A continuación, la versión aceptada en *Psychology & Health*, en el 2019, previa al trabajo de edición y diagramación, del manuscrito "*Re-evaluating the Self Report Habit Index: The cases of Physical Activity and Snacking habits*" (doi: 10.1080/08870446.2019.1585852), por Reyes-Fernández, B; Monge-Rojas, R.; Solano López, A. L.; Cardemil, E. **Por favor, consulte *Psychology & Health* para acceder a la versión final.**

Re-evaluating the Self Report Habit Index: the cases of Physical Activity and Snacking habits

Abstract

Objective. The Self-Report Habit Index (SRHI) was originally reported as one-dimensional; however, habit has been described as characterized by several features. Moreover, one-dimensional models for the SRHI have demonstrated poor fit. Therefore, we aimed to compare multi-dimensional models with a one-dimension model in both snacking and physical activity habits, besides examining further instrument characteristics.

Design. A cross-sectional study was conducted with high school and university students (n = 555).

Main outcome measure. The SRHI adapted for physical activity and for snaking habits was applied at one time point.

Results. Nested models with one factor, two factors, and three factors were compared. Next, a hierarchical second-order model was tested, and further validity issues, as well as invariance between habits, were examined. Three-dimensional models represented a better fit for both habits. However, fit was still inadequate in the snacking version. In addition, discriminant validity concerns emerged for the physical activity SRHI. Moreover, invariance between the snacking and the physical activity versions was not confirmed.

Conclusions. Considering the SRHI as composed by the dimensions of “lack of awareness”, “lack of control”, and “history of behavioural repetition” seems to be more accurate. Nevertheless, our findings suggest that further research is needed.

Key words: Habit, Physical Activity, Snacking, SRHI.

Introduction

Habits, as measured by the Self Report Habit Index (SRHI; Verplanken & Orbell, 2003), are the focus of attention of an increasing number of psychology and health related researchers (e.g., Gardner, de Bruijn, & Lally, 2011), although controversies regarding the conceptualization and measurement of them have not yet been resolved (e. g. Hagger, Rebar, Mullan, Lipp, & Chatzisarantis, 2015). One specific issue regarding the conceptualization of the SRHI is that it has been described as one-dimensional, although habits have been defined in the literature as having several features (Verplanken & Orbell, 2003). By examining several Confirmatory Factor Models for the SRHI, and the invariance between two versions of the SRHI, one applied to snacking and the other applied to physical activity, we expect to shed some light and gain a deeper understanding of the SRHI's dimensionality, its interpretation for different habits, and its limitations.

The habits that were selected in this study on the SRHI dimensionality are relevant in terms of health outcomes. Snacking, or eating between meals, and physical activity have been postulated to have a range of positive (e.g., appetite control, body weight management and improved blood glucose control in diabetics and pre-diabetics) and negative health outcomes (e.g., increased intake of calories, sodium, and saturated fat) (Hess, Jonnalagadda, & Slavin, 2016; Njike, et al. 2016; Kyu el al., 2016). Unhealthy snacking and low physical activity levels have been associated with obesity, which in turn is associated with several cardiometabolic diseases (Mokdad, Ford, Bowman, Dietz, Vinicor, Bales & Marks, 2003). Although physical activity and snacking behaviours could be controlled by conscious efforts, their maintenance over time might be explained, at least partially, by a process of habit formation (Lally & Gardner, 2013). Thus, research

on the measurement of habits might contribute to the study of how behaviours are maintained over time.

Verplanken and Aarts (1999) have defined habits as "learned sequences of acts that have become automatic responses to specific cues, and are functional in obtaining certain goals or end-states" (p. 104). In this conceptualization, habits are distinguished from behaviour and frequent behaviour based on their automaticity. In addition, Verplanken and Orbell (2003) emphasize that habits are behaviours that are intentional (goal-directed action), as well as uncontrollable to a certain extent, because habits are often perceived as difficult to change or overrule. These authors also emphasize that habits are executed without awareness and, as a consequence, they set free cognitive resources to engage in other activities at the same time. Thus, in summary, habits have three broad features: 1) they are expressed as frequent or repeated behaviour, 2) they are experienced as difficult to control, and 3) they are performed without awareness.

Other features have been mentioned as part of habits (Gardner, 2015; Verplanken & Orbell, 2003). One of them, mental efficiency, can be understood as a consequence of the lack of awareness, and is not directly captured by a self-report measure, such as the SRHI. Another feature that has been mentioned in the literature as part of habits is identity (Verplanken & Orbell, 2003), as identity can play a role in motivating someone to perform certain behaviour (Gardner, de Bruijn, & Lally, 2012; Kwasnicka, Dombrowski, White, & Sniehotta, 2016). In addition, frequent behaviours and habits may have effects on individual self-concept or identity (Kwasnicka, Dombrowski, White, & Sniehotta, 2016). However, in these instances, identity is either an antecedent or a consequence, but not an actual habit. Therefore, although the SRHI includes one item that

may reflect identity ("*behaviour x is something that's typically 'me'*") (Gardner, Abraham, Lally, & de Bruijn, 2012), we hold that, because of the use of the term "typical", it also may reflect frequency or repetition of behaviour.

