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Author

Hagger, Martin S, Chatzisarantis, Nikos LD

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An Integrated Behavior-Change Model for Physical Activity

Martin S. Hagger¹ & Nikos L. D. Chatzisarantis¹

¹Health Psychology and Behavioral Medicine Research Group, School of Psychology and Speech Pathology, Faculty of Health Sciences, Curtin University, Perth, Australia.

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Correspondence concerning this article should be addressed to Martin S. Hagger, Health Psychology and Behavioral Medicine Research Group, School of Psychology and Speech Pathology, Faculty of Health Sciences, Curtin University, GPO Box U1987, Perth 6845, WA, Australia. email: martin.hagger@curtin.edu.au, tel +61 8 92662215

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1 **ABSTRACT**

2 We present the Integrated Behavior-Change Model; a comprehensive multi-theory model
3 outlining the psychological factors and processes that impact physical activity behavior. The
4 model integrates hypotheses from social-cognitive, motivational, dual-phase, and dual-systems
5 theories. We provide the theoretical basis for the model and demonstrate its utility in driving
6 future research and developing effective interventions to promote physical activity.

7

8 **SUMMARY FOR TABLE OF CONTENTS**

9 The Integrated Behavior-Change Model is a comprehensive multi-theory model that
10 outlines the psychological factors and processes that determine physical activity.

11 **Key Words:** social-cognitive theory; self-determination theory; autonomous motivation; action
12 planning; implicit processes; dual-systems theories; behavior-change intervention

13

1 INTRODUCTION

2 Research examining the psychological influences on health-related physical activity
3 behavior has typically adopted a single theoretical approach from an array theories and models
4 developed in the field of social psychology (13). The purpose of adopting any theory or model
5 is to effectively and parsimoniously identify the important psychological factors associated
6 with physical activity behavior and the processes by which these factors affect physical activity
7 (14,30). Although many psychological theories applied in physical activity contexts have been
8 shown to be effective in predicting behavior, numerous limitations have been cited including
9 problems with falsifiability (17), weak relations between key constructs, such as the
10 relationship between intention and behavior (33), and identifying the origins of constructs in
11 the theories (13). These limitations have catalyzed the development of integrated models that
12 draw from a number of different theories that directly address these limitations and aim to
13 arrive at more effective explanations of the psychological influences on physical activity
14 (13,18).

15 In the present review, we seek to synthesize our recent theoretical and empirical work on
16 the development of integrated theories of health behavior, and draw further on recent and past
17 social psychological theories, to derive an Integrated Behavior-Change (IBC) model that
18 incorporates the very latest thinking on the psychological influences on behavior change and
19 apply it to physical activity behavior. Our review will begin with outlining social-cognitive and
20 motivational theories that conceptualize behavior as a function of deliberative, conscious
21 processes. Many theories and models applied to physical activity behavior subscribe to this
22 approach and have intention or motivation as the focal construct. The integration of these
23 models will provide the starting point for our IBC model. Our integration capitalizes on the
24 flexibility outlined by Ajzen (1) and others that motivational theories are “open to the inclusion
25 of additional predictors if it can be shown that they capture a significant proportion of the
26 variance in intention or behavior after the theory’s current variables have been taken into

1 account” (p. 199). We would go a step further in our current analysis and propose that
2 additional components integrated into a model should either predict a key dependent variable
3 in the nomological network of relations between variables or serve an explanatory purpose of
4 process or mechanism. Following this principle, we will outline the conceptual basis for
5 incorporating a volitional phase into the integrated model to more effectively account for the
6 process by which intentions are converted into behavior. Volitional processes such as planning
7 have received considerable attention in recent dual-process models of behavior which
8 recognize that motivation may be a necessary but insufficient condition for action. The final
9 link in our model will be to incorporate non-conscious, implicit processes linked to behavioral
10 engagement. We propose that the heavy focus on deliberative, planned action in previous
11 models of physical activity behavior needs revision given the proliferation of evidence
12 demonstrating that behavior is frequently guided by impulsive, automatic factors that operate at
13 an implicit level beyond the conscious awareness of individuals. We draw from dual-systems
14 theories and research on implicit processes to incorporate an impulsive route to behavioral
15 engagement that operates in parallel with the more conscious, deliberative pathways posited in
16 intentional models.

