Determinants of weekly sitting time: Construct validation of an initial COM-B model and comparison of its predictive validity with the Theory of Planned Behaviour

Running head: Determinants of weekly sitting time

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Abstract

Objective: In relation to sitting behaviour, to investigate which theoretical domains best formed the Capability, Opportunity, and Motivation constructs of the COM-B, and compare the predictive validity to the Theory of Planned Behaviour (TPB), taking habit strength into consideration.

Design: Using a prospective design, 186 adults completed measures capturing domains from the Theoretical Domains Framework for the three COM-B constructs, and habit strength, which were examined using a formative measurement model. Predictive validity was then compared to the TPB.

Main Outcome Measures: Self-reported sitting behaviour.

Results: Self-monitoring (behavioural regulation domain) formed Capability; subjective norm (social influences domain) formed Opportunity; intention (intentions domain), positive affect (emotion domain), and perceived behavioural control (beliefs about capabilities domain), formed Motivation. The COM-B strongly predicted sitting behaviour (27% variance explained), with Capability, Opportunity, and habit strength as key drivers. The TPB explained a large amount of variance (23%) in sitting behaviour, with intention and habit strength as key drivers.

Conclusions: The behavioural regulation domain of Capability, the social influences domain of Opportunity, and habit strength were important drivers of sitting behaviour, with comparable variance predicted in the COM-B and TPB. Future research should consider this approach to conceptualise the COM-B for specific populations and behaviours.

Keywords: COM-B; Theory of Planned Behaviour: sitting; sedentary behaviour; Theoretical Domains Framework; habit

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Sedentary behaviour is defined as any activity (during waking hours) that expends less than or equal to 1.5 METS and must occur in a seated or reclined position (Tremblay et al., 2017). In England, adults report spending on average 4.8 hours per weekday being sedentary and 5.3 hours during weekend days (Health and Social Care Information Centre, 2014). Objective measurements suggest this may well be an underestimation, with cohort studies showing an average of 10.3 hours per day in adults (Henson et al., 2013), and between 10.5 (Chastin et al., 2018) and 11.4 hours in older adults (Hajna et al., 2018), all in the UK. Daily sitting time is linked to all-cause mortality (Chau et al., 2013) and risk of mortality through cardiovascular disease (Katzmarzyk, Church, Craig, & Bouchard, 2009), after adjusting for physical activity. Breaking up sitting time and engaging in light activity instead of prolonged sitting could also have important health benefits (Bailey, 2017; Brierley, Chater, Smith, & Bailey, 2019). There is a clear need for intervention, but very few target sedentary behaviour in healthy but inactive adults (Howlett, Trivedi, Troop, & Chater, 2018), and theory use in behaviour change interventions is often inconsistent and poorly described (e.g. Prestwich et al., 2014).

Michie et al. (2017) suggests that interventions should be theory-based and not just theory-inspired. The Health Action Process Approach (HAPA; Schwarzer, 1992) predicts 14% of the variance in objectively-measured sedentary behaviour, but only after the addition of

habit as a predictor of intentions and behaviour (Maher & Conroy, 2016). The Theory of Planned Behaviour (TPB; Ajzen, 1985), measuring the core constructs of attitude, subjective norm, perceived behavioural control, and intention, can provide stronger explanatory power, with the variance explained ranging from 25% (for student's reading/music and computer use) to 60% (for community adult's computer use; Rhodes & Dean, 2009). The TPB may also be better at predicting less volitional (at-work) sedentary behaviour (workday, 43% vs leisure-time, 8%; Prapavessis, Gaston, & DeJesus, 2015). Habit strength (Webb & Sheeran, 2006) and past behaviour (Hagger, Chatzisarantis, & Biddle, 2002) attenuate the intention-behaviour relationship across a range of health behaviours. While the TPB has been successful at explaining some of the variance in sitting behaviour, it omits several potential determinants such as physical ability and environmental context and resources.

Additional physical, psychological, and socio-demographic variables have also been investigated in relation to sedentary behaviour. In Canadian older adults, sitting for over four hours per day is associated with age, retirement, dwelling type, chronic disease, perceptions of health, body mass index (BMI), mood disorder, and sense of belonging to a community (Dogra & Stathokostas, 2014). Van Holle et al. (2015) included an even wider variety of possible determinants and found that only social support from friends and colleagues (and not family) that discouraged sitting was negatively related to total weekend sitting. Further systematic review evidence showed overall sedentary behaviour to be related to positive attitudes towards the behaviour, higher levels of depression, and lower life satisfaction (Rhodes, Mark, & Temmel, 2012). This review concluded that more research was needed on the social, cognitive, and environmental factors that may be important in designing sedentary behaviour interventions (Rhodes et al., 2012). For instance, habits have

been shown to be a strong predictor of sedentary behaviour, alongside temporal fluctuations in intentions (Conroy, Maher, Elavsky, Hyde, & Doerksen, 2013).

The collective body of research on sedentary behaviour has often not utilised models based within a systematic approach to designing behaviour change interventions. The COM-B system, within the Behaviour Change Wheel (Michie, van Stralen, & West, 2011), provides this basis from which to explore and change specific behaviours in targeted populations. The COM-B postulates that the motivation to perform (or not) a behaviour must be stronger than the motivation to carry on as before or engage in a competing behaviour. Motivation can be reflective (e.g. intending to change a behaviour) and/or automatic (e.g. the behaviour being part of one's identity) and is influenced by an individual's Capability and Opportunity specific to that behaviour (Michie et al., 2011). Capability can be psychological (e.g. knowledge of the behaviour) and/or physical (e.g. having the skills to perform the behaviour). Opportunity can be social (e.g. having support for the behaviour from friends or family) and/or physical (e.g. living in an environment conducive to the behaviour).