Despite these conceptualizations that suggest multidimensionality, Verplanken and Orbell (2003) have reported the SRHI to be one-dimensional, based on Principal Components Analyses (PCA). Similarly, Gardner, de Bruijn, and Lally (2012) have reported results for a one-dimensional model of an extended version of the SRHI, this time based on a Confirmatory Factor Analysis (CFA). More recently, Morean and colleagues (2018), after shortening the SRHI to a 6-item version, also arrived at a one-dimensional solution using CFA.

There are important limitations to these studies, however. The PCA approach used by Verplanken and Orbell (2003) uses the total variance to estimate components, without any distinction between common variance and unique variance (specific and error variance) (Kline, 2016). This approach has been shown to produce an incorrect number of dimensions (Conway & Huffcutt, 2003). Although Gardner, de Bruijn, and Lally (2012) used CFA, which is generally considered better than the PCA because it takes error variance into account (Kline, 2016), the fit the authors found for their one-factor solution did not reach the RMSEA accepted threshold for satisfactory fit (i.e., RMSEA = .13).

Similarly, Morean and colleagues (2018), in their study that focused on habitual cigarette, e-cigarette, marijuana, and alcohol use, found a non-satisfactory fit for a one-dimensional model using CFA. The authors then conducted an Exploratory Factor Analysis (EFA), reduced the SRHI to six items, and then reconducted the CFA. Using this shortened version, the authors obtained satisfactory fit indices for a one-factor solution

(RMSEAs between .04 and .06). Nevertheless, plausible solutions for the original 12 items, using a CFA approach, were not reported.

In sum, there is good reason to believe that habits, as measured by the SRHI, are three-dimensional, as they are frequent behaviours, conducted with little to no awareness, and operate with little to no control. Nevertheless, it is important to consider alternative multidimensional options. For example, in the literature "lack of awareness" and "lack of control" are often conceptualized under the general label "automaticity" (e.g., Bargh, 1994; Gardner, 2015). Thus, we also consider the possibility for the SRHI to be two-dimensional, reflecting both a history of behaviour repetition and automaticity.

When comparing different dimensional solutions, a nested models approach that uses structural equation modeling is superior to a PCA approach and to a single model CFA. In particular, the CFA nested model approach takes measurement error into account, and it also permits the comparison of several models in terms of fit (Kline, 2016), which allows for the determination of which model is a better fit to the underlying pattern of data.

Therefore, in this study, we use a nested model approach to determine the dimensionality of the SRHI as it pertains to both snacking and physical activity. We specifically test whether a three-dimensional model represents a better fit (i.e., behavioural repetition, lack of awareness, and lack of control), as we have conceptually argued or, rather, as reported by Verplanken and Orbell (2003), a one-factor solution provides a better fit. In addition, a two-dimensional model is examined as well, consisting of history of behavioural repetition and automaticity (no distinctions between lack of

control and lack of awareness). Further details on the models compared are provided in the methods section.

Given that both snacking and physical activity are conceptualized as habits, we also examine the extent to which the SRHI is equivalent for both. Finally, this study will examine the relationship of both habits with their corresponding behaviours.

Materials and methods

Participants and procedures

Participants were 555 male and female students from two urban high schools and from different university courses at the University of Costa Rica. From the overall sample, 4 participants did not report gender (.7%), 248 (44.7%) were men and 303 (54. 6%) were women. The overall mean age was 17.52 ± 3.53. Almost every participant was Costa Rican (96%), and most were living in San José Province (53%), followed by those living in its neighbouring province, Heredia (35%). 179 participants (32.3%) were university students, and 376 participants (67.7%) were high school students, including students from a vocational high school. The mean age of high school participants was 15.60 ±1.35, and for university students was 21.55 ± 3.28.

Participants were invited to voluntarily enroll in the study, and they gave their written informed consent to participate according to the rules provided by the Costa Rican legislation for research involving human subjects. Written parental informed consent and adolescent assent were required for participants younger than 18 years of age. Participants who were 18 years of age or older only needed to provide written informed consent to participate in the study.

Data were collected through self-report questionnaires, which were completed by participants in their classrooms. Only those who had previously provided signed assents and informed consents took part in the study. The study was approved by the UCR Ethics Committee and data collection took place during 2017.

Measures

The study questionnaire consisted of demographic measures as well as the SRHI (Verplanken & Orbell, 2003). The SRHI can be used to assess a wide range of behaviours, such as taking the bus, watching soap operas, and eating candies, among others (Verplanken & Orbell, 2003). In this study, the SRHI was adapted for physical activity and for snacking. The SRHI consists of a stem ("*Behaviour X is something...*") that is adapted for different behaviours (e.g., "*Physical activity is something...*"), followed by 12 items with 7-point Likert response options that range from completely in disagreement to completely in agreement. A sample item is "…*I do frequently*". Table 1 presents the twelve items of the SRHI. Items are summed and averaged to get an overall SRHI score that ranges between 1 and 7. In this study, the overall SRHI reliability was excellent for both, the habit of physical activity (α = .92) and the habit of snacking (α = .92).