17 In developing the IBC model, we will make reference to a diagrammatic representation of
18 its propositions and hypotheses (Figure 1) and identify the key empirical and theoretical work
19 that supports the proposed effects from our own and others’ research groups (Appendix A,
20 SDC 1, supportive evidence for key effects in integrated behavior change model). Most
21 importantly, we will also outline how the model will serve as a basis of future research on the
22 factors and processes that underpin physical activity behavior and, importantly, inform the
23 design of efficacious interventions that will promote increased physical activity participation.

24 **INTENTIONAL AND MOTIVATIONAL PROCESSES**

25 The majority of theories and models that have been applied to understand physical
26 activity behavior have adopted an information processing or social-cognitive approach. Social-

1 cognitive models assume that physical activity is an intentional behavior and individuals
2 engage in active deliberation of the attributes of the behavior and their beliefs stored in
3 memory regarding its potential value prior to forming an intention to engage in the behavior
4 (2,3). The role of intention, a motivational construct that reflects the extent to which
5 participants will invest effort to pursue an action, is ubiquitous among the theories based on the
6 assumption that intention is the most proximal predictor of behavior. Intention, for example, is
7 a key construct in a number of leading theories of behavior including protection motivation
8 theory and social cognitive theory (3). Most prominent of these theories, however, is the theory
9 of planned behavior (1), which identifies intention as the key mediator of the effects of
10 individuals' personal, social, and control-related beliefs regarding the behavior on actual
11 behavioral engagement. According to the theory, intentions are a function of individuals'
12 beliefs that the behavior will lead to desired outcomes (attitudes), will be consistent with the
13 desires of significant others (subjective norms), and can be enacted through sufficient personal
14 resources and little hindrance from barriers (perceived behavioral control). In fact, the theory is
15 an integration of the theory of reasoned action, which makes the distinction between personal
16 and social antecedents of intention in the attitude and subjective norm constructs, and elements
17 from Bandura's (4) social cognitive theory, with perceived behavioral control closely aligned
18 with self-efficacy. The theory is one of the most frequently applied and tested in health
19 behavior research and numerous meta-analyses have supported its predictive efficacy in health
20 domains (26), particularly physical activity (20). The theory of planned behavior forms the
21 starting point of the proposed IBC model, such that intentions form the most proximal
22 predictor of behavior and mediates the effects of attitudes, subjective norms, and perceived
23 behavioral control on behavior (see Figure 1 and Appendix A, effects 1-4). Meta-analytic
24 reviews of the large number of studies adopting the theory have demonstrated the important
25 contribution it has made to the prediction of health behaviors like physical activity (20,26).

1 A noted limitation of the theory of planned behavior is that the theory is relatively silent
2 on the origins and drivers of the belief-based antecedents of physical activity intentions
3 (9,18,19). In his original theorizing, Ajzen (1) noted that attitudes, subjective norms, and
4 perceived behavioral control were developed over time through experiences with behaviors, or
5 similar actions, that provided scripts or schema regarding the behavior and served as a basis for
6 evaluating whether or not to engage in the behavior, or similar behaviors, on future occasions.
7 A recent line of research has integrated hypotheses from another leading motivational theory,
8 self-determination theory (9,10), as a means to provide a basis for the antecedent beliefs in the
9 theory of planned behavior (18,20). Specifically, motivational orientations from self-
10 determination theory are proposed to lead to individuals forming the belief-based components
11 on the theory of planned behavior, namely, attitudes, subjective norms, and perceived
12 behavioral control consistent with these motives (see Figure 1 and Appendix A, effects 6-8).

13 Self-determination theory is a needs-based, organismic theory of motivation that makes
14 the broad distinction between autonomous and controlled forms of motivation. Individuals who
15 are autonomously motivated with respect to a particular behavior experience a sense of
16 personal choice and autonomy when acting and feel that their actions represent their true self.
17 Autonomously-motivated individuals are also more likely to persist with the behavior without
18 any external reinforcement or contingency. Individuals experiencing their behavior as control
19 motivated, on the other hand, act out of a sense of external pressure and obligation. Control-
20 motivated individuals engage in the behavior only as long as the controlling contingencies are
21 present, and once removed behavior will desist. From a physical activity perspective,
22 autonomous motivation is adaptive because it means participants are more likely to persist with
23 behaviors without any external incentive or reinforcement. This means that fostering
24 autonomous motivation toward physical activity may be an important endeavour in health
25 promotion interventions that aim to increase population activity levels.

