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Cross-Sectional and Prospective Associations between Stress, Perseverative Cognition and Health Behaviours

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Abstract

Objectives: The Perseverative Cognition Hypothesis (proposing negative repetitive thinking has detrimental effects on physical health), has been extended to include health behaviours. This study aimed to examine relationships between perseverative cognition, stress and health behaviours.

Design: Participants (n = 336) completed online surveys twice, 3 months apart.

Main Outcome Measures: Cross-sectional and prospective associations between perseverative cognition (worry, brooding and reflection), stress and health behaviours (sleep, diet, physical activity and alcohol).

Results: Analyses demonstrated associations between worry, brooding and reflection and health behaviours, cross-sectionally and prospectively, including sleep and unhealthy snacking. Adding perseverative cognition variables to models simultaneously, only two associations remained (brooding and unhealthy snacking, worry and poorer sleep quality). Controlling for stress, only the cross-sectional association between brooding and more unhealthy snacking remained significant and no significant interactions with stress were found.

Conclusion: This study evidences associations between components of perseverative cognition and health behaviours cross-sectionally and prospectively.

Key words: perseverative cognition, worry, brooding, reflection, stress, health behaviours

Introduction

Research demonstrates an association between stress and reduced health status (O'Connor, Thayer & Vedhara, 2020). For instance, stress has been identified as a risk-factor in the development of atherosclerosis and as an acute trigger of cardiac events (Steptoe & Kivimäki, 2012), the accumulation of visceral fat (Marniemi et al., 2002), as well as increased cellular aging and chronic disease and shorter life-span (Epel, 2009). Evidence also suggests a behavioural pathway between stress and disease via health behaviours. For instance, evidence supports indirect pathways from stress to sleep (Kim & Dimsdale, 2007) to poorer general, cardiovascular, metabolic, mental and immunologic health as well as greater experience of pain and greater overall rates of mortality (Watson et al., 2015); from stress to alcohol consumption (Grzywacz & Almeida, 2008; Pratt & Davidson, 2009) to increased risk of cancer and cancer-related death (Praud et al., 2016); and from daily stressors to increased between-meal consumption of high fat and high sugar foods (Conner, Fitter & Fletcher, 1999; O'Connor, Jones, Conner, McMillan & Ferguson, 2008) to increased body weight and poorer metabolic outcomes (Duffey, Gordon-Larsen, Steffen, Jacobs Jr, & Popkin, 2009; Pereira et al., 2005).

Perseverative Cognition and Health

Perseverative cognition is the cognitive representation of past stressful events (rumination) or feared future events (worry). The Perseverative Cognition Hypothesis (Brosschot, Gerin, & Thayer, 2006) proposes that, where the physical stressor is absent, the cognitive representation alone induces the physiological stress response. Moreover, when stress is perseverated upon, the damaging physiological activation associated with stress is also protracted, increasing susceptibility to stress-related ill-health. In this sense, the direct relationship between stress and disease is intensified when a stressor is subject to repetitive

thought, as the duration of time that the body is exposed to the damaging physiological stress response is prolonged (for meta-analytic support, see Ottaviani et al., 2016).

In an extension to the Perseverative Cognition Hypothesis, Clancy, Prestwich, Caperon, and O'Connor (2016) proposed additional indirect pathways between perseverative cognition and health outcomes via health behaviours. Little consideration has been given to the relationship between measures of perseverative cognition and health behaviours but, given that research has demonstrated a link between perseverative cognition and physiological parameters associated with the stress response, it is also possible that, as the experience of the stressor is prolonged by worry or ruminative processes, so too may be its detrimental impact on health behaviours.

Rumination can be conceptualized as having both a harmful and an adaptive component: brooding and reflection respectively, though the two tend to be highly related (Segerstrom, Stanton, Alden, & Shortridge, 2003). Treynor, Gonzalez and Nolen-Hoeksema (2003) provided evidence that brooding is the more maladaptive component of rumination as brooding predicted symptoms of depression one year later, whereas, although reflection predicted current depression, it predicted lower levels of depression over time. Although worry has been described as a problem-solving strategy (Brosschot et al. 2006), it has not been reported to have an adaptive component. Providing some evidence that different types of perseverative cognition can be distinguished based on different patterns of associations with health behaviours, Clancy et al.'s (2016) meta-analysis found associations between brooding (but not worry or reflection) and health risk behaviours (e.g. unhealthy eating and substance use). None of these types of perseverative cognitions were associated with health-promoting behaviours (e.g. physical activity and healthy eating). This is somewhat inconsistent with meta-analytic evidence showing negative associations between worry and health outcomes (Ottaviani et al., 2016). However, Clancy et al.'s review comprised of

relatively few studies (k = 19) and only two studies investigated worry that was not specifically-related to health. Health worry may influence behaviour differently to general worry because health worry (instigated through threatening communication, for example) may boost health behaviours, especially with low self-efficacy and response efficacy (Kok, Peters, Kessels, Ten Hoor, & Ruiter, 2018). In a subsequent meta-analysis, Clancy, Prestwich, Caperon, Tsipa and O'Connor (2020), reported significant small- to medium-sized associations between both worry and rumination and poorer quality sleep, shorter sleep duration and longer sleep onset latency.

