The relationship between executive control, conscientiousness and health behaviour

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The candidate confirms that the work submitted is his/her own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

Health is important, but the health of the nation is failing, with chronic diseases, such as cardiovascular disease, cancer and diabetes on the rise. Most of which are related to the performance of negative health behaviours. As a result, improving the health of the population through the promotion of positive health behaviours is a key aim of health professionals and Government. However, to promote positive health behaviours, first, what variables predict health behaviour must be identified. Two prominent variables of interest are cognition and personality. Recently, attention has focussed on executive control (EC) and conscientiousness as predictors of health behaviour. As such, a number of questions have emerged. Firstly, due to the conceptual overlap of these variables, are they related constructs? Secondly, do they have a direct impact on health behaviour? Finally, are they moderating variables, and do they moderate the intention-behaviour relationship? The aim of this PhD was to explore the relations between EC, conscientiousness and multiple health behaviours in healthy samples. Over four studies, participants completed an array of computer, and paper and pencil-based tasks and computer-administered questionnaires. In addition, behavioural intentions and health behaviour performance was measured over a period of 7-14 days using online daily diaries. Using multilevel modelling analysis, three main findings emerged. First, the relationship between EC and conscientiousness is dependent on the measures used. Second, some EC and conscientiousness measures have direct effects on health behaviour; and third, some EC and conscientiousness measures have indirect effects on health behaviour via moderation of the intention-behaviour relationship. The findings highlight EC and conscientiousness are significantly related to health behaviour performance, though the relationships are more complex than shown by previous research. As such, the current findings serve to highlight issues of construct complexity, ecological validity, sample diversity and measurement.

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Chapter 1
Introduction

Health

Health is important. Yet, our society is faced with health issues such as obesity and binge-drinking. The prevalence of these issues is increasing, making the promotion of positive health behaviours (behaviours promoting or protecting health) vital; especially as research suggests various health behaviours including poor diet, physical inactivity, smoking and alcohol consumption are linked to all-cause mortality, coronary heart disease (CHD), and cardiovascular disease (CVD) (Knoops, de Groot, Kromhout, Perrin, Moreiras-Varela, Menotti et al., 2004; van Dam, Li, Spiegelman, Franco, & Hu, 2008). However, changing these health behaviours could reduce the risk of mortality from chronic diseases by 50% (Knoops et al., 2004). This is why finding the predictors of health behaviours, and using these predictors to create health behaviour change interventions is of great interest to health psychologists. Two predictors worthy of investigation are cognition and personality.

Cognition & Health

One internal system that may help control the performance of health behaviours is cognition. Indeed, the relationship between intelligence (IQ) and mortality is well-established (Batty, Deary, Benzeval, & Der, 2010; Batty, Deary, & Gottfredson, 2007; Der, Batty, & Deary, 2009; Shipley, Der, Taylor, & Deary, 2007, 2008; Whalley & Deary, 2001), with reaction time variability and memory span in particular showing strong associations with health and all-cause mortality (Deary & Der, 2005; Deary, Der, & Ford, 2001; Der et al., 2009; Shipley, Der, Taylor, & Deary, 2006; Shipley et al., 2007, 2008). Although researchers are still unclear as to why general cognitive ability is linked to better health outcomes, the literature indicates this may be due to the promotion of positive health behaviours. For example, results from the Whitehall II cohort study revealed that not only was there a relationship between cognition and mortality, but that health behaviours accounted largely for this relationship,

although other factors were also influential (Sabia, Gueguen, Marmot, Shipley, Ankri, & Singh-Manoux, 2010). Others have also investigated the cognition-mortality relationship, specifically focusing on certain aspects of cognition. For example, Amirian, Baxter, Grigsby, Curran-Everett, Hokanson, and Bryant (2010) investigated the role of self-regulation (a function of executive control (EC)) in the cognition-mortality relationship; finding that older adults initial self-regulatory abilities were not only predictive of mortality, but also functional decline over a period of twenty-two months. Nevertheless, it is only of late, that the focus has shifted from general cognitive ability to specific aspects of cognition, and recently, EC particularly, is of increasing interest to health researchers.

Executive control (EC)

Executive control (EC) is an aspect of cognition, and although there are many different ways of referring to EC (e.g., executive control function, executive cognitive function, executive function, cognitive control), and many definitions of EC are available, they all share properties. EC is an over-arching term referring to the higher order "top-down" cognitive processes that allow the co-ordination of thought and action; and although the biological underpinnings of EC are complex, at a basic neuroanatomical level, EC is linked to the prefrontal cortex and anterior cingulate cortex (van Veen & Carter, 2006). As such, EC is a complex construct, as it subsumes an array of functions crucial to the execution of goal-directed behaviour. These functions include goal-setting and maintenance of relevant information for goal execution, attentional set-shifting, response inhibition, working memory, problem-solving, cognitive flexibility, emotion control, self-regulation and planning ability (Royall, Lauterbach, Cummings, Reeve, Rummans, Kaufer et al., 2002; Stoet & Snyder, 2009; Suchy, 2009). It is clear to see that the nature of EC is complicated and it can be difficult to disentangle the separate functions, but Miyake and Friedman (2012) have proposed the separate functions can be classified into three categories: "*updating* (constant monitoring and rapid addition/deletion of working memory contents), *shifting* (switching flexibly between tasks or mental sets), and *inhibition* (deliberate overriding of dominant or pre-potent responses)" (p.9). Intuitively, it is clear to see how the functions encompassed under EC may be

important to health, particularly in the performance of health behaviours due to the planning, inhibition and monitoring skills needed to translate intentions into action to achieve a desired goal, whether that is to eat a healthy diet or exercise more. Indeed, EC as a component of self-regulatory capacity forms a large part of Hall and Fong's (2007) Temporal Self-regulation theory (TST), which indicates the importance of EC in conjunction with other biological (e.g., physiological energy) and social cognitive (e.g., connectedness beliefs and temporal valuations) variables in future health behaviour. Furthermore, TST postulates self-regulatory capacity and behavioural pre-potency as predominant moderators of the intention-behaviour relationship. As such, the literature surrounding EC and health has recently flourished.

