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ARTICLE

The reciprocal relationships between autonomous motivation, social cognitive beliefs and rehabilitation adherence: A cross-lagged panel longitudinal study among post-surgery ACL reconstructed patients

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Abstract

Objective: The objective of this three-wave longitudinal study was to investigate the temporal precedence between the motivational drivers in self-determination theory (SDT) and the social cognitive factors in theory of planned behaviour (TPB).

Method: A total of 236 patients who underwent anterior cruciate ligament (ACL) reconstruction surgery ($M_{age} = 33.58 \pm 10.03$, range = 18 to 59; female = 46.2%) completed surveys assessing autonomous motivation from SDT, and attitude, subjective norms, perceived behavioural control (PBC), and intention from TPB, and rehabilitation adherence, at baseline (T1), and at 2 months (T2) and 4 months (T3) post-baseline.

Results: In a three-wave cross-lagged panel model, autonomous motivation prospectively related to subsequent attitude, subjective norms and PBC, whereas reverse paths were generally small; attitude showed a modest reciprocal link with autonomous motivation. Additionally, a mediation model revealed that T1 autonomous motivation had significant indirect effects on T3 rehabilitation adherence via T2 social cognitive factors and intention, whereas only T1 subjective norms had small indirect effects on T3 rehabilitation adherence through T2 autonomous motivation and intention.

Conclusions: These findings support the notion that autonomous motivation precedes social cognitive factors, as

proposed in the integrated theoretical model of SDT and TPB. Future research, including experimental interventions, can use the integrated theoretical model to promote various health behaviours, such as rehabilitation protocols, healthy eating habits and hygiene practices.

KEYWORDS

ACL injuries, behavioural adherence, self-determination theory, social cognition, theory of planned behaviour

Statement of Contribution

What is already known on this subject?

- The integrated SDT–TPB model proposes that autonomous motivation precedes TPB beliefs and intention that, in turn, predict health behaviour, and this ordering is supported across multiple health contexts.
- Longitudinal tests of this temporal ordering are scarce; one cross-lagged study in injury prevention supported autonomous motivation → TPB beliefs but did not include intention or behaviour, and ACL rehabilitation remains under-tested.
- ACL rehabilitation adherence is crucial for recovery yet commonly suboptimal, highlighting the need to identify motivational drivers of sustained adherence.

What does this study add?

- Autonomous motivation precedes later TPB beliefs in ACL rehabilitation.
- Attitude shows a modest reciprocal link with autonomous motivation.
- Autonomous motivation predicts T3 adherence indirectly via T2 TPB beliefs and intention.

INTRODUCTION

Anterior cruciate ligament (ACL) tears or ruptures are one of the most common sports-related injuries (Prieto-González et al., 2021; Sanders et al., 2016). The annual incidence of ACL rupture that requires surgical intervention is estimated to range between 32 and 78 per 100,000 persons (Gans et al., 2018). Patients are usually prescribed comprehensive rehabilitation programmes before and/or after receiving ACL reconstruction surgery. These programmes entail strength, neuromuscular and fundamental skills training of gradual intensity and power and are designed to reduce pain and swelling, protect and support the integrity of the repaired ligament, and facilitate both physical and psychological recovery (Saka, 2014). Research has highlighted the importance of consistent rehabilitation efforts in promoting functional abilities (e.g., better knee function [Brown et al., 2021], improved quadriceps strength [Gokeler et al., 2014], speed and agility [Królikowska et al., 2018]), the psychological well-being of patients (e.g., restoring confidence [Della Villa et al., 2021], and reduced fear of movement and reinjury [Chmielewski et al., 2008]), and the final outcome of return to pre-injury performance level in sports (Han et al., 2015). Recently, Della Villa et al. (2020) found that each incremental increase in compliance level was associated with a 68% higher probability of successfully returning to sport. However, research has indicated that the low rehabilitation adherence is a pervasive issue in the general community, where

only 30% of patients continue any form of rehabilitation beyond the first 6 months (Ebert et al., 2018). Patients face various psychological barriers, such as underestimation of the effort required to complete rehabilitation, fear of reinjury (Walker et al., 2022), lack of social support and low self-efficacy (Walker et al., 2020). Given these challenges, patients require strong motivation to overcome these obstacles and adhere to their rehabilitation (Pizzari et al., 2002; Sonesson et al., 2017). Previous research has established the applicability of the integrated model of behavioural change in predicting rehabilitation adherence (Lee, Yung, et al., 2020); however, few studies to date have questioned the temporal order of the constituted theories of self-determination theory (SDT; Deci & Ryan, 2013) and the theory of planned behaviour (TPB; Ajzen, 1991) of the integrated model (Hagger & Chatzisarantis, 2009). This study aims to investigate the temporal precedence between the motivational drivers in SDT and the cognitive-behavioural factors in TPB.

