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Being in two minds: The neural basis of experiencing action crises in personal long-term goals

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Although the successful pursuit of long-term goals constitutes an essential prerequisite to personal development, health, and well-being, little research has been devoted to the understanding of its underlying neural processes. A critical phase in the pursuit of long-term goals is defined as an *action crisis*, conceptualized as the intra-psychic conflict between further goal pursuit and disengagement from the goal. In the present research, we applied an interdisciplinary (cognitive and neural) approach to the analysis of processes underlying the experience of an action crisis. In Study 1, a longitudinal field study, action crises in personal goals gave rise to an increased and unbiased (re)evaluation of the costs and benefits (i.e., *rewards*) of the goal. Study 2 was a magnetic resonance imaging study examining resting-state functional connectivity. The extent of experienced action crises was associated with enhanced fronto-accumbal connectivity signifying increased *reward*-related impact on prefrontal action control. Action crises, furthermore, mediated the relationship between a dispositional measure of effective goal pursuit (action orientation) and fronto-accumbal connectivity. The converging and complementary results from two methodologically different approaches advance the understanding of the neurobiology of personal long-term goals, especially with respect to the role of rewards in the context of goal-related conflicts.

Keywords: Long-term goals; Action crisis; Action orientation; Resting-state functional connectivity; Nucleus accumbens.

"Human beings are, by nature, goal-oriented organisms" (Emmons, 1996, p. 314). Meaningful (i.e., nonreflexive and nonaccidental) human behavior, almost without exception, has its origins in long-term goals (e.g., becoming a professional sportsman) that, by giving life structure and purpose, substantially contribute to an individual's sense of fulfillment and well-being. However, despite the theoretical and practical relevance of the concept, "neuroscientists have yet to examine long-term goals" (Berkman & Lieberman, 2009, p. 104). Previous neuroscientific research has focused exclusively on separate goal-

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related (sub)processes or short-term goals. This is mainly attributable to the current method in functional magnetic resonance imaging (fMRI) research of analyzing goal-related cognitive processes task-based, that is, in the context of experimentally induced tasks lasting seconds or minutes. As a consequence, interdisciplinary research that, in the realm of idiographic (i.e., everyday life) long-term goals, links neuroscientific to cognitive-behavioral data is lacking (cf. Berkman & Lieberman, 2009).

In the present research, we therefore applied an interdisciplinary and multi-methodological approach to the analysis of long-term goals, more precisely, the examination of cognitive and neural processes associated with an *action crisis*. An action crisis is conceptualized as the critical phase in the pursuit of long-term goals in which individuals, as a consequence of a loss of goal attainability (e.g., due to repeated setbacks) and/or desirability, become caught (in the decision) between further goal pursuit and disengagement from the goal (Brandstätter, Herrmann, & Schüler, 2013; Brandstätter & Schüler, 2013). Even though a goal has long been implemented and is being actively pursued, it is *re*-evaluated and weighed up against potential alternatives. Thus, in an action crisis, an individual, in the course of goal pursuit, becomes preoccupied with an *additional task* characteristic of goal setting (i.e., the *pre*decisional phase that precedes goal pursuit). An action crisis, therefore, includes *doing the splits* between a volitional task (goal striving) and a motivational task (goal setting) whereby, as a consequence, the way of processing information cannot be perfectly tuned to either of them (cf. cognitive tuning; Gollwitzer, Heckhausen, & Steller, 1990). Whereas volitional processes, for example, are facilitated by *selectively* analyzing and *partially* evaluating information relevant to the focal goal, motivational processes benefit from *objectivity* and *impartiality*, essential prerequisites to rational decision making (cf. mindset theory; Gollwitzer, 2012). An action crisis, however, results not merely in a competition for resources between the cognitively conflicting tasks of *striving* for the focal goal ("how" level) and *re-evaluating* it ("why" level; Trope & Liberman, 2010), but between the focal goal and potential alternatives that become more salient in an action crisis (Shah, Friedman, & Kruglanski, 2002). As a consequence of *being in two minds*, and consistent with the idea that the reconsideration of alternative goals undermines goal commitment and the development of effective means (Shah & Kruglanski, 2002), individuals in an action crisis have been shown to suffer from impaired goal progress. Furthermore, as personal goals constitute an individual's self-concept and self-value, action crises, especially in highly self-relevant goals, pose a serious threat to health and well-being (Brandstätter et al., 2013).

An action crisis thus represents a critical phase in goal striving that typically precedes but not necessarily leads to goal disengagement (Herrmann & Brandstätter, 2014). Especially with self-relevant long-term goals, goal disengagement does not represent a discrete event but, as "the self is partly made up of the person's goals" (Carver & Scheier, 2005, p. 528), results from a lengthy and difficult process (Klinger, 1977). The present research, by applying the concept of an action crisis, attempts to delineate the cognitive (Study 1) and neural (Study 2) characteristics of these goal disengagement processes in everyday life. Goal disengagement, although highly relevant to self-regulation, has until recently received almost no attention (Brandtstädter, 2007; Carver & Scheier, 1998; Wrosch, Scheier, Miller, Schulz, & Carver, 2003). A *process-based* perspective on long-term goals, furthermore, has only been subject to theoretical considerations (Klinger, 1977).

In Study 1, as the first step (*quantitative aspect*), we analyzed, in a longitudinal field study, the long-term consequences of an action crisis on the re-consideration of goal-related costs and benefits (i.e., goal-related rewards), which should be emphasized following the experience of an action crisis (hypothesis 1). As the second step (*qualitative aspect*), drawing on Brandstätter and Schüler (2013), we tested whether an action crisis counteracts *goal shielding*, defined as self-regulatory processes enhancing the value of the focal goal (e.g., in comparisons with potential alternatives) in the course of goal pursuit (Achtziger, Gollwitzer, & Sheeran, 2008; Shah et al., 2002). Because an action crisis represents a decision-making process, which benefits from open-mindedness, it was hypothesized that goal (re)evaluation in an action crisis is not biased in favor of the goal. Pros and cons of a goal were assumed to be deliberated on or rather elaborated to the same extent in an action crisis (hypothesis 2).