EC& Health

There is a growing body of research demonstrating a relationship between EC and health, particularly in relation to chronic illnesses, with obesity in adults and children (Boeka & Lokken, 2008; Chelune, Ortega, Linton, & Boustany, 1986; Cserjesi, Luminet, Poncelet, & Lenard, 2009; Cserjesi, Molnar, Luminet, & Lenard, 2007; Elias, Elias, Sullivan, Wolf, & D'Agostino, 2003; Gunstad, Paul, Cohen, Tate, Spitznagel, & Gordon, 2007), HIV (Stern, Liu, Marder, Todak, & et al., 1995), chronic pain (Solberg, Roach, & Segerstrom, 2009), pulmonary disease (Parekh, Blumenthal, Babyak, LaCaille, Rowe, Dancel et al., 2005), cardiovascular function (Elias et al., 2003; Thayer, Hansen, Saus-Rose, & Johnsen, 2009; Waldstein, Jennings, Ryan, Muldoon, Shapiro, Polefrone et al., 1996; Waldstein, Tankard, Maier, Pelletier, Snow, Gardner et al., 2003), and survival rate in individuals with chronic illness (Hall, Crossley, & D'Arcy, 2010) all being linked to poor EC. A number of nuances emerge from the relationship between EC and health. For instance, with regards to HIV, it was not only found that HIV positive (HIV+) individuals had poor EC, but of those who died during the course of the study their decline in EC progressed at a rapid rate (Stern et al., 1995). A similar trend was found in relation to cardiovascular disease, such that increasing severity in disease level was associated with more EC problems (Waldstein et al., 2003). Furthermore, specifically in regards to hypertension, the research indicates EC deficits are exclusive to young men (Elias et al., 2003; Waldstein et al., 1996). This

suggests there are sex differences within this area of research that need to be explored as it is unclear whether such a finding has emerged due to there being differences in disease prevalence rates among the sexes or the health behaviours they engage in that could protect them from or put them at risk of a disease, or as the authors suggest differences in how they treat their disease. For example, in Elias et al. (2003) a higher proportion of women compared to men were being treated for their hypertension. Overall this highlights that there has been a great deal of research into EC with particularly patient-based/unhealthy individuals, but there is relatively little research focusing on the EC of healthy individuals and how it may impact their behaviour. Furthermore, research with healthy individuals also has the advantage of elucidating causal effects.

Establishing causality is a strong limitation to the research with unhealthy samples. Although many studies of EC and health with unhealthy samples controlled for co-morbid illnesses within their analyses, it is still unclear whether these diseases are the result of poor EC or poor EC is the result of these diseases. Indeed, it may be that EC and health have a complex reciprocal relationship. One way of attempting to untangle this relationship is to investigate whether there is a relationship between EC and the performance of health behaviours. It makes intuitive sense that human beings ability to plan, inhibit irrelevant responses, be flexible, monitor and regulate behaviour has a bearing on our health. It may be that EC influences whether we engage in protective and/or risky health behaviours. Indeed, in a study by Magar, Phillips, and Hosie (2008), it was found that poor EC, specifically self-regulation, was associated with increased approval for risky social and health behaviours, and increased performance of risky behaviours, including greater alcohol consumption. Furthermore, normal healthy populations can be investigated when investigating health behaviour performance, thus allowing the causality issue to be, to some degree, disentangled; as such individuals will have no co-morbid problems. It is important to answer these questions as it will be vital should interventions need to be established, as it will allow health behaviour change interventions to focus on those that need to be targeted and the health behaviours that need to be

targeted. Nevertheless, behaviour is ultimately influenced by numerous factors, and another potentially influential factor on health behaviour is personality.

Personality & health

Another construct with a significant role in health, and health behaviour performance is personality. Personality reflects the individual differences in the way individuals think, feel and behave, and is believed to remain relatively stable over time and situations. In recent years, most research on personality and health has focused on the Five Factor Model of personality (openness, conscientiousness, extraversion, agreeableness and neuroticism) (McCrae & Costa, 1987). The personality trait of conscientiousness has received a great deal of interest with numerous research papers demonstrating consistent links between mortality, health behaviours and longevity (Bogg & Roberts, 2004; Friedman, Tucker, Tomlinsonkeasey, Schwartz, Wingard, & Criqui, 1993; Kern & Friedman, 2008). Conscientiousness is characterized by goal/achievement striving, advanced planning, self-control and delay of gratification, thus a highly conscientious individual is organized, diligent, disciplined, cautious and dependable (McCrae & Costa, 1987). Furthermore, conscientiousness has six underlying facets: *orderliness* (the propensity to be prepared), *industriousness* (to be hardworking and determined), *self-control* (response inhibition), *responsibility* (to be dependable), *virtue* (acting with decorum) and *traditionalism* (to be rule-abiding and uphold societal conventions) (Roberts, Lejuez, Krueger, Richards, & Hill, 2014). It is important to recognize these underlying facets as it has been indicated that certain facets are more influential on health than others (Bogg & Roberts, 2004).

Conscientiousness has two potential pathways to better health. Firstly, via direct effects on health, as evidence suggests conscientious individuals are at a lower risk of physical and mental illnesses (Goodwin & Friedman, 2006). Secondly, via indirect effects on health through behaviour, as evidence suggests conscientious individuals have a higher likelihood of performing positive behaviours, such as exercise and healthy eating, and a lower likelihood of performing negative behaviours, such as smoking, consuming alcohol, using drugs and engaging in risky driving and sexual practices (Bogg & Roberts, 2004). There have been two meta-analyses to date conducted on the

relationship between conscientiousness and longevity, while also considering health behaviour (Bogg & Roberts, 2004; Kern & Friedman, 2008). These have concluded that higher conscientiousness is associated with greater longevity, particularly highlighting the facets of achievement and order (Kern & Friedman, 2008); and highlighting the significant positive association between high conscientiousness and greater engagement in protective health behaviours and the significant negative association between high conscientiousness and less engagement in risky health behaviours (Bogg & Roberts, 2004). Conversely, no such meta-analysis or systematic review has been undertaken exploring the relationship between executive control and health behaviour. Thus a key aim of the PhD was to produce such a review.

EC & conscientiousness

There are strong reasons for investigating the relationship between EC and personality. Indeed, a recent review suggested more research should be conducted investigating EC and personality in parallel (Hofmann, Schmeichel, & Baddeley, 2012). This is due to the clear connections between the three broad facets of EC (updating, shifting, and monitoring) and self-regulation (a construct encompassed by conscientiousness within self-control). The review further points to the lack of research on EC and self-regulation using task-switching paradigms, thus the relationship between mental flexibility and self-control is unclear, but will be addressed in the current PhD work.