Despite some support for an association between perseverative cognition and health behaviours (Clancy et al., 2016; Clancy et al. 2020), there are a number of important issues that remain unresolved. First, from these reviews, it is unclear whether perseverative cognitions are directly associated with health behaviours or whether they simply serve to intensify the association between stress and health behaviours, but are not associated with health behaviours in the absence of stress. It is therefore important to empirically test whether the association between perseverative cognition and health behaviours is still apparent when stress is included in the analytical model and whether perseverative cognition moderates the association between stress and health behaviours. Second, as noted above, the number of studies testing the associations between perseverative cognition and health behaviours (apart from sleep) is relatively few which make it difficult to establish firm conclusions given the different types of perseverative cognition and range of health behaviours. For instance, given that reflection can be considered a more adaptive component of rumination, there is reason to theorise that it may relate differently to health behaviours than worry or brooding, perhaps motivating positive health behaviours. However, in Clancy et al.'s (2016) review, reflection was not associated with either health-promoting or health-risk behaviours. More studies assessing the association between perseverative cognition (worry, brooding and reflection)

and stress-sensitive health behaviours are needed. Third, few studies included in the Clancy et al. (2016) review employed validated measures of perseverative cognition and longitudinal designs were limited in both meta-analytic reviews. Fourth, it is unknown, when considered together, which components of perseverative cognition emerge as the strongest predictors of health behaviours. Understanding the predictive utility of one type of perseverative cognition whilst controlling for other types would enable researchers designing interventions to target the most appropriate component of perseverative cognition for each behaviour. Alternatively, if types of perseverative cognition additively predict the behaviour (i.e. more than one type of perseverative cognition remains significant), then intervention studies could target them in combination.

The current study addressed these key limitations. The cross-sectional and prospective associations between stress, perseverative cognition (worry, brooding and reflection) and health risk (unhealthy snacking and alcohol) and health promoting (physical activity, fruit and vegetable intake, sleep) behaviours at 0 months (Time 1) and 3 months (Time 2) were investigated using, where possible, validated measures. Moreover, the moderating role of the different types of perseverative cognition in stress-health behaviour relations was considered, as well as the predictive utility of each component of perseverative cognition (worry, brooding and reflection) were considered simultaneously within the same model. Considering perseverative cognition predictors simultaneously is important from an intervention perspective, in order to understand the unique variance explained in health behaviours by each type of perseverative cognition. Note that directional predictions were not made in relation to reflection given that there is limited evidence in this area and there is the potential for it to relate negatively to health behaviours, given that it is a type of perseverative cognition, or positively, given that it is a potentially adaptive form of perservative cognition.

Hypotheses

I. A) Worry and B) brooding will be positively associated with health-risk behaviours and negatively associated with health-promoting behaviours at both time-points.

II. Reflection will be associated with health-risk behaviours and health-promoting behaviours at both time-points.

III. A) Worry and B) brooding will be positively associated with health-risk behaviours and negatively associated with health-promoting behaviours at both time-points, when stress is included in the analytical model.

IV. Reflection will be associated with health-risk behaviours and health-promoting behaviours at both time-points when stress is included in the analytical model.

V. Positive associations between Time 1 stress and Time 1 health-risk behaviours, and negative associations between Time 1 stress and Time 1 health-promoting behaviours, will be moderated by A) worry and B) brooding such that these associations will be stronger at higher levels of worry and brooding.

VI. Positive associations between Time 1 stress and Time 1 health-risk behaviours and negative associations between Time 1 stress and Time 1 health-promoting behaviours will be moderated by reflection.

VII. Positive associations between stress change and change in health-risk behaviours (from Time 1 to Time 2), and negative associations between stress change and change in health-promoting behaviours (from Time 1 to Time 2), will be moderated by A) worry and B) brooding with stronger associations at higher levels of worry and brooding.

VIII. Positive associations between stress change and change in health-risk behaviours (from Time 1 to Time 2), and negative associations between stress change and change in health-promoting behaviours (from Time 1 to Time 2) will be moderated by reflection.

IX. Worry, brooding and reflection will additively predict unique variance in Time 1 health-risk behaviours and health-promoting behaviours, and in the change in health-risk and health-promoting behaviours (from Time 1 to Time 2).

Method

Participants

Five hundred and sixty-two participants (79% female; 88% British; 81% of White ethnicity; 52% students; mean age = 27.7 years (SD = 10.4); mean BMI = 23.8 (SD = 5.4)) were recruited via posters and participant databases at the university, social media, and Call for Participants and Prolific Academic websites and subsequently completed the baseline (Time 1) survey. Of these, 336 completed the follow-up (Time 2) survey (80% female; 90% British; 81% of White ethnicity; 48% students; mean age = 28.6 (SD = 10.5); mean BMI = 24.1 (SD = 5.5)), representing a 40% attrition rate, Participants were not eligible for the study if they were under 16, not resident in the United Kingdom or if they were not fluent in English. Participants received a £5 voucher or study credits after completing both surveys, although those recruited through Prolific Academic were paid £2.50 after each survey due to website rules.

Design

A longitudinal survey design was employed in which all variables (aside from trait variables) were measured at Time 1 and then again at 3-month follow-up (Time 2). Trait variables (worry, brooding and reflection) were only measured at Time 1 as these were expected to remain stable over time. Participants completed measures of predictor variables (worry, brooding, reflection, stress and demographics) prior to outcome variables (unhealthy snacking, fruit and vegetable consumption, physical activity, alcoholic drinks and sleep).

Measures

Unless indicated, high scores represented higher levels of the particular construct. Reported Cronbach's alphas are from the current study.

Perseverative Cognition

Worry (α = .94) was measured using the previously validated (van Rijsoort, Emmelkamp, & Vervaeke, 1999) 16-item Penn State Worry Questionnaire (Meyer, Miller, Metzger, & Borkovec, 1990). Items, rated on a 5-point scale (1 = 'not at all typical of me', 5 = 'very typical of me'), included 'my worries overwhelm me' and 'many situations make me worry'. The tendency towards brooding (α = .81; items include 'think 'what am I doing to deserve this?') and reflection (α = .80; items include 'go away by yourself and think about why you feel this way') when feeling down, sad or depressed, were each measured using 5 items from the Ruminative Responses Scale (Treynor et al., 2003). Responses options included 'almost never', 'sometimes', 'often' and 'almost always'. Previous research supports the two-factor model (brooding and reflection) and found them to be differentially predictive of depression (Treynor et al., 2003).

Stress

Perceived stress in the past month (Time 1, α = .89; Time 2, α = .90) was measured using the 10-item Perceived Stress Scale (Cohen, 1988) which has been validated previously (Roberti, Harrington, & Storch, 2006). Items included 'in the last month, how often have you felt difficulties were piling up so high that you could not overcome them?' and 'in the last month, how often have you been upset because of something that happened unexpectedly?' Responses range from 0 ('never') to 4 ('very often').