The COM-B plays a crucial role in determining what influences health behaviour, known as a behavioural diagnosis, and was developed around the same time as the second iteration of the Theoretical Domains Framework (TDF; Cane, O'Connor, & Michie, 2012). This TDF has been mapped on to the COM-B and provides further detail on the behavioural determinants that might encompass Capability, Opportunity, and Motivation (Cane et al., 2012). Cane et al's (2012) comprehensive discriminant content validation is the only peer-reviewed framework that provides a detailed breakdown of the potential contents of each TDF domain (and broader COM constructs). Because there are so many potential indicators researchers have to decide which domains (and associated indicators) are most likely to be

related to the behaviour, based on the literature and the availability of relevant published measures.

Using the COM-B as a guiding framework, this paper makes a contribution to the theoretical groundwork, for the development of an intervention model to reduce sitting behaviour by identifying important indicators for defining the core constructs. Previous research on physical activity has shown that a formative measurement approach, using domains from the TDF, can be utilised to test the construct and predictive validity of the COM-B (Howlett, Schulz, Trivedi, Troop, & Chater, 2017). Capability (represented by the behavioural regulation domain) and Motivation (represented by the social/professional role and identity, beliefs about capabilities, and intentions domains) were the key drivers of moderate to vigorous physical activity (MVPA; Howlett et al., 2017). Opportunity was also measured but only had a small indirect effect on MVPA through Motivation.

The current study first explores the construct validity of the COM-B for sitting behaviour. The three main constructs (Capability, Opportunity, and Motivation) of the COM-B are broad in nature and it has been previously theorised that the exact content of each may vary depending on the population and target behaviour (Howlett et al., 2017). Therefore, it is likely that for sitting behaviour the COM-B constructs may be comprised of different indicators more relevant for the performance and context of sitting than for, say, physical activity. The present study uses a detailed breakdown of each construct to pick the most suitable indicators for sitting. This study then compares the predictive validity of the COM-B against the TPB for weekly sitting time. The frequent use of the TPB in cross-sectional and prospective studies examining sitting makes it an ideal model to compare with the COM-B.

According to Fishbein and Ajzen (2010) and Ajzen (2002, 2011) past behaviour enables probing into the sufficiency of the TPB variables in explaining a specific behaviour merely through intention and perceived behavioural control. This is done by evaluating whether past behaviour can account for additional variance in intention and behaviour beyond that of the antecedent variables of the TPB. They also point out that past behaviour can only be regarded as a proxy measure of habit strength as it impinges on current behaviour as a result of temporal stability rendering statistical results difficult to interpret (e.g. separating true habituation from semi-automatic processes). Ajzen (2002) explains in detail, why rather than using past behaviour a better measure to use would be habit strength as it enables exploration of the extent with which the target behaviour is under the control of environmental cues (and not cognitive control). To test the sufficiency of both models and because of the role that habit and past behaviour play in weakening the intention-behaviour relationship, a measure of habit strength was included as a control in both models. The four main aims of this study were:

1. To explore which measures representing TDF domains would be important formative indicators of the three constructs, Capability, Opportunity, and Motivation of the COM-B in a sample of adult participants;
2. To examine the predictive validity of these constructs in relation to sitting time over a one-week period taking habit strength into consideration;
3. To evaluate Motivation as a mediator for Capability and Opportunity with respect to weekly sitting time;
4. To compare the predictive validity of the COM-B model and the TPB, controlling for habit, in relation to levels of sitting over a one-week period.

Method

Participants

This study used a prospective survey design using questionnaires representing TDF domains, completed at baseline, and self-reported sitting collected seven days later. Participants were eligible if they were over 18 years, resided in the UK, and were physically able to perform physical activity. Data were collected between November 2014 and April 2015 using opportunistic sampling. In total 214 participants completed an online survey, but 11 were excluded (one was under 18, 10 were not residents of the UK) and 17 did not respond to contact requests for a follow-up phone call. The final sample size was 186, and average age and BMI were 38 years old and 24.58kg/m^2 respectively. Full demographic information is included in Table 2. A sensitivity analysis was conducted retrospectively to ensure that the sample size (N = 186) provided sufficient statistical power for the PLS-SEM analysis. Following recent recommendations (Kock & Hadaya, 2018) the sample size was large enough to detect a path coefficient of β = .18 with a power of .80 and an alpha error of 5% calculated by using their Inverse Square Roots method (formula 5).

Measures

Measures were selected based on published components mapped onto TDF domains listed within Table 2 of Cane et al. (2012). Domains were selected for components relevant for sitting behaviour and where representative published questionnaires could be identified. There were also components of TDF domains that were deemed unnecessary to measure. For example, for the knowledge domain there were no clear government guidelines for sitting at the time and, therefore, this could not be measured. Three measures were identified as defining the Capability construct, six for Motivation and four for Opportunity

(see Table 2 for descriptive statistics). The wording of several measures (highlighted in Table 1) was adapted from the original physical activity questionnaires to be relevant for weekly sitting time. The following measures were used as formative indicators for Capability, Opportunity, and Motivation.

Insert Table 1 about here

Capability construct (3 measures)

Physical ability was measured with the 10-item physical functioning scale of the Medical Outcomes Short Form Survey (Ware & Sherbourne, 1992). The items were activities one might do during a typical day (e.g. climbing several flights of stairs). Participants were then asked about how much their health limits them in these activities and, if so, how much on a scale from 1 '*Yes, limited a lot*' to 3 '*No, not limited at all*'.

Ability to self-monitor was measured by two adapted items which asked participants to rate how much they agreed with statements such as, 'I constantly monitored myself whether I spent long periods sitting (Watching TV, using the computer or at work)' on a scale from 1 '*Completely disagree*' to 4 '*Totally agree*', retrospectively over the past week (Sniehotta, Scholz et al., 2005). This scale showed good internal consistency (α = .80).

