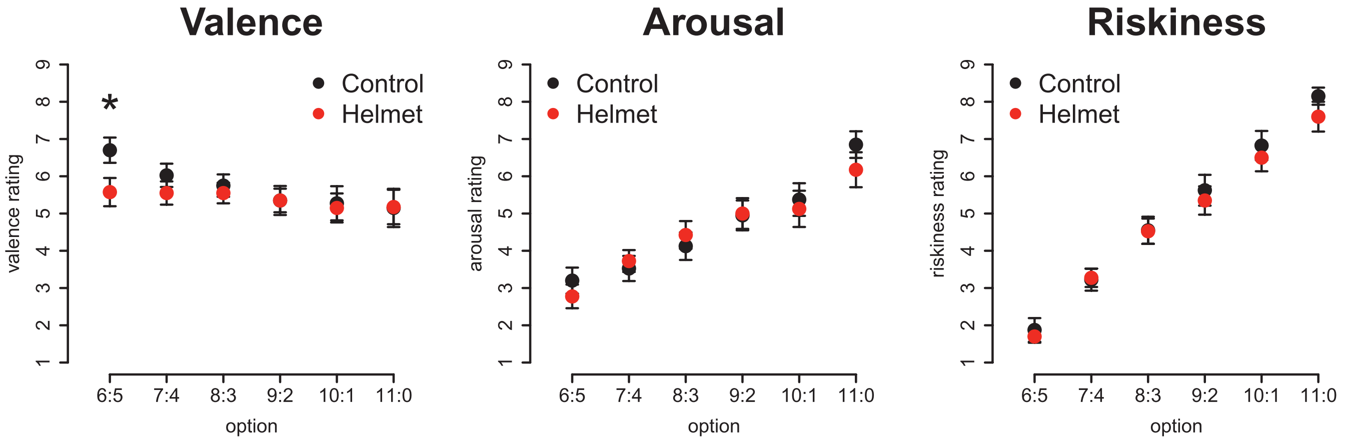

FIGURE 4 Ratings of risk options on the scales valence, arousal, and riskiness showing that participants rated riskier options as less positive, more arousing, and riskier. Participants in the control group rated the safest option 6 or 5 cents as more positive than participants in the helmet group. Error bars are standard errors of the mean

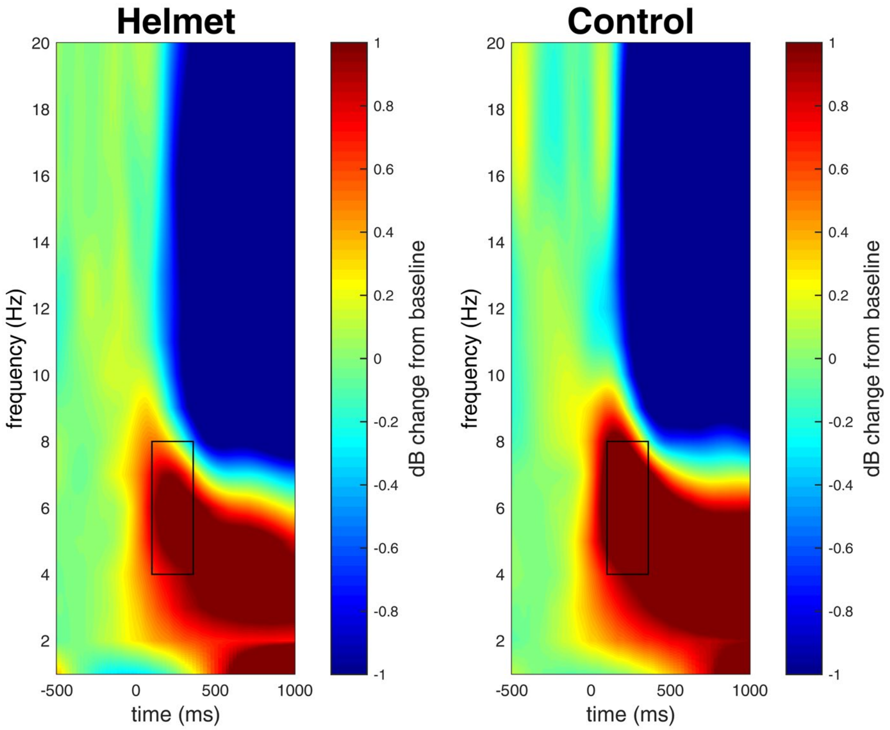

FIGURE 5 Participants wearing a bike helmet showed lower frontal midline theta power at FCz compared to participants without helmet during their decision time. At time 0, the risk options are presented. Black rectangles indicate the analyzed window from 100 ms to 360 ms after option presentation in the theta range (4–8 Hz)

Schmidt et al., 2018), would be reduced when participants wear a bike helmet and that lower cognitive control would be associated with riskier behavior. In line with this association, we found decreased levels of frontal midline theta power when participants wore a bike helmet while making their decisions, an indicator of reduced cognitive control and decreased activation of the anterior cingulate cortex (Holroyd & Umemoto, 2016).

In contrast to the results reported by Gamble and Walker (2016), participants of the helmet group did not generally prefer the riskier option. Frontal midline theta power and percentage of risky choices were not significantly associated in our study, which might be due to this lacking main effect of the helmet on risk decisions (Figure 3). Instead, participants with helmet chose the riskier option in about half of trials, no matter what the alternative option was. In previous studies using our risk paradigm, we consistently found that participants' choices depended on the level of risk of the alternative option, as in the control group in Figure 3 (Schmidt et al., 2013, 2017, 2018, 2019; Schmidt & Hewig, 2015). Therefore, we interpret the zero regression in the helmet group (Figure 3) as a change in risk preferences relative to controls. In particular, when they had to decide between the safest and the riskiest option, the participants in the helmet group chose the riskier option significantly more often than did the participants in the control group. In line with this observation, participants in the helmet group also rated the safest option as significantly less positive compared to the control group. This difference in valence ratings between the two groups suggests that participants in the helmet group did not simply act randomly, choosing the riskier option in about half of trials. Instead, they appear to have chosen the riskier over the safest option relatively more often because they evaluated the latter option less positively.