1 The proposed links between autonomous motivation and the belief-based antecedents of
2 intentions in the theory of planned behavior in our integrated model are wholly consistent with
3 the original conceptualization of self-determination theory (9). Deci and Ryan proposed that
4 autonomous motivation toward a given behavior or activity will lead to approach-oriented
5 beliefs toward performing the behavior and intentions to engage in the behavior in future.
6 Although the specific processes linking autonomous motivation with beliefs regarding action
7 were proposed in the original conceptualization of the theory, no formal hypotheses were
8 outlined. The integration of hypotheses from both theories addresses this gap by adopting
9 constructs representing the behavioral, normative, and control-related beliefs from the theory
10 of planned behavior in an integrated motivational model.

11 In terms of the mechanisms underpinning these proposed effects, autonomous motivation
12 reflects the extent to which individuals perceive a behavior, like physical activity, fulfils basic
13 psychological needs, particularly the need for autonomy. The presence of psychological needs
14 is an important unifying premise within self-determination theory. The theory proposes that
15 people need to feel as if they are the origin of their own behavior, that is, to be autonomous,
16 and actively seek out behaviors that satisfy this need for autonomy (10). An individual who is
17 autonomously motivated toward physical activity will, therefore, will be motivated to fulfil this
18 need in the future by bringing their systems of beliefs that underpin intentions in line with
19 those motives and forming intentions to pursue the physical activity in the future. We focus on
20 autonomous motivation in the IBC model for three reasons: (a) autonomous motivation is a key
21 determinant of adaptive behavioural outcomes, while controlled forms of motivation have been
22 shown to have a relatively limited role; (b) differentiation between the various forms of
23 autonomous motivation is relatively superfluous as many of these forms of regulation share
24 considerable variance (19) and are promoted through autonomy-support techniques rendering

1 fine-grained distinction redundant; and (c) a single autonomous motivation construct
2 maximizes model parsimony.

3 Our research has suggested that that individuals can and do make the distinction between
4 beliefs that are autonomous and controlled in nature (28,29), and those beliefs significantly
5 predict behavior (29). The addition of autonomous motivation from self-determination theory,
6 therefore, provides a basis for the origin of the psychological antecedents of future behavior.
7 Furthermore, the inclusion of the theory of planned behavior also has a reciprocal explanatory
8 role in self-determination theory. It provides an explanation as to how autonomous motivation
9 is implicated in the decision-making processes and converted into future action. This is
10 consistent with the complementarity goal of theoretical integration (13).

11 A key hypothesis of the IBC model is that the belief-based constructs from the theory of
12 planned behavior and intentions will mediate the effects of autonomous motivation from self-
13 determination theory on actual physical activity behavior. Our research has provided support
14 for the proposed mediation relationships in numerous behavioral domains, including physical
15 activity (19,21). In addition, a meta-analytic path analysis of 34 the studies that have integrated
16 the theory of planned behavior and self-determination theory since our initial tests has provided
17 support for the proposed pattern of effects and established that the effects remain after
18 controlling for past behavior (18). The effect of autonomous motivation as a distal predictor of
19 intentions mediated by the belief-based constructs from the theory of planned behavior, forms
20 the ‘motivational sequence’ at the core of our proposed model.

21 **VOLITIONAL PROCESSES AND DUAL-PHASE MODELS**

22 A prominent critique of the theory of planned behavior is the consistently imperfect link
23 between intentions and actual behavioral engagement (33) and the relatively poor performance
24 of interventions aimed at changing intentions in affecting a concomitant change in behavior
25 (35). This means that while many people may have positive intentions to engage in physical

1 activity in the future, they fail to carry out or enact their intentions. This shortfall in the link
2 between intentions and action has been labelled the intention-behavior ‘gap’. Researchers have
3 indicated that a substantial number of participants report positive intentions toward health
4 behavior but fail to act (31,33). This has presented researchers with a considerable challenge:
5 how to foster a more effective enactment of intentions among the substantial proportion of
6 ‘inclined abstainers’?