Study 2 was an fMRI study conducted to determine *neural* correlates of an action crisis. The identification of changes in neural connectivity patterns between regions responsible for action control and motivation (i.e., goal-related rewards) should substantiate the construct of an action crisis, deepen the understanding of its underlying mechanisms and consequences, and contribute to the understanding of the neurobiological basis of motivational processes in the pursuit of long-term goals.

To test our hypotheses, we pursued a *nomothetic-idiographic* approach to personal goals (Brunstein, 1993; Emmons, 1986). For the purpose of measurement accuracy and in order to capture the "nucleus" of an individual's goal system, the participants had to list their primary *idiographic* long-term goals that were assessed in relation to *nomothetic* variables (i.e., action crisis). Nomothetic variables were averaged across personal goals for statistical analyses.

STATISTICAL ANALYSES

Cross-lagged path and mediation analyses were performed using AMOS® (version 20); regression analyses and correlations were calculated with SPSS® (version 20; IBM® SPSS® Statistics Inc., Armonk, NY). Bootstrap estimates in mediation analyses were based on 1000 bootstrap samples.

STUDY 1

In Study 1, goal (re)evaluation, which was assumed to become pronounced in an action crisis (hypothesis 1), was operationalized as the frequency with which participants deliberated on the costs and benefits of goal disengagement and further goal pursuit. Whereas assigned *post*decisional deliberation on a goal, in the absence of an action crisis, has been shown to result in a "defensive focus on the pros of goal pursuit" (Nenkov & Gollwitzer, 2012, p. 117), that is, goal shielding, an action crisis was hypothesized to lead to *unbiased* cost–benefit thinking (hypothesis 2). The hypothesized directionality in the relationship between action crisis and cost–benefit thinking was tested with cross-lagged panel analyses (Kenny & Harackiewicz, 1979).

The paper is partly based on data previously used in a published report concerning goal-relevant resources (Schnelle, Brandstätter, & Knöpfel, 2010). The present findings do not overlap with previously reported data.

Method

Participants and procedures

A sample of 283 (228 women) students (M_{age} = 23.5 years, SD_{age} = 6.58 years) completed a questionnaire at time point 1 (T1) at the beginning and a web-based questionnaire at time point 2 (T2) at the end of the semester (14 weeks later).

Personal goals

At T1, the participants had to define four personally relevant long-term goals, two academic and two leisure goals.

Action crisis

Action crises were assessed with the Action Crisis Scale (ACRISS; Brandstätter & Schüler, 2013; see Supplementary material, Section A).

Cost–benefit thinking

At T1 and T2, the participants indicated the frequency with which they had recently thought about the costs (CC) and benefits of continuing (BC) as well as the costs (CD) and benefits of disengaging (BD) from the goal (Brandstätter & Schüler, 2013). By averaging BC and CD, we compiled an index of the deliberation intensity of the pros of the goal (i.e., deliberation in favor of further goal pursuit). Analogously, CC and BD were used as an index of the deliberation intensity of the cons of the goal (i.e., deliberation in favor of goal disengagement) (see Supplementary material, Section A).

Results

Means (SDs) and zero-order correlations between the continuous study variables are reported and discussed in the Supplementary material (Section B).

To obtain evidence regarding the directionality in the relationship between action crises and cost–benefit thinking, that is, whether an action crisis precedes increased cost–benefit thinking, we conducted cross-lagged panel analyses (Kenny & Harackiewicz, 1979). For detailed information on the statistical analyses, see Supplementary material (Section C).

Hypothesis 1 could be confirmed in the full cross-lagged path model (see Supplementary Figure 1) and, subsequently, the theoretically driven *Model 1*, which had excellent indices of fit (see Figure 1). (For reasons of clarity, in the following, the deliberation intensity of the pros of the goal, i.e., deliberation in favor of further goal pursuit, is abbreviated as *goal pursuit* whereas the deliberation intensity of the cons of a goal is abbreviated as *goal disengagement*.)