In addition, the frequency of vigorous physical activity was measured through the single item: "*How many days did you engage in vigorous physical activity in the past week?*". A definition of vigorous physical activity was provided just before the item: "*Vigorous physical activity is that one that produces sweating and rapid heartbeat. It makes you breathe stronger than normal.*" Snacking behaviour was measured through

several questions focused on how many days of the week participants ate chips, cookies, chocolates, pastries, or fast food. There were five questions, one for each of these snack categories. The average number of days for all these snack categories was taken as an index of weekly snacking frequency.

Data Analyses

In order to examine whether one, two, or three dimensions better reflect the underlying structure of the SRHI, CFA nested models were compared. Models are nested if one is a proper subset of the other (Kline, 2016). The more complex model is called the full model.

As discussed, we hypothesized the SRHI to be three-dimensional. The three dimensions of the 12 original SRHI items can be classified, as shown in Table 1, in the following three categories: history of behavioural repetition, lack of awareness, and lack of control.

Insert Table 1 here

If a three-factor solution is confirmed for the SRHI for snacking and physical activity habits, we will further examine the possibility that habit is a second-order factor with loadings on each of the first order factors. A second-order model has the advantage that it tests whether the higher order factor account for first order factors (Byrne, 2005). From a theoretical point of view, it can be expected that the first-order dimensions are indicators of habit as a second order factor. From a methodological perspective, however, a second order factor can only be identified with three or more first-order factors (Byrne,

2005). Thus, the first-order dimensionality has to be established before adding a second order factor.

Before testing a second-order model, it is necessary to assess whether there is substantial correlation among first-order factors supported by a defensible theoretical foundation. If the SRHI has multiple dimensions, then it is expected that those dimensions are potential indicators of habits.

To determine the dimensionality of the SRHI, we therefore designed three nested models, where constraints to the variance and covariance of dimensions (Di) were set, depending on the different assumptions of dimensionality. The assumed correspondence of items onto three dimensions is shown in Table 1. In the **first model**, the variances of Di1, Di2, and Di3, as well as the covariances among them, were constrained to be equal. By doing so, we examined the fit of a one-dimensional model. This unique dimension could be interpreted as "habit." In the **second model**, the variances of Di2 and Di3, as well as the covariance between them, were constrained to be equal. The covariance between Di1 and Di2 was also constrained to be equal to the covariance between Di1 and Di3. The assumed dimensions in this model were "automaticity" and "history of behavioural repetition". Finally, in the **third model**, no constraints in factor variances and covariances were set. "History of behavioural repetition", "lack of awareness", and "lack of control" were assumed to be distinct dimensions. The first and the second models were nested within the third model. This analysis was performed for both the snacking and the physical activity habits.

Besides the overall fit estimate chi square ($\chi 2$), other fit indexes reported in this manuscript were the chi square to degrees of freedom ratio, the comparative fit index (CFI), the Tucker-Lewis Index (TLI), and the root mean square error of approximation (RMSEA). CFI and TLI values close or above to 0.95 and RMSEA values close or below to 0.06 (Hu & Bentler, 1999) were considered to indicate adequate fit. Nested models were compared by means of the chi-square difference test (Kline, 2016).

In the event a multi-dimensional model proved to be a better fit for both snacking and physical activity than a one-dimensional model, then discriminant validity will be examined and reported. The statistical formula provided by Fornell and Larcker (1981) will be used to test the discriminant validity of the latent variables in the three-factor model. If the average variance extracted (AVE) for each construct is greater than the square of the correlation (R2) between constructs, discriminant validity is demonstrated.

Additionally, if a three-dimensional model is confirmed to be a better fit, habit as a second-order factor, with loadings on each of the first-order factors, will be added to the model and its fit will be reported. There must be at least three first-order factors to identify a second order factor, as these first-order factors are presumed indicators of the construct of habit. In principle, the logic behind hierarchical factor analysis is the same as in classic non-hierarchical factor analysis; there are measures for manifest variables (items), and when these variables correlate, they might be indicators of a latent variable (Gorsuch, 1983).

The factor itself cannot be directly measured—it is a latent dimension. Likewise, in hierarchical factor analysis, the correlation of first-order factors can be interpreted as a

second-order factor (Bollen, 1989). An advantage of hierarchical confirmatory factor analysis is that it allows for the modeling of abstract variables: in this case, habit as a second order factor with first order factors as indicators.

Additionally, the association between habit dimensions and behaviours is reported as evidence of convergent validity. From a theoretical perspective, we should expect habits and frequency of behaviours to be correlated. The association between scores of related variables is referred as convergent validity (Furr, 2018).

Finally, we examined the equivalence between snacking and physical activity habits, as measured by the SRHI, at different levels, by means of several progressively constrained models: 1) an unconstrained model, 2) a model that constrains the factor measurement loadings of both habits to be equal, 3) a model that constrains measurement loadings and intercepts of both habits to be equal, 4) a model that keeps the constraints of the previous models and also constrains the structural weights of both habits, 5) a model that adds to the previous constraints equivalence in structural residuals, and 6) a model that constrains to equivalence the measurement residuals.

