Dynamic Patterns of Personality States, Affect and Goal Pursuit Before and During an Exercise Intervention: A Series of N-of-1 Trials Combined with Ecological Momentary Assessments

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ABSTRACT

Prior studies have failed to identify the dynamics between the momentary manifestation of personality traits (namely personality states) and cognitive-affective mechanisms in relation to physical activity. The current study modelized the temporal associations between daily personality states, affect (valence) and pursuit of personal goals before and during a physical exercise intervention. Single cases using an A (10 days) -B (42 days) design paired with ecological momentary assessments was used in 10 inactive adults. Idiographic network analyses and generalized additive models were performed. The magnitude of the association between personality states, affect and pursuit of personal goals were modified during the intervention. Their respective weight of the variables in the networks during the exercise intervention followed an individual pattern. The intervention was associated with a systematic change in levels of pursuit of personal goals, with seven participants showing a non-linear association. The complexity of individual networks before and during the intervention stresses the importance of an idiographic level of analysis, especially in the context of an exercise intervention.

HIGHLIGHTS

- Idiographic levels of association between personality states, affect and pursuit of personal goals can be modified during a physical exercise intervention.
- The respective weight of personality states, affect and pursuit of personal goals in the idiographic networks during the exercise intervention follows an individual pattern.
- The physical activity intervention is associated with a systematic non-linear change in the level of goal facilitation and goal conflict.

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1. INTRODUCTION

Exercising has been associated with various health outcomes such as physical and mental health. While interventions to increase physical activity levels have mainly been focusing on group interventions (Burke et al, 2006), a better understanding of the individual psychological characteristics show a promising avenue to develop successful and durable individualized interventions, particularly when studied at the daily level (Lapointe et al, 2023). Indeed, psychological effects of physical exercise were examined with a pre- and post-assessments in most of previous interventional studies. Thus, intra-individual pattern of psychological constructs and their respective associations need to be studied. In this perspective, affective experience, personal goals and personality are propitious psychological constructs.

Multiple individuals' health behaviors have been correlated with many personality traits (Kern & Friedman, 2011; Turiano et al, 2018). Particularly those identified in the Five Factors Model have been associated with physical activity behaviors, highlighting the ways in which different dimensions of personality influence behavior and health outcomes (Ferguson, 2013; Wilson & Dishman, 2015). This model is an integrative framework that describes regularities in behavior and organizes them into broad personality categories that are composed of the following five dimensions of personality traits (McCrae & Costa, 1987): *Openness*, which describes the regulation of reactions to novelty; *conscientiousness*, which describes the regulation of hardworking behaviors to obtain a long-term goal and to accept the constraints associated with this goal; *extraversion*, which describes individuals' sensibility to "rewards" regulation system as well as positive and pleasant emotions and cognition control; *agreeableness*, which describes the regulation of the tone in relations and dialogues with others, and *neuroticism*, which describes individuals' sensibility to perceive a real or symbolic threat, and reactivity to this threat. Each person manifests different levels of these traits, hence representing the variability in individuals' personalities through behavior. These traits influence a variety of important behaviors and life outcomes (Soto & John, 2016).

Research fails to establish a clear link between PA behaviors and personality traits. To date, three meta-analyses observed positive PA associations with openness, conscientiousness and extraversion, and a negative association with neuroticism. In the case of agreeableness, conflicting findings were found (Rhodes & Smith, 2006; Sutin et al., 2016; Wilson & Dishman, 2015). PA levels were also reported to be associated with longitudinal personality trait trajectories (e.g., lower PA levels are associated with a decline in conscientiousness over time (Stephan et al., 2018). Inversely, personality traits tend to be associated with PA levels on the long term

(e.g., within-person level decrease of PA is longitudinally associated with all personality traits variations (Jokela et al., 2018). A theory involving a situationist perspective allows a more complex understanding of the interactions between the expression of personality traits from moment to moment, distinguishing their psychological and behavioral components. This Whole Trait Theory (WTT) can contribute to better understanding the specific psychological mechanisms underlying this phenomenon.

Fleeson's WTT integrates the Five Factors Model to provide "an explanatory account of the manifestation of personality traits through behavior". Specifically, the WTT states that "individuals have unique personality structures that are sensitive to daily situations they encounter" (Fleeson & Jayawickreme, 2015). For example, during the course of a few days, people can shift in the intensity at which they manifest their personality trait, often due to the context with which they interact (i.e., from being very extraverted during a social event to less extraverted while reading a book). The WTT hypothesizes that the change in the manifestation of each personality traits is causing the manifestation of *personality states*. They are defined as "having the same affective, behavioral, and cognitive content as a corresponding trait" (Pytlik Zillig et al., 2002). However, contrary to personality traits, which apply on a monthly or yearly scale, personality states last for only a few minutes or hours. Sharing many proprieties and consequences with traits is known as isomorphism. That is, personality states are similar to traits in affective and behavioral content but are manifested in a momentary experience (Fleeson & Jayawickreme, 2015). As illustrated by Fleeson & Jayawickreme (2015), "an extraverted state has the same content as extraversion (talkativeness, energy, boldness).), but applies as an accurate description for only a few hours as opposed to the months or years that a trait description applies". A way to understand the difference between personality traits and personality states is with the methodological tools used to measure the two concepts. Personality traits are measured with long questionnaires such as the Big Five as individuals' results are relatively stable through time (Bleidorn et al., 2021). However, personality states need to be measured several times per day (with very short questionnaire) for several consecutive days, to capture their daily variations. Ecological momentary assessments (EMA) enable the repeated sampling of subjects' current behaviors and experiences in real time, in the participants' natural environment (Bentley et al., 2019).

The WTT proposes that cognitive-affective mechanisms (e.g., affect and personal goals) moderate the environmental or individual factors and the variation of personality states (Fleeson & Jayawickreme, 2015). These mechanisms are part of a system regulated by structural elements before producing a behavior. The structural elements are the *inputs*, the *intermediates,* and

the *outputs*. Figure 1A illustrates the WTT hypothesized associations.

Among the different cognitive-affective mechanisms, respective associations between affect, personal goal pursuit and personality states have been previously examined in studies based on the WTT (Heller et al., 2007; Kritzler et al., 2020; Wilt et al., 2017). When trait-state isomorphism (e.g., shared properties between corresponding traits and states) are assessed, it needs to be completed in the participants' natural environment and measured with EMA (Bentley et al., 2019). This assessment method involves repeated sampling of subjects' current behaviors and experiences in real time to capture daily variations in personality states. The following section reviews the existing evidence on the association between personality states, affect and personal goals.