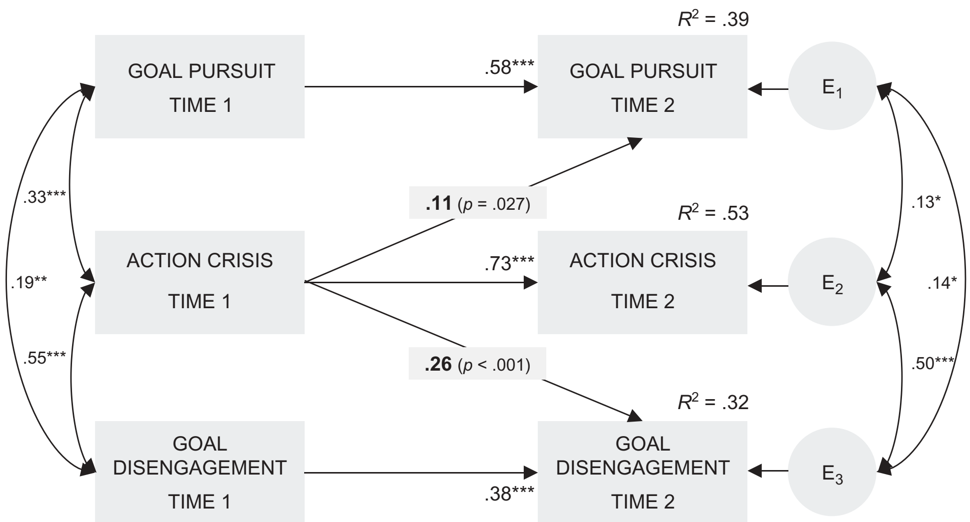

Figure 1. Cross-lagged path model for the prediction of cost–benefit thinking at T2 from action crisis (averaged over all goals) at T1 [$X^2_{(4)}$ = 4.870, p = .301, X^2/df = 1.217, *NNFI* = .995, *CFI* = .999, *RMSEA* = .028 (CI = .000–.098; PCLOSE = .609)] (Study 1).
Notes: Goal pursuit = deliberation intensity of the pros of the goal, that is, in favor of further goal pursuit; goal disengagement = deliberation intensity of the cons of the goal, that is, in favor of goal disengagement. Squares indicate observed variables. A circle indicates a residual error in the prediction of an observed variable. Single-headed arrows represent regression paths. Double-headed arrows represent synchronous correlations. Above endogenous observed variables, R^2 indicates the total amount of explained variance. Regression paths not considered in the model did not reach significance in the full cross-lagged path model (see Supplementary Figure 1) and were therefore excluded in the final model. Correlation coefficients are statistically significant at *p < .05, **p < .01, and ***p < .001. For regression paths, exact probabilities are reported. Standardized maximum-likelihood parameters are used.

Completely in line with hypothesis 1, an action crisis was longitudinally associated with an increase in cost–benefit thinking.

To test hypothesis 2, we set the regression paths from action crises at T1 to goal pursuit and goal disengagement at T2 in *Model 1* to equality. Hence, the resultant (more parsimonious) *Model 2*, in accordance with hypothesis 2, specified the effects of an action crisis on the deliberation of the pros *and* cons of a goal as being equally strong. Because *Model 1* and *Model 2* did not differ significantly ($\Delta X^2_{(1)}$ = 1.59, p = .207), in which case the more parsimonious model is to be preferred, hypothesis 2 was supported by the model comparison. Therefore, the conclusion may be drawn that an action crisis does not merely give rise to an increased (re)consideration of a goal (hypothesis 1) but that this cost–benefit thinking is *unbiased* (hypothesis 2). An action crisis, thus, gives rise to a cognitive orientation that counteracts goal shielding.

STUDY 2

In continuation of Study 1, in which characteristics of an action crisis were explored on a *cognitive* level, Study 2 aimed at uncovering the *neural* activity pattern underlying changes in information processing (i.e., unbiased cost–benefit thinking) in an action crisis. Thereby, Study 2 represents a new approach to the analysis of the neurobiology of personal long-term goals (Berkman & Lieberman, 2009).

From a theoretical point of view, the conflict characteristic of an action crisis (i.e., *doing the splits* between a motivational and a volitional task) may be adequately accounted for by the investigation of brain regions subserving action control (i.e., volition) and motivation (i.e., goal-related rewards). Whereas the prefrontal cortex instantiates a neural system for cognitive control and planning (i.e., volitional abilities relevant to the pursuit of long-term goals; Miller & Cohen, 2001; Tanji, Shima, & Mushiake, 2007), the nucleus accumbens (NAcc), part of the ventral striatum, is central to the brain's reward system and provides a link between motivationally relevant emotional processes (e.g., reward anticipation or subjective preferences) and action (Mogenson, Jones, & Yim, 1980). Importantly, the NAcc receives regulatory influences from the prefrontal cortex (Sesack & Grace, 2010).

In an action crisis, as a consequence of reduced (i.e., counterbalanced) goal shielding (cf. Study 1), a goal should lose its predominance over competing alternatives, whereby an individual's behavior becomes more susceptible to incentives associated with alternative goals (Shah et al., 2002) as well as goal-irrelevant temptations (Förster & Denzler, 2009; Kruglanski et al., 2002). Therefore, from a neural perspective, an action crisis should re-instigate or interfere with prefrontal cortical self-control mechanisms crucial to future-oriented behavior, more precisely, the pursuit of *long-term* goals (Miller & Cohen, 2001; Tanji et al., 2007). As a result, subcortical reward-related (*short-term* and *long-term*) impact on behavior should be increased. The pursuit of "long-term task goal[s]" (p. 1488) in the context of increased reward-related impact on action control has been examined in an fMRI study by Diekhof and Gruber (2010). Even though in the respective study the focus was on an experimentally induced and thus nomothetic goal, the results of this study may be applicable to (idiographic) long-term goals and are therefore of importance to the present research.

In the study of Diekhof and Gruber (2010), the subjects were confronted with a "desire-reason dilemma" (p. 1489) in which actions favoring the successful performance of a task goal ("reason") had to be preferred over immediately available rewards ("desire"). This specific experimental context was characterized by increased negative functional connectivity between left anteroventral prefrontal/lateral frontopolar cortex (FPC) and bilateral NAcc. In addition, interindividually, behavioral success in favoring the task outcome despite the presence of reward-related distractors (i.e., *effective* goal pursuit) was predicted by the extent of FPC-NAcc negative functional connectivity.

Because, in an action crisis, the influence of goal-related (cf. Study 1) as well as goal-independent incentives and temptations (Shah et al., 2002) on action control is assumed to be increased, the neurobiological findings reported by Diekhof and Gruber (2010) provide an excellent framework for the investigation of the neural basis of experiencing action crises in idiographic long-term goals. As, in the study of Diekhof and Gruber (2010), good task performance (i.e., high effectiveness of goal pursuit) was characterized by *decreased* fronto-accumbal connectivity, the opposite pattern was hypothesized to underlie the experience of an action crisis that has been shown to impair goal progress (low effectiveness of goal pursuit) (Brandstätter et al., 2013). Thus, we expected increased positive or decreased negative functional connectivity between left FPC and NAcc to be associated with an action crisis (hypothesis 3).