Considering the wide age range among participants (high school students mean age =15.60 ±1.35, and university students mean age= 21.55 ±3.28), we aimed to identify possible age-related biases in filling out the questionnaires; therefore, we split the sample by the age median (16 y. o.) and examined invariance between participants who were 16 years or younger, and those who were older than 16. Invariance was determined using the chi square difference test, when compared with the unconstrained model.

Analyses were performed with SPSS 23 and AMOS 23, for the SEM analyses the estimation method was maximum likelihood.

Results

Habit of Snacking

The overall SRHI mean for snacking was 3.01 (SD = 1.49). Table 2 presents mean and standard deviations for each of the SRHI items, as well as the correlations among them.

Insert Table 2 here

The normality of each of the items was investigated in terms of its skewness (1.20 to 0.20) and kurtosis (−1.48 to .25). These values were all within the levels recommended for a CFA with maximum-likelihood estimation (skew>2, kurtosis>7; West, Finch, & Curran, 1995).

Dimensions

As depicted in Table 3, in the one-factor model, the fit indices were poor (indices did not meet criteria proposed by Hu and Bentler, 1999). The two-factor model had a somewhat better fit, although it was still not adequate. The three-factor model fit the data better that the other two models. However, its indices were not at an acceptance level: absolute fit (RMSEA) was higher than the maximum level recommended (.06), and relative fit indexes (CFI and TLI) were slightly below the level of .95. Thus, using the terminology of Hu and Bentler (1999), this model did not fit the data adequately.

Insert Table 3 here

Nevertheless, although the fit was not satisfactory, the chi square difference test showed that the three-factor model had a better fit than the one-factor model ($\Delta \chi 2$ (5) = 852.773, $p < .001$), and the two-factor model ($\Delta \chi 2$ (3) = 600.940, $p < .001$). The three first-order factor model is depicted in Figure 1. Additionally, we calculated Cronbach's alpha for each of the dimensions of the three-factor model. It was $\alpha = .89$ for history of behavioural repetition, $\alpha = .90$ for lack of awareness, and $\alpha = .84$ for lack of control.

Insert Figure 1 here

We established discriminant validity of each of these latent variables by comparing each construct's average variance extracted (AVE) with its squared correlations with other constructs (Fornell, & Larcker, 1981)[1]. The highest squared correlation between factors was .64; no AVE was lower than that. Consequently, discriminant validity was confirmed.

Snacking habit as a second order factor

After finding that a three-factor model fit the data better, and considering the substantial correlation among factors, we specified habit, in a hierarchical model, as a second-order factor. That is, we assume that the three factors found are indicators of the habit of snacking. A second order factor with only three indicators is therefore identified, and the fit is not expected to be different from the first-order model (χ^2 (51) = 316.257, $\chi^{2/}$df= 316.241, CFI =.94, TLI =.92, RMSEA = .09 [.08-.10]). Nevertheless, we obtained the factor loadings of the second order factor on its indicators: the loading from snacking

[1] The average variances extracted and composite reliabilities were calculated using the Validity Master Tab of the Stats Tool Package provided by James Gaskin (2016).

habit to behaviour repetition made it emerge as its best indicator (β = .96). It was followed by the loading from habit to lack of awareness (β = .84), and by the loading from habit to lack of control (β = .67).

Afterwards, we examined participants' age-related invariance (younger vs older to 16 years), confirming it in terms of measurement weights (Δ $\chi 2$ (9) = 6.08, p = .73), structural weights (Δ $\chi 2$ (11) = 11.32, p = .41), structural covariances (Δ $\chi 2$ (12) = 11.51, p = .48), and structural residuals (Δ $\chi 2$ (15) = 18.32, p = .24). However, there was no invariance at the level of measurement residuals (Δ $\chi 2$ (27) = 46.91, p < .05), where the constrained model fit significantly worse than the unconstrained model. Nevertheless, measurement residuals are not part of the latent variables, and have been considered inconsequential for the interpretation of latent means (Vandenberg & Lance, 2000).

Habit of Physical Activity

The overall SRHI mean was 3.81 (SD = 1.56) for physical activity. Table 4 presents the zero-order correlations, means, and standard deviations for each item.

Insert Table 4 here

The normality of each of the items for the physical activity SRHI was investigated in terms of its skewness (-.46 to .59) and kurtosis (−.48 to -.79). These values were all within the levels recommended for a CFA with maximum-likelihood estimation (skew>2, kurtosis>7; West, Finch, & Curran, 1995).

Dimensions

The fit for the nested models for physical activity is reported in Table 5. The one factor model had a poor absolute fit, since the fit index was quite above the maximum level (RMSEA > .06), and relative fit indexes (TLI and CFI) were not above the level recommended by Hu and Bentler (1999). The two-factor model, although better, also did not meet recommended levels. Only in the three-factor model was absolute fit at the recommended level (RMSEA = .06), and the relative fit indices (TLI and CFI) were above the minimum level (.95). Using Hu and Bentler (1999) terminology, the fit indexes for the three-factor model indicate adequate fit.