7 One approach has been to integrate the theory with dual-phase models of action which
8 propose an additional ‘volitional’ phase between the formation of an intention to act and actual
9 behavioral enactment. Heckhausen and Gollwitzer (23) recognized that having an intention was
10 frequently insufficient for behavioral engagement because people either forgot to carry out
11 their intention or failed to identify and recall cues to initiate the intention. In their action-
12 control model, they proposed a volitional phase in which individuals formed a plan to act after
13 they had settled upon an intended course of action. The plan comprised the identification of a
14 cue in the environment that would be linked to the initiation of the behavior (e.g., “If my alarm
15 clock chimes at 12 noon, I will collect my gym bag and go for a workout at my local fitness
16 center”). According to the model, the plan would stimulate the efficient recall and enactment of
17 the intention and was referred to as an action plan or ‘implementation intention’. As action
18 plans are formed after the formation of intentions, they act in a post-decisional manner in a
19 separate ‘volitional’ phase. Action plans have been shown in laboratory and field experiments
20 to promote effective behavioral enactment, and, therefore a stronger intention-behavior
21 relationship, by facilitating efficient recall of the intention (22). The volitional phase and action
22 planning construct has been the subject of a considerable body of research and meta-analyses
23 in numerous behavioral domains (12), including physical activity (5), have demonstrated that
24 furnishing intentions with action plans is effective in promoting better behavioral enactment.
25 Following this evidence, we propose a volitional ‘phase’ to our model with action planning

1 forming an important moderator of intention-behavior relationship to account for the
2 insufficiency of intentions (see Figure 1 and Appendix A, effect 5).

3 **IMPLICIT PROCESSES AND DUAL-SYSTEMS THEORY**

4 The development of our integrated model so far has focused on factors and processes that
5 require cognitive processing and deliberation prior to forming an intention to engage in
6 physical activity. This is consistent with the premise from social-cognitive and motivational
7 theories, like the theory of planned behavior and self-determination theory, that physical
8 activity tends to be a behavior that requires forethought and planning to be enacted (2,10).
9 However, researchers are increasingly recognizing that health behavior, including physical
10 activity, is influenced by non-conscious, impulsive factors that have their effects on action
11 beyond the awareness of the individual (6,24,29). Such processes mean that individuals may
12 engage in physical activity spontaneously with little conscious involvement or protracted
13 deliberation. A typical example might be a student who is passing by some people in the park
14 playing a ball game and chooses to join in without prior planning or deliberation over the
15 merits or detriments of the decision, and without being aware of the factors that have driven his
16 behavior. Theoretically, there is recognition that many behaviors are likely to be enacted via
17 either a deliberative route, mediated by the intentional and motivational factors delineated in
18 our model thus far, or a spontaneous route which directly effects behavior unmediated by
19 intentions. It is also possible that behaviors may be controlled by both routes, with the relative
20 contribution of each determined by the characteristics of the behavior and the context in which
21 it is being conducted. In the IBC model, we propose to incorporate implicit constructs that
22 affect physical activity alongside the integrated components from social-cognitive and needs-
23 based theories in order to account for both routes.

24 We draw from dual-systems theories of motivation to build implicit processes into our
25 integrated model, particularly Strack and Deutch's (34) influential reflective-impulsive model.

1 Drawing from previously-developed attitude models that proposed dual routes to behavior, the
2 reflective-impulsive model recognizes that role that deliberative or *reflective* and spontaneous
3 or *impulsive* systems have on behavior, and proposed that behavior is a function of both
4 systems. The reflective route requires the utilization of stored knowledge about a behavior
5 (e.g., beliefs) and available social information to arrive at a decision to act. The impulsive
6 system affects behavior through the activation of behavioral or motivational schema, stored
7 ‘ways of behaving’ based on previous experience, usually through cues or elements in the
8 environment that trigger nodal information linked to the schema. Behaviors likely to be
9 determined by the impulsive system tend to be those that are relatively simple, have been
10 performed repeatedly in the past, conform to the features of ‘habitual action’, and for which
11 individuals tend to have well-learned or ingrained schema that is highly accessible to the
12 individual when cued. Behaviors determined by the impulsive system may be behaviors like
13 tooth-brushing and operating the pedals in an automobile. Behaviors largely controlled by the
14 reflective system include those that are more complex, have not been performed as frequently
15 in the past, and for which individuals do not have an elaborate or well-learned schema.