Integrated model of behavioural change

The integrated model combines two well-studied social psychological theories, SDT and the TPB, to provide a detailed motivational sequence for understanding health behaviours (Hagger & Chatzisarantis, 2009). Specifically, the central tenet of SDT is that the social environment plays a pivotal role in shaping the quality of an individual's motivation, which in turn has significant implications for their subsequent behaviour (Deci & Ryan, 2013). Environments that satisfy the basic psychological needs of autonomy, competence and relatedness promote autonomous motivation, which is endorsed by individuals who view their actions as aligned with their intrinsic goals, interests and values. In contrast, a needs-thwarting climate undermines autonomous motivation and instead gives rise to controlled motivation, where individuals feel pressured or urged into action out of external reasons or contingencies. Individuals driven by autonomous motivation tend to demonstrate more effective self-regulation and experience more adaptive outcomes than those driven by controlled motivation. Taken together, SDT operates at a generalized contextual and dispositional level and is used to explain the origin of the antecedents of intentional behaviour (Hagger & Chatzisarantis, 2007). The TPB complements the motivational framework by specifying the social cognitive belief system that shapes behavioural intention, which is considered the most immediate and predictive determinant of actual behaviour (Ajzen, 1991). These social cognitive beliefs include attitudes (i.e., an individual's personal appraisal of the target behaviour), subjective norms (i.e., the perceived expectations exerted by significant others and the individual's motivation to comply with such expectations), as well as the perceived behavioural control ([PBC], perceived capacity, available resources and potential barriers that may facilitate or hinder the ability to execute the behaviour). Therefore, the TPB charts the proximal determinants of behaviour, representing the cognitive and situational factors that influence actions. The unity of the two theories addresses their respective shortcomings. While SDT provides the underlying motivational basis prior to the social cognitive beliefs, the TPB bridges the gap between motivation and behaviours by offering formalized belief-based factors that explain how these motivational drivers translate into actual behavioural engagement (Hagger & Chatzisarantis, 2007). By integrating these complementary theories, the integrated model describes a more complete regulatory and decision-making process that governs human behaviour.

The theoretical integration was supported by meta-analytic evidence demonstrating a positive association between autonomous motivation and social cognitive beliefs (Hagger & Chatzisarantis, 2007, 2009) and was tested in a wide variety of health contexts, such as physical activity participation (Hagger & Chatzisarantis, 2009), healthy eating (Girelli et al., 2016), blood donation (Williams et al., 2019), sport injury prevention (Lee, Standage, et al., 2020) and the prevention of infectious diseases (Chung et al., 2017; Wan et al., 2024). Notably, the integrated model has been suggested as a more comprehensive approach to better explain and predict patients' adherence to ACL injury rehabilitation programs (Chan, Lee, et al., 2017) on the basis of the evidence from studies that have independently investigated the factors of SDT (Chan et al., 2009) or the TPB (Niven et al., 2012). More recently, Lee, Yung,

et al. (2020) found a significant association between patients' perceptions of psychological need support from their physiotherapists and their autonomous motivation for the treatment. This autonomous motivation directly predicted key social cognitive beliefs and was indirectly linked to patients' adherence to the post-surgical rehabilitation program. Aside from ACL rehabilitation, the integrated model has shown predictive utility in adherence to other types of injury management, including the prevention of sports injuries (Chan, Zhang, et al., 2020) and domestic injuries (Chiu et al., in press), as well as the rehabilitation of occupational injuries (Chan & Hagger, 2012; Chan, Webb, et al., 2017).

Temporal order of the integrated model

The rationale for positioning SDT prior to the TPB within the integrated model was grounded in theoretical and conceptual considerations (Hagger & Chatzisarantis, 2009). This perspective aligns with SDT's proposition (Deci & Ryan, 2013; Ryan & Deci, 2020) that motivational orientations drive a strategic alignment of beliefs, enabling future behaviours that align with personal motives and needs. A recent study (Chan, Zhang, et al., 2020) investigating the reciprocal relationships between autonomous motivation from SDT and factors from the TPB in a sport injury context also supports the temporal ordering of factors in the integrated model. It was found that autonomous motivation from SDT was more likely to be the antecedent of the social cognitive constructs from the TPB. However, this study focused exclusively on the reciprocal relationships within a sport injury prevention setting and did not include intention and behavioural adherence from the integrated model (Chan, Zhang, et al., 2020). Therefore, the findings were unable to identify which psychological factors (from SDT or the TPB) serve as distal or proximal predictors of intention and behaviour. To provide robust evidence for the temporal order of the integrated model, it is important to investigate the interplay of autonomous motivation and social cognitive factors in predicting behavioural intention and adherence (Chan, Zhang, et al., 2020). Therefore, further research is needed to comprehensively test the integrated model by including these essential constructs and examining the reciprocal relationships between autonomous motivation and social cognitive factors across different health contexts.

The present study

The present study adopted a three-wave cross-lagged panel design to examine the dynamic interplay between autonomous motivation in SDT and the social cognitive factors in the TPB within the context of ACL rehabilitation. Data were collected at baseline (T1) and at 2 months (T2) and 4 months (T3) post-baseline. Based on the integrated theoretical model of SDT and the TPB (Hagger & Chatzisarantis, 2009) and previous empirical studies (Chan, Zhang, et al., 2020; Lee, Yung, et al., 2020), we hypothesized the following:

H1. Cross-lagged effects of autonomous motivation on future social cognitive factors (i.e., attitude, subjective norm and PBC) would be positive and significant. (See Figure 1).