Affect is defined as any mental state of pleasure or displeasure (valence) with some degree of arousal (Russell, 2003). Important here is the valence dimension, which refers to the hedonic quality or pleasantness of an affective experience (Feldman, 1995). Previous research has suggested that extraversion and neuroticism are fundamentally affective in nature (McNiel & Fleeson, 2006) and other analyses point to the affective nature of the other traits of the Five Factors Model as well (Kritzler et al., 2020; Wilt et al., 2017). Studies using an experimental method where state extraversion and state neuroticism were manipulated reported that extraversion states were associated with self-reported positive affect, and neuroticism states were associated with self-reported negative affect (McNiel et al., 2010; McNiel & Fleeson, 2006). Furthermore, EMA studies showed that within-person variability in extraversion, agreeableness and openness states were associated with variability in positive affect, whereas within-person variability in neuroticism was strongly associated with variability in both positive and negative affect (Bleidorn & Denissen, 2015; Fleeson et al., 2002; Wilt et al., 2017). Contrary to valence, research has failed to find associations between arousal and personality states (Kuppens et al, 2017). In essence, the literature supports the shared isomorphism between personality states with positive and negative affect.

Personal goals are represented as future-oriented representations of what individuals strive for in various
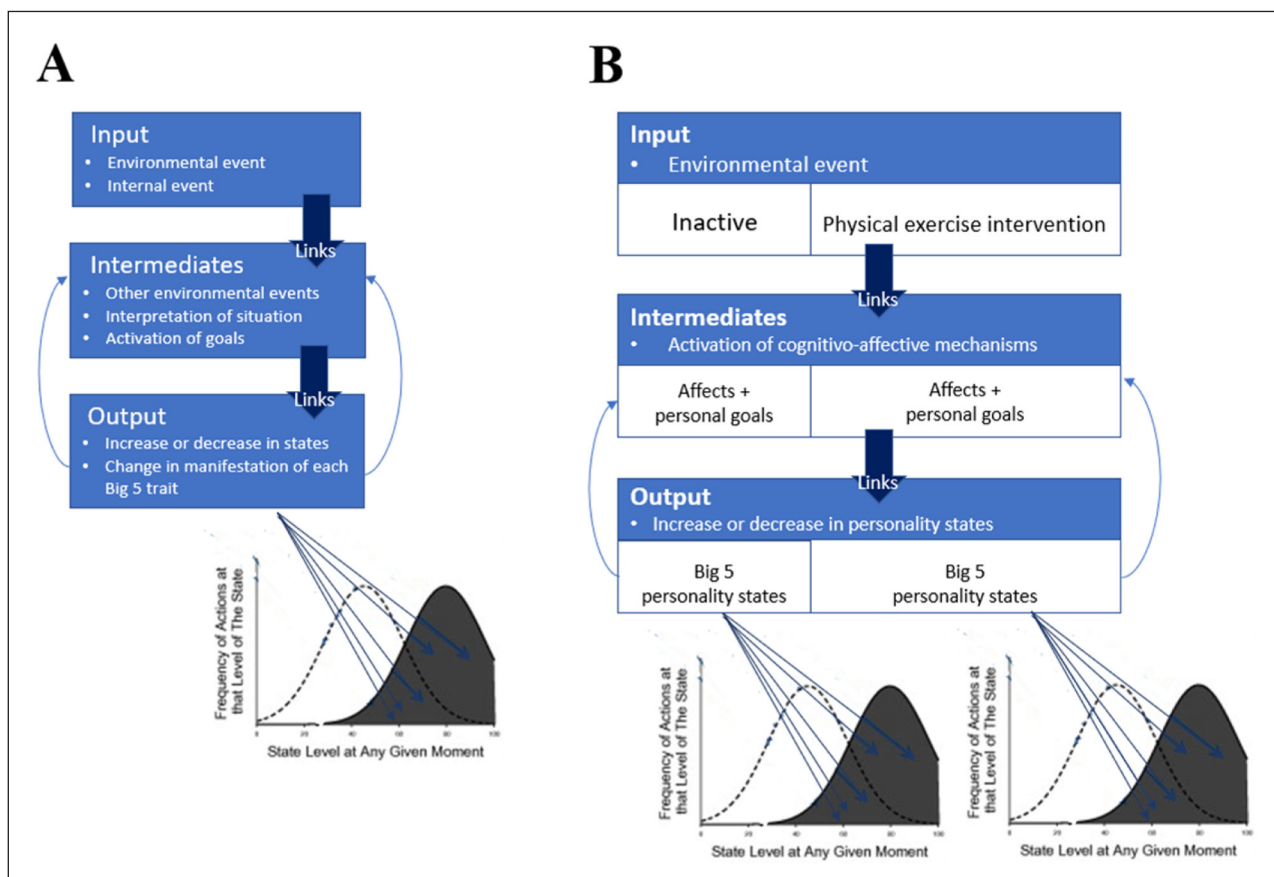
Figure 1 Graphic representation of Whole trait theory structural elements (inspired from Fleeson and Jayawickreme, 2015), and their respective characterisation in the current study.

Note: *Inputs* represents internal/external events related to the context, such as a change in health behavior (e.g. PA sessions) (Matz & Harari, 2020). *Intermediates* are other internal/external events that are significantly modified by the *inputs* such as cognitive-affective processes. *Outputs* are the finality of the system resulting in an increase or decrease on the manifestation of behavior which will respond to the *inputs*, namely personality states.

life domains (Austin & Vancouver, 1996). Specifically, pursuing personal goals implies affective, cognitive, and behavioral response patterns (Elliot & Friedman, 2007). Studies investigating the relationships between personality states and goals revealed that state extraversion, state conscientiousness and state neuroticism are associated with pursuing a specific personal goal (Heller et al., 2007; McCabe & Fleeson, 2016). For example, Heller (2007) showed that participants feeling more extraverted per moment were pursuing a higher number of approach goals, and participants feeling more neurotic per moment were pursuing a higher number of avoidance goals. Regarding state extraversion, another EMA study showed that the relationship between personal goals and positive affect was partially mediated by state extraversion (McCabe & Fleeson, 2012). When studied in relation with affect, personal goals (approach and/or avoidance goals) and positive affect were mediated by neuroticism and extraversion states. Personal goals and negative affect were also mediated by neuroticism and extraversion (Heller et al., 2007). Evidence supports that personality states, affect valence and the pursuit of personal goals are associated, however the mechanisms responsible for the directionality of the associated remain unclear.

To our knowledge, associations between personality states and PA have been examined in two studies. The first study measured neuroticism, extraversion, and conscientiousness states in two independent samples for 24 and 10 consecutive days, respectively. Results showed that intraindividual levels of conscientiousness, extraversion, and neuroticism states were associated with PA (Mõttus et al., 2017). A second study investigated the effect of spending time in the gym on personality states in a large sample. Results demonstrated that going to the gym was associated with all five personality states. Participants had lower level of openness and neuroticism, and higher level of agreeableness, conscientiousness, and extraversion during and after spending time in the gym. Except for Openness, these associations were not modified when the personality states "history" (four hours before) were added in analyses (Matz & Harari, 2020). Despite these findings, scientific evidence still lacks in considering the temporal dimension and the dynamics patterns of personality states on PA behavior, as well as the potential effect of PA on personality states variability.