Investigating goal-related processing in an action crisis in a brain imaging study is associated with considerable conceptual and methodological demands. First, an individual's *long*-term goals exert a pervasive influence on cognition and behavior, even outside awareness (e.g., Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trotschel, 2001), and an action crisis in a highly self-relevant goal (e.g., "Should I drop out of university?") typically lasts several months (cf. Study 1). An action crisis, therefore, is likely to become manifest in *intrinsic* brain properties, especially in light of research on procedural priming (cf. Förster, Liberman, & Friedman, 2009) which suggests that cognitive procedures, once activated (by the demands of a task), influence the way of information processing in subsequent (independent) tasks. Procedural priming effects have been shown to last several days (Smith, Stewart, & Buttram, 1992) and, importantly, to result from the experience of action crises (Herrmann, 2014). Second, by definition, an action crisis represents a real-life phenomenon with high interindividual variance regarding the content of idiographic long-term goals. As a result, implementation in task-based fMRI appears inadequate (cf. Berkman & Lieberman, 2009).

As a consequence, an action crisis was mapped on the neural level in a *task-free* setting. "Resting-state" functional connectivity (rsFC) is defined as the degree of coupling between brain regions *in the absence of any task*, as reflected by the interregional coherence of the spontaneously changing signal measured during fMRI (Fox & Raichle, 2007). rsFC is considered to index intrinsic neuronal processes ("intrinsic connectivity") (Fox & Raichle, 2007), for example, memory consolidation (Albert, Robertson, Mehta, & Miall, 2009; Wang, Liu, Li, & Zang, 2012). A growing literature adds to the fact that interindividual variability in rsFC accounts for aspects of personality and behavior (Kelly, Biswal, Craddock, Castellanos, & Milham, 2012). In the present research, rsFC was related to the extent to which individuals were currently experiencing action crises in personal goals.

As Diekhof and Gruber (2010) reported FPC-NAcc functional coupling to be *positively* associated with trait impulsivity, we expected trait-related, goal-relevant self-regulatory abilities (i.e., state versus action orientation; Kuhl, 1994b) to be *negatively* related to fronto-accumbal coupling. Importantly, action orientation, the volitional ability to regulate basic affect (Baumann, Kaschel, & Kuhl, 2007), has been linked to prefrontal executive functions (Koole, 2004; Kuhl & Koole, 2004) and could be consistently identified as a predictor of effective goal pursuit (e.g., Baumann, Kaschel, & Kuhl, 2005; Brunstein, 1989, 2001; Kuhl, 1981, 1992, 1994b) and protective factor for the experience of action crises in personal goals (Herrmann & Brandstätter, 2013). Therefore, we hypothesized action crises in personal goals to mediate the relationship between action orientation and fronto-accumbal decoupling. Action-oriented individuals, due to a reduced extent of experienced action crises, were assumed to show increased fronto-accumbal decoupling (hypothesis 4).

To complement our approach, we also analyzed fronto-accumbal structural connectivity. We found evidence that white matter integrity between left NAcc and left FPC is modulated by action orientation (see Supplementary material, Section H).

The paper is partly based on data previously used in a published report concerning relations between anxiety and connectivity in limbic pathways (Baur, Hänggi, Langer, & Jäncke, 2013). The present findings do not overlap with previously reported data.

Method

Participants and procedures

For fMRI, we analyzed data of 33 healthy participants (18 women, M_{age} = 24.9 years, SD_{age} = 4.57 years). None of the subjects was part of the data set of Study 1. Questionnaires were sent to participants 1 week prior to the fMRI examination. For detailed information about the sample, exclusion criteria, ethics, psychometrics (e.g., control variables), and fMRI scanning, see Supplementary material (Sections D and E).

Personal goals

As in Study 1, the participants were asked to state (three) personally relevant long-term goals from different areas of life they were currently striving for.

Action crisis

See Study 1.

Action orientation

Action orientation was assessed using the Action Control Scale (ACS-90; Kuhl, 1994a).[1]

Regions of interest definition

Based on previous evidence (Diekhof & Gruber, 2010) and our theorizing on action crises, we focused on the left and right NAcc as well as the left FPC in an *a priori* regions-of-interest (ROI) approach (see Figure 2A). Connectivity was assessed between left NAcc and left FPC as well as between right NAcc and left FPC. For details regarding the definition of ROIs, see Supplementary material (Section E).

Resting-state functional connectivity

Preprocessing was carried out with DPARSF toolbox (Chao-Gan & Yu-Feng, 2010) using functions of SPM 8 (www.fil.ion.ucl.ac.uk/spm/software/spm8) and is described in detail in Supplementary material (Section E). Preprocessed fMRI data were subjected to REST toolbox 1.6 (Song et al., 2011) extracting the mean blood oxygenation level-dependent signal time course for each ROI and for each subject. Next, signal time courses (exemplarily shown in Figure 2B) were cross-correlated between left respectively right NAcc and left FPC. Finally, correlations were r-to-z-transformed to improve normal distribution for group-level statistics. To complement ROI-based analyses, we