H2. Cross-lagged effects of social cognitive factors on future autonomous motivation would be non-significant. (See Figure 1).

H3. The indirect effects of T1 autonomous motivation → T2 social cognitive factors → T2 intention → T3 rehabilitation adherence would be positive and significant. (See Figure 2).

H4. The indirect effects of T1 social cognitive factors → T2 autonomous motivation → T2 intention → T3 rehabilitation adherence would be non-significant. (See Figure 2).

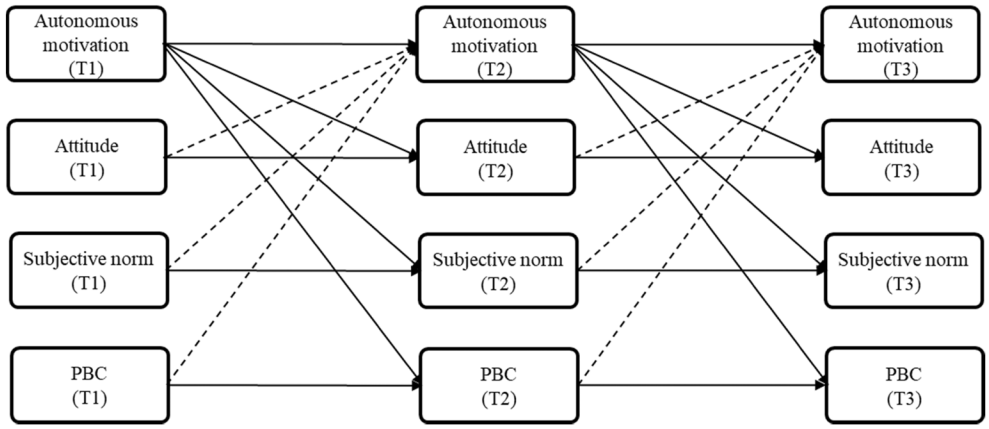

FIGURE 1 Hypothesized reciprocal cross-lagged relations across adjacent time points (H1–H2). Solid lines were hypothesized to be positive and significant (H1) and dashed lines were hypothesized to be non-significant (H2). Autoregressive paths are displayed for completeness but were not part of the hypotheses. PBC, perceived behavioural control.

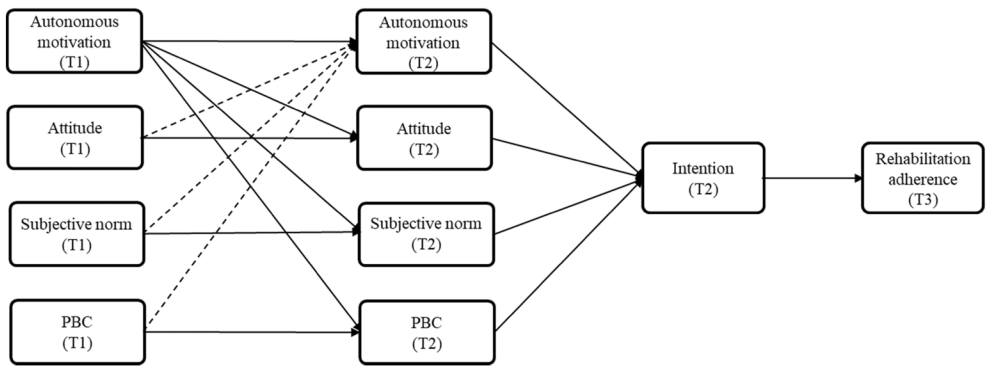

FIGURE 2 Hypothesized indirect-effects model (H3–H4). Solid lines were hypothesized to be positive and significant (H3) and dashed lines were hypothesized to be non-significant (H4). PBC, perceived behavioural control.

METHOD

Participants and procedure

Ethical approval was obtained from the Human Research Ethics Committee of the last author's institution (#2020-2021-0428). We sent out invitations through Prolific, a participant recruitment platform targeting individuals in the United Kingdom from July 2021 to August 2021. To be eligible for inclusion in the study, participants needed to meet the following criteria: (1) adults aged between 18 and 60 years, (2) had been diagnosed with ACL rupture and (3) had undergone ACL reconstruction within the last 12 months. A total of 2031 individuals were assessed for eligibility, and informed consent was sent to the 287 individuals who met the inclusion criteria. Finally, 236 patients who underwent ACL reconstruction surgery ($M_{age} = 33.58 \pm 10.03$, range = 18–59; female = 46.2%) agreed to participate in the study. The participants were asked to complete a survey package at baseline (T1), as well as at the 2nd (T2) and 4th month (T3) after the baseline, which assessed autonomous motivation from SDT, attitude, subjective norms, PBC and intention from the TPB, and rehabilitation adherence. On average, participants had experienced ACL rupture 9.43 months ago ($SD = 5.03$). Our baseline assessment occurred at 6.61 ($SD = 3.39$) months after ACL reconstruction, with follow-up assessments taken at 2 and 4 months later

(≈8 and 10 months post-operation). These time points fall within the mid-to-late rehabilitation phase—when ongoing strength, neuromuscular and sport-specific retraining are recommended—and precede typical return-to-sport time frames (>9–12 months; Grindem et al., 2016; Kaplan & Witvrouw, 2019). Baseline assessments revealed that 83 participants (35.2%) reported suffering from meniscus injuries in addition to ACL rupture.