As described in the studies previously presented, personality states' association with cognitive-affective mechanisms and PA tends to be studied in silos. However, evidence suggests potential bidirectional associations between personality states, pursuit of personal goals and PA, and that PA is prospectively associated with personality states and affect change in short term. Previous investigations identified a bidirectional association between daily levels of affect and PA behaviors (Kanning & Schoebi, 2016). Repeated PA sessions were also associated with negative affect reduction (Reed & Ones, 2006). Additionally, personal goals pursuit has been associated with PA levels. Presseau's prospective studies showed that the level of daily intergoal conflict and facilitation were negatively and positively associated with self-reported and objectively measured PA, respectively (Presseau et al., 2010, 2013). Collectively, personality states, affect and goal pursuit can be considered as interconnected and an evolving system that is modifiable by PA (Heino et al., 2021).

In light of the existing literature, four limits have been identified: 1) When personality states are studied in regards to affect, pursuit of personal goals or PA, the five states are not systematically included; 2) The potential cognitive-affective mechanisms associated within WTT were systematically studied in silo in relation to the WTT, instead of being integrated together; 3) No previous studies has examined the effects of an intervention (*input*) on cognitive-affective outcomes (*intermediates*) and personality states (*output*) (see details in Figure 1B); 4) All previous associations have been tested at a nomothetic level (i.e., within-group, not individuals, see e.g. (Chevance et al., 2021). Hence, idiographic networks are better suited to answering questions of intraindividual personality processes that are not easily testable within factor models (see Beck & Jackson, 2021).

The current study aimed at examining the temporal dynamic patterns of associations between personality states, affect and pursuit of personal goals before and during an exercise intervention using N-of-1 trials (see Figure 1B for a visual representation). We adopted an idiographic approach because it helps to understand the heterogeneity of responses to a behavior change intervention (Chevance et al., 2021) and to model individual trajectories of the psychological constructs (Heino et al., 2021; Kwasnicka & Naughton, 2020). With respect to the WTT, the following five exploratory hypotheses were formulated: 1) Affect and goal pursuits, before and after the intervention, will be significantly associated with the five personality states; 2) The respective within-day associations between personality states, affect and pursuit of personal goals identified during baseline will be modified by the intervention without common pattern between the participants; 3) The centrality (i.e., the strength of the variable in the network) of affect or goals pursuit will be more important during the intervention than before the intervention; 4) The affective valence will be significantly increased by the intervention; 5) The effects of the intervention on personality states and the pursuit of personal goals temporal patterns will be exploratory.

2. METHOD

2.1 PARTICIPANTS

The data collection occurred between September and November 2020 in Montreal. Participants were recruited from an ad on Facebook. Inclusion criteria were: 1) adults aged from 20 to 65 years old; 2) physically inactive; 3) at ease with reading and understanding the French language; 4) living in a 20 km radius of the Université du Quebec à Montréal. The physical inactivity status was operationalized as a self-reported weekly PA assessed during a screening interview using the Global PA questionnaire. Inactivity status was determined with a validated cut-off of > 600 MET-min/week. Exclusion criteria were: 1) a self-reported diagnosis of severe mental illness or substance use disorder; 2) a sensory disorder; 3) pregnant women; 4) a physical disability; 5) a positive answer to the PA Readiness Questionnaire, which states the necessity for the participant to seek further advice from a doctor or a qualified exercise professional before beginning an exercise intervention (Canadian Society for Exercise Physiology, 2002). This study was approved by the Ethics Committee of Université du Québec à Montréal (certificate number: 4080).

2.2 STUDY DESIGN AND PROCEDURES

A series of N-of-1 trials using an A-B design was combined with daily EMA measures and accelerometry to collect data (Bentley et al., 2019). The baseline consisted of a 10-day baseline period. The intervention period lasted for 42 days and participants were asked to attend two weekly individual supervised exercise sessions. During the total duration of the study (52 consecutive days), participants were prompted by the app EthicaData. The app prompted participants to answer the questions about personality states, affect and personal goals pursuit three times each day (between 9 am and 11 am, 1 pm and 4 pm, and 6 pm and 9 pm), with a minimum of 1.5h between prompts. In total, 156 data points for each participant were collected. As explained by Vieira (2017), the number of repeated measurements is the sample size of an n-of-1 study; more measurements lead to a better measure of the variability in the outcome of interest and improved precision of parameter estimates. Regarding dynamic regression modelling (i.e., generalized additive model [GAM]), Keele & Kelly (2006) has been shown to be appropriate to use with relatively small sample sizes (e.g. 50 data points). No formal power simulation/calculation was performed to estimate the within-person sample size requirements.

To objectively verify PA levels during the baseline and the intervention, the participants wore a wrist-worn accelerometer (GENEActiv), during the 52-day study, at all times (Hees et al., 2013). This waterproof device could be worn during sleep of when in the water, and was worn on the opposite side of the dominant hand. To control the possible intervention effect on level of personal goal conflict as well as facilitation and personality traits, two questionnaires from initial assessments were repeated at the end of the intervention (i.e., personality traits and pursuit of personal conflicting and facilitating goals). The study design is represented in Table S1, available as supplementary files.

2.3 MEASURES

2.3.1 Baseline evaluations

The data collection was conducted by the same research staff member to insure homogeneity during the meeting. Participants completed a sociodemographic, general health as well as a tobacco, alcohol and cannabis consumption online questionnaire (see Additional information on the baseline questionnaires section in the supplementary files). This data was collected to characterize the study sample.

Personality traits. Based on the Five Factors Model, the validated 30-item French version of Big-Five Inventory (BFI) was used to measure personality traits (Plaisant et al., 2010). Participants had to report the degree of approval on 30 auto-descriptive items designed to assess each of the five factors with a Likert scale from 1 "strongly disapprove" to 5 "strongly approve". The 30-item BFI has been shown to have good psychometric properties with good reliability, retest reliability, and factor structure (Plaisant et al., 2010).

Level of conflict and facilitation between personal goals. An adapted personal project assessment was used to measure the level of conflict and facilitation between personal goals (Presseau et al., 2010, 2013). Participants were informed of the following definition for personal goal, based on Little's (2006): "things you choose to do or things you have to do; they may be things you are working towards or things you are trying to avoid. Personal goals may be related to any aspect of your daily life: university, work, home, leisure and community, among others". Following Presseau's (2013) method for assessing personal goals, participants were instructed to list 3 to 8 personal projects in which they were regularly engaged in. Each participant evaluated their level of conflict and facilitation between all personal goals with a scale from 1 "No conflict/facilitation between goals" to 10 "Strong level of conflict/facilitation". The mean scores indicated a representation of the conflict and facilitation level for each goal. Participants' personal goals were used for the daily goal pursuit evaluation.