Ability to plan for action was measured by four adapted items about when, where, how, and how often, participants had made detailed plans to avoid long periods of sitting on a scale from 1 '*Completely disagree*' to 4 '*Totally agree*', retrospectively over the past week (Sniehotta, Schwarzer, et al., 2005). This scale showed excellent internal consistency (α = .97).

Opportunity construct (4 measures)

Barriers and facilitators in the local environment (within a 20 minute walk from residence) were measured with the Neighbourhood Environment Scale (Echeverria et al., 2004) which consisted of 10 items, with responses on a scale from 1 (*Strongly agree*) to 5 (*Strongly disagree*). This scale showed acceptable internal consistency (α = .72).

The availability and condition of local resources (within a 20 minute walk from residence) was also explored using the Presence of Recreational Facilities Index (Echeverria et al., 2004) consisting of six items. The availability of each type of facility was measured based on a yes or no answer. The condition of the facilities was then measured on a scale from 1 (*Excellent*) to 4 (*Poor*) if applicable.

Subjective norms were measured with three adapted items (Francis et al., 2004), which referred to how important it was to significant others that individuals would avoid long periods of sitting over the next week, and was rated on a 7-point scale from 1 (*Strongly disagree*) to 7 (*Strongly agree*). This scale showed average internal consistency (α = .66). This measure was also used in the TPB analysis.

Social support was measured with 10 items from the Social Support for Exercise Behaviour Scale (Sallis et al., 1987). Five items assessed support for physical activity from friends, acquaintances or co-workers, and five items measured support from family (members of household), on a scale from 1 (*None*) to 5 (*Very often*). Both scales showed excellent internal consistency (α = .88 and α = .89, respectively).

Motivation construct (6 measures)

Self-efficacy was measured with an adapted Self-Efficacy Scale for avoiding long periods of sitting (Schwarzer & Renner, 2009), which consisted of five items exploring participants' ability to carry out their behavioural intention in the face of challenges, such as

'even when I am tired'. The items were measured on a scale from 1 (*Very uncertain*) to 4 (*Very certain*) and showed excellent internal consistency (*α* = .90).

Perceived behavioural control (PBC) was measured with four adapted items (Francis et al., 2004). Each item referred to the amount that the individual will avoid long periods of sitting over the next week. Three items were rated on a 7-point scale from 1 (*Strongly disagree*) to 7 (*Strongly agree*), and included statements such as 'The decision to avoid long periods of sitting over the next week is beyond my control'. One item asked participants to rate how difficult it was going to be to avoid long periods of sitting over the next week on a scale from 1 (*Very difficult*) to 7 (*Very easy*). This scale showed very good internal consistency (*α* = .82). This measure was also used in the TPB analysis.

Attitude were measured with four adapted items (Francis et al., 2004). Each item referred to the participants' attitudes towards avoiding long periods of sitting in terms of how harmful, healthy, enjoyable, and boring they viewed it on a set of 7-point scales anchored by positive and negative views (e.g. 1 = *Very unhealthy* to 7 = *Very healthy*). One item was removed (Avoiding long periods of sitting (Watching TV, using the computer or at work) is harmful to beneficial), which improved the internal consistency (from *α* =.61 to *α* = .70). This measure was also used in the TPB analysis.

Intention was measured with three adapted items (Francis et al., 2004). Each item referred to how much the individual intended to avoid long periods of sitting over the next week with statements such as 'I expect to avoid long periods of sitting over the next week'. Each item was rated on a 7-point scale from 1 (*strongly disagree*) to 7 (*strongly agree*) and showed good internal consistency (*α* = .79). This measure was also used in the TPB analysis.

Exercise self-identity was assessed by the nine-item Exercise Self-Identity Scale (Anderson & Cychosz, 1994), which measures whether exercise is descriptive of an

individual's self-concept, on a scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). This scale showed excellent internal consistency (α = .96).

Positive and negative affect were measured using the International Positive and Negative Affect Schedule Short Form (Thompson, 2007), which consisted of 10 items that cover negative (e.g. afraid) and positive (e.g. inspired) affect. Participants were asked on a scale from 1 (*Never*) to 5 (*Always*) how often they had felt each item over the last week. The scales showed good (positive, α = .83) and acceptable (negative, α = .75) internal consistency, respectively.

Habit

Habit strength was measured with an adapted Self-Report Habit Index (Verplanken & Orbell, 2003), containing 12 items exploring the history of repetition, automaticity (lack of control, lack of awareness, efficiency), and expressing one's identity related to sitting behaviour. The items were prefaced by 'Sitting for long periods of time (e.g. Watching TV, using the computer or at work) is something…' Participants were then asked to rate the extent to which they agreed with each statement (e.g. 'I do without thinking') based on a 7-point scale from 1 (*Disagree strongly*) to 7 (*Agree strongly*). This scale showed excellent internal consistency (α = .95).

Dependent variable

Sitting behaviour was measured with the International Physical Activity Questionnaire (IPAQ; Craig et al., 2003). Two questions assessed the usual amount of time in minutes/hours that each individual had spent sitting on a weekday and weekend day over the last seven days. The weekday amount was multiplied by five and the weekend by two; this gave a total amount for the last week. The questionnaire was administered over the

phone to increase the likelihood of participants accurately estimating their time spent sitting (Rzewnicki, Auweele, & Bourdeaudhuij, 2003).