Measures

Autonomous motivation

Participants' autonomous motivation towards rehabilitation exercise was measured using the five-item adapted from the Treatment Self-Regulation Questionnaire (TSRQ) for a rehabilitation context (Chan et al., 2009, 2011; Williams et al., 1996). The item stem was 'I have remained in treatment and carry out rehabilitation exercise because…'. Participants rated each statement (e.g., 'I feel like it's the best way to help myself') on a seven-point Likert scale (1 = *Not at all true*; 7 = *Very true*). The scale was suggested to be reliable (i.e., $\alpha = .82$) in a previous study (Lee, Yung, et al., 2020). In the present study, the TSRQ showed acceptable reliability at all time points (i.e., $\alpha > .75$).

Social cognitive factors and intention

We adopted the 17-item injury rehabilitation version of the TPB scale (Ajzen, 2002; Lee, Yung, et al., 2023). The scale consists of four subscales, namely attitude (5 items; e.g., 'Following the prescribed treatment protocols or guidelines for my rehabilitation in the forthcoming month is valuable'), subjective norms (3 items; e.g., 'Most people who are important to me think that I should follow the prescribed treatment protocols or guidelines for my rehabilitation in the forthcoming month'), PBC (5 items; 'I have complete control over following the prescribed treatment protocols or guidelines for my rehabilitation in the forthcoming month') and intention (3 items; e.g., 'I intend to carry out the prescribed rehabilitation exercise for the forthcoming month'). The items were rated on a seven-point Likert scale from 1 (*Strongly disagree*) to 7 (*Strongly agree*). The scale demonstrated adequate reliability (i.e., $\alpha > .80$) in previous studies (Lee, Yung, et al., 2020, 2023). In the present study, the Cronbach's alpha coefficients of the scale at all time points were > .70.

Rehabilitation adherence

The six-item Rehabilitation Adherence Inventory (RAI; Lee et al., 2024) was adopted to assess participants' rehabilitation adherence. The participants rated the items (e.g., 'I fully commit to the rehabilitation programme') on a seven-point Likert scale (1 = *Strongly disagree*; 7 = *Strongly agree*). The validity (e.g., factorial, discriminant and predictive validity) and reliability (i.e., $\alpha = .90$) of the RAI were supported in a recent validation study (Lee et al., 2024). In the present study, the RAI showed excellent reliability at T3 (i.e., $\alpha = .94$).

Data analysis

Statistical analyses were performed via SPSS version 26.0 (IBM Corp, 2019) and Mplus version 7.4 (Muthén & Muthén, 2017). Preliminary analyses involved generating means, standard deviations, bivariate correlations, skewness, kurtosis and reliability coefficients of the study variables. To test H1 and H2, we fit a three-wave cross-lagged panel model (T1 → T2 → T3; Model 1, Figure 1) with stationarity

constraints (equal autoregressive and cross-lagged paths across adjacent lags) (Lucas, 2023). Constraints were evaluated with the Satorra–Bentler scaled χ^2 difference. To test H3 and H4, another path model (Model 2; Figure 2) was developed to examine the indirect effects of autonomous motivation and social cognitive factors at T1 on rehabilitation adherence at T3 via the cross-lagged paths (i.e., autonomous motivation and social cognitive factors at T2). H3 would be supported if autonomous motivation has significant indirect effects toward prospective rehabilitation adherence in this pathway: T1 autonomous motivation → T2 social cognitive factors → T2 intention → T3 rehabilitation adherence. Conversely, H4 would be supported when social cognitive factors have non-significant indirect effects toward future rehabilitation adherence in this pathway: T1 social cognitive factors → T2 autonomous motivation → T2 intention → T3 rehabilitation adherence. Indirect effects were evaluated using bias-corrected bootstrap confidence intervals (5000 resamples). Inference was based on the CI (effects are considered statistically significant when the 95% CI does not include 0).

The model fit was assessed using conventional fit indices, including the comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square error of approximation (RMSEA) and Standardized Root Mean Square Residual (SRMR). Values exceeding .90 for the CFI and TLI, and below .08 for the RMSEA and SRMR, were considered to be benchmarks for indicating acceptable model fit (Hu & Bentler, 1999). In terms of managing missing data, it is worth noting that 48 and 79 participants did not complete the T2 and 3 assessments, respectively. This resulted in a retention rate of 20.33% and 33.48%, which fell within the typical longitudinal studies' attrition ranges (Gustavson et al., 2012). Based on the results of Little's Missing Completely at Random (MCAR) test (Little & Rubin, 2019), $\chi^2 = 58.89$, $df = 72$, $p = .87$, it was suggested that there was no clear pattern in the missing data. To address the missing data, we employed the maximum likelihood with robust standard errors (MLR) estimation method. This approach adjusts the likelihood function by ensuring that each case contributes information to the variables in our analyses (Muthén & Muthén, 2017).