Unhealthy Snacking

Ten types of unhealthy snack foods (sugared squash/still soft drinks (not including fruit juice); sugared fizzy drinks; sausages, pies or burgers; chips, potato crisps; savoury

snacks; ice cream; cakes/other sweet pastries; sweet biscuits; chocolate confectionary and sugared confectionary) were listed and participants were asked to indicate the frequency of consuming these particular snacks in the past month ('never', 'less than once a month', 'less than once a week', 'once a week', '2-4 days a week', '5-6 days a week', 'once a day, everyday', '2-3 times a day, everyday', 'more than 3 times a day. Everyday'). Brown, Ogden, Vogele, and Gibson (2008) used this measure in children, but the food types and response options were deemed equally applicable to self-report in adults here. Responses were coded 0-9 and summed (Time 1, $\alpha = .79$; Time 2, $\alpha = .78$). This measure was also adapted for use in adults by Cropley, Michalianou, Pravettoni, and Millward (2012).

Fruit and Vegetables

Fruit and vegetable consumption were measured using a quantity-frequency measure created for this study. Participants were asked (in separate items), in a typical week in the past month, how many days each week they ate fruit and vegetables. Responses options ranged from 0-7 days. They were then asked (again in separate items) how many portions of fruit and vegetables they consumed on days when they did eat fruit and vegetables. A link to a website (http://www.nhs.uk/Livewell/5ADAY/Pages/Portionsizes.aspx) explaining portion sizes was provided. The number of days that each fruit and vegetable was eaten was multiplied by the portions of each fruit and vegetable typically eaten on these days to indicate the portions of fruit and vegetables eaten in a typical week in the past month.

Physical Activity

The Leisure Time Exercise Questionnaire (Godin & Shephard, 1985) validated in healthy adults, assessed physical activity. Participants were asked how many times per week, in a typical 7-day period in the past month, they engaged in various activities for more than 15 minutes in their free time. The categories were 'strenuous exercise (heart beats rapidly)', 'moderate exercise (not exhausting)' and 'mild exercise (minimal effort)'. Example activities

were provided but some of the suggested example activities were removed due to expected lack of relevance to the sample (e.g. yodelling). As per the original scoring instructions, the number of weekly episodes of strenuous activity was multiplied by 9, moderate activity was multiplied by 5 and light activity was multiplied by 3. These products were then summed to produce a weekly exercise score. Participants were also asked to indicate how often in the same time-period they engaged in any regular activity long enough to work up a sweat. Responses options were 'often', 'sometimes' or 'never/rarely' (coded 1-3). This was reverse scored and added to the weekly exercise score to estimate total physical activity.

Alcoholic Drinks

A quantity-frequency measure of alcohol consumption, adapted from Stockwell et al. (2004), asked participants how often they drank in the past month ('everyday', '5-6 days per week', '3-4 days per week', '1-2 days per week', '2-3 days per month', 'about one day a month', 'less often', 'don't drink' or 'prefer not to say') and how many standard drinks they usually had on days when they were drinking ('13 or more drinks', '11-12 drinks', '7-10 drinks', '5-6 drinks', '3-4 drinks', '1-2 drinks', 'didn't drink' or 'prefer not to say'). From this, weekly drinking was estimated. A link was provided explaining what a standard drink represents (http://www.drinkaware.ie/facts/what-is-a-standard-drink).

Sleep

Three single sleep items were taken from the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989): sleep onset latency, total sleep time in hours and minutes and a rating of sleep quality ('very good' = 1, 'fairly good' = 2, 'fairly bad' = 3, 'very bad' =4). These questions referred to 'the majority of days and nights in the past month'. Higher scores refer to longer sleep onset latency, more sleep time and lower levels of sleep quality. The Pittsburgh Sleep Quality Index has shown good test-retest reliability and to be predictive of sleep log data (Backhaus, Junghanns, Broocks, Riemann, & Hohagen, 2002).

Procedure

Participants accessed a link to the online survey. In the first survey, participants read study information, consented and then provided their demographic details (e.g., age, sex, height, weight and education). The following measures were then completed in the following order: worry, brooding and reflection, perceived stress in the past month, sleep duration, sleep onset latency, sleep quality, physical activity, snack food intake, fruit and vegetable consumption and alcohol. At Time 2, participants were contacted by email with a link to the second survey. The same health behaviours were measured in the same order and participants were debriefed at the end. The surveys were completed from June 2016 to January 2017. Ethical approval was granted by a university ethics committee (Ethics number: 16-0158, date of approval 02.06.16).

Method of Analysis

All analyses were conducted using SPSS software. Correlational analyses assessed whether worry, brooding and reflection were associated with health behaviours and health outcomes cross-sectionally and prospectively. A series of multiple regression analyses (using the enter method), conducted separately for worry, brooding and reflection, tested whether perseverative cognition predicted health behaviours cross-sectionally (before and after controlling for stress), and whether they moderated associations between stress and health behaviours. Equivalent longitudinal analyses were conducted with baseline behaviour added as a covariate and stress change (Time 2 stress subtracted from Time 1 stress) across the two time-points as the predictor being moderated by the perseverative cognition constructs (measured at Time 1). To assess whether components of perseverative cognition predicted unique variance in Time 1 and 2 health behaviours, worry, brooding and reflection were entered simultaneously into further cross-sectional and longitudinal multiple regressions

(which we term 'competition models'). Note that regression models were not adjusted for any of the measured demographic variables.

Due to the large number of analyses, a Bonferroni correction was applied to reduce the type 1 error rate. This consisted of dividing the alpha level by the number of comparisons (Haynes, 2013). Outcomes which would typically be considered significant ($p < .05$) were not interpreted as such here unless they met the corrected alpha level. Alphas were corrected per block of analyses (i.e. each set of analyses had 7 outcomes, so 0.05/7 = .007). Therefore, .007 was the corrected alpha level and outcomes were considered significant if $p < .007$.