[1] In the present research, for several reasons, no specific hypotheses were proposed with respect to the two subcomponents of action orientation (and subscales of the ACS-90; Kuhl, 1994a), failure-related action orientation (AOF) and decision-related action orientation (AOD) (cf. Herrmann & Brandstätter, 2013). First, the two subscales of the ACS-90 have been reported to “assess a common dimension [what] is corroborated by the fact that they correlate strongly and have a partially overlapping factor structure” (Kuhl, 1994b, p. 12). Second, failure-related (SOF) and decision-related (SOD) *state* orientation are functionally deeply intertwined as (a) both subscales are associated with restricted self-access and (b) increased and prolonged negative affect, which is characteristic of SOF, results in a reduction of positive affect typical of SOD. In a similar vein, preoccupation (SOF), for example, typically occupies self-regulatory functions crucial to the initiation and maintenance of intentions (SOD) (Kuhl, 1992, 1994b). Third, the pursuit of long-term goals, especially under high demands, is typically associated with a multitude of different setbacks and obstacles, the overcoming of which requires both the downregulation of negative (AOF) and upregulation of positive affect (AOD) (Jostmann & Koole, 2010). In line with this reasoning, Herrmann and Brandstätter (2013), in two longitudinal field studies, reported similar effects of AOF and AOD on the development of action crises over time. However, to clarify the role of AOF and AOD with respect to hypothesis 4, we performed additional exploratory analyses (see Supplementary material, Section F).

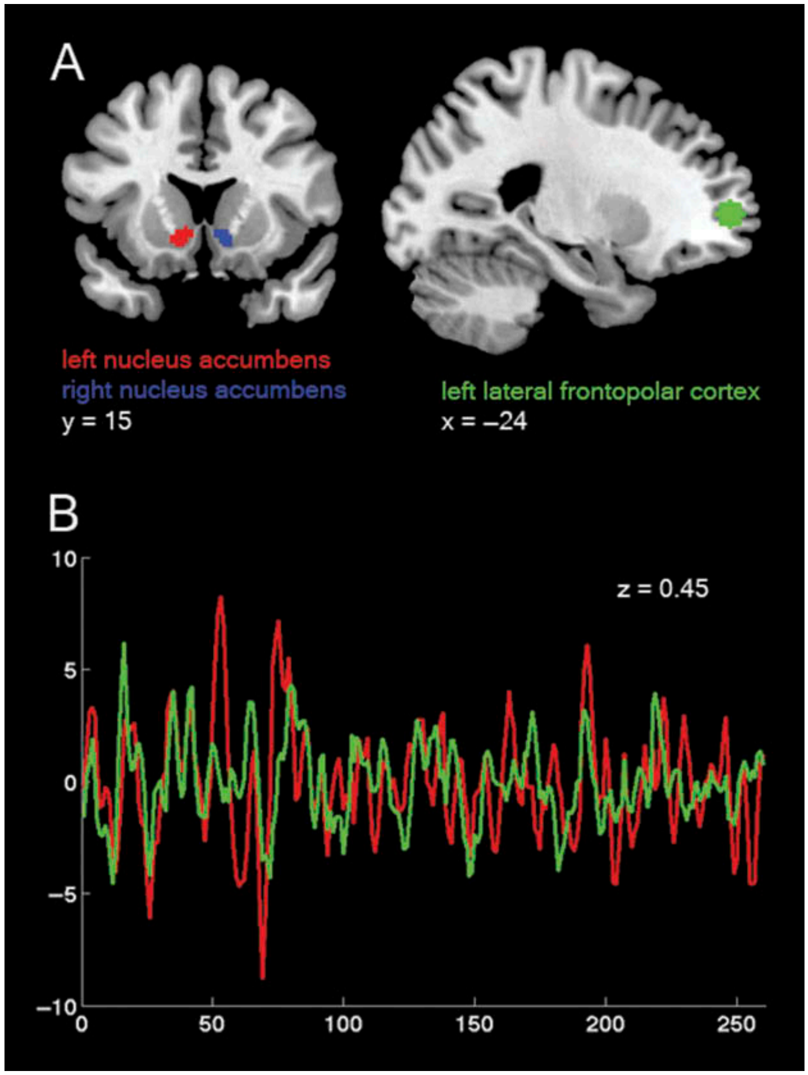

Figure 2. (A) Regions of interest, coronal (left) and sagittal (right) coordinates reported in Montreal Neurological Institute standard space. (B) Hemodynamic signal time course across 260 brain scans (corresponding to 10 min of resting-state functional magnetic resonance imaging) for left nucleus accumbens (red) and left lateral frontopolar cortex (green), respectively, exemplarily shown for one subject. The *z*-value represents the correlation between the two time courses.

also set an exploratory whole-brain approach. This comprised a seed-based analysis of rsFC of left and right NAcc (see Supplementary material, Section G). Using NAcc as seed is of interest and should yield valid results, as pointed out by a combined rsFC and structure-based meta-analytic study (Cauda et al., 2011).

Statistical analyses

FPC-NAcc rsFC, as represented by the *z*-value derived from the ROI analysis, was linked to the extent the participants were experiencing action crises in personal goals using multiple regression analyses.

Results

Means (SDs) and zero-order correlations between the major study variables are reported in Supplementary Table 2 (see Supplementary material, Section F).

Action crisis and functional connectivity

Completely in line with hypothesis 3, rsFC between frontal and accumbal ROIs, even after having controlled for action orientation and neuroticism, could be predicted by the extent to which participants were experiencing action crises in personal goals (for left NAcc-left FPC connectivity: $\beta = .43$, $p = .025$; for

TABLE 1
Hierarchical multiple regression analyses predicting left NAcc-left FPC connectivity and right NAcc-left FPC connectivity from action crises regarding personal goals (Study 2)

	Left NAcc-left FPC connectivity		*Right NAcc-left FPC connectivity*	
Predictor	*ΔR*^{2}	β	*ΔR*^{2}	*β*
Step 1	.12		.14	
Control variables[a]				
Step 2	.14*		.15*	
Action crisis		.43*		.44*
Total R^2	.27*		.29*	
n	33		33	

Notes: NAcc = nucleus accumbens; FPC = anteroventral prefrontal/lateral frontopolar cortex. For action crisis, values are averaged over the three personal goals.
[a]Control variables included action orientation and neuroticism.
*$p < .05$.

right NAcc-left FPC connectivity: $\beta = .44$, $p = .018$; see Table 1).