RESULTS

Preliminary analysis

Descriptive statistics, including means, standard deviations, zero-order correlations, skewness, kurtosis and reliability coefficients, for all measured variables are presented in Table 1. All zero-order correlations among the study variables were statistically significant, rs = .23 to .75 at $p < .01$, except the T2 attitude–T3 subjective norms correlation ($r = .20$, $p < .05$).

Reciprocal models

To address stability across lags, we estimated a three-wave CLPM with stationarity constraints (Lucas, 2023). The constrained model fit well, χ^2 (16) = 26.48, CFI = .99, TLI = .94, RMSEA = .05, SRMR = .07 and the constraints did not worsen fit relative to the unconstrained model (χ^2 (6) = 9.28); Satorra–Bentler scaled $\Delta\chi^2$ (10) = 14.47, $p = .15$. Given the relatively modest sample size and the number of equality constraints tested, this non-significant Satorra–Bentler scaled χ^2 difference test should be interpreted as providing limited evidence for stationarity (i.e., equality of autoregressive and cross-lagged effects across adjacent lags). Accordingly, we retained the constrained (stationarity) model for parsimony and interpret the equality of effects cautiously. The parameter estimates for Model 1 are displayed in Figure 3. The parameter estimates for Model 1 supported H1. Specifically, autonomous motivation significantly predicted prospective attitude (β range = .12 to .13, ps range = .02 to .03), subjective norms (β range = .15 to .16, ps = .01), and PBC (βs = .19, ps = .01). For H2, PBC did not predict later autonomous motivation at either lag (βs = .02, ps = .79). Subjective norms showed only a borderline pattern, marginal at T0 to T1 ($\beta = .14$, $p = .04$) and non-significant at T1 to T2 ($\beta = .15$, $p = .05$). In

TABLE 1 Zero-order correlations, descriptive statistics and reliability coefficients of the study variables at three timepoints ($N = 236$).

Components	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T1															
1. Autonomous motivation	1														
2. Attitude	.42	1													
3. Subjective norms	.59	.50	1												
4. PBC	.59	.60	.65	1											
T2															
5. Autonomous motivation	.52	.38	.47	.46	1										
6. Attitude	.33	.55	.30	.43	.44	1									
7. Subjective norms	.37	.43	.43	.47	.62	.56	1								
8. PBC	.49	.45	.44	.55	.61	.64	.68	1							
9. Intention	.45	.46	.39	.50	.65	.63	.74	.70	1						
T3															
10. Autonomous motivation	.54	.34	.47	.47	.56	.40	.45	.46	.47	1					
11. Attitude	.31	.59	.37	.46	.40	.61	.51	.47	.56	.52	1				
12. Subjective norms	.33	.23	.41	.29	.40	.20	.54	.39	.46	.60	.47	1			
13. PBC	.49	.49	.53	.63	.53	.48	.56	.66	.64	.62	.60	.64	1		
14. Intention	.42	.43	.36	.46	.49	.45	.52	.46	.65	.66	.63	.64	.72	1	
15. Adherence	.37	.49	.40	.45	.48	.56	.50	.49	.65	.59	.69	.47	.65	.75	1
Mean	5.98	5.56	6.00	5.86	5.94	5.51	5.84	5.84	5.97	5.98	5.52	5.88	5.85	5.84	5.61
SD	.90	.72	.94	.85	.94	.79	1.02	.92	.96	.89	.78	.91	.84	1.07	.98
Cronbach's α	.75	.70	.85	.82	.77	.75	.88	.85	.88	.78	.74	.81	.81	.91	.94
Skewness	−1.40	−.58	−1.34	−.97	−1.07	−.58	−.82	−.99	−1.12	−1.15	−.65	−.63	−.80	−1.04	−1.04
Kurtosis	2.38	.75	2.87	1.61	.52	.41	.41	1.27	1.18	1.28	.42	−.11	.43	1.06	1.58

Note: All zero-order correlations are statistically significant at $p < .01$, except T2 attitude–T3 subjective norms ($p < .05$).
Abbreviation: PBC, perceived behavioural control.

contrast, attitude was unexpectedly associated with later autonomous motivation at both lags (βs = .14, ps < .01). Hence, H1 was supported, and H2 was partially supported.