Results

MANOVA on continuous Time 1 variables identified differences between those who completed both surveys (completers) and those who only completed survey 1 (drop-outs), $F(14, 465) = 1.87$, $p = .03$. Main effects of completion status were found on age (completers: $M = 28.62$, $SD = 10.50$; drop-outs: $M = 26.35$, $SD = 10.10$), $F(1, 469) = 4.08$, $p = .04$), worry (completers: $M = 56.90$, $SD = 14.32$; drop-outs: $M = 55.29$, $SD = 13.87$), $F(1, 469) = 4.20$, $p = .04$), and fruit and vegetable consumption, (completers: $M = 29.06$, $SD = 20.30$; drop-outs: 32.16, $SD = 26.21$, $F(1, 469) = 4.72$, $p = .03$), but not on BMI, brooding, reflection, stress, sleep onset latency, total sleep time, sleep quality, physical activity or alcohol. For categorical Time 1 variables (sex, nationality, ethnicity, employment status and education), chi-square analyses revealed no significant differences between completers and drop-outs ($p > .05$).

The percentage of missing data was analysed across Time 1 and Time 2. Missing value analysis was conducted on the full dataset before totals had been computed. Less than 1% of data was missing overall at both time points. An expectation maximization chi-square test (Little, 1988) was non-significant at Time 1 (all participants), χ^2 ($df = 3201$) = 3227.42, $p = .37$, and Time 2 (completers only), χ^2 ($df = 5384$) = 5494.33, $p = .14$, indicating data was

missing completely at random. Listwise deletion was subsequently used as method of dealing with missing data which would not substantially increase bias in the estimates over other methods (Kang, 2013).

Hypotheses I-II: Perseverative cognition will be associated with health behaviours

Descriptive statistics and Pearson's correlations between the study variables are reported in Table 1. As correlations between worry, brooding and reflection measures were not high (all are below .7), analysing these variables as individual predictors was justified.

In support of Hypothesis IA, worry was significantly correlated with poorer sleep quality at Time 1, $r = .25$, $p < .001$, and 2, $r = .24$, $p < .001$, and more unhealthy snacking at Time 1, $r = .17$, $p < .001$, and 2, $r = .17$, $p = .002$. However, worry was not significantly correlated with sleep onset latency, total sleep time, physical activity, fruit and vegetable intake or alcohol consumption at Time 1 or 2.

In support of Hypothesis IB, brooding was significantly correlated with longer sleep onset latency at Time 1, $r = .15$, $p < .001$, and 2, $r = .19$, $p < .001$, poorer sleep quality at Time 1, $r = .21$, $p < .001$, and 2, $r = .23$, $p < .001$, and more unhealthy snacking at Time 1, $r = .24$, $p < .001$, and 2, $r = .20$, $p < .001$. However, brooding was not significantly correlated with total sleep time, physical activity or fruit and vegetable and alcohol consumption at either time-point.

In support of Hypothesis II, reflection was significantly associated with longer sleep onset latency $r = .16$, $p < .001$, and sleep quality at Time 1, $r = .15$, $p < .001$. However, reflection was not significantly correlated with sleep onset latency or sleep quality at time 2, or total sleep time, physical activity or fruit and vegetable and alcohol consumption at either time-point.

[insert Table 1]

Hypotheses III-IV: Perseverative cognition will predict health behaviour when controlling for stress

Hypothesis IIIA was not supported as, when stress was included in the models, worry no longer significantly predicted any health behaviour outcomes. *In support of Hypothesis IIIB,* brooding, still predicted more unhealthy snacking at Time 1, $\beta = .24$, $p < .001$, when stress was included in the model (see Table 2), however brooding did not predict any outcomes prospectively (see Table 3). *There was also no support for Hypothesis IV* as reflection did not predict any health behaviour outcomes at Time 1 when stress was included in regression models, nor did reflection predict any health behaviour outcomes at Time 2 when stress change was included.

As there was a 40% attrition rate, it is therefore possible that the results presented in Table 3 may have a degree of potential selection bias in the follow-up sample, and that drop-out is non-random. As a sensitivity analysis to check that the OLS estimates in prospective analyses (Table 3) are not a reflection of any such bias, we estimated Heckman two-step selection models (Heckman, 1979) in Stata 13 for each of the final steps in the OLS regression is Table 3. Overall, there was a 98% level of replication for both the direction and significance of individual effects. Thus, overall, the pattern of results in Table 3 replicates when potential selection bias is modelled.

[insert Tables 2 & 3]

Hypotheses V-VIII: Perseverative cognition will moderate stress-health behaviour associations cross-sectionally and prospectively

There were no significant interactions between worry and stress, brooding and stress, or between reflection and stress on any health behaviour outcomes, at either time point, offering *no support for Hypothesis VA, VB and Hypothesis VI respectively*.

Hypothesis IX: Worry, brooding and reflection will additively predict unique variance in behaviour

Hypothesis IX received little support. More than one type of perseverative cognition was not simultaneously significant, explaining unique portions of variance in behaviour in an additive fashion in cross-sectional (see Table S1) or prospective (see Table S2) analyses. There were instances, however, where one type of perseverative cognition was significant after controlling for other types of perseverative cognition. Higher levels of brooding, $\beta = .27$, $p < .001$, but not worry or reflection, predicted more unhealthy snacking at Time 1, and predicted sleep onset latency at Time 2, $\beta = .19$, $p = .006$, when stress was included in the model. At Time 1, worry, but not brooding or reflection, predicted poorer sleep quality $\beta = .21$, $p < .001$, but this was no longer significant when stress was included in the model.

Discussion

In this study, somewhat consistent with Hypotheses I and II, worry, brooding and reflection were each associated with health behaviour outcomes. However, when added into models with stress, only associations between brooding and unhealthy snacking remained, providing limited supported for Hypothesis III-IV. There was no evidence to suggest that perseverative cognition moderates the relationship between stress and health behaviour, cross-sectionally or prospectively (Hypotheses V, VI, VII and VIII). Different types of perseverative cognition did not additively predict health behaviour, failing to support Hypothesis IX.