The primary reason to investigate EC and conscientiousness in tandem is that EC processes and the characteristics of conscientiousness seem to conceptually overlap (Vainik, Dagher, Dube, & Fellows, 2013); particularly, in terms of sharing features such as inhibitory control, goal-setting, planning and self-monitoring. However, as of yet no meaningful relationships between these two variables have been found, with current findings producing opposing results (Edmonds, Bogg, & Roberts, 2009; Matthews & Zeidner, 2012). Therefore, there is a need for more research to establish whether there is an association between EC and conscientiousness, and if so to explore the nature of this relationship. Are EC and conscientiousness measuring the same constructs?

Do these variables have similar or independent effects on health behaviour performance? These are vital questions that will be addressed in this PhD thesis.

Furthermore, EC and conscientiousness share similar brain mechanisms. EC has largely been linked to the frontal lobes of the brain (Tsuchida & Fellows, 2013; van Veen & Carter, 2006), with specific associations having been found between EC and the dorsolateral prefrontal cortex (Adams, Gilman, Koeppe, Kluin, Lohman, Berent et al., 1995), as well as the anterior cingulate cortex (Paus, 2001; Royall et al., 2002; Suchy, 2009; van Veen & Carter, 2006). Similarly, conscientiousness has also been linked to the lateral prefrontal cortex; an area responsible for planning and self-regulation (DeYoung, Hirsh, Shane, Papademetris, Rajeevan, & Gray, 2010). These links to the prefrontal cortex are particularly important, as it has been suggested that although anatomical differences are genetically determined, there is plasticity within the brain system, thus these substrates could be modified, which could have a positive impact on behaviour (Joseph, Alonso-Alonso, Bond, Pascual-Leone, & Blackburn, 2011).

In addition, as previously alluded to, both EC and conscientiousness have independent links to health both directly and indirectly. However, the evidence-base for EC is not as yet as clearly defined as the evidence-base for conscientiousness. The implications for the lack of a strong evidence-base for EC are two-fold. First, this highlights the need for a review of the literature on EC and health behaviour. To date there is no comprehensive review of the literature on EC and all health behaviours, leaving us with the vital question: What research is available, and what conclusions can be made from this research? Answering these questions will be a primary aim of the PhD. Second, this highlights the need for more research to be conducted investigating the relationship between EC and health behaviour. This PhD aims to explore the relationship between EC and health behaviour performance in a novel manner, implementing a variety of objective and subjective measures of EC and health behaviour, using new methodologies and complex statistical techniques.

PhD objectives

The research conducted in the current PhD aims to explore the relationship between executive control, conscientiousness and health behaviours and had three primary objectives:

1) Undertake a comprehensive review of the literature to establish a current consensus of findings and identify issues warranting address.
2) Establish the nature of the relationship between EC and conscientiousness.
3) Assess EC and conscientiousness as direct predictor, mediator and moderator variables on health behaviour.

Chapter 2
Systematic and meta-analytic review of the relationship between executive control and health behaviours

Introduction

For nearly a century there has been concern over the link between health behaviours and mortality. For instance, over forty years ago the Alameda County study (Belloc & Breslow, 1972) showed that various behaviours (e.g., good sleeping and eating habits, not smoking and drinking) were associated with improved health and decreased mortality. Subsequently considerable research effort has explored the determinants of such health behaviours with a focus on individual characteristics. For example, health cognitions, such as intentions, attitudes and self-efficacy (see Conner & Norman, 2005 for a review), have been one focus and personality traits (see Bogg & Roberts, 2004 for a review) another. More recently researchers have looked at executive control as a predictor of health behaviours. Here we provide a systematic review and meta-analysis of such studies.

Executive control (EC) is an umbrella term for the higher order "top-down" cognitive processes that allow the co-ordination of thought and action. EC is multifaceted in nature and includes an array of functions relevant to the execution of goal-directed behaviour. The four key domains of EC are *inhibition* (exerting deliberate control over pre-potent responses), *shifting* (flexibility in switching between tasks/mental sets), *updating* (monitoring and updating working memory) and planning (Miyake & Friedman, 2012; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Proficiency in these different functions has been suggested to be important to the performance of health behaviour. For example, the ability to inhibit undesirable responses should be conducive to successful avoidance of behaviours such as snacking and smoking. Individuals high in EC are assumed to be more likely to successfully initiate behaviour change and maintain that change in pursuit of their goals (Allan, 2008; Allan, Johnston, & Campbell, 2011; Brega, Grigsby, Kooken, Hamman, & Baxter, 2008; Hall, Dubin, Crossley, Holmqvist, & D'Arcy, 2009; Wong & Mullan,

2009). However, there are other EC functions than the four key domains. For example, the EC function “planning ahead” should be conducive to successful engagement with health behaviours which require actions to keep one's future health protected, such as healthy eating and physical activity.

Early research about the relationship between EC and health behaviours focused on vulnerable populations (e.g., the elderly, Brega et al., 2008), but a more recent focus has been on the relationship in healthy populations (Allan, Sniehotta, & Johnston, 2013; Hall, Fong, & Epp, 2013; Pentz & Riggs, 2013; Todd & Mullan, 2013; Veling, Aarts, & Stroebe, 2013b). Despite this growing body of literature, to date, there are no meta-analytic reviews on the relationship between EC and health behaviour. The current research aims to fill this gap by reporting such a meta-analysis. In addition to examining the average size of the relationship between EC and health behaviour the review examines heterogeneity, potential biases, and a test of various moderators.

In particular, we considered four groups of moderators of the relationship between EC and health behaviours: type of health behaviour; type of EC measured; sample; and methodological factors. The relationship between EC and health behaviour has been tested in a number of different health behaviours. We tested for differences between each of these behaviours. The different health behaviours vary in a number of important ways, including whether they are approach or avoidance behaviours, how habitual they are, and whether they are addictive or not. Approach behaviours are health-enhancing behaviours which individuals are encouraged to perform more, whereas avoidance behaviours are health-damaging behaviours which individuals are encouraged to perform less. Although EC could be important for the performance of both types of health behaviour, the assumed direction of association is different. Increasing EC is assumed to be associated with increasing performance of approach behaviours, but decreasing performance of avoidance behaviours. There are no strong theoretical reasons to expect overall measures of EC to be stronger predictors of approach or avoidance behaviours (and whether this might vary as a function of approach versus avoidance behaviours is returned to later).