2.3.2 EMA questionnaires

EMA outcomes of interest were personality states (10 items), affect (3 items), and investment in personal goal pursuit (3 to 8 items). EMA items are presented in Table 2 in the supplementary files.

Personality states. Different approaches exist to measure personality states, and no consensus exists (Horstmann & Ziegler, 2020). The brief validated scales

are the most frequently used method (Kritzler et al., 2020). Personality states were assessed with the validated French version of the Ten Item Personality Inventory (Courtois et al., 2020). Participants used a bipolar ("Not at all" – "Strongly") visual-analog scale starting with "Right now, I feel…" to indicate the extent to which of the 10 statements described their personality during that moment of the day. For example,

Affect. Since we were interested in measuring the valence of affect, we used the first three items of the validated Swedish Core affect Scale using a bipolar visual-analog scale: 1) Right now, I am feeling…displeased/pleased; 2) Right now, I am feeling…sad/glad; 3) Right now, I am feeling…depressed/happy (Västfjäll & Gärling, 2007). For each observation, a total mean score was calculated to ease the interpretation of results.

Pursuit of personal goals. Pursuit of personal goals were assessed through an idiographic measure. The listed personal goals during the initial evaluation were included in EMA application. Participants assessed how much time and/or energy they put in pursuing their goals since the last notification using a bipolar visual-analog scale (0 "Not at all" – 100 "Strongly") (Presseau et al., 2010, 2013). To characterize their daily level of goal conflict and goal facilitation, item scores were weighted based on the baseline mean of conflict/facilitation levels associated with personal goals.

2.4 INTERVENTION

The exercise intervention was initially planned to begin in the fitness center of the university, however, it was closed due to the COVID-19 pandemic. Thus, participants attended one-hour supervised individual exercise sessions two times per week for six weeks, either in a park close to the participant's home or online during rainy days (more details are available in the Sanitary measures section in the supplementary files). The trainings were given by a trained kinesiologist from the study personel (an example of a training session is available in Table S3 in the supplementary files).

2.5 STATISTICAL ANALYSES

2.5.1 Contemporaneous associations during the baseline and during the intervention

To examine the idiographic dynamic associations among personality states, affect and pursuit of personal goals, graphical vector autoregressive models were performed together with network visualization (Beck & Jackson, 2021; Epskamp et al., 2018). These idiographic networks allowed to identify the most critical psychological factor(s) and association(s) variations within individuals and phases A/B. Our outcomes also enabled to show the impact of personality states on each other. Contemporaneous and temporal networks were obtained for each participant. In the idiographic contemporaneous network, the edges represent associations between the

factors, after controlling for all the other symptoms in the previous and same time point (Borsboom, 2017). The nodes and edges represent the variables and the associations between variables, respectively. In the idiographic temporal network, the edges indicate which factor predicts other factors in the next time point.

To prevent overfitting, these networks were regularized using a variant of the least absolute shrinkage and selection operator. As recommended for the relatively short EMA time series (Beck & Jackson, 2020), the hyperparameter (gamma) was set to 0, thus the Bayesian Information Criterion was used to optimize prediction accuracy. Also, as recommended by Mansueto et al. (2022), the number of nodes was reduced to improve the sensibility of idiographic networks. The personality states and affect items were consequently aggregated, with one node for each personality stated and one node for affects. More details about network analyses are available in the Supplemenary files.

2.5.2 Centrality indices during the baseline and during the intervention

The network was further analyzed by calculating two types of centrality indices: outstrength, instrength. Outstrength estimates how much information a factor sends directly to other factors (i.e., number of edges departing from the node). Instrength estimates how much information a psychological factor receives directly from other factors (i.e., number of edges arriving at the node) (Epskamp et al., 2018). We conducted a visual analysis of the centrality indices plots to identify the highest centrality indices in the networks at baseline and during the intervention.

2.5.3 Temporal patterns of personality states, affect, and pursuit of personal goals

Temporal patterns of personality states, affect, and pursuit of personal goals were modelled at idiographic level using GAMs. The data were aggregated by day and construct because the *mgcv* package does not allow generalized additive mixed model computation for time series. The GAM is an extension of the generalized linear model in that one or more predictors may be specified using a smooth function (Shadish et al., 2014). This nonparametric model allows non-linear relationships to be flexibly modelled without specifying the functional form, with non-normal distribution of variable and with missing data (Chevance et al., 2021). Non-linearity in GAM was based on the effective degrees of freedom (edf) of the smoothing terms, with edf >3 indicating a non-linearity shape (Chevance et al., 2021).

2.5.4 Sensitivity analyses

To control for a potential personality trait levels modification, a second measure was performed after the intervention. Pre- and post-intervention BFI scores were presented

with radar charts and visually analyzed (available in Supplementary files). Pursuit of personal goals was also controlled with visual analyses. Furthermore, we conducted a visual analysis and randomization tests with available accelerometer data to verify if participants increased their device-measured PA level (Bulté & Onghena, 2012). The R code and data for this study are available at: https://osf.io/umq35.

3. RESULTS

3.1 Participant characteristics

Nine females and one male were recruited. All sociodemographic characteristics from initial assessments are presented in Table 1. They were aged between 24 and 63 years old (M = 40.8, SD = 16.9). Annual income varied between < 20k$ and 60k$–90k$, and education level ranged from High school to master's degree. The EMA missing values ranged from 3.2% to 33.1% (M = 13.2, SD = 10.3) (see Table S2 in the supplementary files for more details). All participants attended all supervised physical exercise sessions, except for participant 329 who missed only one session. Unfortunately, we encountered a battery dysfunction with the GENEActiv accelerometers during the intervention, hence the number of consecutive days measuring exercise data ranged from 30 to 49. Due to a technical problem, accelereometry data were available for only 9/10 participants. Daily total time spent exercising measured by acceleometry ranged between 128 and 245 minutes. All participants' daily physical activity time (min/day) during the baseline and the intervention period are available in the Accelerometry data section in the supplementary files.

The following section presents contemporaneous and temporal networks findings, and centrality indexes results.

Shared patterns of associations found in the idiographic contemporaneous networks during the baseline and the intervention are presented below in the following order: personality states' association with affect valence, and personality states' association with personal goals. Then, temporal networks and centrality strongest indexes among participants are presented both during the baseline and the intervention, however temporal network analysis could not be conducted for three participants because the model was not converging. Furthermore, exhaustive network analysis from one participant are presented. Findings for other participants are available in Additional results (participant #) section in the supplementary files.