This study has provided novel evidence of associations between components of perseverative cognition and some stress-sensitive health behaviours both cross-sectionally and prospectively. Clancy et al. (2016), in their systematic review, categorised behaviours into health-risk or health-promoting categories, rather than considering behaviours individually, due to the limited number of eligible papers. In the current study, correlational

analyses revealed that components of perseverative cognition were associated with several health behaviours both cross-sectionally and prospectively. Furthermore, this study was able to go beyond the findings of the Clancy et al. (2016) and Clancy et al. (2020) systematic reviews and meta-analyses by testing whether components of perseverative cognition were predictive of health behaviours when stress was included within analytical models and whether they moderated the association between stress and health behaviours, as was proposed by Clancy et al. (2016) in their extension to the Perseverative Cognition Hypothesis (Brosschot et al., 2006).

The findings of this study suggest that, when controlling for stress, brooding predicted more unhealthy snacking. This association also remained significant when worry and reflection were added to the model. This association is consistent with the study by Cropley et al. (2012), where an associaion was reported between work-related affective rumination and more unhealthy eating. However, as there a few studies of brooding and eating behaviour to date, it is suggested that future research aims to test the replicability of this association. The findings regarding fruit and vegetable reflect those of the Clancy et al. (2016) review and meta-analysis in which perseverative cognition was not predictive of health-promoting behaviours. The limited evidence in this area is mixed as Cropley et al. (2012) found no association between rumination and healthy food intake, including fruits and vegetables, whereas Ferrer, Bergman, and Klein (2013) found that health worry predicted higher fruit and vegetable intake. Although, as mentioned, health worry may have the potential to motivate health behaviours in a way that general worry may not.

Worry and brooding were associated with poorer sleep quality cross-sectionally and prospectively, and brooding was associated with longer sleep onset latency, cross-sectionally and prospectively. Reflection was also associated with longer time taken to fall asleep and poorer quality sleep, although only cross-sectionally. These findings are broadly consistent

with the Clancy et al. (2020) meta-analysis which reported significant small- to medium-sized associations between both worry and rumination and poorer quality sleep, shorter sleep duration and longer sleep onset latency. However, here, total sleep time was not associated with any type of perseverative cognition. In the competition model, only the association between worry and sleep quality remained significant, suggesting that this type of perseverative cognition is the stronger predictor of poor quality sleep and potentially a better intervention target. Nonetheless, all of these associations were reduced to non-significance when stress was added to the models, suggesting that targeting perseverative cognition may be less effective than stress management interventions, or interventions which target both. However, this remains to be tested. The only prospective association which remained significant when accounting for baseline behaviours and stress change was that between brooding and longer sleep onset latency, and this only met the corrected significance level in the competition model. As such, this finding is to be treated cautiously. It is suggested that future research assesses whether associations with unhealthy snacking and poorer sleep can be replicated, possibly within an experimental context to test causality.

Physical activity was not associated with any type of perseverative cognition. This reflects findings reported in the Clancy et al. (2016) review, which suggested that perseverative cognition was associated with health-risk, but not health-promoting behaviour. Likewise, neither worry, brooding or reflection predicted alcohol consumption or fruit and vegetable intake. Aldridge-Gerry et al. (2011) found that emotional rumination predicted more daily drinking but, overall, there are too few studies assessing the association between perseverative cognition and alcohol intake (especially in adults) to understand how components of perseverative cognition relate to this behaviour.

This study may have been limited by a number of factors. Firstly, levels of depression and anxiety were not measured, despite the fact that rumination has been shown to be

associated with depression (Nolen-Hoeksema, 2000) and worry is reported to be a central aspect of anxiety disorders and particularly generalized anxiety disorder (Borkovec, 1990). As such, depression and anxiety may partially account for associations perseverative cognition and health behaviours and/or be determinants or subsequent outcomes of these relations. Secondly, it is possible that by asking demographic questions prior to self-reported health behaviours, socially desirable responding may have occurred, and it is advised that future research takes this into consideration.

Finally, naturalistic studies employing multiple daily measurements and objective measures of stress and behaviour, such as that by Weise, Ong, Tesler, Kim, and Roth (2013) and Gartland, O'Connor, Lawton, and Bristow (2014), may better assess temporal associations between stress, perseverative cognition and health behaviour. Similarly, global retrospective measurements such as those employed in this study are limited by recall bias and do not adequately capture how behaviour changes across time and situations on a day-to-day basis (Shiffman, Stone, & Hufford, 2008). Future studies could employ ecological momentary assessment methodology such as daily diaries to better understand the temporal associations between these variables and overcome issues associated with global retrospective reporting, as well as provide an opportunity to utilise state measures of perseverative cognition.

It is notable that there was a lack of significant interactions between perseverative cognition variables and stress. The lack of significant interactions may reflect the problems with the measurement of worry, rumination, reflection and stress. For instance, Verkuil, Brosschot, and Thayer (2007) found that trait worry only accounted for 24% of the variance in daily worry, and Ottaviani et al. (2016) found that state and trait perseverative cognition predicted different physiological outcomes. State measures may better characterise the full extent of variations in perseverative cognition between individuals. Moreover, in this study,

the stress measure only captured perceptions of stress. Other appraisal-based measures, including measures of recent chronic stress (O'Connor & Ferguson, 2016), may yield clearer findings regarding stress and perseverative cognition interactions. In addition, of particular relevance to the longitudinal findings, there was no reason to expect changes in stress over the study period, or in health behaviours. Future studies may wish to address this by, perhaps, assessing these variables pre- and post a substantial stressful period (e.g., pre-post academic examinations) and/or over a longer period of time.

It is also suggested that future research investigates potential bidirectional associations between perseverative cognition and health behaviours by measuring both perseverative cognition and health behaviours over time. This may be important as Pigeon, Pinquart and Conner (2012) reported an association between sleep disturbance and an increased relative risk of suicidal ideation, suggesting that poor sleep may lead to negative thought patterns. This effect may also extend to other health behaviours.