Health behaviours also differ in a number of other ways that might have consequences for their relationship with EC. In particular, EC might be expected to be more important for non-habitual compared to habitual behaviours as once any behaviour has become habitual it is likely that other external or internal influences on behaviour lose the influence they once had (Wong & Mullan, 2009). However, on the other hand, it is also possible that health-degrading behaviours that are habitual in nature, such as smoking, can only be successfully controlled if the pre-potent responses elicited by these habits are effectively inhibited. In addition we examined differences in the predictive power of EC for addictive behaviours (e.g., alcohol, smoking, and drug use) compared to non-addictive behaviours (e.g., exercising). Using the logic used in relation to habit we expected EC to show stronger impacts on non-addictive behaviours because of the greater potential for individual factors to have an influence.

The type of EC measure employed is a further potential moderator of its relationship with health behaviour. This is because many EC measures focus on successful response inhibition assumed to be particularly important in promoting avoidance behaviours such as snacking (Allan et al., 2011; Hall, 2012) and alcohol consumption (Christiansen, Cole, Goudie, & Field, 2012; Colder & O'Connor, 2002). There are also other aspects of EC that have been highlighted as having an impact on health behaviour, including the ability to plan ahead (Allan et al., 2013; Hall, Elias, Fong, Harrison, Borowsky, & Sarty, 2008a) and working memory (Hofmann, Gschwendner, Friese, Wiers, & Schmitt, 2008; Houben, Wiers, & Jansen, 2011b; Romer, Betancourt, Brodsky, Giannetta, Yang, & Hurt, 2011). It is less clear that these EC measures should be stronger predictors of avoidance behaviours compared to approach behaviours. We therefore examined type of EC measure as a potential moderator of the relationship between EC and health behaviour both overall and for approach and avoidance behaviours. EC measures also differ in the extent to which they are based on self-reports of performance (e.g., the Dysexecutive questionnaire (DEX), Wilson, Alderman, Burgess, Emslie, & Evans, 1996) or more objective measures of performance (e.g., Go/No-go task, Hall, Fong, Epp, & Elias, 2008b). Which measure is most accurate or predictive

of action is open to debate, though performance measures tend to be preferred over self-report measures. Objective measures are considered to be less open to bias, although the ecological validity of these measures is unclear. On the other hand, self-report measures are open to desirability bias, although it might be argued that individuals may be best placed to judge their own functioning. For example, in research using self-report measures of EC with clinical samples, Laws, Patel, and Tyson (2008) found schizotypal individuals exhibited high awareness of the EC difficulties they experienced in daily life. In addition, these different measures may tap different aspects of EC. Assessing which measure is most strongly related to health behaviours could provide insights into their relative importance and potential for future research.

EC develops over time and does not begin to reach full functionality until an individual's early twenties (Eshel, Nelson, Blair, Pine, & Ernst, 2007; Lyon & Krasnegor, 1996; Romine & Reynolds, 2005). We therefore explored the impact of sample age on the relationship between EC and health behaviours.

A final set of factors examined were methodological. In particular we examined whether studies employed cross-sectional versus longitudinal designs and used self-report versus more objective measures of health behaviour. Cross-sectional designs, where all variables are measured in the same session, are more open to consistency biases (Armitage & Conner, 2001) and showing longitudinal effects is important. Similarly, showing that EC impacts on objectively measured health behaviours that are also presumably less open to biased reporting strengthens claims for the validity of the relationship between the two.

In contrast, previous systematic reviews have gone some way to explaining the relationship between EC and health behaviours, but have only considered a small range of behaviours, including physical activity/eating behaviour (Joseph et al., 2011), substance abuse (Blume & Marlatt, 2009); and medication adherence (Lovejoy & Suhr, 2009). As such, the conclusions that can be gleaned are to some extent only generalisable to specific behaviours. The Lovejoy and Suhr (2009) review is a particularly good example of this, as it examines neuropsychological function and medication adherence in HIV positive individuals only. Nevertheless, all three reviews conclude poor EC has

a detrimental impact on health behaviour. However, still to date, there is no existing systematic review of the literature on EC and multiple health behaviours in healthy populations despite the increasingly mature nature of the literature base. Thus, in addition to conducting a meta-analysis on this literature a systematic review will also be undertaken.

In summary, the present meta-analysis and systematic review[1] examined the relationship between EC and behaviour across a range of health behaviours. The review focuses on healthy populations and tests the impact of various moderators of this relationship.

Method

Search and Inclusion/Exclusion Criteria

A range of search strategies were employed to obtain relevant studies. First, four electronic databases (Web of Science, PsycInfo, MEDLINE and Embase) were searched between October and December 2013for peer-reviewed journal articles available in English published in any year using the following search strings: executive control, executive control function*, executive function*, executive cognitive function*, cognitive control, cognitive function*, health behavio?r*, behavio?r*. Second, the reference list of each article was searched and a citation search was conducted on all articles included within the review to find any relevant literature that may have been missing from the database searches. Studies were then excluded if: (i) participants were older adults (>60 years) to avoid detriments in EC as a consequence of age-related decline, unless normal cognitive function could be confirmed; (ii) participants were from a high-risk population. This is when individuals are within an environment that is conducive to risky behaviour; for example, a family history of alcoholism; (iii) participants were chronic alcohol drinkers or drug users, as once again use of these substances impairs EC (Paul, Brickman, Cohen, Williams, Niaura, Pogun et al., 2006; Sullivan, Rosenbloom, & Pfefferbaum, 2000; Verdejo-Garcia & Perez-Garcia, 2007); (iv) participants had incurred head trauma or had mental or physical

[1] A review protocol is not available and this research received no external funding.

disease/disorder; all of which have been shown to impair EC (see Suchy, 2009 for a summary). Studies were included if they were undertaken on normal healthy populations, used any measure of EC plus health behaviour, and reported the relationship between the two plus the sample size[2].Where correlations between EC and health behaviour were not reported authors were contacted requesting this data. Based on these search criteria and inclusion/exclusion criteria a total of 49 papers (containing 52 independent tests, N = 11,335) were retained in the review (see Figure 2.1).