Insert Table 5 here

Moreover, the chi square difference test showed a better fit for the third model, when compared to the first ($\Delta \chi 2$ (51) = 393.804, $p < .001$) and the second one ($\Delta \chi 2$ (2) = 235.925, $p < .001$). The three first-order factor model is depicted in Figure 2. Additionally, we calculated Cronbach's alpha for each of the dimensions of the three-factor model. It was $\alpha = .90$ for history of behavioural repetition, $\alpha = .85$ for lack of awareness, and $\alpha = .78$ for lack of control. They all were between acceptable and excellent.

Insert Figure 2 over here

We examined discriminant validity for each of these latent variables by comparing each construct's average variance extracted (AVE)[2] with its squared correlations with

[2]The average variances extracted and composite reliabilities were calculated using the Validity Master Tab of the Stats Tool Package provided by James Gaskin (2016).

other constructs (Fornell & Larcker, 1981). This raised some concerns related to discriminant validity, since the AVEs of behavioural repetition (.70) and lack of control (.55) dimensions were lower than their squared correlation (.72). The AVE of lack of awareness (.53) was also lower than its squared correlation with history of behavioural repetition (.57). Discriminant validity is the extent to which a given latent variable discriminates from other latent variables. When discriminant validity is not established, researchers cannot be sure whether results confirming hypothesized structural paths are real or whether they are a result of statistical discrepancies. Some steps for addressing discriminant validity concerns may be taken (Farrell, 2010), although they may include changes in the indicators or changes in the specified model. This goes beyond the aim of the present study. Further comments are included in the discussion section.

Physical activity habit as a second order factor

We specified habit as a hierarchical second order factor for physical activity in the complete sample, based on the theoretical assumption that the three dimensions found are indicators of the construct of habit. Considering that the model is just identified, the fit indices are the same as for the first order three-factor model (χ^2 (51) = 169.206, $p < .001$, CFI =.97, TLI =.96, RMSEA = .06 [.05-.07]). By specifying a second-order factor, we obtained factor loadings from habit to each of its dimensions: the loading to behaviour repetition was $\beta = .96$, suggesting it was the best indicator of the habit of physical activity. It was followed by the loading to difficulty of control ($\beta = .88$), and then by the loading to lack of awareness ($\beta = .79$).

We also examined invariance between participants who were $\leq$ 16 years of age, and those > 16 years old, and confirmed it in terms of measurement weights ($\Delta \chi 2$ (9) =

6.08, p = .73), structural weights (Δ χ2 (11) = 11.32, p = .41), structural covariances (Δ χ2 (12) = 11.51, p = .48), and structural residuals (Δ χ2 (15) = 18.32, p = .24). However, there was no invariance at the level of measurement residuals (Δ χ2 (27) = 46.91, p < .05), where the constrained model fitted significantly worse than the unconstrained model. Since residuals are not part of the latent constructs, lack of measurement residuals has been considered inconsequential (Vandenberg & Lance, 2000). Residual indicator variance has two sources: random measurement error and specific variance (Little, 2013). To expect random measurement error across groups to be equal has been considered not very reasonable (Kline, 2016), and to identify an explanation of the age specific residual variance is out the scope of the present manuscript.

Relationship of the SRHI with physical activity and snacking behaviours

Relationships between behaviour and either the SRHI or parts of it have been reported previously as evidence of convergent validity (Verplanken and Orbell, 2003; Gardner et al., 2012). In this study, the association of each of the SRHI dimensions with self-reported behaviour, as well as with the second order habit construct were examined.

In our data, weekly frequency of vigorous physical activity had a correlation of *r* = .51 (*p* < .001) with the construct of history of behavioural repetition, a correlation of *r* = .47 (*p* < .001) with lack of control, and a correlation of *r* = .37 (*p* < .001) with lack of awareness. The correlation of the habit of physical activity (second order factor) with physical activity behaviour was *r* = .57 (p < .001).

For snacking behaviour, there was a correlation of $r = .50$ ($p < .001$) with history of behavioural repetition, a correlation of $r = .25$ ($p < .001$) with lack of control, and a correlation of $r = .42$ ($p < .001$) with lack of awareness. The correlation of the habit of snacking (second order factor) with snacking behaviour was $r = .50$ ($p < .001$).

Does the second order model equally fit for snacking and physical activity habits?

Constraints were set to check whether, at different levels, the hierarchical second-order model fitted the data well for both habits. Table 6 summarizes the results.

Insert Table 6 over here

When no constraints were set between habits, the model fit well. Progressively equal constraints were set between habits for factor loadings (measurement weights), intercepts, structural weights, structural covariances, structural residuals, and measurement residuals. In the most restrictive model, the RMSEA was still acceptable, although with a worse fit than the other models. The unconstrained model had a better fit than the measurement weights model ($\Delta \chi 2$ (9) = 59.81, $p < .001$), the measurement intercepts model ($\Delta \chi 2$ (21) = 369.87, $p < .001$), structural weights model ($\Delta \chi 2$ (23) = 387.36, $p < .001$), structural covariances model ($\Delta \chi 2$ (24) = 387.44, $p < .001$), structural residuals model ($\Delta \chi 2$ (27) = 433.846, $p < .001$), and the measurement residuals model ($\Delta \chi 2$ (39) = 467.417, $p < .001$).