3.2 CONTEMPORANEOUS ASSOCIATIONS DURING THE BASELINE

3.2.1 Personality states and affect

During baseline, contemporaneous networks showed no significant associations between state openness and affect valence, except for three participants where they were positively correlated (participant 302, 477 and 481). No associations were found between state conscientiousness and affect valence. State extraversion was positively associated with affect in five participants (participant 329, 378, 448, 480 and 481). State agreeableness was positively associated with affect valence in six participants (participant 302, 329, 378, 448, 480 and 481). Lastly, state neuroticism was negatively associated with affect valence in six participants (participant 302, 329, 448, 477, 480 and 481).

3.2.2 Personality states and personal goals

During baseline, contemporaneous networks showed associations between personal goal pursuit and state openness in two participants (participant 329 and 480).

ID	AGE	SEX	EDUCATION	INCOME	COUPLE	CHILDREN	BMI	HEALTH DISEASE	ALCOHOL USE	CANNABIS USE	SSS	EMA RATES
302	26	F	Bachelor's	<20k$	No	–	40	–	No	No	5	15.4%
329	24	F	Bachelor's	40k$–60k$	Yes	–	42	Asthma	No	No	7	13.2%
333	47	F	Bachelor's	60k$–90k$	Yes	2	25	Celiac disease	No	No	9	28.3%
346	54	F	Cegep	40k$–60k$	Yes	2	23	–	No	No	7	5.6%
378	28	F	Bachelor's	<20k$	No	–	22	–	Low risk	No	5	18.9%
477	58	M	Cegep	60k$–90k$	Yes	2	46	–	Low risk	No	6	4.1%
479	63	F	High school	60k$–90k$	Yes	2	28	–	Low risk	No	6	4.3%
481	24	F	Bachelor's	<20k$	No	–	20	Ecxema, asthma	No	No	6	31.4%
480	24	F	Cegep	<20k$	No	–	19	–	No	Low risk	5	6.6%
448	60	F	Master	60k$–90k$	Yes	2	25	–	No	No	6	3.9%

Table 1 Participants' characteristics at baseline.

Note: ID = Identification, BMI = Body Mass Index, SSS = Subjective social status, F = Female, M = Mal.

State conscientiousness and personal goal pursuit presented various associations among participants: with goal conflict, four showed a negative association (participant 329, 333, 477 and 480), and one a positive association (participant 302). With goal facilitation, one showed a positive association (participant 480) and another one revealed a negative association (participant 333). State extraversion was variously associated with personality goal pursuit: with goal conflict, two demonstrated a positive association (participant 346 and 481) and one a negative association (participant 477). With goal facilitation, two showed a positive association (participant 329 and 480) and another one a negative association (participant 477). State agreeableness was positively associated with goal conflict in one participant (participant 378), negatively associated with goal conflict in one participant (participant 477), and negatively associated with goal facilitation in one participant (participant 302 and 378). Three participants showed a negative association between state neuroticism and goal facilitation (participant 387, 480 and 481) and three revealed a positive association with goal conflict (participant 378, 477 and 481).

To resume, during the baseline period, personality states extraversion, agreeableness and neuroticism were the most repeatedly associated states with affect valence during the baseline among the participants. Openness and conscientiousness states were also associated with affect, however in a less important amount among participants. Pursuit of personal goals presented varying associations with personality states, yet recurrent associations were observed among participants: state conscientiousness was negatively associated with goal conflict, and state neuroticism was negatively associated with goal facilitation and positively associated with goal conflict.

3.3 CONTEMPORANEOUS ASSOCIATIONS DURING THE INTERVENTION

Our results showed that the associations between personality states, affect valence and pursuit of personal goals at the individual level identified in the baseline phase were modified by the intervention, except for participant 448 (e.g., see Network analysis (participant 448) section in the supplementary files). All ten participants showed new associations in the network during the intervention, and in eight participants, the associations observed during the baseline were no more significant during the intervention. All personality states showed different associations with personal goals during the intervention among participants. Globally, state conscientiousness and state extraversion's positive association with affect, and state neuroticism's negative association with affect valence were observed in a greater number of participants during the intervention.

3.4 TEMPORAL ASSOCIATIONS AND STRONG CENTRALITY INDICES
3.4.1 Outstrength level
Based on a visual analysis of centrality indices plots, we identified the highest centrality indices during both the baseline and the intervention for each participant and compared them to find common patterns. First, we identified the variables with the highest outstrength level, which estimates nodes that send the most edges (Bringmann et al., 2019; Wasserman & Faust, 1994). Among the seven participants with available data, five participants on seven presented at least one variable that remained strong in the network during the intervention. The other two participants showed completely different temporal networks during the intervention. For example, in participant #329, openness and extraversion states presented the highest outstrength levels during the baseline, whereas during the intervention, it was agreeableness and neuroticism states.

3.4.2 Instrength level
As for the instrength levels, which estimates nodes that receive the most edges from other variables (Bringmann et al., 2019; Wasserman & Faust, 1994), three participants on seven presented at least one variable that remained strong in the network during the intervention. The four others showed completely different temporal networks during the intervention. For example, in participant #346, agreeableness state and affect valence presented the highest instrength levels during the baseline, whereas during the intervention, it was neuroticism and openness states.

3.4.3 Visual analysis of temporal networks
Based on our visual analysis of temporal networks, cognitive-affective variables at *t-1* were temporally associated with personality states in only three participants during the intervention : goal conflict was positively associated with agreeableness in participant #302; goal facilitation was positively associated with neuroticism, agreeableness and consciousness, and was negatively associated with extraversion; goal conflict was positively associated with openness, and was negatively associated with neuroticism in participant 346.

Different personality states temporal patterns emerged from participants during the intervention. For four participants (participants 302, 329, 333, 346), extraversion state outstrength levels remained stable in both phases. In other words, the intervention did not vary the degree to which state extraversion tends to funnel the flow of activation across other variables. Also found in four participants (participant 302, 329, 333, 477), agreeableness state instrength levels increased during the intervention, that is agreeableness state increased in the quantity of information it receives directly from other variables. The instrength levels of neuroticism states also

increased in four participants (participant 329, 333, 346, 378) during the intervention. However, the main result observed from our data is that all participants presented different patterns.

Our results suggest that the intervention may be considered as a 'trigger' of modification of the outstrength and the instrength levels of the variables of interest in almost half of the participants. All participant's analyses and networks are available in the Network analysis (participant #) section in the supplementary file. Below are complete descriptions of a network analysis (participant #333). We chose to present this participant's data as a case study to illustrate due to the complexity between the variables before and during the exercise intervention.