Coding

Each correlation coefficient provided (including where studies provided multiple correlations between EC measures and health behaviours) was rounded to two decimal places before being subjected to further calculations. The correlations were coded such that a positive relationship indicated an association between EC and health behaviour in the predicted direction (i.e., higher EC was associated with more approach behaviours and with less avoidance behaviours). Where approach and avoid behaviours were combined and could not be accurately separated, the study was excluded from the meta-analysis.

In addition, each study was coded into health behaviour category, health behaviour type, habitual or not, and addictive or not. In relation to health behaviour category there were sufficient studies to enable us to distinguish five behaviours: fruit and vegetable consumption (e.g., Allom & Mullan, 2012), exercise/physical activity (e.g., Hall, Fong, Epp, & Elias, 2008b), medication adherence (e.g., Andrade, Deutsch, Celano, Duarte, Marcotte, Umlauf et al., 2013), snack consumption (e.g., Allan et al., 2011), alcohol consumption (e.g., Mullan, Wong, Allom, & Pack, 2011). A further category or 'other behaviours' included breakfast consumption (e.g., Wong & Mullan, 2009), sleep (e.g., Kor & Mullan, 2011), sun protection behaviours (e.g., Allom et al., 2013), smoking (e.g., Harakeh, de Sonneville, van den Eijnden, Huizink, Reijneveld, Ormel et

[2]Where multiple correlations available from a study, these were averaged to create an overall correlation coefficient for that study.

al., 2012) and drug use (e.g., Patrick, Blair, & Maggs, 2008). In relation to health behaviour type we coded behaviours into approach behaviours (e.g., exercise) where health benefits were associated with increasing the behaviour and avoidance behaviour (e.g., snacking) where health benefits were associated with decreasing the behaviour. In relation to habitualness of behaviour Ouellette and Wood (1998) usefully suggest two dimensions along which habitual behaviours can be categorized: frequency of performance (e.g., daily versus yearly) and consistency of context (stable context versus unstable context). With habitual behaviours tending to be more frequently performed in stable contexts. We therefore compared the impact of EC on habitual (those performed frequently in stable contexts) compared to non-habitual health behaviours (all other behaviours). In relation to addictiveness we coded behaviours involving taking of substances, such as alcohol, tobacco or drugs that can cause a person to consistently take or crave these substances as addictive while other behaviours were coded as not addictive.

EC measures were coded into type of EC measure reflecting the main EC functions highlighted in the current literature (e.g., response inhibition, planning, working memory, other). Studies that failed to report the EC function they were measuring or used self-report measures that could not be accurately categorized were excluded from this analysis. Where studies measured multiple EC functions these were separated and used in the analyses of individual EC types. Furthermore, EC measures were coded as either objective or self-report. Measures were coded as objective if they used neuropsychological tests, such as the Stroop task, Go/No-Go task, tower tasks, etc. and coded as self-report if they used measures such as the Dysexecutive questionnaire (DEX) or Behavior Rating Inventory of Executive Functioning (BRIEF). Where both objective and self-report EC measures were used in a single study these were separated out for analysis. Sample in each study was coded into children/adolescents versus students/adults. Studies using a mixed sample were thus excluded[3]. Finally, we coded each study for design

[3]In two instances (Edmonds et al, 2009; Murphy & Garavan, 2004) different EC measures had different sample sizes. These were averaged for inclusion in the meta-analysis.

(prospective, cross-sectional)[4] and whether the measure of health behaviour was self-report or objective (e.g., consummatory behaviour, medication adherence as measured by MEMS cap etc). Coding was agreed upon by three individuals trained to PhD level.

Analysis

Random effects meta-analysis was conducted using the comprehensive meta-analysis program (Borenstein, Hedges, Higgins, & Rothstein, 2005) with effect size estimates weighted by sample size. A random-effects analysis was chosen to reflect the varying effect sizes of the populations included in the studies in the current review and thus as random-effects analysis accounts for the heterogeneity of the studies it is more reflective of real-world data (Hunter & Schmidt, 2000). Number of studies (*k*), total sample size (*n*), mean effect sizes (r_+) and 95% confidence intervals (*95%CI*), and heterogeneity estimates (*Q* statistic) were computed and are reported in Table 2. We also used the Duval and Tweedie (2000) trim and fill procedure to identify potential publication bias. A moderator variable was considered to be significant based on a significant Q test. In such instances we report the mean effect size (r_+) at each level of the moderator variable and the associated 95%CI.

[4] As only baseline correlations were used in the meta-analysis calculations in some instances (e.g., Andrade et al. (2013), Ettenhofer et al. (2010), Fernie et al. (2013), Hall et al. (2008b, study 1, study 2), Houben et al. (2012), Pentz & Riggs (2013), Pieters et al. (2012), Riggs et al. (2010a), Romer et al. (2011)), some prospective studies became cross-sectional and were entered into the analysis as such. In contrast, only time 2 correlations were available for Harakeh et al. (2012), post-test correlations (dismissing pre-test and follow-up correlations) were used for Houben et al. (2011), and only correlations between baseline executive control and follow-up behaviour were available for Todd & Mullan (2013).