Indirect effects significance

The Model 2 (see Figure 4) showed adequate fit to the data, $\chi^2 = 28.17$, $df = 12$, CFI = .98, TLI = .93, RMSEA = .08 [90% CI = .04 to .11], SRMR = .05. The mediation results were presented in Table 2. In support of H3, the results revealed that T1 autonomous motivation had significant indirect effects on T3 rehabilitation adherence via T2 attitude, subjective norm, PBC and intention ($\beta = .10$, 95% CI [.05 to .17]). Regarding H4, the indirect effects of T1 attitude and PBC on T3 rehabilitation adherence mediated by T2 autonomous motivation and intention were not statistically significant (βs = .02, 95% CI [−.01 to .05]). However, contrary to H4, T1 subjective norms had small but significant indirect effects on T3 rehabilitation adherence through T2 autonomous motivation and intention ($\beta = .03$, 95% CI [.01 to .06]). Thus, H3 is supported, whereas H4 is only partially supported.

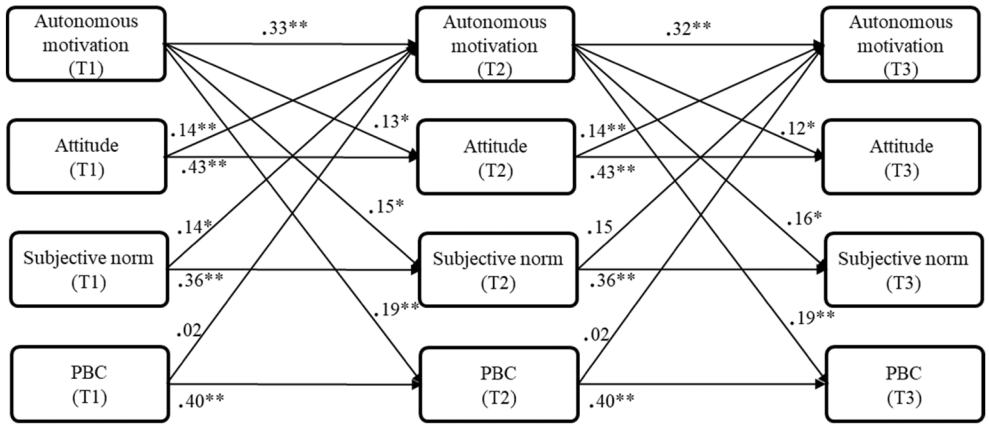

FIGURE 3 Model 1 results: Estimated structural model (standardized coefficients). PBC, perceived behavioural control. *$p < .05$, **$p < .01$.

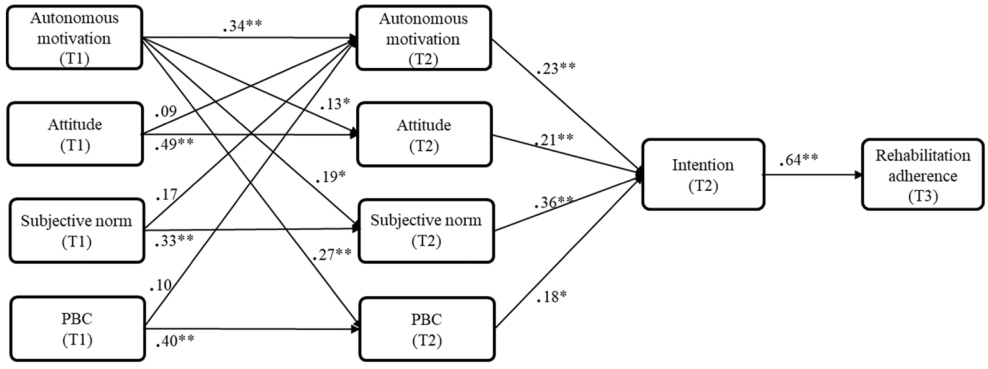

FIGURE 4 Model 2 results: Mediation model with autoregressive controls (standardized coefficients). PBC, perceived behavioural control. *$p < .05$, **$p < .01$.

TABLE 2 Results from the mediation analyses for Model 2.

Paths	Mediator (s)	Indirect effects [95% CI]
T1 autonomous motivation → T3 rehabilitation adherence	T2 attitude, subjective norm, PBC, intention	.10 [.05, .17]
T1 attitude → T3 rehabilitation adherence	T2 autonomous motivation, intention	.02 [−.01, .05]
T1 subjective norm → T3 rehabilitation adherence	T2 autonomous motivation, intention	.03 [.01, .06]
T1 PBC → T3 rehabilitation adherence	T2 autonomous motivation, intention	.02 [−.01, .05]

Abbreviation: PBC, perceived behavioural control.

DISCUSSION

The present research aims to explore the reciprocal relationships between autonomous motivation from SDT and the three social cognitive factors (i.e., attitude, subjective norms, PBC) from the TPB in predicting rehabilitation adherence among patients recovering from ACL rupture. Overall, the results aligned with the integrated model (Chan, Zhang, et al., 2020; Hagger & Chatzisarantis, 2009; Lee,

Yung, et al., 2020): H1 was supported and H2 was partially supported. Specifically, our Model 1 revealed that autonomous motivation typically preceded the development of social cognitive factors in ACL rehabilitation. The only consistent deviation was attitude, which showed a modest reciprocal link with autonomous motivation. The indirect effects model (Model 2) reinforced this ordering: T1 autonomous motivation was related to T3 adherence primarily through its influence on T2 TPB beliefs and intention, whereas reverse chains via autonomous motivation were small, with a minor exception for subjective norms. Taken together, these findings position autonomous motivation as an upstream driver of belief formation and intention in ACL rehabilitation, with only limited reciprocal influence—mainly via attitude—and converge with prior reports showing a similar autonomous motivation–attitude interplay.