3.5 TEMPORAL PATTERNS OF PERSONALITY STATES, AFFECT, AND PERSONAL GOALS

Detailed results of the GAMs performed for the five personality states, affect valence and personal goal conflict and goal facilitation for each participant are available in Table 2. There is a significant effect of the exercise intervention on the temporal patterns of

personality states. State neuroticism was significantly modified by the intervention in nine participants, with 6 showing a non-linear association. State conscientiousness was significantly modified by the intervention in 8 participants, five showing a non-linear association, two showing a negative association and one showing a positive association. State extraversion and agreeableness were significantly modified by the intervention in both seven participants, with four showing a non-linear association, two showing a negative association and one showing a positive association. Finally, the intervention significantly modified state openness in only five participants, three showing a non-linear association, one showing a negative association and one showing a positive association. Based on our analyses, goal conflict and goal facilitation were the only two variables that have been significantly modified by the intervention in all participants, presenting mostly non-linear associations.
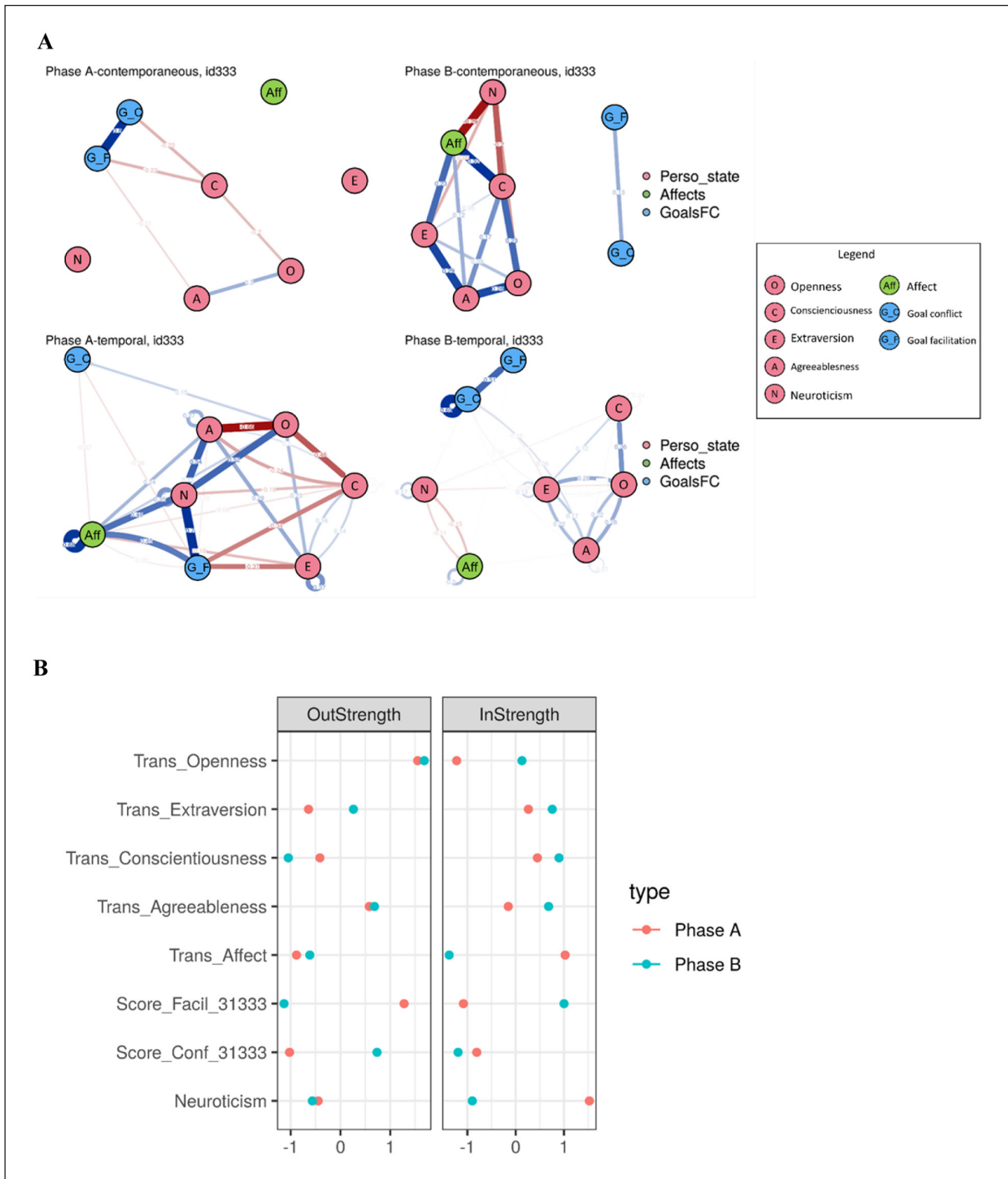
3.6 PARTICIPANT 333

Contemporaneous network. During baseline (see Figure 2-A, top left), we found no associations between

ID[1]		O[2]	C[3]	E[4]	A[5]	N[6]	AFF[7]	CONF[8]	FACIL[9]
302	sig[10]	○[11]	○	●[12]	●	●	●	●	●
	shape	–	–	↘[13]	↘	↝[14]	↘	↗[15]	↝
329	sig	●	●	●	●	●	●	●	●
	shape	↝	↝	↗	↝	↝	↘	↝	↘
333	sig	●	●	●	●	●	●	●	●
	shape	↝	↝	↝	↝	↘	↘	↝	↝
346	sig	○	○	○	●	●	●	●	●
	shape	–	–	–	↝	↝	↝	↘	↝
378	sig	●	●	●	●	●	●	●	●
	shape	↘	↝	↝	↝	↝	↘	↝	↘
448	sig	●	●	●	●	○	●	●	●
	shape	↝	↝	↝	↘	–	↝	↝	↝
477	sig	○	●	○	○	●	○	●	●
	shape	–	↗	–	–	↘	–	↝	↝
479	sig	○	●	●	○	●	○	●	●
	shape	–	↘	↝	–	↝	–	↘	↝
480	sig	○	●	○	○	●	○	●	●
	shape	–	↝	–	–	↝	–	↝	↝
481	sig	●	●	●	●	●	○	●	●
	shape	↗	↘	↘	↝	↗	–	↝	↝

Table 2 Generalized Additive Models for five personality states, affect, and goal conflict and facilitation.

Note: [1]ID = Identification, [2]O = Openness, [3]C = Conscientiousness, [4]E = Extraversion, [5]A = Agreeableness, [6]N = Neuroticism, [7]Aff = affect, [8]Conf = Conflicting goals, [9]Facil = Facilitating goals, [10]sig = significance (p = .05), [11]○ = no significant association, [12]● = significant association, [13]↘ = negatively linear, [14]↝ = non-linear, [15]↗ = positively linear.

Figure 2 Participant 333 contemporaneous and temporal networks **(A)** and centrality plots **(B)**.

Note A: The networks illustrate the dynamic between each of the variable of interest, namely affect (Aff), goal conflict (G_C_, goal facilitation (G_F), openness state (O), conscientiousness state (C), extraversion state (E), agreeableness state (A) and neuroticism state (N).