In conclusion, these findings partially support the association between perseverative cognition and health-risk behaviours and poorer sleep found in recent systematic review and meta-analyses (Clancy et al., 2016; Clancy et al. 2020). Specifically, this study has demonstrated an association between brooding, worry and reflection and health-risk behaviours both cross-sectionally and prospectively, including sleep onset latency, sleep quality and unhealthy snacking. Perseverative cognition was also unrelated with health promoting be haviour (physical activity and fruit and vegetable intake). Perseverative cognition did not moderate the relationship between stress and health behaviours. Future studies should test whether such moderator relationships can be detected using more sensitive measures of perseverative cognition, stress and health behaviours.

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Data Availability Statement

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

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Table 1. Descriptive Statistics and Pearson's Correlations between Study Variables

	N	*M (SD)*	1	2	3	8	16
1. Worry	549	56.25 (14.14)	-				
2. Brooding	558	10.96 (3.63)	.58***	-			
3. Reflection	558	9.70 (9.70)	.30***	.55***	-		
8. Stress T1[a]	548	19.50 (7.36)	.61***	.64***	.42***	-	
9. Sleep Onset Latency (minutes) T1	541	38.88 (44.64)	.11**	.15***	.16***	.19***	-
10. Total Sleep Time (minutes) T1	552	436.13 (84.34)	-.11*	-.11**	-.12**	-.16***	-
11. Sleep Quality T1	560	2.27 (0.73)	.25***	.21***	.15***	.36***	-
12. Physical Activity T1[b]	561	48.26 (37.09)	-.03	-.11*	.04	-.05	-
13. Unhealthy Snacks T1	545	26.37 (8.55)	.17***	.24***	.07	.16***	-
14. Fruit and Vegetable Portions (per week) T1[c]	562	30.31 (22.89)	-.08	-.06	.01	-.05	-
15. Alcohol Units T1	562	6.14 (9.13)	-.06	-.02	.03	.00	-
16. Stress Change[a] (T1 - T2)	320	-0.49 (5.74)	.13*	.16**	.16**	.39***	-
17. Sleep Onset Latency (minutes) T2	328	38.08 (35.19)	.15**	.19***	.03	-	-.09
18. Total Sleep Time (minutes) T2	335	432.12 (76.37)	.00	-.10	-.08	-	.11
19. Sleep Quality T2	334	2.19 (0.70)	.24***	.23***	.10	-	-.11
20. Physical Activity T2	331	49.25 (41.39)	.00	-.04	-.07	-	-.02
21. Unhealthy Snacks T2	330	24.15 (8.07)	.17**	.20***	.09	-	-.04
22. Fruit and Vegetable Portions (per week) T2	334	28.20 (15.56)	-.07	-.08	-.02	-	.04
23. Alcohol Units (per week) T2	336	4.67 (6.30)	-.00	-.01	.03	-	-.08

Note. ***Correlation is significant at the .001 level, **significant at the .01 level, *significant at the .05 level, [a]Perceived stress at T1 was only correlated with T1 outcomes and stress change was correlated with T2 outcomes only, [b]Physical activity scores at Time 1 had extreme outliers which were truncated to 2 SDs above the mean, [c]Time 1 weekly Fruit and Vegetables portions had extreme outliers at the upper end which were truncated to 2 SDs above the mean.

Table 2. Hierarchical Regressions of Cross-sectional Associations between Perseverative Cognition and Stress with Health Behaviours

	Sleep Onset Latency	Total Sleep Time	Sleep Quality	Physical Activity	Unhealthy Snacking	Fruit and Vegetables	Alcohol
Step 1: Worry							
Worry	.12**	-.09*	.25***	-.02	.16***	-.08	-.06
R^2	.01	.01	.07	.00	.03	.01	.00
ΔF	6.96**	4.49*	36.82***	.29	14.16***	3.15	1.66
Step 2: Stress							
Worry	.00	-.00	.05	.00	.11*	-.07	-.09
Stress	.19**	-.15**	.33***	-.05	.08	-.01	.05
R^2	.04	.02	.14	.00	.03	.01	.01
ΔR^2	.02	.02	.07	.00	.00	.00	.00
ΔF	11.53**	7.85**	43.54***	.72	2.27	.03	.85
Step 3: Moderator							
Worry	.01	-.02	.06	.01	.11	-.08	-.10
Stress	.18**	-.15**	.33***	-.05	.09	-.01	.06
Worry x Stress	.04	-.09*	.01	.02	-.04	-.02	-.06
R^2	.04	.03	.14	.00	.03	.01	.01
ΔR^2	.00	.01	.00	.00	.00	.00	.00
ΔF	.95	4.07*	.11	.14	.87	.23	1.78
Step 1: Brooding							
Brooding	.17***	-.13**	.21***	-.10*	.24***	-.06	-.01
R^2	.03	.02	.05	.01	.06	.00	.00
ΔF	16.35***	8.69**	25.97***	5.75*	32.43***	1.78	.03
Step 2: Stress							
Brooding	.09	-.05	-.03	-.12*	.24***	-.05	-.02
Stress	.14*	-.11*	.38***	.02	.00	-.01	.01
R^2	.04	.02	.13	.01	.06	.00	.00
ΔR^2	.01	.01	.08	.00	.00	.00	.00
ΔF	6.02*	4.21*	52.06***	.19	.00	.05	.06
Step 3: Moderator							