As ratings of riskiness and arousal did not differ significantly between groups, we assume that participants of both groups differentiated properly between the six different options of the risk game. The difference in their behavior thus cannot be based on improper conceptualizations of the different risk levels or on the fact that the different risk levels evoked similar arousal in the helmet wearers. Instead, we assume that wearing a bike helmet resulted in decreased cognitive control during task performance and reduced sensitivity to risk over decisions that are completely unrelated to bicycling and physical safety.

In contrast to the study by Gamble and Walker (2016), we did not find differences between groups concerning sensation-seeking scores measured by the SSS-V. This discrepancy could be due to several reasons. First, we used a different risk paradigm in order to avoid a critical feature of the BART, as used by Gamble and Walker. This task requires participants to gradually inflate a virtual balloon to increase their winnings. Every time they incrementally inflate the balloon, the probability of a burst increases. If the balloon bursts, the winnings on that trial are lost. Thus, on each step of the trial, the participant decides between either accepting the risk of inflating the balloon further or terminating the trial to receive their accumulated winnings, so the dependent variable is the number of times participants pressed the button for inflating the balloon on the trials where the balloon did not burst. Crucially, each time participants inflate the balloon, the expected value—which is the product of the balloon value and the probability not to burst—changes. While a fixed amount of money is added to the balloon value after each successful inflation, the probability to burst increases faster after each inflation, such that the optimal expected value is achieved at the midway point after 64 inflations (Lejuez et al., 2002). Therefore, participants make up to 128 responses on each trial, and the total number of presses varies across trials, making it difficult to associate neural activity with any one response value. By contrast, the task in our study involved one choice per trial, allowing us to relate frontal midline theta power to that decision. In addition, participants in the BART do not know the probability distribution of the outcomes, which makes it an uncertainty game instead of a risk game (De Groot & Thurik, 2018).

Second, in contrast to the previous study, the participants in our experiment wore an electrode cap in addition to the bike helmet. Further, participants in the control group did not wear a baseball cap with an eye tracker mounted on it, as we could not place a baseball cap on top of the electrode cap. Instead, we placed the eye tracker on the table in front of the participants in the control group. Although we cannot rule out the possibility that this modification affected the results, we think that it is more plausible that the differences in the observed results are due to the differences in the tasks themselves. Likewise, the participants in the helmet group reported wearing a helmet more often than the participants in the control group. We do not think that the slightly higher frequency of helmet usage in the helmet group can explain the results. If it affected the task at all, being accustomed to wearing a helmet should lead to a habituation effect (thereby reducing the observed effect sizes).

In our study, we address methodological shortcomings of the original study summarized by Radun and Lajunen (2018). We report how we recruited participants, we made every effort to make the cover story valid, we asked participants if they have been suspicious concerning the real purpose of the helmet and made it very clear after the debriefing that it is essential not to tell other potential participants about the real purpose of the helmet. Participants were all surprised when they were debriefed, suggesting that they did not know about the real purpose of the helmet before.

We attribute the effect of the bike helmet on risk behavior to reduced cognitive control, mirrored by lower frontal midline theta power during the risk decisions. In our previous study (Schmidt et al., 2018), frontal midline theta power was higher in anxious participants who also showed less risky behavior. In our present study, we did not find differences in anxiety scores between the experimental groups, in line with the results reported in Gamble and Walker (2016). Further, participants wearing a helmet did not report feeling safer or having been affected by the helmet in any way. Therefore, the observed frontal midline theta power effect was not due to differences in anxiety in our study. In contrast, based on our earlier research, anxiety reflects itself more likely in more cognitive control (Schmidt et al., 2018). This is in line with the adaptive control hypothesis (Cavanagh & Shackman, 2015). According to this hypothesis, the brain process involved in cognitive control affects both cognitive and emotional processes. When the alarm calls for cognitive control, the feeling becomes more aversive. Note that, in our present study, we cannot differentiate if frontal midline theta power reflects the alarm signaling that cognitive control is needed or the actual application of cognitive control.

The finding that the helmet participants did not generally prefer the riskier option is in line with criticism (Pless, 2016; Radun et al., 2018) of the risk compensation theory or risk homeostasis theory, which postulates that safety features lead to riskier behavior (Trimpop, 1996). Rather, our findings suggest that the effects of helmets on risky decision making may be mediated by their impact on cognitive control levels.

Another relevant concept in this regard is priming. According to this concept, the bike helmet might act as a conditional stimulus (prime) to activate cognitive and emotional processes simultaneously that have been generally associated with the purpose of helmets. For example, helmet wearing could reduce anxiety about potential injury and other dangers, while also reducing levels of negative affect. Thus, the bike helmet could prime feelings of safety that relax cognitive control, which in turn affects risky behavior.

Taken together, we found reduced frontal midline theta power in individuals wearing a bike helmet compared to participants without a bike helmet when they made decisions under risk in a computerized game. As lower frontal midline theta power represents a valid indicator of less cognitive control (Cavanagh & Shackman, 2015), we conclude that wearing a bike helmet is associated with lower cognitive control and lower sensitivity to risk differences.

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