Note B: Centrality indices that are located to the right are the ones that receive (instrength) or send (outstrength) the most edges.

personality states and affect valence. Goal facilitation and goal conflict were negatively associated with conscientiousness ($r = -0.23$ and $r = -0.23$, respectively), and goal facilitation was negatively associated with agreeableness ($r = -0.11$). During the intervention (see Figure 2-A, top right), three personality states became positively associated with affect valence: conscientiousness ($r = 0.32$), extraversion ($r = 0.23$) and agreeableness ($r = 0.12$), whereas neuroticism was

negatively associated ($r = -0.29$) with affect valence. The baseline associations between personality states and goals conflict and facilitation were no longer significant.

Instrength (temporal network). Instrength estimates nodes that receive the most edges from other variables (Bringmann et al., 2019; Wasserman & Faust, 1994). For participant 333 temporal network, at baseline (see Figure 2-B), affect valence was most frequently involved in the shortest lagged indirect connections

between other constructs. During the intervention (see Figure 2-B), Goal facilitation became the most important variable in the network. Personality states extraversion, conscientiousness and Agreeableness did not vary significantly, however they kept a high level in both phases

Outstrength (temporal network). Outstrength estimates nodes that send the most edges (Bringmann et al., 2019; Wasserman & Faust, 1994). For participant 333, at baseline (see Figure 2-B), personality state openness and goal facilitation were the strongest variables in the network. During the intervention (see Figure 2-B), the activation properties of goal facilitation decreased and became the less important, contrary to openness which kept the same strength. Goal conflict's level increased and became the second most important variable of the network.

3.7 SENSITIVITY ANALYSES

Based on visual analysis, BFI, goal conflict and goal facilitation pre- and post-intervention scores were relatively similar among participants, except for participant 333. All figures are available in the supplementary files (see Figure S1 and Figure S2). A visual analysis of figures suggested that among 7/9 of participants with available accelerometer data, they increased their device-measured PA level. However, randomization tests suggested that a significant increase of physical activity level was only observed for participant 333 ($p = 0.04$).

4. DISCUSSION

4.1 MAIN FINDINGS

The aim of the present study was to examine the temporal dynamic patterns of associations between personality states, affect valence and pursuit of personal goals before and during an exercise intervention using N-of-1 trials. Whereas previous studies examined our outcomes of interest in silo, this study expands upon the current literature by using a network analysis approach to merge the dynamic relations between the variables of interest, within single individuals. Our data support that personality states, affect valence and personal goal pursuit are considered as interconnected and an evolving system that is modifiable by an exercise intervention. Our level of analysis helps to better understand how personality states in relation to cognitive-affective variables are linked with PA change.

4.2 SHARED ISOMORPHISM BETWEEN PERSONALITY STATES, AFFECT AND PERSONAL GOALS

We partially found support our first hypothesis, namely that the five personality states would be significantly associated with affect valence and personal goal

pursuits during the baseline period. First, our findings showed that the five personality states were associated with affect valence and personal goal pursuits before the intervention. However, important variations (i.e., level and directions of associations) between participants were observed. Our results are not as similar with previous EMA studies, where all five personality states showed a within-person association with affect (Kritzler et al., 2020; Wilson et al., 2017). In our case, the most noteworthy result was the consistent strong positive association between both state extraversion and agreeableness and affect valence, and the negative association between state neuroticism and affect valence in both five and seven participants, respectively, which have been reflected in previous studies (McNiel et al., 2010; McNiel & Fleeson, 2006; Wilt et al., 2017).

It reveals the affective nature of personality states, that is when participants were feeling more extraverted and agreeable, their affect valence were more positive, and inversely, when they were feeling more neurotic, they reported their affect valence to be more negative. As affect valence were measured every day, three times per day, during the baseline period and during the intervention, we were able to capture the difference of association after having introduced physical activity sessions. Interestingly, three participants showed no associations between personality states and affect valence during the baseline period, however it changed during the physical activity intervention.

Regarding personal goals, our results revealed recurrent associations with two personality states among participants: state conscientiousness was negatively associated with goal conflict, and state neuroticism was negatively associated with goal facilitation and positively associated with goal conflict. In other words, when participants reported a higher level of goal conflict, they reported lower level of state conscientious. Inversely, when they were feeling more neurotic, they reported lower levels of goal facilitation and higher levels of goal conflict. This is coherent with the proprieties associated with state conscientious and neuroticism reported in previous EMA investigations (Heller et al., 2007; McCabe & Fleeson, 2016). Indeed, conscientious state is associated with goal achievement and neuroticism is associated with individuals' sensibility to perceive a real or symbolic threat, and reactivity to this threat that could be translated with perception of threat in achieving personal goals. However, these studies also found associations between personal goals and extraversion states (Heller et al., 2007; McCabe & Fleeson, 2016). The discrepancy between their results and ours could be explained by the longer period of data collection and the nature of the idiographic analyses used in the present study, which allowed the detection of person-specific associations that might not appear at the group level. One participant showed no associations between personality states and

the pursuit of personal goals, which remained the same during the intervention. This may also be due to the level of difficulty of choosing personal goals: some participants mentioned having a hard time to think about their own personal goals. As this task requires a certain level of abstraction and cognitive resources, this exercise of self-reflection on their own daily lives might not be easily accessible for all participants (Caprara & Cervone, 2000).

4.3 CHANGES IN PERSONALITY STATES, AFFECT AND PURSUIT OF PERSONAL GOALS ASSOCIATIONS

Our second hypothesis postulated that the respective associations between personality states, affect valence and pursuit of personal goals identified during the baseline would be modified by the intervention, without common pattern between the participants. We partially found support for our hypothesis. Indeed, contemporaneous networks were modified during the intervention phase for all participants except one (participant 448). In our case, state conscientiousness and state extraversion's positive association with affect valence, and state neuroticism's negative association with affect valence were observed in a greater number of participants during the intervention. The networks change may be partially explained by the effects of physical exercise on personality stated. Indeed, a previous investigation showing that time spent in a gym was associated with a modification of personality states at short term (Matz & Harari, 2020). This result could be the first demonstration of an exercise intervention effects on the dynamic of modelized associations.

Our third hypothesis postulated that the exposition to the same input (i.e., exercise intervention) among participants would increase the centrality of affect valence or personal goals pursuits in temporal networks. As described in the WTT, external events activate affect valence and personal goals pursue which would in turn generate a change in the manifestation of the personality states, in other words, a change in the personality states in response to the initial external event. However, our results showed that none of these two constructs had a dominant centrality index in the networks during the intervention. In other words, the weight (instrength and outstrength) of each variable in the networks had increased or decreased differently among participants during the intervention. Our results partially support the WTT because personality states could drive affect valence and personal goals in some participants, instead of both affect valence and personal goals driving personality states. In a more practical sense, the elements that gained centrality during the intervention should be considered as 'drivers' of individual networks. Hence, knowing the strongest 'drivers' in a network could help to develop future personalized behavior change interventions. However, it is important to carefully interpret these possible interventional effect because our

time series were relatively short, and our results may be influenced by the length phases (Bringmann et al., 2022).