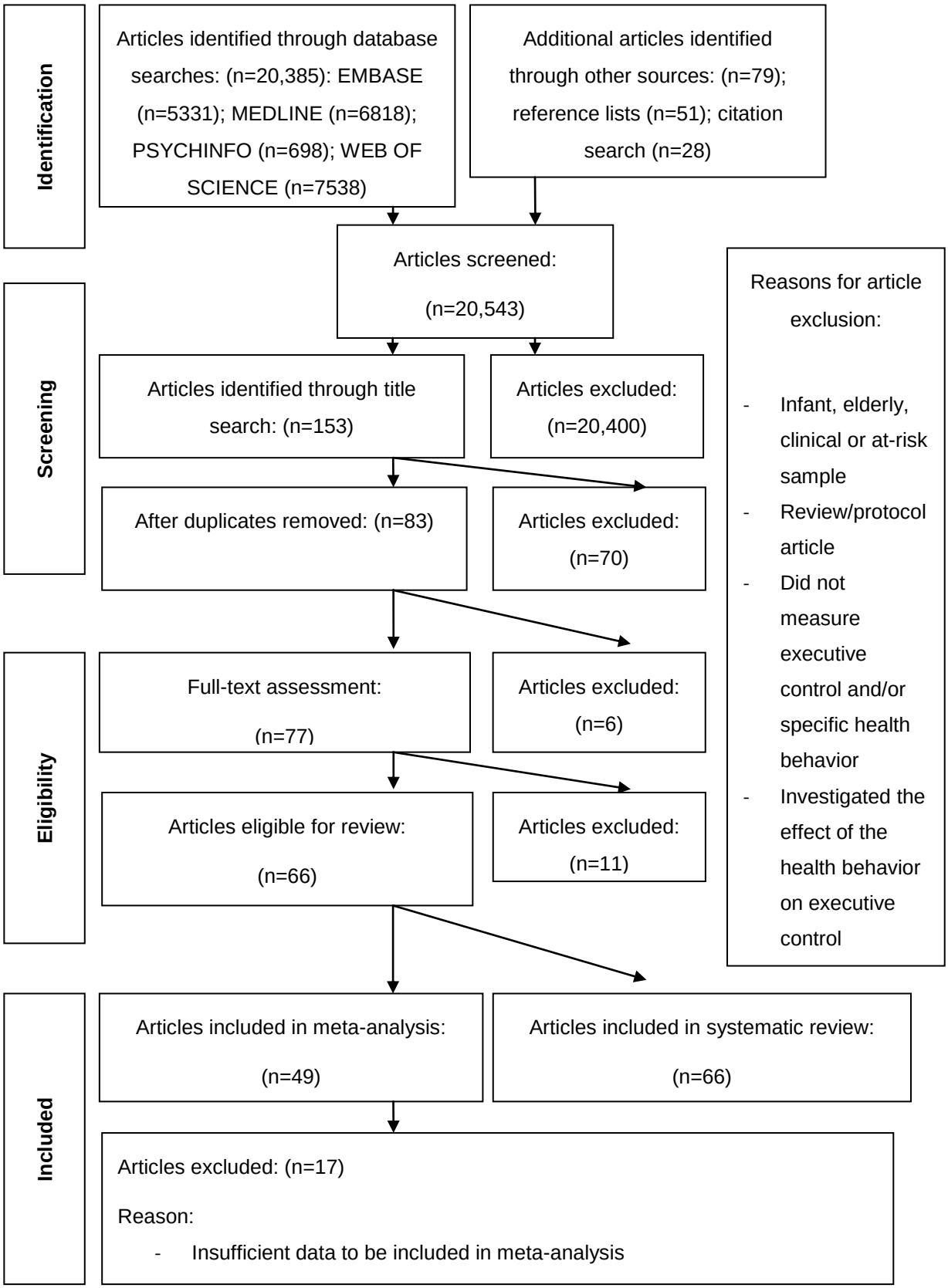


Figure 2.1: Systematic research review and meta-analysis search strategy and screening process

Results

Study characteristics

Forty-nine articles covering fifty-two tests were included in the meta-analysis, whereas sixty-six articles covering seventy-one tests were included in the systematic review (See Figure 2.1, Table 2.1 for full details). Sample sizes for individual tests ranged from 27 to 15,792 participants. Most studies included a sample of both sexes; but one study recruited a solely male sample (Solomon & Halkitis, 2008) whereas eight only recruited females (Guerrieri, Nederkoorn, & Jansen, 2012; Hofmann, Friese, & Roefs, 2009; Hofmann et al., 2008; Houben, 2011; Houben & Jansen, 2011; Nederkoorn, Guerrieri, Havermans, Roefs, & Jansen, 2009; Patrick et al., 2008). Snack and alcohol consumption were the most frequently examined behaviours, although studies also examined breakfast consumption, fruit and vegetable consumption, exercise, sleep, sun protection, medication adherence, smoking, and drug use. More studies have examined avoidance compared to approach behaviours, non-habitual compared to habitual behaviours, addictive compared to non-addictive behaviours. Response inhibition measures were the most commonly used EC measures, with more studies using objective compared to self-report measures. There were also more studies on adults compared to children/adolescents and a greater use of cross-sectional compared to longitudinal designs in the studies included in the meta-analysis, but in the systematic review longitudinal designs were more popular, and self-report compared to objective measures of health behaviour. An important recent development within this area has been the growing emergence of intervention-type studies manipulating EC in an attempt to exert a change in health behaviour, namely reducing unhealthy eating and alcohol consumption. Eleven studies came under the category of an intervention.

Meta-analysis: Overall effects

Across 52 tests with a total sample size of 11,335 the overall effect size (r_+) was .145 (p<.001, 95%CI = .106—.183). This equates to a small effect size (Cohen, 1992)and indicates that increasing EC is significantly associated with greater performance of health behaviours (i.e., more approach behaviours and less avoidance behaviours; see Table 2.2). Trim and fill analyses (Duval &

Tweedie, 2000) in the Comprehensive Meta-Analysis program revealed 0 tests were trimmed and the estimate of effect size and confidence interval remained unchanged. In addition, Egger's regression intercept was .725 (two-tailed p-value = 0.144), this indicating no evidence of publication bias in the meta-analysis.

Meta-analysis: Moderating effects

In relation to type of health behaviour, moderation analysis revealed similar small but significant effects for approach (r_+ = .164) and avoidance (r_+ = .137) health behaviours, which did not significantly differ from one another (Q = 0.49, p = .485). However, it is worth noting that our coding disguises the fact that these relationships are in different directions, that is a positive relationship for approach behaviours and a negative relationship for avoidance behaviours. Taking account of this direction of effect indicated a significant difference between approach and avoidance behaviours (Q= 61.48, p< .001). Individual health behaviours also showed a number of differences (Table 2.2). In particular, medication adherence (r_+ = .264) was significantly higher than exercise (r_+ = .097; Q = 27.07, p< .001), fruit and vegetable consumption (r_+ = .097; Q= 27.07, p< .001), and alcohol consumption (r_+ = .088; Q = 10.79, p< .001), but not significantly different from snack consumption (r_+ =.187; Q = 2.76, p=.097).

With regards to habitualness of behaviour, moderation effects revealed significant impacts on habitual health behaviours (r_+ = .221) and non-habitual health behaviours (r_+ =.108), which significantly differed from one another (Q = 7.44, p = .006).