Reciprocal relationship

Consistent with our hypotheses and the integrated model of SDT and the TPB (Hagger et al., 2002; Hagger & Chatzisarantis, 2009), autonomous motivation generally preceded later TPB beliefs—attitude, subjective norms and PBC—across waves. Extending beyond prior research focused on sport injury prevention (Chan, Zhang, et al., 2020), our study investigated this reciprocal relationship in the context of ACL rehabilitation. Particularly, we observed the same overall ordering with one nuance: attitude was also prospectively related to autonomous motivation, indicating a modest reciprocal link, whereas subjective norms showed only a borderline pattern and perceived behavioural control did not. This reciprocity is theoretically plausible within an SDT–TPB frame: when reasons for rehabilitation are self-endorsed, people tend to appraise the behaviour more favourably (stronger attitude); conversely, a more favourable, value-congruent attitude may facilitate internalization, reinforcing autonomous reasons over time (Ryan & Deci, 2000). Even with this nuance, the broader pattern underscores the antecedent role of autonomous motivation in shaping individuals' beliefs and behaviours (Caso et al., 2024; Chan, Zhang, et al., 2020; Phipps et al., 2020; Wan et al., 2024). The underlying mechanism is that individuals form beliefs on the basis of internal factors (Ajzen, 1991), including motivational orientations (Deci & Ryan, 2000). Individuals who endorse autonomous motivation towards specific behaviours are inclined to sustain those behaviours over time, fostering feelings of satisfaction and positive emotions as a result. Hence, autonomous motives inform the formation of beliefs and intentions regarding future behaviour, underscoring an adaptive process where individuals align their beliefs with their motives to pursue congruent behaviours (Chan, Zhang, et al., 2020; Hagger & Chatzisarantis, 2009).

Notably, T1 subjective norms were positively associated with Time 2 autonomous motivation in Model 1, which is inconsistent with the integrated model of SDT and the TPB (Hagger & Chatzisarantis, 2009) and findings from previous studies (Chan, Zhang, et al., 2020). Conventionally, the relationship between autonomous motivation and subjective norms has been perceived as the weakest as compared to the connections with the other two social cognitive factors, attitude and PBC (Chatzisarantis et al., 2006; Hagger et al., 2006). This perception stems from the fact that subjective norms emphasize the perception of social expectations regarding a specific behaviour, which seemingly contradicts the nature of autonomous motivation, characterized by independence from external demands or pressures (Chatzisarantis et al., 2006; Hagger et al., 2006). One possible explanation for this finding is that participants might perceive their significant others (e.g., physiotherapists, family, friends) as psychological needs supportive, thus enabling subjective norms to predict future autonomous motivation (Chan et al., 2014; Lee, Yung, et al., 2020). This suggests that individuals may interpret the desires of significant others as supportive, leading to the internalization of potentially controlling contingencies into supportive autonomous motives. In addition, the subject norms exhibited some theoretical overlaps with the psychological needs of SDT. For autonomy needs, positive subjective norms, such as encouragement and support from significant others, empower individuals with a sense of control, respect and ownership over their rehabilitation process, nurturing autonomy and thereby enhancing autonomous motivation (Deci & Ryan, 2000). Regarding competence needs, perceiving belief and support from one's social network

fosters feelings of competence in managing rehabilitation challenges (Chan et al., 2009). For relatedness needs, positive subjective norms may foster a supportive social environment characterized by empathy, understanding, shared goals. This sense of connection satisfies the need for relatedness, motivating individuals to autonomously engage in rehabilitation activities to maintain valued social connections (Deci & Ryan, 2000). Studies have also emphasized the significant role of subjective norms in predicting physical activity participation and exercise motivation among breast cancer patients (Pinto & Ciccolo, 2010; Weisenbach & McDonough, 2014).

Another potential explanation for this finding could be attributed to methodological limitations inherent in the TPB subjective norms scale (Ajzen, 2002), as discussed in Kim et al. (2019)'s study. Research has highlighted the intricate nature of subjective norms and suggested that future researchers measure subjective norms indirectly (Kim et al., 2019). The indirect measure involves considering the sources of participants' beliefs, such as physiotherapists, family, or friends, and assessing their personal salience. The participants are then prompted to report their subjective norms, focusing solely on the selected normative referents. Similarly, La Barbera and Ajzen (2020) proposed including the subdimensions of subjective norms, namely injunctive (reflecting perceived behavioural expectations of important social referents) and descriptive (indicating whether these referents are themselves perceived to perform the behaviour) norms into the measurement of subjective norms. Future studies may benefit from employing both strategies for measuring subjective norms to elucidate the interplay between autonomous motivation and subjective norms.