Thus, we examined the model for partial invariance. Those loadings and intercepts with the largest differences between habits were not constrained and then partial invariance by means of a non-significant $\Delta\chi 2$ was examined, as suggested by Van de Schoot, Lugtig, and Hox (2012). The loadings of items 11, 6, and 9, and the intercepts

of items 4, 9, 1, 2, 3, 7, 10 presented differences between the snacking data and the physical activity data that contributed to changes in fit as reflected in the chi square difference test. All the items from the dimension of lack of control as well as 3 out of 4 items from the dimension of history of behavioural repetition and 3 out of 5 items from the dimension of lack of awareness were not invariant either in their factor loadings or in their intercepts. Only items 5, 8, and 12 ("*Behaviour x is something ...I do without thinking, ...I start doing before I realize I'm doing it, ...I have been doing for a long time*") were equal between snacking and physical activity in their loadings and intercepts (scalar invariance). This suggests that the meaning of most items is different in these two habits, and the overall SRHI for both behaviours is not completely comparable. Constraints in the structural weights from the dimensions of lack of control and the lack of awareness had to be released in order to obtain a non-significant $\Delta\chi$ 2 between the configural model and the structural weights model.

Discussion

Our findings suggest that the SRHI is multi-dimensional, and not one-dimensional as originally reported by Verplanken and Orbell (2003), or even more recently by Morean et al (2018). We believe that the difference in findings might be due to a different statistical approach, and to the use of a modified number of items, that may not reflect the structure of the original instrument. In our study, we used a nested model approach with data from the original 12 items, and we found that the first-order CFA models with three dimensions for both snacking and physical activity habits presented better fit than models with one or two dimensions.

Moreover, these three dimensions could be indicators of habit as a construct. Our analyses suggest that habit consists of a history of behavioural repetition, lack of awareness/automaticity, and lack of control. This three-dimensional model fits the data better for both habits than the other solutions tested, although the lack of scalar invariance shows that the meaning of the SRHI as applied to physical activity was not equivalent to the meaning of the SRHI as applied to snacking. This difference should not be surprising, since snacking and physical activity may be experienced as different in terms of their cultural meaning, the topography of the behaviours associated to them, and the physiological mechanisms and effects of them (Bherer, 2015; McGannon & Smith, 2015; Rozin, 2005; Wouters, Jacobs, Duif, Lechner, & Thewissen, 2018).

In this article, we have also reported the association of these dimensions with self-reported behaviours, which offers evidence of convergent validity. The invariance found by age suggests it can be used in different age groups. Only residual invariance was not confirmed, but the assumption that random measurement error must be equal between groups has been considered not very reasonable (Kline, 2016).

Considering this lack of invariance between snacking and physical activity habits, as well as the discriminant validity concerns that rose for the case of the SRHI as applied to physical activity, it is plausible that different versions of the SRHI should be developed for different habits, or perhaps even different measurement models should be estimated for different habits. This may have implications not only for habit measurement, but also for theory development. This option should be considered given our findings on fit, particularly for the snacking version of the SRHI, which obtained a non-satisfactory fit

(RMSEA = .09). Nevertheless, we consider our findings to support the notion that three dimensions is a better solution than the other models.

Overall, evidence of age-related invariance was found. However, residual invariance was not confirmed. The requirement of reaching residual invariance is controversial (Little, 2013), although future research may try to identify residual specific age-related causes of variance for the SRHI.

The specific roles of each of the three SRHI dimensions reported in this manuscript might be further studied. Would baseline levels of the perceived lack of control moderate a self-regulatory intervention for changing snacking behaviours? Would lack of control play a relevant role in maintenance of a regular performance of physical activity? Would a consciousness raising intervention for individuals with high lack of awareness better address their needs for behaviour change? In addition, is it more difficult, longitudinally, to develop lack of awareness and lack of control for physical activity than for dietary behaviours? Further research is required to adequately answer to these questions.

Limitations

Because the SRHI is a self-report measure of habits, some study limitations must be considered. First, the very nature of habits makes them difficult to access consciously, and so habit reports may be biased due to recall inaccuracies. Therefore, inferences of specific habits from the SRHI scores should be made with caution. Objective measures

could be used for criterion validity and further examination of both the general habit construct and any of its dimensions.

The association of some components of the SRHI to objective measures has been estimated previously. For instance, what we called here “lack of awareness”, has been correlated, under the label of “automaticity”, with attentional bias (Orbell & Verplanken, 2010). In some specific circumstances, attentional bias may favour cognitive efficiency, which, as stated in the introduction, is not directly measured by the SRHI, but can be theoretically related to lack of awareness. Other associations with objective measures or cognitive tasks may be tested.