4.4 AFFECT DURING THE INTERVENTION

Our fourth hypothesis proposed that the valence of daily affect would significantly increase due to the intervention. Our results showed that the intervention did not increase positive affect. In fact, the exercise intervention modified affect valence in six participants: four presented a negative linear association, and two showed a non-linear association, which reflects incoherence with previous literature (Williams & Evans, 2014). A strong body of research supports the improvement of affective valence during and after an exercise intervention (Kanning & Schoebi, 2016; Powell et al., 2009; Schwerdtfeger A et al., 2010). More specifically, in both Powell (2009) and Schwerdtfeger's (2010) studies, higher exercise levels predicted high positive affective states during the course of a day. Our results did not corroborate these findings and go beyond by supporting the opposite idea. Indeed, our GAMs showed a no significant effect in four participants, and a non-linear association for two.

4.5 FINDINGS AS A WHOLE

Globally, our findings may suggest that constructs considered as intermediates in WTT (goal, affects) could be differentially activated by the nature or characteristics of intervention (i.e., input). Also, these intermediates postulated in WTT could be specific for one or several personality states (output).

Our study examined the effects of a physical activity intervention on cognitive-affective variables such as personality states, affect valence, and pursuit of personal goals. We found that the intervention led to changes in goal conflict and goal facilitation, with the shape of the relationship varying among participants. The non-linearity of the association with goal conflict and goal facilitation suggests that exercise gives rise to individual variations in specific cognitive-affective variables. In support of this idea, Kwasnicka et al. (2020) suggested that when non-active adults follow an exercise intervention, the amount of time they invest in both facilitating goals and conflicting goals may occur with individual patterns.

Furthermore, our results support the idea that the intervention was associated with changes in daily state neuroticism, state conscientiousness, state extraversion, and state agreeableness level, with the shape of the relationship also varying among participants. These findings provide insights into the mechanisms underlying the effect of an exercise intervention and highlight the importance of considering the complexity of change mechanisms. The effects of our intervention on personality states dynamic patternsmay also be considered as potential mechanism explaining the previous longitudinal associations found between high

level of PA on personality traits trajectories at long term (Stephan et al., 2014).

Our results stress the important contribution of personality theories at the idiographic level. While the network analyses show partial support for the application of the WTT in a physical exercise intervention context, future studies should test it with other health behavior interventions, such as a food diet intervention or in smoking cessation context.

Overall, our findings contribute to a granular understanding of the temporal interaction between cognitive-affective variables and personality states before and during an exercise intervention, and provide novel insights into the dynamics of these variables. Traditional approaches often imply that the change and the reactions to change are linear, hence omitting to look at the complexity of change mechanisms (Heino et al., 2021). To our knowledge, this is the first attempt to test the WTT hypotheses using an integrative and dynamic approach (Ruissen et al., 2021). We combined EMA with an idiographic approach which allowed to measure personal goal pursuit's variations, as recommended in previous literature (Ruissen et al., 2021).

This study has several strengths. First, all participants had a notable adherence rate to the intervention and EMA questionnaires. Our methodology also contributed to modelize the connectedness between variables before and during an intervention and helps to comprehend how much of the network differ from one person to another. Additionally, the combination of our network analyses and GAMs provides a complete portrait of the evolution of associations, weights, and temporal dynamics. Finally, levels of goal conflict and goal facilitation were relatively similar pre- and post-intervention, thus our idiographic measures were reliable during the study.

4.6 LIMITATIONS

Our study presents several limitations. First, temporal models for three participants did not converge. Second, a battery dysfunction occurred with the GENEActiv accelerometers during the intervention, hence the number of consecutive days of collected exercise level data varies among participants. Third, participants' PA levels were relatively high during the baseline phase. This may be explained as a reaction effect to physical activity assessments (Wilding et al., 2016, Konig et al., 2022). Fourth, we performed separate GAMs for each variable because, as expected, the distribution of our dependent variables (i.e., personality state) were not normal. Thus, it exhibits a high risk for type 1-error for these results. Fifth, the replicability and accuracy of our network models can be limited because we performed our analyses with relative short time series and complex models. These models also prevented us from examining gradual or abrupt changes between A and B phases in

networks with an adequate test (e.g., Kernel Change Point detection).

Sixth, an additional observational phase after the intervention could help us to identify whether networks return to their initial structure. Seventh, a conceptual or empirical overlap between examined constructs, or their possible low variability during A phase should be considered. It might have influenced network associations and centrality indices (Bringman et al, 2019; Bringman et al, 2022). Finally, the use of N-of-1 makes it difficult to generalize/integrate data at the nomothetic level. As mentionned by Barbot & Perchec (2015), there is no consensus on how to integrate information from these multiple cases to generalize to the group level. However, promising directions to integrate the idiographic and the nomothetic approaches are being developed (e.g., meta-analyses of single-case studies, recurrence quantification techniques combining analysis of individual time series with findings generalizable to the group level, work on the disaggregation of effects over time, and "bottom-up" approach in replicated time-series designs) (Barbot & Perchec, 2015; Haslbeck et al, 2021).

5. CONCLUSION

Taken together, these findings suggest consistent evidence for the dynamics between personality states, affect and pursuit of personal goals to be varying differently in nodes and in strength among individuals during a physical exercise intervention. Although our results did not support that affect valence and personal goals systematically drive personality states, they indicate that physical exercise could modify the intraindividual levels of goal conflict and goal facilitation in a non-linear manner. These results need to be replicated and confirmed, however they represent a good first step in better understanding the cognitive-affective mechanisms underlying the manifestation of personality states in a behavior change context. Future studies could use a protocol similar to ours in order to test the dynamics between cognitive-affective mechanisms with an exercise intervention including behavior change techniques targeting these mechanisms. Researchers should design future n-of-1 with an A-B-A design, with longer duration for each phase. Future interventional studies using idiographic networks should also be based on the best balance between a priori power analysis (often requiring long time series) and feasibility of behavior change interventions. For instance, a very long A phase (e.g., >30 days) may be associated with high drop-out rates. They could also use a protocol similar to ours in order to test the dynamics between cognitive-affective mechanisms with exercise intervention including behavior change techniques targeting these

mechanisms. Finally, in interventional studies, more adapted network analyses could be carried out such as Time-Varying vector autoregressive models.

ABBREVIATIONS

PA: Physical activity
WTT: Whole trait theory
EMA: Ecological momentary assessment
GAMs: generalized additive models

ADDITIONAL FILE

The additional file for this article can be found as follows:

- **supplementary file.** Supplementary Online Material. DOI: https://doi.org/10.5334/hpb.43.s1

COMPETING INTERESTS

The authors have no competing interests to declare.

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