With regards to addictiveness of behaviour, moderation effects revealed significant impacts on both addictive (r_+ = .078) and non-addictive (r_+ = .173) health behaviours, which did significantly differ from one another (Q = 5.54, p = .019). Moderation effects revealed that the four different types of EC measure did not produce significantly different relationships with performance of health behaviours (Q = 4.41, p = .220). However, response inhibition (r_+ = .129) and other measures of EC (r_+ = .123) were associated with significant effects, while planning (r_+ = .082) and working memory (r_+ = .021) measures were not

associated with significant effects. When comparing approach versus avoid behaviours for each type of EC measure, no significant differences were found (response inhibition Q = 0.49, p = .486; planning Q = 1.90, p = .169; working memory Q = 2.27, p = .132; and other Q = 0.69, p = .405). Both objective (r_+ = .120) and self-report (r_+ = .242) EC measures had significant impacts on health behaviours, although the effect for self-report measures was significantly stronger (Q = 7.52, p = .006).

Moderation effects revealed significant impacts on both children/adolescent samples (r_+ = .127) and student/adult (r_+ = .142) samples, which did not significantly differ from one another (Q = 0.14, p = .714).

In relation to methodological factors there were significant effects for both cross-sectional (r_+ = .163) and prospective (r_+ = .102) designs, and these effects did not significantly differ from one another (Q = 2.19, p = .139). In addition, studies using both objective (r_+ = .160) and self-report (r_+ = .138) health behaviour measures reported significant effects of EC on behaviour, and these effects did not significantly differ from one another (Q = 0.15, p = .704).

Table 2.1

Summary of studies included in review

Author	Sample and design	EC measures	Health behaviour	Significant
Allan et al. (2013)	Study 1: Prospective, n=72 students; mean age 19.8	‘Zoo Map’ task	Snacking behaviour	Significant
Allan et al. (2011)	Study 1: Prospective; n=50 students (49 included in analysis); mean age 22 Study 2: Correlational; n=52 students; mean age 21	Study 1: GNG, Tower Task, Verbal Fluency Task, Trail Making Task and the DEX Study 2: GNG and the Stroop Task	Study 1: Fruit, vegetable and snack consumption[5] Study 2: Snack consumption	Mixed results

[5]In the published paper, the four executive function measures were not analysed separately, but in the meta-analysis they are included as separate entities. Also, in the current review looks at consumption, but in the original paper the outcome was the size of the intention-behaviour gap.

Allan, Johnston, and Campbell (2010)	Empirical; n=62 students intending to avoid calorific snacks, mean age 20.4	Stroop Task, Tower Task and a Fluency Task	Chocolate consumption	Mixed results
Allom et al. (2013)	Study 1: Prospective; n=218 students (209 included in analysis; ages 16-45 (mean 20.06) Study 2: Prospective, n=227 students (178 included in analysis), ages 17-44 (mean 19.41)	TOL, WCST, and IGT	Sun protection behaviours	Mixed results
Allom and Mullan (2012)	Prospective; n= 218 students (209 included in analysis), ages 16-45 (mean 20.06)	IGT and TOH	Fruit and vegetable consumption	Mixed results
Andrade et al. (2013)	Longitudinal; n=80 HIV positive adults	Neuropsychological battery of 7 domains, including executive functioning	Medication adherence	Significant
Bagner, Williams, Geffken, Silverstein, and Storch (2007)	Cross-sectional; n=130 children with a diagnosis of type 1 diabetes and their guardian; ages 8-19 (mean 12.7)	BRIEF	Medication adherence	Significant

Blume, Schmaling, and Marlatt (2005)	Prospective; n=117 alcohol dependent/abusive adults; ages 18-50	Controlled Oral Word Association Test, Ruff Figural Fluency Test, Wisconsin Card Sorting Test, Wechsler Memory Scale-Revised (WMS-R)	Readiness to change drinking behaviour	Mixed results
Bogg, Fukunaga, Finn, and Brown (2012)	Cross-sectional; n=27 students; ages 18-23 (mean 20.11)	Auditory Consonant Trigram test	Alcohol consumption	Non-significant
Castellanos-Ryan, Rubia, and Conrod (2011)	Longitudinal; n=76 adolescents; ages 14-16	GNG and Stop tasks, and digit span	Alcohol consumption and drug use	Mixed results
Christiansen et al. (2012)	Cross-sectional, n=97 university staff and students; ages 18-59 (mean 28.95)	GNG	Alcohol consumption	Significant
Colder and O'Connor (2002)	Retrospective; n=106 undergraduates; mean age 19.11	GNG Task and a Inhibitory Control Scale	Alcohol consumption	Significant
Edmonds et al. (2009)	Cross-sectional; n=147 students	GoStop task and IGT.	Wellness maintenance[6] and substance risk	Significant

[6]Wellness maintenance excluded from meta-analysis due to being a combination of approach and avoidance behaviours, but substance risk included.

Ettenhofer, Foley, Castellon, and Hinkin (2010)	Prospective observational study; n=91 HIV positive adults; mean age 42.25	Executive functioning	Medication adherence	Significant
Ettenhofer, Hinkin, Castellon, Durvasula, Ullman, Lam et al. (2009)	Cross-sectional; n=431 HIV positive adults; mean age 42.79	Trail Making Test (Part B), Stroop Test, Short Category Test and the WCST	Medication adherence	Significant
Fernie, Peeters, Gullo, Christiansen, Cole, Sumnall et al. (2013)	Cross-lagged prospective; n= 287 adolescents; ages 12-13 (mean 13.33)	Stop-Signal task	Alcohol consumption	Significant
Fernie, Cole, Goudie, and Field (2010)	Correlational/retrospective; n=75 social drinkers from university students and staff (68 included in analyses); mean age 19.34	GNG and Stop Signal Task	Alcohol consumption[7]	Non-significant
Graziano, Geffken, Williams, Lewin, Duke, Storch et al. (2011)	Cross-sectional; n=109 adolescents diagnosed with type 1 diabetes and their guardian; ages 12-18 (mean 15.23)	BRIEF	Medication adherence	Mixed results

[7]Alcohol Use Index used in analysis rather than separate alcohol measures.