Procedure

This research was approved by the University of Hertfordshire Health and Human Science Ethics Committee with Delegated Authority (protocol number: aLMS/SF/UH/00079). A survey link was posted on social media sites (Facebook, Twitter, LinkedIn), relevant online forums (postgraduate, research), and distributed by email and online by University and Public Health colleagues. After providing informed consent, participants provided a preferred contact time for the follow-up phone call (one week later), alongside health and demographic information, and then completed all questionnaires, before a short debrief screen. The day before the follow-up phone call was due, a reminder email was sent. Participants who then answered the call were asked the IPAQ sitting questions for the past seven full days. An attempt to call was made on up to three occasions if the first call was not answered. Participants were then debriefed fully and thanked over the phone.

Analysis

Partial Least Squares (PLS) structural equation modelling was employed using SmartPLS 3 software (Garson, 2016; Hair Jr et al., 2014; Ringle, Wende, & Becker, 2015). The default settings of the PLS algorithm were used to obtain the weights for the outer (i.e. the measurement model for the COM-B) and inner model (i.e. the path model of the constructs for the COM-B and TPB). Multicollinearity was tested within the inner and outer model, with VIF < 5 as the suggested cut-off (Garson, 2016). Final measurement models were established through model trimming by removing statistically non-significant ($p > .05$) indicators step by step. The standardised root mean square residual (SRMR) was used to assess model fit

overall with .08 used as cut-off for acceptability (Hu & Bentler, 1998). Estimates for the direct and indirect path coefficients of the inner models were obtained as well as the explained variance (R^2) for the endogenous variables, Motivation (COM-B), intention (TPB), and weekly sitting time (both models).

Results

Overall this sample reported sitting for an average of seven hours per day, making them more sedentary than the national self-reported average of five hours per day (Health and Social Care Information Centre, 2014). There were no differences in weekly sitting time by sex, and no relationship between sitting behaviour and age, and sitting and BMI. Descriptive statistics for all formative indicators and the dependent variable are presented in Table 2.

Insert Table 2 about here

COM-B construct and predictive validity

The results for the PLS analysis of the fully specified model showed a good fit overall (SRMR = .07) and the cross loadings confirmed that each formative indicator had its highest loading on the appropriate composite COM-B construct (Figure 1). Multicollinearity was not a problem in the inner model (VIF all < 1.8) or outer model (both VIF < 2.3). Statistically unreliable indicators were then removed one at a time if weights were small and non-significant (p > .10), leaving a fully trimmed outer model (see Figure 1). Each construct had one salient indicator with a substantial weight (> .50); self-monitoring on Capability; subjective norm on Opportunity; intention on Motivation.

Insert Figure 1 about here

The residuals in the final trimmed model were small (SRMR = .04) and the cross loadings again confirmed that each formative indicator was most strongly associated with its proposed construct suggesting sufficient discriminant validity. The standardised betas for Capability and Opportunity on sitting behaviour are negative because the wording of the items referred to avoiding long periods of sitting (non-performance of the behaviour). Multicollinearity was not a problem in the inner model (VIF all < 1.2) or outer model VIF < 1.9).

The fully trimmed model explained 44% of the variance in motivation and 27% of the variance in sitting behaviour. Capability (β = .17, 95% confidence intervals (CI), .04 to .33, p = .019), Opportunity (β = .25, 95% CI, .14 to .36, p < .001), and habit (β = -.48, 95% CI, -.62 to -.36, p < .001) were all significant predictors of Motivation. Capability (β = -.15, 95% CI, -.27 to -.02, p = .028), Opportunity (β = -.18, 95% CI, -.30 to -.06, p = .005), and habit (β = .38, 95% CI, -24 to .48, p < .001) had a direct effect on sitting behaviour, with Motivation not reaching significance (β = -.15, 95% CI, -.31 to .00, p = .062).

Theory of Planned behaviour predictive validity

The fully specified TPB path diagram (see Figure 2) showed that PBC, attitude, subjective norm, and habit were all highly predictive (p < .001) of intention, and that intention and habit in turn strongly predicted sitting behaviour (p < .001). PBC, however, did not independently predict sitting behaviour in contrast to the original TPB model. This path was, therefore, removed from the final trimmed model. The standardised direct effect of intention on sitting behaviour and habit on intention, and the indirect effects of attitude, subjective norm, and PBC on sitting behaviour are negative because the wording of the items referred to avoiding long periods of sitting (non-performance of the behaviour). The

full specified model explained a large amount of the variance in intention (58%) and a medium amount in sitting behaviour (23%).

Insert Figure 2 about here

The final trimmed TPB path diagram showed that PBC, attitude, subjective norm, and habit were all highly predictive ($p < .001$) of intention, and that intention and habit in turn strongly predicted sitting behaviour ($p < .001$). The final trimmed model explained a large amount of the variance in intention (58%) and sitting behaviour (23%). Subjective norm (*IE* = -.04, 95% CI, -.09 to -.01), attitude (*IE* = -.04, 95% CI, -.08 to -.00), PBC (*IE* = -.08, 95% CI, -.17 to -.02), and habit (*IE* = .03, 95% CI, .00 to .08) all had an indirect effect on sitting behaviour through intention. Intention modestly reduced sitting behaviour (*DE* = -.18, 95% CI, -.33 to -.03) whereas habit strongly increased it (*DE* = .36, 95% CI, .22 to .48). Intention on its own accounted for 13% of the variance in sitting behaviour, but when controlling for habit strength it was only 2%. Overall, habit had by far the largest total effect on sitting behaviour, followed by intention, PBC, attitude, and subjective norm respectively.