Brooding	.07	-.04	-.04	-.12*	.26***	-.05	-.02
Stress	.14*	-.12*	.38***	.02	-.00	-.01	.01
Brooding x Stress	.08	-.06	.07	-.01	-.09*	-.01	.00
R^2	.05	.03	.14	.01	.07	.00	.00
ΔR^2	.01	.00	.01	.00	.01	.00	.00
ΔF	2.98	2.17	3.29	.03	4.76*	.01	.00
Step 1: Reflection							
Reflection	.18***	-.13**	.16***	.04	.07	.01	.04
R^2	.03	.02	.03	.00	.01	.00	.00
ΔF	16.88***	9.76**	13.85***	.85	2.43	.02	.70
Step 2: Stress							
Reflection	.12*	-.09	.01	.08	.00	.03	.04
Stress	.15**	-.10*	.35***	-.08	.16**	-.07	-.01
R^2	.05	.03	.13	.01	.03	.00	.00
ΔR^2	.02	.01	.10	.01	.02	.00	.00
ΔF	9.48**	4.84*	61.60***	3.16	11.82**	1.92	.05
Step 3: Moderator							
Reflection	.11*	-.09	.01	.07	.01	.02	.04
Stress	.15**	-.10*	.35***	-.08	.16**	-.06	-.01
Reflection x Stress	.05	.01	.01	.04	-.07	.06	-.01
R^2	.05	.03	.13	.01	.03	.01	.00
ΔR^2	.00	.00	.00	.00	.01	.00	.00
ΔF	1.08	.10	.07	.96	2.69	1.76	.06

Note. *$p < .05$, **$p < .01$, ***$p < .001$. Worry: n = 516-536, Brooding: n = 522-543, Reflection: n = 523-544. Coefficients are standardized betas.

Table 3. Hierarchical Regressions of Prospective Associations between Perseverative Cognition and Stress Change with Health Behaviours

	Sleep Onset Latency	Total Sleep Time	Sleep Quality	Physical Activity	Unhealthy Snacking	Fruit and Vegetables	Alcohol
Step 1: Time 1 Dependent Variable							
Baseline Behaviour	.52***	.55***	.55***	.54***	.70***	.53***	.43***
R^2	.27	.31	.31	.30	.48	.28	.19
F	110.04***	135.34***	135.57***	124.54***	275.26***	122.02***	70.85***
Step 2: Worry							
Baseline Behaviour	.51***	.56***	.54***	.54***	.68***	.53***	.43***
Worry	.05	.03	.06	.07	.06	-.02	.02
R^2	.28	.31	.31	.29	.49	.28	.19
ΔR^2	.00	.00	.00	.00	.00	.00	.00
ΔF	0.81	0.35	1.57	1.80	1.63	0.10	0.14
Step 3: Stress Change							
Baseline Behaviour	.52***	.57***	.56***	.55***	.68***	.54***	.43***
Worry	.07	.01	.08	.06	.07	-.03	.03
Stress Change	-.15**	.17**	-.19***	.03	-.07	.11*	-.06
R^2	.30	.33	.35	.29	.49	.29	.19
ΔR^2	.02	.03	.04	.00	.01	.01	.00
ΔF	8.71**	12.24**	16.42***	0.42	3.05	4.69*	1.39
Step 4: Moderator							
Baseline Behaviour	.53***	.57***	.56***	.55***	.68***	.54***	.44***
Worry	.08	.01	.08	.07	.07	-.03	.01
Stress Change	-.14**	.17**	-.19***	.04	-.07	.10*	-.07
Worry x Stress Change	-.08	-.02	.02	-.05	-.02	.03	.11*
R^2	.30	.33	.35***	.30	.49	.29	.20
ΔR^2	.01	.00	.00	.00	.00	.00	.01
ΔF	2.25	0.12	0.23	0.86	0.20	0.28	4.71*
Step 1: Time 1 Dependent Variable							
Baseline Behaviour	50***	.56***	.56***	.53***	.70***	.59***	.43***
R^2	.25	.31	.31	.28	.49	.34	.19

F	97.01***	139.59***	140.88***	122.21***	285.49***	163.35***	72.01***
Step 2: Brooding							
Baseline Behaviour	.47***	.55***	.54***	.54***	.69***	.58***	.43***
Brooding	.10	-.02	.10*	.04	.03	-.04	-.00
R^2	.26	.31	.32	.28	.49	.34	.19
ΔR^2	.01	.00	.01	.00	.00	.00	.00
ΔF	3.75	0.13	4.54*	0.55	0.63	0.68	0.00
Step 3: Stress Change							
Baseline Behaviour	.49***	.57***	.56***	.54***	.70***	.60***	.43***
Brooding	.13*	-.04	.13**	.03	.05	-.06	.01
Stress Change	-.17**	.16**	-.18***	.02	-.06	.12**	-.07
R^2	.28	.34	.35	.28	.49	.36	.19
ΔR^2	.03	.03	.03	.00	.00	.02	.01
ΔF	11.32**	11.50**	15.26***	0.21	2.32	7.09**	1.93
Step 4: Moderator							
Baseline Behaviour	.49***	.56***	.56***	.53***	.69***	.60***	.43***
Brooding	.13*	-.05	.13**	.03	.05	-.06	.01
Stress Change	-.16**	.15**	-.18***	.02	-.06	.12*	-.08
Brooding x Stress Change	-.06	.06	-.03	.06	-.03	.10*	.05
R^2	.29	.34	.35	.29	.49	.37	.19
ΔR^2	.00	.00	.00	.00	.00	.01	.00
ΔF	1.31	1.65	0.33	1.47	0.38	4.33*	1.06
Step 1: Time 1 Dependent Variable							
Baseline Behaviour	.50***	.56***	.56***	.53***	.70***	.54***	.42***
R^2	.25	.32	.31	.28	.48	.30	.17
F	96.99***	143.24***	143.07***	120.02***	280.89***	132.23***	66.73***
Step 2: Reflection							
Baseline Behaviour	.50***	.56***	.56***	.53***	.70***	.54***	.42***
Reflection	-.03	-.02	.04	-.06	.01	-.02	.00
R^2	.25	.32	.32	.28	.49	.30	.17
ΔR^2	.00	.00	.00	.00	.00	.00	.00
ΔF	0.45	0.26	0.64	1.72	0.10	0.14	0.01