16 As assumed in many social-cognitive models, physical activity is likely a behavior that is
17 largely under the control of the reflective system given the number of considerations that one
18 needs to give in order to engage in physical activity. Generally speaking, physical activity,
19 particularly formal types of exercise that involve equipment, transport, venue, costs and other
20 considerations, require considerable planning. Nevertheless, there is evidence to suggest that
21 some forms of physical activity may be affected by implicit motivational factors beyond the
22 awareness of the individual. For example, research has shown that implicit attitudes toward
23 physical activity are significantly related to physical activity participation when controlling for
24 explicit attitudes measured by self-report (6).

25 The close link between implicit attitudes and habitual action has been proposed as a
26 mechanism underlying the effects of implicit attitudes on physical activity. According to Calitri

1 et al. (6), frequency of performance is likely to make the decision-making process that precedes
2 action less dependent on explicit deliberation. Instead, repeated experience will have resulted
3 in individuals' storing a strong mental representation or schema of the action in memory and
4 the presentation of cues that activate the schema will lead to efficient behavioral enactment by-
5 passing deliberative routes to action. This means that implicit attitudes toward physical activity
6 impact physical activity participation directly, independent of explicit attitudes and intentions.
7 Consistent with this research and dual-systems theories, we have incorporated implicit attitudes
8 into the IBC model as a direct effect on actual behavior (see Figure 1 and Appendix A, effect
9 9).

10 Recently, we have investigated the effects of implicit motives based on self-
11 determination theory and their effects on health behavior, including physical activity (24). We
12 proposed, based on previous research and propositions from the reflective-impulsive model,
13 that autonomous and controlled forms of motivation may operate at both explicit and implicit
14 levels. In particular, we subscribed to the proposals of Levesque and Pelletier (25) who found
15 that implicit forms of motivation from self-determination theory reflected more trait-like,
16 dispositional individual differences in generalized self-determined motivation, referred to as
17 chronic motivational orientations. We were interested whether these generalized motivational
18 orientations, which were not tied to a particular behavioral domain, predicted multiple health-
19 related behaviors including physical activity alongside more explicit measures of motivation
20 from self-determination theory. Results indicated that both implicit and explicit forms of
21 autonomous motivation had significant unique effects on physical activity behavior. Consistent
22 with dual-systems theory, the effect of explicit motivation on physical activity participation
23 was mediated by intentions while the effect of implicit motivation was direct and unmediated,
24 supporting the notion that this variable reflects spontaneous and impulsive influences on
25 physical activity behavior. Although the effect sizes of the implicit autonomous motivation
26 were relatively modest, it likely implies that for some individuals dispositional motivational

1 orientations affect their physical activity participation beyond their awareness and suggests
2 spontaneous engagement in activity in accordance with the impulsive route in dual systems
3 theories. Consistent with dual-systems theory and our preliminary evidence, we have included
4 an independent direct effect of implicit autonomous motivation from self-determination theory
5 on actual physical activity behavior parallel to the explicit motivational factors and implicit
6 attitudes (see Figure 1 and Appendix A, effect 10). This will provide a basis for testing the
7 extent to which physical activity behavior is controlled by explicit and implicit processes.

8 **ADVANCING THE INTEGRATED BEHAVIOR-CHANGE MODEL**

9 The purpose of the IBC model is to provide a comprehensive representation of the
10 important psychological processes that affect physical activity behavior. The model serves as a
11 guide for researchers in developing future studies on the antecedents of physical activity and
12 forms a template for practitioners in the development of effective interventions that will
13 promote health-related physical activity. It is unique as it draws its predictions and hypotheses
14 from multiple theories with different perspectives and integrates them into single model.
15 Furthermore, the model provides a means to identify the relative contribution of different
16 psychological constructs and proposed processes or pathways to physical activity behavior. It
17 also provides the basis for comparative research in which the effects of the model constructs
18 and processes on exercise behavior are contrasted across populations or contexts. In this
19 section we outline means by which the integrated model can be tested, avenues for future
20 research, and the practical value of the model as a guide for the development of interventions
21 to promote physical activity.