Discussion

Of the variables included in this research, Capability was defined solely by self-monitoring (Psychological Capability), Opportunity was defined solely by subjective norms (Social Opportunity), and Motivation was defined by intention and PBC (both related to Reflective Motivation), and positive affect (Automatic Motivation). Capability, Opportunity, and habit predicted Motivation and sitting behaviour, but Motivation did not predict sitting. Strength of habit was the most important predictor of sitting behaviour followed by Opportunity and Capability. This is supported by previous research showing that habit and past behaviour can weaken the impact of intention on behaviour (Webb & Sheeran, 2006)

and increase the predictive validity of models such as the TPB related to physical activity (Hagger et al., 2002), and the Health Action Process Approach (HAPA) related to sitting (Maher & Conroy, 2016).

Self-monitoring was the most important Capability indicator, but action planning did not contribute. In this sample those that self-monitored how often they disrupted periods of sitting were able to modestly reduce their sitting behaviour, but did so without making detailed plans about how and when they were going to do this, possibly because of constraints such as job role (Ojo, Bailey, Hewson, & Chater, 2019). Physical health was not an important contributor to Capability. The inclusion criterion was that participants had to be able to perform physical activity. Although, this excluded participants living with serious physical challenges, it does not mean that the sample were free of long-term conditions (e.g. diabetes, hypertension). Knowledge was not measured as guidelines on sitting were not introduced until after data collection had finished (Buckley et al., 2015). However, these published guidelines are still quite vague (break up working hours with 2 hours of standing/light activity progressing to 4 hours), only specify advice for people with desk-based jobs, and only focus on working hours so have limited applicability to more volitional sitting during leisure time. The guidelines also only specify the amount that an individual should stand, and not how often sitting should be broken up, so it would be useful if this was added to the guidance.

For the Opportunity construct subjective norm was the most important indicator, consistent with previous analysis of MVPA (Howlett et al., 2017). These types of norms are injunctive rather than descriptive (what others actually do), with previous research suggesting this may be the most important type of norms for some forms of sedentary behaviour (Prapavessis et al., 2015). Social support for physical activity, the surrounding

neighbourhood environment, and presence of recreational facilities were not important sources of Opportunity for sitting behaviour. This may be due to the fact that these measures were more heavily focused on physical activity and not directly tapping into sitting behaviour. For the Motivation construct the most important indicator was intention, consistent with many other theories of behaviour such as the TPB and HAPA. The two other potential indicators of Motivation were positive affect and PBC, suggesting that generalised levels of positive affect and perceptions of how much control participants had over their sitting, helped form Motivation. This supports previous research that those with higher levels of happiness and personal control beliefs, driven by autonomous motivation are more likely to engage in behaviours known to be protective of health (Cook & Chater, 2010; Hagger, Hardcastle, Chater, Mallet, Pal, & Chatzisarantis, 2014).

The biggest diversion from the theorised relationships in the COM-B was that Motivation did not drive weekly sitting time. Based on the answers to the IPAQ, completed over the phone, the majority of sitting appeared to be desk-based while working or studying (less volitional and more habit driven) and not in leisure time (more volitional and potentially less habitual). There are two main reasons for this. Firstly, habit has been found to contribute more significantly to objectively-measured sedentary behaviour than planning and intentions (Maher & Conroy, 2016), and habit strength attenuates the intention-behaviour relationship across a range of behaviours (Webb & Sheeran, 2006). Secondly, Motivation may have played a key role if attempts to break up sitting or sitting bout length had been measured rather than total sitting time. Even if participants had a high motivation to avoid prolonged periods of sitting (and managed it successfully) it may have had only a small effect on total sitting time. For example, standing for a few minutes every hour while working or studying at a computer may have only reduced daily sitting time by half an hour.

A parallel analysis of the predictive validity of the TPB predicted a large amount of variance in intentions to avoid sitting for large periods and in total sitting time, although the relationship between the two was quite weak. This is consistent with previous evidence of an intention-behaviour gap, whereby, intentions are easier to predict and change than behaviours such as physical activity (Rhodes & de Bruijn, 2013). Again, the inclusion of habit often weakens the relationship between intentions and behaviour (Webb & Sheeran, 2006), and this proved consistent with the introduction of a variable controlling for habit strength in this study. The variance explained by the COM-B model in this study was similar than for the TPB (27% vs 23%) and was quite consistent with other TPB analyses for sedentary behaviour in general (e.g. Prapavessis et al., 2015; Rhodes & Dean, 2009).

Even with the introduction of a measure controlling for habit strength, the analysis confirmed that the structural pathways proposed by the TPB were largely supported, apart from the direct route from PBC to sitting. This may be due to desk-based sitting (for work, study, or lecturing) being perceived to be out of individual control. The variance explained was consistent with previous tests of the model in overall sedentary behaviour (Prapavessis et al., 2015; Rhodes & Dean, 2009). Dividing sitting behaviour into total sitting time (e.g. during leisure, computer use at work, and transport) and number of times sitting time has been broken up, may provide greater explanatory accuracy in future studies.

The strengths of this approach were the statistical modelling using formative indicators to operationalization the constructs based on a published discriminant content validation of the TDF, and the time lag between the measurement of constructs and sitting behaviour. The limitations included opportunistic sampling, the data-driven validation of the model, and omitting some TDF domains that were not measured and/or deemed appropriate to the behaviour (memory, attention, and decision making; reinforcement;

knowledge; optimism). For example, optimism was not included because although there are validated measures of optimism (e.g., Helweg-Larsen & Shepperd, 2001), they are not directly related to the behaviour in question, and there is little evidence from previous research of a link between optimism and sitting. However, as positive affect was found to be significant, and there is evidence that positive affect and optimism are inter-related (Kim, Lee, Chun, Han, &, Heo, 2017; Taber, Klein, Ferrer, Kent, & Harris, 2016), future research should consider this TDF construct. Future research should also consider the behavioural, normative, and control beliefs that can be measured as pre-cursors to attitude, subjective norm, and PBC from the TPB that are not present within this study. Additionally, the measures for social support, neighbourhood environment, presence of recreational facilities, and identity were primarily physical activity related. This may have limited their applicability for sitting specifically, and future attempts at testing the COM-B for sitting should develop measures that are potentially more suitable for sitting.