Step 3: Stress Change							
Baseline Behaviour	.51***	.57***	.58***	.53***	.70***	.56***	.41***
Reflection	-.01	-.05	.06	-.07	.03	-.03	.01
Stress Change	-.14**	.17***	-.19***	.05	-.07	.11*	-.05
R^2	.27	.34	.35	.28	.49	.31	.18
ΔR^2	.02	.03	.03	.00	.01	.01	.00
ΔF	7.90**	12.71***	15.86***	0.94	3.01	4.73*	1.08
Step 4: Moderator							
Baseline Behaviour	.52***	.55***	.58***	.52***	.70***	.56***	.42***
Reflection	-.01	-.06	.07	-.07	.03	-.04	.01
Stress Change	-.14**	.17***	-.19***	.05	-.07	.11*	-.06
Reflection x Stress Change	-.05	.11*	-.01	.05	.00	.03	-.03
R^2	.27	.36	.35	.29	.49	.31	.18
ΔR^2	.00	.01	.00	.00	.00	.00	.00
ΔF	1.15	6.11*	0.09	1.16	0.00	0.51	0.30

Note. *$p < .05$, **$p < .01$, ***$p < .001$. Worry: n = 292-312, Brooding: n = 297-315, Reflection: n = 297-317. Coefficients are standardized betas.

Table S1. Hierarchical Regressions Assessing the Cross-Sectional Competition Models

	Sleep Onset Latency	Total Sleep Time	Sleep Quality	Physical Activity	Unhealthy Snacking	Fruit and Vegetables	Alcohol
Step 1: Perseverative Cognition							
Worry	.03	-.04	.21***	.05	.04	-.05	-.07
Brooding	.09	-.03	.05	-.21**	.27***	-.06	-.00
Reflection	.12*	-.11*	.07	.14**	-.09	.05	.06
R^2	.04	.02	.07	.03	.07	.01	.01
F	6.78***	3.82*	13.46***	4.50**	12.14***	1.33	0.97
Step 2: Stress							
Worry	-.02	-.00	.08	.06	.04	-.05	-.08
Brooding	.04	.01	-.08	-.20**	.27***	-.06	-.02
Reflection	.10	-.09	.03	.14**	-.09	.05	.05
Stress	.13*	-.11	.36***	-.01	-.00	-.00	.04
R^2	.05	.03	.14	.03	.07	.01	.01
ΔR^2	.01	.01	.07	.00	.00	.00	.00
ΔF	4.44*	3.47	39.37***	0.02	0.00	0.00	0.38
Step 3: Moderator							
Worry	-.01	-.02	.08	.06	.02	-.05	-.09
Brooding	.02	.03	-.11	-.19**	.30***	-.05	-.03
Reflection	.11*	-.11*	.04	.13*	-.09	.03	.06
Stress	.13*	-.11	.36***	-.01	.00	-.01	.04
Worry x Stress	-.01	-.07	-.05	.05	.02	-.03	-.09
Brooding x Stress	.09	-.06	.12*	-.08	-.09	-.04	.08
Reflection x Stress	-.00	.07	-.03	.06	-.02	.09	-.03
R^2	.05	.04	.14	.03	.08	.01	.01
ΔR^2	.01	.01	.01	.00	.01	.01	.01
ΔF	1.22	1.93	1.41	0.77	1.68	1.05	1.01

Note. *$p < .05$, **$p < .01$, ***$p < .001$, n = 509-528. Coefficients are standardized betas.

Table S2. Hierarchical Regressions Assessing the Prospective Competition Models

	Sleep Onset Latency T2	Total Sleep Time T2	Sleep Quality T2	Physical Activity T2	Unhealthy Snacking T2	Fruit and Vegetables T2	Alcohol T2
Step 1: Time 1 Dependent Variable							
Baseline Behaviour	.52***	.56***	.56***	.54***	.70***	.57***	.43***
R^2	.27	.32	.31	.30	.49	.33	.18
F	108.33***	139.26***	135.48***	126.39***	274.28***	147.72***	68.11***
Step 2: Perseverative Cognition							
Baseline Behaviour	.51***	.56***	.53***	.55***	.68***	.57***	.43***
Worry	-.03	.06	.01	.05	.06	.01	.02
Brooding	.18*	-.06	.12	.07	.00	-.05	.01
Reflection	-.11	-.01	-.03	-.10	-.01	.01	-.01
R^2	.29	.32	.32	.31	.49	.33	.18
ΔR^2	.02	.00	.01	.01	.00	.00	.00
ΔF	2.62	0.42	1.70	1.61	0.67	0.23	0.08
Step 3: Stress Change							
Baseline Behaviour	.51***	.57***	.55***	.56***	.68***	.58***	.43***
Worry	-.03	.05	.01	.05	.06	.00	.02
Brooding	.19**	-.06	.13	.07	.01	-.05	.01
Reflection	-.09	-.02	-.01	-.10	.00	-.01	-.00
Stress Change	-.16**	.15**	-.18***	.03	-.06	.13**	-.07
R^2	.32	.34	.35	.31	.49	.34	.19
ΔR^2	.03	.02	.03	.00	.00	.02	.01
ΔF	10.45**	10.24**	13.47***	0.28	2.25	6.82**	1.70
Step 4: Moderator							
Baseline Behaviour	.52***	.55***	.55***	.55***	.68***	.59***	.43***
Worry	-.02	.04	.01	.05	.06	.01	.01
Brooding	.20**	-.05	.14*	.06	.02	-.08	.01
Reflection	-.10	-.03	-.02	-.10	-.00	.02	.00
Stress Change	-.15**	.15**	-.17***	.03	-.06	.11*	-.08

Worry x Stress Change	-.05	-.04	.04	-.08	-.03	-.03	.12*
Brooding x Stress Change	-.04	.03	-.07	.07	-.03	.14	.01
Reflection x Stress Change	-.01	.10	.03	.03	.02	-.04*	-.04
R^2	.33	.35	.35	.31	.50	.35	.20
ΔR^2	.01	.01	.00	.01	.00	.01	.02
ΔF	0.89	1.93	0.47	1.08	0.29	1.74	1.84

Note. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$, n = 281-300. Coefficients are standardized betas.