22 **Testing the Model**

23 The IBC model has been derived from hypotheses from multiple psychological theories
24 and, while there is evidence to support these hypotheses separately, there is a need for
25 empirical confirmation of the proposed pattern of effects in a full test of the model. The
26 majority of studies adopting the component theories of the model have adopted prospective,

1 correlational studies. In the tests, researchers tend to administer self-report measures of the key
2 psychological constructs to samples of participants and follow these up with self-report and,
3 preferably, objective measures of physical activity behavior at a subsequent point in time
4 (14,15). These studies are somewhat limited in the sense that they do not permit inferences of
5 causality, but enable researchers to ascertain the fit of the theoretically-determined network of
6 relationships among the proposed constructs with the data (17). This is the case with tests of
7 the component theories of the IBC model such as the theory of planned behavior (16), self-
8 determination theory (19), and dual-systems theory (24) conducted in our lab. Furthermore, we
9 have also provided comprehensive evidence to support one of the key integrated components
10 of the proposed model, the links between autonomous motivation from self-determination
11 theory and constructs from the theory of planned behavior, in a meta-analysis of research
12 incorporating both theories, the majority in physical activity contexts (18). There is, therefore,
13 evidence drawn from our own studies to support some of the hypotheses proposed in the
14 integrated model and we have used this evidence alongside our theoretical proposals to aid its
15 construction.

16 There is a need, of course, for comprehensive tests of the model in its entirety to
17 provide complete support for the proposed network of relations derived from the multiple
18 theories and models, known as nomological validity. Such tests need to adopt appropriate
19 measures and designs, including psychometrically-sound self-report measures advocated by
20 researchers for the component psychological and behavioral constructs, with appropriate
21 statistical power to test the effects, and the adoption of optimal statistical analytic methods
22 such as path or latent-variable analysis. In tests of the model, data collected from an
23 appropriate sample should fit with a model of the hypothesized effects specified a priori.
24 Action planning, as a proposed moderator of the intention-behavior relationship, should be
25 tested using interaction effects within the model. It is also important that there are multiple
26 high-powered replications of the model in diverse samples. This will provide more robust

1 evidence for the proposed relationships in the model and also enable researchers to test whether
2 the hypothesized effects generalize to multiple populations such as younger and older samples,
3 males and females, and clinical and non-clinical groups (e.g., patients vs. non-patients, obese
4 vs. normal weight). Given the central role that replication plays in building evidence for effects
5 in psychology, and science in general, such multiple tests are sorely needed.

6 While we acknowledge the likelihood that the majority of future tests of the IBC model
7 will be prospective and correlational in design, we recognize the need for experimental and
8 intervention research designs to better enable the inference of causality and provide robust
9 evidence for the model. Specifically, studies that independently manipulate the key
10 psychological constructs antecedent to physical activity in the model and examine their effects
11 on psychological and behavioral outcomes are needed. This would provide much more
12 effective evidence to support the hypothesized pattern of effects of the model. While
13 correlational tests of the model can be relatively comprehensive, it is methodologically
14 challenging to include manipulations of constructs in a model that proposes a complex network
15 of relations among multiple constructs. We therefore recognize that experimental and
16 intervention studies adopting the model will be of hybrid design examining the effects of
17 experimentally-manipulated psychological variables alongside other non-manipulated variables
18 (7,8). A good example of this type of design comes from an intervention study in which we
19 manipulated school children's autonomous motivation toward physical activity by providing
20 autonomy support and examined its effects on salient mediators (autonomous motivation,
21 intentions) and physical activity behavior (8). A combination of experimentally-manipulated
22 variables, represented as dummy-coded predictor variables, and non-manipulated self-reported
23 variables was used to test a network of relationships in a path analytic model. Finally, the effect
24 of action planning as a proposed moderator of the intention-behavior relationship within our
25 integrated model would be most effectively tested using experimental manipulation and

1 analyzing the effect of the interaction between the manipulation and intentions on physical
2 activity.