Implications and future considerations

Research shows that an absence of physical activity may not be the same as sedentary behaviour (van der Ploeg & Hillsdon, 2017), that the two behaviours could have health-related risk factors independent of each other (e.g. Chau et al., 2013; Katzmarzyk et al., 2009), and that replacing prolonged sitting with light activity could be highly beneficial (Bailey, 2017). There is, however, some debate regarding the quality of the evidence base for separating sedentary behaviour completely from inactivity (Stamatakis et al., 2018). If we are to fully understand the potential influences on sitting behaviour, there is a need to develop questionnaires measuring key psychological drivers/antecedents. This study adapted measures designed for physical activity which may have not been ideal for

examining the intricacies of sitting behaviour. More so than physical activity, there also needs to be a distinction between more and less volitional (and habitual) behaviour. Many modern jobs and educational environments necessitate long periods of sitting at a desk (and during commuting) and a lack of (perceived) control (and subsequent planning), both in terms of total sitting time and when it can be interrupted (Ojo et al., 2019). Sitting is highly habitual in nature with the same contextual cue encountered repeatedly every day making the behaviour more automatic (Gardner & Lally, 2013). This may mean that less volitional and more habitual sitting has a different set of drivers, that are more externalised (e.g. workplace conventions or lectures at university), than more volitional leisure-time sitting. A similar analysis with attempts at breaking up long periods of sitting or sitting bout length, as the target behaviour, would also be beneficial in future studies.

Breaking up long periods of workplace sitting is a challenging prospect, with recent research highlighting some of the problems that employees perceive when trying to stand in meetings (Mansfield et al., 2018). Employees reported feeling uncomfortable at breaking accepted norms by standing and were wary of the power dynamics, either as the group leader (too controlling), or a group member (challenging authority; Mansfield et al., 2018). However, there is evidence to suggest that breaking up large amounts of sitting with treadmill desks may have important health benefits (Champion et al., 2018) and that the use of active workstations does not deplete cognitive performance or productivity (Ojo, Bailey, Chater, & Hewson, 2018). Habit strength and to a lesser degree subjective norm were the consistent predictors of sitting behaviour from both models and, therefore, may be an important consideration to target in future interventions.

Conclusion

This study provided preliminary data on the proposed structure of the COM-B model for weekly sitting time and the COM-B explained sitting behaviour comparably to the TPB when strength of habit was taken into consideration. Habit strength and subjective norm were consistent predictors of sitting behaviour and may need to be addressed in future interventions, particularly for working and studying where sitting habits and norms in meetings, at the desk, and in lectures/tutorials are influential. For future conceptualisations of sedentary behaviour there is a need for greater clarity in quantitative guidelines, both for measuring knowledge and the development of action plans (akin to those for physical activity of 150 minutes per week). Furthermore, the development of validated measures representing the full range of bio-psycho-social drivers underpinning this behaviour would be beneficial.

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Table 1. Mapping of COM-B to the TDF domains, with the appropriate questionnaire measures representing key components for sitting behaviour (based on Cane et al., 2012).

COM-B construct	TDF Domain	Indicator and adapted measure
Capability	Knowledge	*No quantitative guidelines*
	Memory, attention and decision making	*No appropriate validated measures*
	Behavioural regulation	Self-monitoring (Sniehotta, Scholz et al., 2005) - *modified* Action planning (Sniehotta, Schwarzer, Scholz, & Schüz, 2005) - *modified*
	Physical ability (Skills)	Ability (Medical Outcomes Short Form Survey; Ware & Sherbourne, 1992)
Opportunity	Social influences	Social support (family and non-family) (Social Support for Exercise Behaviour Scale; Sallis et al., 1987) Social/group norms (subjective norm; Francis et al., 2004) - *modified*
	Environmental context and resources	Barriers and facilitators (Neighbourhood Environment Scale; Echeverria et al., 2004) Resources/material resources (Presence of Recreational Facilities Index; Echeverria et al., 2004)

Motivation	Social/professional role and identity	Identity (Exercise Self-Identity Scale; Anderson & Cychosz, 1994)
	Optimism	*No appropriate validated measures*
	Beliefs about capabilities	Self-efficacy (Physical Exercise Self-Efficacy Scale; Schwarzer & Renner, 2009) - *modified* Perceived behavioural control (Francis et al., 2004) - *modified*
	Beliefs about consequences	Beliefs (Attitude; Francis et al., 2004) - *modified*
	Intentions	Intention (Francis et al., 2004) - *modified*
	Goals	Covered by action planning (included in capability)
	Reinforcement	*No appropriate validated measures*
	Emotion	Positive/ negative affect (International Positive and Negative Affect Schedule Short Form; Thompson, 2007)

Table 2. Sample demographics and descriptive statistics for the dependent variables and all formative indicators (*N* = 186).