Limitations and future directions

It is important to acknowledge several key methodological limitations in the current study that may affect interpretation and identify emerging directions for future research. First, the participants recruited for this study were exclusively patients from the United Kingdom who experienced ACL ruptures, limiting the generalizability of our findings beyond this specific population. Future studies should explore the reciprocal relationships between the SDT and TPB constructs among more diverse populations from various cultures and with different medical conditions (Chan, Yang, et al., 2015). Second, the present study's relatively small sample size necessitated the adoption of path modelling instead of structural equation modelling (SEM) to mitigate measurement bias. To increase the study's power and investigate effects more comprehensively, future research should aim to recruit larger sample sizes and utilize SEM. Third, our reliance on self-report scales, including the evaluation of rehabilitation behaviour, poses limitations despite the favourable validity of the data supporting the RAI (Lee et al., 2024). Concerns persist regarding social desirability, and the exclusive use of self-report measures likely introduces common method variance, potentially inflating the covariance between measures using similar response type (Chan, Ivarsson, et al., 2015; Chan, Stenling, et al., 2020). Researchers are encouraged to incorporate non-self-reported or external measures, such as evaluations by physiotherapists and actual visits to rehabilitation clinics, to assess patients' rehabilitation adherence more accurately.

In addition, while cross-lagged panel models elucidate temporal relationships among constructs, they do not establish causation, as these data are inherently correlational (Chan, Zhang, et al., 2020). Therefore, our findings cannot definitively conclude that autonomous motivation causes changes in social cognitive factors; this inference remains theoretical. Future research should prioritize randomized controlled designs to elucidate causal relationships within the integrated model of SDT and the TPB (Lee et al., 2021). Lastly, although our stationarity-constrained three-wave cross-lagged panel model clarifies temporal ordering and stabilizes estimates, a standard cross-lagged panel model still blends stable between-person differences with within-person changes; estimates should therefore be interpreted as descriptive rather than causal (Lucas, 2023). Moreover, while the stationarity constraints did not significantly worsen fit ($\Delta\chi^2 = 14.47$, $df = 10$, $p = .15$), this offers limited evidence for equality of effects given the modest sample and number of constraints. Future research should employ larger samples with at least four measurement occasions to implement a

random-intercept cross-lagged panel model that can not only effectively separate trait-like stability from within-person dynamics but also enable rigorous tests of time-invariance and precise cross-lag estimates (Lucas, 2023; Orth et al., 2021).

CONCLUSION AND IMPLICATIONS

The current study investigated the dynamic interplay between autonomous motivation, as proposed by SDT, and the social cognitive factors outlined in the TPB within the context of ACL rehabilitation, employing a three-wave longitudinal study design. The theoretical underpinnings aligning with the integrated model of SDT and the TPB (Hagger & Chatzisarantis, 2009) were substantiated by our findings. Empirically, utilizing a cross-lagged path model, we discovered that patients' autonomous motivation significantly predicted their future rehabilitation adherence over a four-month period. This underscores the crucial role of nurturing autonomous motivation among individuals undergoing ACL rehabilitation, particularly considering the extended duration of their rehabilitation journey. According to SDT (Deci & Ryan, 1985; Ryan & Deci, 2020), satisfying the three psychological needs, namely autonomy, competence and relatedness, is effective in fostering individuals' autonomous motivation (Lee et al., 2021; Lee, Yung, et al., 2020; Ryan & Deci, 2000). Strategies, such as providing choices in rehabilitation exercise to fulfil autonomy needs, enhancing patients' proficiency in exercise through demonstrations and encouragement to meet competence needs, and fostering a supportive environment through active listening and acceptance by significant others such as physiotherapists, may contribute to satisfying relatedness needs (Chan et al., 2009; Lee, Datu, et al., 2023; Lee, Yung, et al., 2023). The present research consolidates the theoretical framework of the integrated model of SDT and the TPB. Future research endeavours, including experimental interventions, can capitalize on the integrated model to promote various health behaviours, such as rehabilitation protocols, healthy eating habits and hygiene practices. Manipulating individuals' autonomous motivation by addressing their psychological needs presents a promising avenue for enhancing intervention effectiveness in promoting sustained health behaviour change.

AUTHOR CONTRIBUTIONS

Alfred S. Y. Lee: Conceptualization; investigation; methodology; validation; visualization; writing – original draft; software; formal analysis; data curation. **Roni M. Y. Chiu:** Conceptualization; investigation; writing – original draft; methodology; validation; writing – review and editing; visualization; data curation. **Patrick S. H. Yung:** Funding acquisition; conceptualization; investigation; visualization; supervision; resources; project administration; writing – review and editing. **Michael T. Y. Ong:** Conceptualization; investigation; funding acquisition; supervision; resources; project administration; visualization; writing – review and editing. **Derwin K. C. Chan:** Conceptualization; investigation; funding acquisition; writing – original draft; writing – review and editing; visualization; validation; methodology; software; project administration; data curation; supervision; resources; formal analysis.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

CONSENT TO PARTICIPATE

Informed consent was obtained from all participants involved in this study.

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