3 **Guiding Intervention Design**

4 An important role for psychological models applied to predict physical activity
5 behavior, including the integrated model, is their role in guiding the design of interventions to
6 promote physical activity participation. One of our key intentions in developing the integrated
7 model is that it will not only facilitate the identification of the psychological variables linked to
8 physical activity but to also pinpoint the factors that should be the targets for intervention. A
9 recent advance in psychological theory-based approaches to behavior-change interventions has
10 been the development of taxonomies of unique behavior-change techniques that have been
11 shown empirically to impact on behavior through the mediation of the theoretical construct the
12 technique is purported to change (30). The techniques can then be used as content for
13 interventions to promote health related behavior, such as physical activity, delivered by various
14 means such as print communication (e.g., leaflets, websites), media campaigns (e.g., posters,
15 radio advertisements), and personal communication (e.g., primary-care workers). Our
16 integrated model is expected to be able to provide a comprehensive, evidence-based guide for
17 interventions by identifying the key factors that impact on physical activity in a given
18 population.

19 Each of the antecedent constructs comprising the integrated model has an associated
20 behavior-change technique. Autonomy support is a behavior-change technique that specifically
21 targets changes in autonomous motivation and involves the provision of choice, rationale,
22 acknowledgement of conflict, and support for personally-valued outcomes (27). Attitudes,
23 subjective norms, and perceived behavioral control can be promoted through communicating
24 information targeting the salient beliefs associated with each construct for the given
25 population. For attitudes, the communication will involve promoting the salient advantages of
26 exercise and dispelling disadvantages, for subjective norms it will involve highlighting the

1 importance of salient others' beliefs, and for perceived behavioral control it will involve the
2 promotion of facilitating factors and dispelling barriers (7). Action planning can be promoted
3 by prompting the formation of an 'if-then' plan in which the individual identifies an event or
4 critical situation salient for them and link it with a physical activity initiation behavior (12,22).
5 In order to make an evidence-based decision as to which of these techniques will be optimally
6 effective in changing physical activity behavior in an intervention, formative correlational
7 research identifying the constructs that are most effective in predicting physical activity is
8 needed. This will lead intervention designers' to make appropriate decisions as to the
9 techniques to include in their intervention content.

10 There is also a need for appropriately-designed intervention research in which the
11 identified techniques are independently manipulated using factorial designs and their effects on
12 physical activity behavior and proposed mediators examined in the model. For example an
13 intervention that includes independent manipulations of autonomous motivation, using
14 autonomy support, and constructs from the theory of planned behaviour, using communications
15 to change beliefs, would be appropriate. Results would be expected to demonstrate that the
16 autonomy support manipulation would only affect distal variables such as intention and
17 behavior in the model through autonomous motivation while the effects of manipulation of
18 attitudes or perceived behavioral control would be exclusively through these constructs (8).

19 It must be noted that means to change implicit factors has been somewhat more
20 contentious than means to change explicit variables in the integrated model. By their nature,
21 implicitly held beliefs should be immune to change or variation from information processed
22 explicitly, which is the case for the majority, if not all, of the behavior-change techniques
23 catalogued in recent taxonomies. Means to change implicit factors may occur through priming,
24 that is, the activation of the implicitly-held information relating to the construct by presenting
25 cue information that is processed implicitly or without conscious awareness of the individual.
26 Priming manipulations have been typically carried out in the laboratory using computer-based

1 or pen-and-paper tasks in which information related to the primed construct, such as pictures or
2 words, is presented to the individual incidental to the task (e.g., word-search tasks). In practical
3 situations, such information may be presented through posters or advertisements that do not
4 have explicit content but seek to prime a positive activity attitude or motive. There is some
5 research indicating that placing posters encouraging stair use in atria and foyers of public
6 places increases stair use, and, although the authors have provided an explanation based on
7 explicit processes for the effect (11), they have not ruled out the possibility that such posters
8 may exert their effects by priming implicit physical activity attitudes or motives similar to
9 laboratory-based association tasks. This is a new and exciting avenue of research and
10 investigating the role of manipulating implicit attitudes and motives in the context of the
11 integrated model may provide an indication as to how implicit behavior-change techniques,
12 such as messages with content aimed at implicit constructs, may promote physical activity
13 participation alongside more explicit behavior-change techniques.