Characteristics		Means (SD)[a] and frequencies (percentages)[b]	Formative indicators (range) and dependent variables	Mean (SD)
Age[a]		38.25 (14.12)	Physical Health (1-3)	2.87 (.26)
			Self-Monitoring (1-4)	2.11 (.80)
BMI[a]		24.58 (4.67)	Action Planning (1-4)	1.83 (.81)
			Self-Efficacy (5-20)	13.44 (3.64)
Female[b]		132 (71%)	Attitudes (1-7)	5.45 (.97)
			Intentions (1-7)	4.93 (1.49)
Smoker[b]		10 (5%)	Perceived Behavioural (1-7) Control	4.31 (1.70)
			Positive Affect (5-25)	17.68 (3.55)
Highest	Up to A Level	43 (23%)	Negative Affect (5-25)	10.36 (3.40)
education level	Bachelors degree	60 (32%)	Exercise Self-Identity (1-7)	4.77 (1.88)
(or equivalent)[b]:	Masters degree	62 (33%)	Subjective Norm (1-7)	3.45 (1.36)
	PhD	22 (12%)	Social Support (Non-family) (5-25)	9.05 (5.17)

			Social Support (Household) (5-25)	8.42 (4.58)
Employment[b]:	Full-time work	88 (47%)	Local Environment (10-50)	37.64 (6.51)
	Part-time work	30 (16%)	Availability (1-6)	3.45 (1.37)
	Full-time student	37 (20%)	Condition (1-4)	3.02 (.66)
	Other	32 (17%)		
			Habits (1-7)	4.53 (1.64)
Household	£0-25000	22 (12%)		
Salary[b]:	£25-50000	63 (34%)	Sitting (Minutes per week)	2946.71 (967.48)
	£50-75000	34 (18%)		
	Over £75000	32 (17%)		
Marital Status[b]:	Married	81 (43%)		
	Living with partner	32 (17%)		
	Single	53 (28%)		
	Other	21 (11%)		

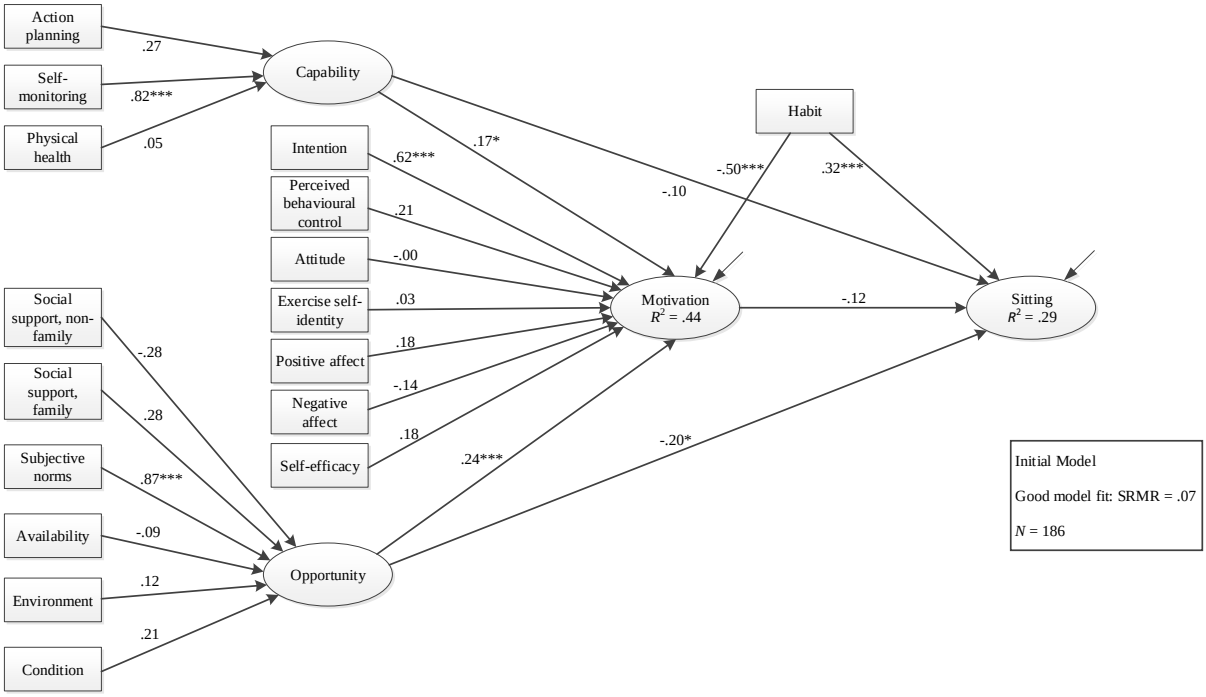

Figure 1a

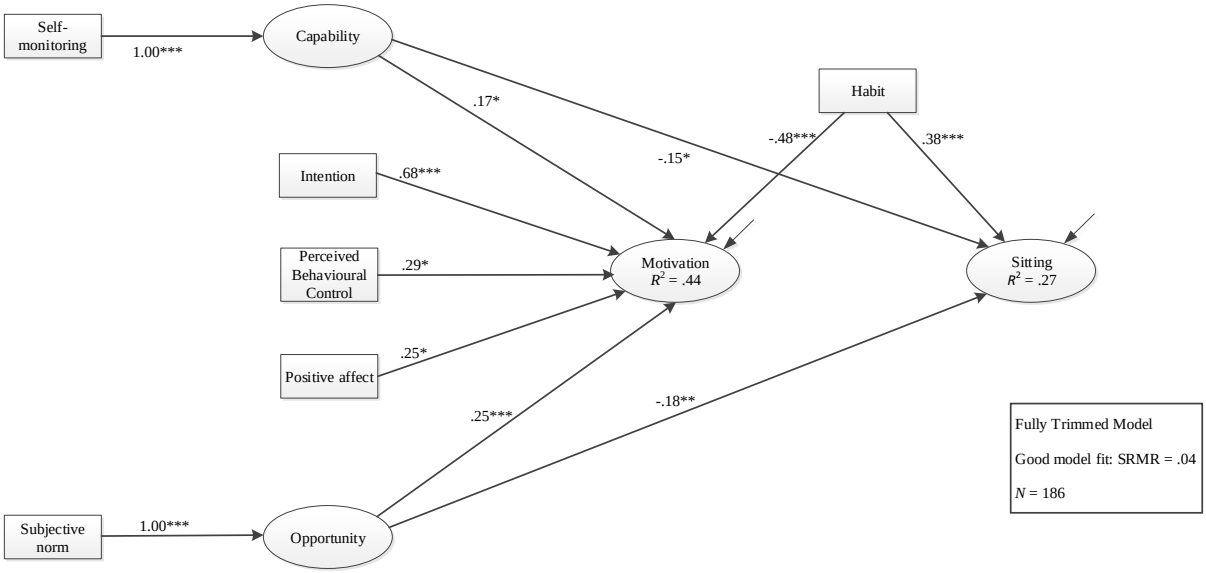

Figure 1b

Figure 1a. Fully specified formative measurement model of the COM-B for sitting behaviour. Constructs are represented by ovals and observed variables by rectangles.