Last, caution is warranted with regards to generalization of findings, because the diversity of the study participants characteristics is somewhat limited (e.g., age, sex, residence area). Therefore, this study should be replicated in different samples to confirm the dimensionality of the SRHI for snacking and physical activity, just like for other habits.

Conclusion

This study suggests that the three-dimensional model is a better fit to the data than one and two-dimensional models when SRHI is applied to physical activity and snacking. History of behavioural repetition, lack of control, and lack of awareness appeared as dimensions or indicators of the higher order factor of habit. However, some changes to the SRHI could be made to improve fit to data from specific habits, and address validity concerns. This could be done in future research.

Overall, there was invariance of the 12 items SRHI results between younger and older participants for both physical activity and snacking habits. Each dimension, as well as habit as a second order factor, was correlated with self-reported behaviour. Although the SRHI for both, snacking and physical activity habits, show similar results in terms of dimensionality, no scalar invariance between them was found, suggesting that for respondents the items differ in meaning depending on the target habit.

The SRHI must be used and interpreted with caution, since further studies on its properties are needed.

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606 Table 1. *Items and hypothesized dimensions of the Self Report Habit Index*

Dimensions	Items
	Stem: Behaviour X is something . . .
(Di1) History of behavioural repetition	1. …I do frequently. 7. …that belongs to my (daily, weekly, monthly) routine. 11. …that's typically "me." 12. …I have been doing for a long time.
(Di2) Lack of awareness	2. …I do automatically 3. …I do without having to consciously remember. 5. …I do without thinking. 8. …I start doing before I realize I'm doing it. 10. …I have no need to think about doing.
(Di3) Lack of control	4. …that makes me feel weird if I do not do it. 6. …that would require effort not to do it. 9. …I would find hard not to do.

607 Note: in the two dimensions alternative items mentioned in this table to belong to "lack if awareness" and
608 "lack of control" become together under the assumed dimension of "automaticity".

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Table 2. *Zero-order correlations, means, and standard deviations for snacking SRHI items*

Item	1	2	3	4	5	6	7	8	9	10	11	12
1												
2	.701***											
3	.583***	.767***										
4	.375***	.394***	.370***									
5	.480***	.678***	.741***	.402***								
6	.392***	.409***	.382***	.541***	.382***							
7	.618***	.610***	.562***	.449***	.536***	.446***						
8	.380***	.555***	.617***	.372***	.703***	.382***	.472***					
9	.395***	.415***	.407***	.588***	.406***	.792***	.451***	.393***				
10	.454***	.573***	.643***	.382***	.637***	.409***	.511***	.673***	.396** *			
11	.691***	.668***	.611***	.442***	.564***	.453***	.704***	.488***	.498** *	.575***		
12	.640***	.603***	.501***	.405***	.471***	.513***	.666***	.420***	.491** *	.484***	.738***	
Mean	4.07	3.49	3.22	2.44	3.15	3.08	3.29	2.95	2.93	2.99	3.63	3.93
(SD)	(2.06)	(2.18)	(2.11)	(1.92)	(2.18)	(2.25)	(2.15)	(2.08)	(2.15)	(2.10)	(2.28)	(2.32)

Note: *** p. < .001

Table 3. *Fit Indices for the SRHI in the Snacking Habit*

	One-Factor model	**Two-Factor model**	**Three-Factor model**
Chi square	χ^2 (56) = 1168.890	χ^2 (54) = 917.180	χ^2 (51) = 316.241
Chi square/df	20.873	16.985	6.201
CFI	.76	.81	.94
TLI	.72	.77	.92
RMSEA	.19, 90% CI [.18-.20]	.17, 90% CI [.16-.18]	.09, 90% CI [.08-.10]

Table 4. *Zero-order correlations, means, and standard deviations for physical activity SRHI items*

Item	1	2	3	4	5	6	7	8	9	10	11	12
1												
2	.563***											
3	.554***	.603***										
4	.497***	.329***	.380***									
5	.457***	.562***	.605***	.348***								
6	.443***	.365***	.386***	.519***	.404***							
7	.732***	.523***	.521***	.470***	.442***	.465***						
8	.341***	.461***	.426***	.279***	.523***	.363***	.359***					
9	.585***	.441***	.461***	.586***	.415***	.551***	.588***	.385***				
10	.401***	.479***	.529***	.280***	.573***	.428***	.446***	.512***	.411***			
11	.674***	.530***	.575***	.538***	.464***	.503***	.685***	.387***	.633***	.492***		
12	.668***	.472***	.478***	.503***	.406***	.473***	.714***	.332***	.551***	.411***	.728***	
Mean	4.57	3.97	3.69	3.90	3.51	3.27	4.68	3.03	3.58	3.40	3.93	4.20
(SD)	(2.06)	(2.10)	(2.13)	(2.31)	(2.10)	(2.11)	(2.32)	(1.98)	(2.12)	(2.00)	(2.13)	(2.33)