14 **SUMMARY**

15 In this review we have presented the IBC model; a comprehensive model drawing from
16 multiple theoretical perspectives aimed at examining the psychological factors and processes
17 involved in physical activity participation. The model is unique in that it attempts to bring
18 together perspectives from intentional and motivational, volitional, and dual-systems theories
19 into a unified model that not only identifies the multiple unique psychological factors linked to
20 physical activity behavior, but the mechanisms involved. It also guides the development of
21 interventions to promote physical activity behavior by identifying the variables and, by
22 implication, the behavior-change techniques that will be optimally effective in changing
23 physical activity behavior. Our model begins with the premise that physical activity is a
24 behavior that is largely driven by intentions, and a leading theory of intention, the theory of
25 planned behavior (1), provides the core set of hypotheses about which we have constructed our
26 model. We incorporated an organismic, needs-based theory of motivation, self-determination

1 theory (9), as a means to explain the origins of the direct belief-based behavioral antecedents in
2 the theory of planned behavior. This is presented in the IBC model as a motivational sequence
3 in which motives from self-determination theory predict physical activity intentions mediated
4 by the belief based antecedents from the theory of planned behavior. We also incorporated
5 hypotheses from Heckhausen and Gollwitzer's (23) dual-phase model to introduce a volitional
6 phase, separate from the intentional phase, in which action planning is key construct in
7 promoting effective and efficient conversion of intentions into behavior. Finally, we have
8 incorporated hypotheses from dual-systems theories (34) to account for implicit processes on
9 physical activity behavior. This is in recognition that behavior is impacted by factors that
10 operate outside individuals' awareness and based on evidence that implicit processes have
11 statistically significant effects on physical activity behavior (6,24).

12 In the construction of our model we have outlined the theoretical basis for the integration
13 of its component hypotheses supported by evidence from our own work and that of others. We
14 look to future research to develop complete tests of the theory using prospective non-
15 experimental correlational designs. We expect such tests to include appropriate measures,
16 design, samples, and analyses, and we anticipate that multiple replications by different research
17 teams and in multiple populations will assist in supporting the nomological validity of the IBC
18 model. Multiple replications in independent samples using non-experimental designs may form
19 the starting point for future experimental and intervention research, which is also needed to
20 build strong converging evidence for the propositions of the integrated model. We do not
21 expect experimental tests to comprehensively manipulate all of the variables in the proposed
22 model. The required number of experimental cells, and, therefore, sample size, would render
23 such an endeavour impractical (32). We do, however, recognize the need for effective
24 experimental evidence for the proposed effects in the model that is factorial in design including
25 manipulations that target key individual constructs in the model, likely those with the strongest
26 effects identified in non-experimental research, with appropriate control or comparison groups

1 for each. Experimental tests should therefore seek to test the differential effects of
2 manipulations of multiple constructs in the model. Intervention research should also adopt
3 similar designs in field settings. Furthermore, interventions based on the model should involve
4 the careful mapping of behavior-change techniques identified in taxonomies on to the
5 integrated model constructs in order to arrive at appropriate content.

6 The IBC model represents our attempt to bring together leading theories, and
7 accompanying evidence, in order to arrive at a comprehensive perspective on the psychological
8 processes involved in physical activity behavior. We recognize that although our model needs
9 to stand up to the rigor of empirical testing, we also acknowledge the need to be fluid and
10 flexible and open to new information and evidence that may assist in its modification and
11 refinement. We encourage researchers to test and challenge our new model and continue the
12 process of theory development to further understanding of the factors and mechanisms that
13 impact physical activity behavior.

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SUPPLEMENTAL DIGITAL CONTENT (SDC1)

Appendix_A.pdf

Figure caption

Figure 1. Schematic diagram of the Integrated Behavior-Change (IBC) Model for physical activity. The model depicts deliberative (reflective) and spontaneous (impulsive) pathways for the effects of motivational and psychological constructs from multiple theories on physical activity participation. The deliberative pathway comprises the distal effects of autonomous motivation from self-determination on physical activity mediated by constructs from the theory of planned behaviour (attitudes, subjective norms, perceived behavioral control, intention). The spontaneous pathway involves the effects of implicit attitudes and motivation on physical activity. The intention-behavior relationship is proposed to be moderated by action planning, depicted as a broken line directed at the path between intention and behavior. Broken lines between constructs indicate direct effects proposed to be non-significant or unsubstantive relative to the indirect effects. Other non-significant direct effects include the effects of attitude, subjective norms, and perceived behavioral control on behavior. Numerals reflect the hypothesized paths in the model.