Figure 1b. Final trimmed path model of the COM-B for sitting behaviour.

Note: **p* < .05, ***p* < .01, ****p* < .001, [a]*p* < .10; all coefficients standardised.

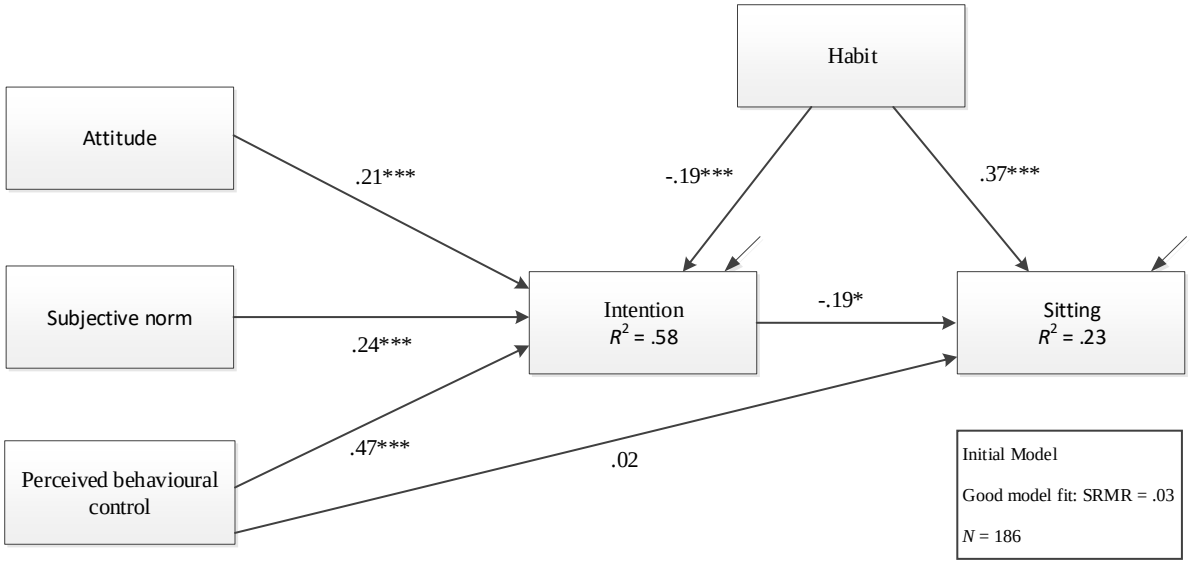

Figure 2a

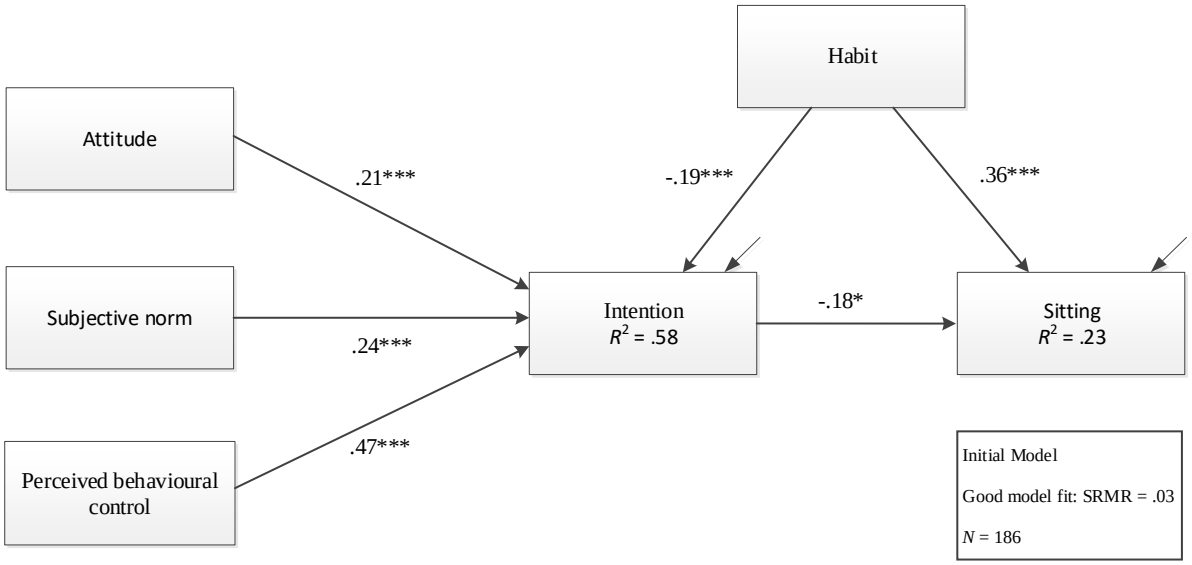

Figure 2b

Figure 2a. Fully specified path model of TPB for sitting behaviour.

Figure 2b. Final trimmed path model of TPB for sitting behaviour.

Note: *p < .05, **p < .01, ***p < .001; all coefficients standardised.