The exploratory whole-brain approach confirmed the association of FPC-NAcc rsFC with action crises. Additional regions outside of our primary hypothesis are shown and discussed in the Supplementary material (Section G).

Action orientation, action crisis, and functional connectivity

In order to test hypothesis 4, that is, whether action crises in personal goals mediated the relationship between action orientation and fronto-accumbal decoupling (see Supplementary material, Supplementary Table 2, Section F), we performed two mediation analyses (Hayes, 2009), for left NAcc-left FPC connectivity (see Figure 3) and for right NAcc-left FPC connectivity (see Figure 4).[1]

By explaining 55% (left NAcc-left FPC connectivity) or rather 72% (right NAcc-left FPC connectivity), respectively, of the relationship between action orientation and fronto-accumbal decoupling, action crises in personal goals significantly mediated the relationship between predictor and outcome variable (for statistical details, see Tables 2 and 3).

GENERAL DISCUSSION

The concept of an action crisis is defined as the intra-psychic conflict between further goal pursuit and disengagement from the goal and represents a methodologically new approach that provides critical insight into goal disengagement *processes*. Even though not every action crisis leads to goal disengagement, the ACRISS (Brandstätter & Schüler, 2013) allows for analyzing situational circumstances and dispositional factors under which the focal goal, *in* the course of goal pursuit, becomes questioned and, at least in some cases, relinquished (Herrmann & Brandstätter, 2014). In the present research, we applied the ACRISS to study the cognitive (Study 1) and neural (Study 2) basis of questioning a goal (i.e., experiencing an action crisis) in the midst of goal pursuit.

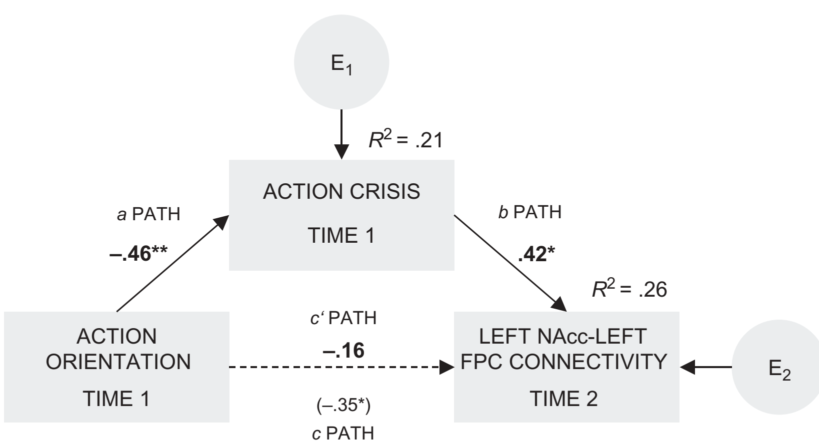

Figure 3. A mediation model of action orientation, action crisis (averaged over all goals), and left NAcc-left FPC connectivity. Action crisis was a significant mediating factor between action orientation and left NAcc-left FPC connectivity.
Notes: NAcc = nucleus accumbens; FPC = frontopolar cortex. R^2 indicates the total explained variance (i.e., the total effect on left NAcc-left FPC connectivity). Dotted regression paths are not significant. Bold regression paths are statistically significant (*$p < .05$, **$p < .01$).

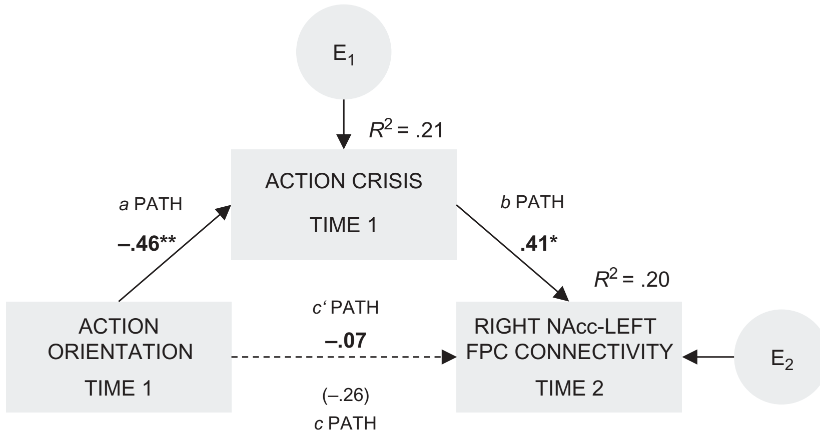

Figure 4. A mediation model of action orientation, action crisis (averaged over all goals), and right NAcc-left FPC connectivity. Action crisis was a significant mediating factor between action orientation and right NAcc-left FPC connectivity.
Notes: NAcc = nucleus accumbens; FPC = frontopolar cortex. R^2 indicates the total explained variance (i.e., the total effect on right NAcc-left FPC connectivity). Dotted regression paths are not significant. Bold regression paths are statistically significant (*p < .05, **p < .01).

TABLE 2
Mediation analysis of action crisis partly accounting for the association between action orientation and left NAcc-left FPC connectivity (Study 2)

Effect	*Standardized estimate*	*C.R.*	*SE*	*95% CI*	*p*
c path (total effect)	−.35	−2.13			= .034
a path	−.46	−2.90			= .004
b path	.42	2.47			= .014
a × *b* (indirect effect)	−.19		.10	(−.450, −.033)	= .016
c′ path (direct effect)	−.16	−.94			= .347

Notes: CI = confidence interval. C.R. = critical ratio. Maximum likelihood estimates are provided for the *c* path, *a* path, *b* path, and *c′* path. For the standardized indirect effect (*a* × *b*), bootstrap estimates with confidence intervals are provided.