Note: *** $p < .001$

627 Table 5. *Fit Indices for the SRHI in the Physical Activity Habit*

	One-Factor model	**Two-Factor model**	**Three-Factor model**
Chi square	χ^2 (56) = 563.252	χ^2 (54) = 405.126	χ^2 (51) = 169.213
Chi square/df	10.058	7.502	3.318
CFI	.86	.91	.97
TLI	.84	.88	.96
RMSEA	.13, 90% CI [.12-.14]	.11, 90% CI [.10-.12]	.06, 90% CI [.05-.07]

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Table 6. *Model fit at different invariance levels*

	Chi square	CFI	TLI	RMSEA
Unconstrained	χ^2 (102) = 485.462	.95	.94	.058, 90% CI [.053-.074]
Measurement weights	χ^2 (111) = 545.279	.95	.94	.059, 90% CI [.054-.074]
Measurement intercepts	χ^2 (123) = 855.338	.91	.91	.073, 90% CI [.069-.078]
Structural weights	χ^2 (125) = 872.820	.91	.91	.073, 90% CI [.069-.078]
Structural covariances	χ^2 (126) = 872.909	.91	.91	.073, 90% CI [.069-.078]
Structural residuals	χ^2 (129) = 919.308	.91	.90	.074, 90% CI [.070-.079]
Measurement residuals	χ^2 (141) = 1002.869	.90	.90	.074, 90% CI [.070-.079]

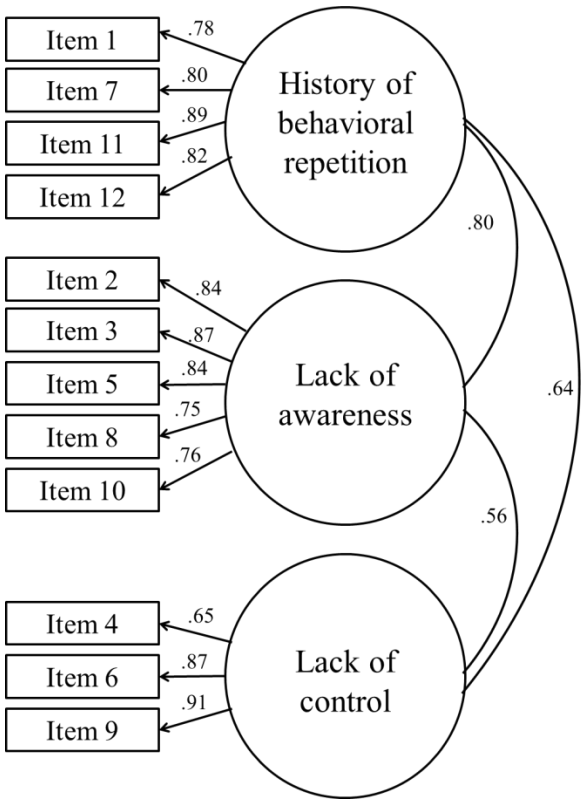

Figure 1. Note. Standardized coefficients. All factors loadings and correlations are significant at the level $p < .001$. N = 555. Composite reliability is 0.89 for History of Behavioral Repetition (AVE = 0.68), 0.90 for Lack of Awareness (AVE = 0.66), and 0.85 for Lack of Control (AVE = 0.66).

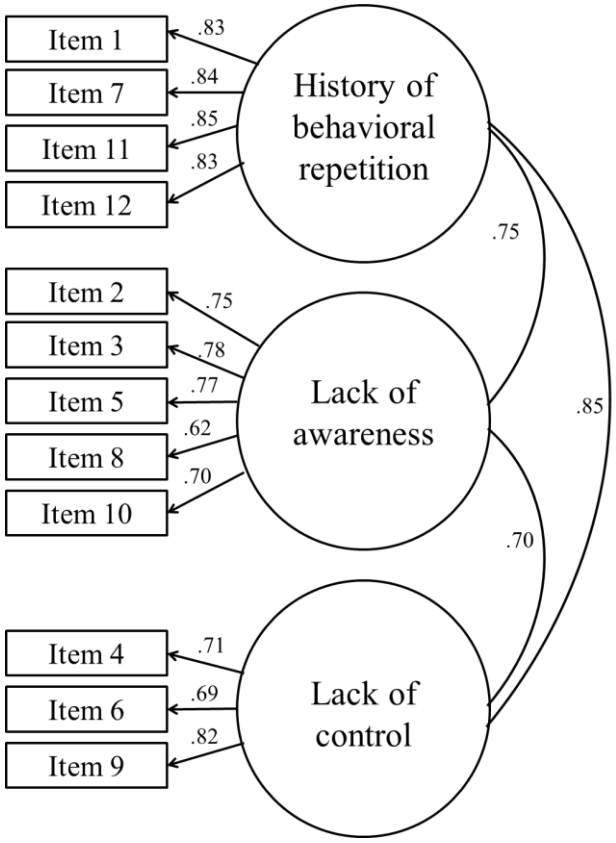

Figure 2. Standardized factor loadings and standardized errors for the error variances. All factors loadings and correlations are significant at the $p < .001$ level. N = 555. Composite reliability is 0.90 for History of Behavioral Repetition (AVE = 0.70), 0.84 for Lack of Awareness (AVE = 0.53), and 0.78 for Lack of Control (AVE = 0.55).