TABLE 3
Mediation analysis of action crisis partly accounting for the association between action orientation and right NAcc-left FPC connectivity (Study 2)

Effect	*Standardized estimate*	*C.R.*	*SE*	*95% CI*	*p*
c path (total effect)	−.26	−1.51			= .132
a path	−.46	−2.90			= .004
b path	.41	2.31			= .021
a × *b* (indirect effect)	−.19		.11	(−.452, −.025)	= .022
c′ path (direct effect)	−.07	−.40			= .691

Notes: CI = confidence interval. C.R. = critical ratio. Maximum likelihood estimates are provided for the *c* path, *a* path, *b* path, and *c'* path. For the standardized indirect effect (*a* × *b*), bootstrap estimates with confidence intervals are provided.

In line with our theorizing, in Study 1, an action crisis gave rise to an increased and unbiased re-evaluation of goal-related costs and benefits (i.e., rewards) and thereby reduced goal shielding (Shah et al., 2002). Whereas an unbiased goal re-evaluation, that is, an objective and impartial perspective, may support an adequate resolution of the conflict, it is likely to interfere with the pursuit of the goal.

In Study 2, we aimed at identifying a neural activity pattern that forms the basis of increased goal-related cost–benefit thinking in action crises (cf. Study 1). Because in an action crisis impairments in the behavioral pursuit of the goal are most likely attributable to increased reward-related impact on prefrontal action control (cf. goal shielding, Study 1; see also Brandstätter & Schüler, 2013), we assessed functional connectivity between NAcc and FPC in individuals varying in the extent of experienced action crises in personal long-term goals. In line with our hypotheses, we found that FPC-NAcc rsFC was positively correlated with the degree of experienced action crises. Conversely, FPC-NAcc rsFC was negatively associated with action orientation. Furthermore, action crises mediated the relationship between action orientation and FPC-NAcc rsFC.[1] (For exploratory moderation analyses of the relationship between action crises and rsFC (i.e., moderated mediation analyses; cf. Hayes, 2012), see Supplementary material, Section F.)

Whereas the NAcc is well known for representing an interface between motivation and action, the functions of the FPC (as opposed to other prefrontal areas) have only recently become subject to empirical research. Lesion studies, for example, point to a role that the FPC plays in decision making (Gläscher et al., 2012; Kovach et al., 2012). In an action crisis, an individual is captured in the decision between further goal pursuit and disengagement from the goal (Brandstätter et al., 2013). Furthermore, perfectly in line with the concept of an action crisis and the present results, FPC activity is implicated in the process of exploring alternative goals while keeping the focal goal in mind (Daw, O'Doherty, Dayan, Seymour, & Dolan, 2006; Koechlin, Basso, Pietrini, Panzer, & Grafman, 1999), weighing the advantages of foregone alternative courses of action (Boorman, Behrens, & Rushworth, 2011), and behavioral switching (Boorman et al., 2011; Boorman, Behrens, Woolrich, & Rushworth, 2009). The left FPC, moreover, along with its functional connectivity to the NAcc, has been shown to play a key role in attention-deficit/hyperactivity disorder, which is characterized by deficient action control (i.e., impulsive behavior) (Dias et al., 2013).

The main result of Study 2 is fully consistent with fMRI research demonstrating the importance of FPC-NAcc negative connectivity for (task) goal-related "desire-reason dilemma[s]" (Diekhof & Gruber, 2010, p. 1489). In the respective study, in an experimental setting in which the pursuit of a long-term *task* goal required participants to abstain from immediate rewards (Diekhof & Gruber, 2010; Diekhof et al., 2012), subjects exhibited FPC-NAcc negative functional connectivity. Moreover, the connectivity pattern was pronounced in subjects who performed the task more successfully (i.e., showed a more effective goal pursuit). This was interpreted as an improved top-down inhibition of the NAcc by the FPC in those subjects, resulting in a better capacity to shield the focal goal against reward-related temptations (Diekhof & Gruber, 2010, p. 1492). In the task-free setting of the present research, we obtained an analogous result. Experiencing an action crisis, which is associated with *in*effective goal pursuit (Brandstätter et al., 2013), was linked to increased FPC-NAcc rsFC (corresponding to reduced negative connectivity). Reduced top-down inhibition of the NAcc, here, is an interpretation that would be consistent with the idea that in action crises (a) the subject's reconsideration of the focal goal is paralleled by an increased impact of "unspecific" temptations (i.e., "hedonic" impulses unrelated to the focal goal), and (b) that such temptations specifically disturb (bottom-up) FPC-centered maintenance of a "non-hedonic" goal in the goal maintenance system ("intention memory"; Kuhl & Kazén, 1999). Thus, an impaired *de*segregation of neural subsystems centered in the left FPC and NAcc could provide an explanation of the negative consequences of action crises on goal pursuit (Brandstätter et al., 2013). In support of this line of thought, behavioral stability has been shown to be reflected by the magnitude of the segregation of specific resting-state networks (Kelly, Uddin, Biswal, Castellanos, & Milham, 2008).

An alternative interpretation for increased FPC-NAcc rsFC in action crises might be the transmission of motivational inputs to the FPC (bottom-up) as a mechanism to update implemented task-sets (Sakai & Passingham, 2006). This interpretation converges with Koechlin and Hyafil (2007, p. 594) who construed the FPC as a system for "protecting the execution of long-term mental plans . . . and for generating new, possibly more rewarding, behavioral or cognitive sequences." In this case, bottom-up flow of reward-related information from the NAcc to the FPC, rather than interfering with goal shielding in the FPC (cf. section above), would be *in favor of* the focal goal. These scenarios would be in accordance with the concept of an action crisis as an *adaptive* phase in goal striving (Brandstätter et al., 2013).

Increased fronto-accumbal decoupling in action-oriented individuals, in the light of the study reported by Diekhof and Gruber (2010) and in line with previous research (e.g., Goschke & Kuhl, 1993; Kazén, Kaschel, & Kuhl, 2008), can be understood in the context of the *adaptive maintenance* of difficult intentions (cf. goal shielding; Shah et al., 2002). Adaptive self-regulation in action-oriented individuals, however, is characterized not merely by the adaptive maintenance and implementation of intentions but the "flexible, context-sensitive *balance* [emphasis added] between maintenance of, and disengagement from, one's intentions" (Kuhl, 1992, p. 104). State-orientation, in direct contrast, is associated with *maladaptive over-maintenance* that finds expression in both behavioral passivity and rigidity (i.e., context-blind perseveration) and, in accordance with the present results, is theoretically more likely to be associated with increased fronto-accumbal coupling (Jostmann & Koole, 2009). Over-maintenance is mainly ascribed to falsely internalized and thus external (i.e., not self-concordant) goals with which one does not fully identify. If a goal is based on external suggestions instead of one's own preferences, goal pursuit inevitably results in need frustration and, consequently, impaired impulse control (i.e., rumination and intrusions; Kuhl, 1992, 2000) that has been associated with increased fronto-accumbal coupling (Diekhof & Gruber, 2010).

It seems most probable that functional connectivity in the brain is attributable to a combination of more transient ("state") and more long-lasting ("trait") aspects. In fact, neuroscientific research indicates that rsFC may be ascribed to both dynamic states (Schultz, Balderston, & Helmstetter, 2012) and more stable personality traits (Adelstein et al., 2011). Correspondingly, in Study 2, FPC-NAcc rsFC was associated with action orientation (trait) *and* action crises (state) (cf. Supplementary material, Supplementary Table 2). However, for two statistical reasons, the conclusion seems warranted that the (more proximal and constitutive) effect of action crises on fronto-accumbal dynamics exists independent of the (more distal) influence of trait action orientation. First, the relationship between action crises and FPC-NAcc rsFC was not merely more profound than between action orientation and FPC-NAcc rsFC but remained when controlling for action orientation. Second, action crises mediated the relationship between action orientation and FPC-NAcc rsFC. Correspondingly, action orientation, when controlling for action crises, was not significantly associated with rsFC (cf. direct effects in Tables 2 and 3).

Resting-state fMRI results of Study 2 underscore the significance of connectivity between FPC and NAcc for (long-term) goal-related processing, especially in the face of increased impact of goal-relevant rewards on action control (i.e., in an action crisis). Study 2, thereby, extends and complements previous approaches that applied task-based fMRI to examine similar goal-related neural processes in the context of long-term *task* goals (Diekhof & Gruber, 2010; Diekhof et al., 2012).

Resting-state fMRI enables to map how an individual's subjective constitution is linked to *intrinsic* neural processes (Kelly et al., 2012). Following this idea, and in order to reduce "acute" and unspecific effects (e.g., biases through action crisis-related affect and stress), the participants in Study 2 were neither prompted to actively think about their long-term goals nor instructed to perform goal-related tasks during the scan. Therefore, goal-related questionnaires were completed by the participants at home. Results remained significant when controlling for state anxiety (analyses not shown). The examination of subjects that vary in the extent of experienced action crises in a task-*in*dependent quasi-experimental setting allowed for connecting constitutive aspects of the pursuit of long-term goals with resting-state connectivity. A task-based (i.e., experimental) approach, on the contrary, would have required to dissociate goal-related long-term from task-specific effects (cf. Berkman & Lieberman, 2009). Therefore, our results have specific implications for the neurobiological dynamics underlying the pursuit of long-term goals.

Limitations and future directions

Our results do not allow any inferences about the directional nature (top-down vs. bottom-up) of fronto-accumbal dynamics and the nature of electrophysiological processes (inhibitory vs. excitatory) at neuronal transition zones in the presence of an action crisis. Thus, either of the discussed interpretations (cf. above), or a combination of both, may be true. Due to the focus on ROI-based analyses in the FPC and NAcc, we refrain from statements about larger goal-related functional networks across the whole brain. Given these limitations, future studies may (a) use further methods as a complement to fMRI, (b) explicitly address the issue of neuronal inhibition/excitation of NAcc by the FPC, (c) analyze effective connectivity to estimate causal relationships within prefronto-striatal routes, and (d) examine additional regions interacting with FPC and NAcc in action crises. Third-party regions such as medial prefrontal cortex might have mediated the observed fronto-accumbal functional interactions. Follow-up analyses could evaluate whether fronto-accumbal connectivity, possibly in interaction with action orientation, predicts the outcome and/or the overcoming of an action crisis.

CONCLUDING REMARKS

We would like to draw attention to altered FPC-NAcc rsFC as a constitutive characteristic and/or adaptive mechanism in response to the experience of an action crisis. To the best of our knowledge, the present research is one of the very first to link motivationally relevant cognitive processes (Study 1) to NAcc-related functional connectivity in the resting state (Study 2). It also represents a new approach to the analysis of the neural underpinnings of the pursuit of long-term goals. The practical relevance of the analysis of neural mechanisms that form the basis of the experience of an action crises appears evident when considering the enormous significance of personal goals for affect, cognition, and behavior (Moskowitz & Grant, 2009).

Supplementary material

Supplementary material is available via the 'Supplementary' tab on the article's online page (http://dx.doi.org/10.1080/17470919.2014.933715).

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