Guerrieri et al. (2012)	Cross-sectional; n=61 female undergraduate students; mean age 21.43	Stop Signal Task	Food intake	Non-significant
Guerrieri, Nederkoorn, Schrooten, Martijn, and Jansen (2009)	Study 1: 2x2 between-subjects design; n=46 female undergraduates; mean age 20.4 Study 2: 2x3 between-subjects design, n=66 female undergraduates; mean age 20.8	Stop Signal Task	Healthy eating	Mixed results
Guerrieri, Nederkoorn, and Jansen (2008)	Quasi-experimental 2 X 2 X 2 between-subjects design; n= 78 children, ages 8-10 (mean 9)	Stop signal task	Food intake	Non-significant
Hall et al. (2013)	Prospective; n=208 adults; ages 18-89 (mean 45.21)	Stroop task and Go/No-go Task	Exercise and fatty food consumption	Significant

Hall, Zehr, Ng, and Zanna (2012)	Prospective; Study 1: n=276 social science students (273 included in analyses); mean age 20.58; Study 2: n=161 adults (153 included in analyses); mean age 19.45	Go/No-go Task	Exercise	Significant
Hall (2012)	Prospective; 208 healthy adults, ages 18-89 (mean 45.21)	Stroop Task and Go/No-go Task	High-fat food consumption	Significant
Hall et al. (2009)	Prospective; n=516 healthy adults, ages 65-99 (mean 78.84)	Digit span subtest (DS) subtest of the WAIS-R	Mortality (exercise, smoking and alcohol consumption)	Mixed results
Hall et al. (2008b)	Prospective; Study 1: n=64 undergraduates; Study 2: n=121 undergraduates; mean age 19	GNG[8]	Exercise and healthy dietary choice	Significant

[8]Due to the reaction times for Go and No-go trials being moderately correlated the authors created an overall reaction variable, which was used in the meta-analysis.

Hall et al. (2008a)	Functional imaging (fMRI) study; Study 2: n=64 young adults, mean age 19.03	Stroop Task, TOH and GNG	Exercise	Significant
Hall, Elias, and Crossley (2006)	Cross-sectional; n=217 healthy adults; ages 20-100 (mean 54.90)	Stroop Task	Two risky behaviours: smoking and alcohol consumption Two protective behaviours: sleep habits and exercise	Mixed results
Harakeh et al. (2012)	Prospective cohort; n=2, 230 adolescents (2,149 included in time 2 assessment); mean age 16.3	Memory-search task and a shifting-set task.	Smoking[9]	Mixed results
Henges and Marczinski (2012)	Cross-sectional; n=109 undergraduate students, ages 18-21 (mean 19.6)	Cued GNG	Alcohol consumption	Significant
Hinkin, Hardy, Mason, Castellon, Durvasula, Lam et al. (2004)	Prospective observational design; n=148 HIV positive adults; ages 25-69 (mean 44.2)	Short Category Test, Trail Making Test (Part B) and the Stroop Test	Medication adherence	Significant

[9]Only daily smoking correlations included in meta-analysis. Smoking onset correlations dismissed.

Hofmann et al. (2009)	Experimental; n=122 female students (118 included in analyses); mean age 23	Operation Span Task, Stop Signal Paradigm	Candy consumption	Significant
Hofmann et al. (2008)	Experimental; Study 2: n=119 (117 included in analyses) female undergraduates, ages 18-44 (mean 22.38)	Computation Span	Candy consumption	Significant
Houben, Havermans, Nederkoorn, and Jansen (2012)	Mixed design; n=57 heavy student drinkers; mean age 20.91	Stop Signal Task[10]	Alcohol consumption	Mixed results
Houben (2011)	Experimental; n=32 female undergraduates (29 included in analyses); mean age 21.15	Stop Signal Task	Healthy eating[11]	Significant

[10] Due to this paper being an intervention study post manipulation correlations were used.

[11] Total calories consumed assessed in meta-analysis.

Houben and Jansen (2011)	Experimental; n=69 female undergraduate chocolate cravers (63 included in analyses); mean age 20.08	Go/No-go Task	Chocolate consumption	Significant
Houben, Nederkoorn, Wiers, and Jansen (2011a)	Experimental; n=52 heavy student drinkers; mean age 22.37	Go/No-go Task	Alcohol consumption	Significant
Houben et al. (2011b)	Experimental; n=48 heavy drinkers; mean age 44.33	A Working Memory (visuospatial) Task, Digit span backwards and a Letter span Task[12]	Alcohol consumption	Significant
Houben and Wiers (2009)	Correlational; n=71; mean age 20.49	Stroop Task	Alcohol consumption	Significant

[12]Due to this paper being an intervention study post manipulation correlations were used.

Jones, Guerrieri, Fernie, Cole, Goudie, and Field (2011)	Experimental; n=53 undergraduate social drinkers; mean age 19.89 (Disinhibited), 20.23 (Restrained) conditions[13]	Stop Signal Task	Alcohol consumption	Significant
Junger and van Kampen (2010)	Cross-sectional; n=201 adolescents; ages 15-20	Corsi Block-tapping Task[14]	Dietary habits and exercise	Mixed results
Khurana, Romer, Betancourt, Brodsky, Giannetta, and Hurt (2013)	Longitudinal cohort; n=358 adolescents; mean age 11.4	Backward digit span, Corsi block tapping, letter two-back, and spatial working memory	Alcohol consumption	Significant
Kor and Mullan (2011)	Prospective study; n=273 psychology undergraduates (257 included in analyses); ages 16-56 (mean 19.9)	Visual GNG	Sleep hygiene behaviours	Significant

[13] Correlations were provided collapsed between the two groups.

[14] Dismissed memory span forward and backwards and just used memory scores for forward and backward.

McNally, Rohan, Pendley, Delamater, and Drotar (2010)	Cross-sectional; n=235 children with a diagnosis of type 1 diabetes for a minimum of a year; ages 9-12 (mean 10.54)	BRIEF	Medication adherence	Significant
Mullan et al. (2011)	Prospective study; n=153 students; mean age 20.1	TOH, Stroop Task, IGT and the WCST	Binge-drinking	Mixed results
Murphy and Garavan (2011)	Retrospective; n=89 students consuming alcohol a minimum of once a week (84 included in analyses); ages 18-30 (mean 20.8)	Alcohol Stroop Task and GNG	Alcohol consumption	Mixed results
Nederkoorn et al. (2009)	Study 1: Cross-sectional; n=57 female students, mean age 20 Study 2: Cross-sectional, n=94 undergraduate students; mean age 20.3	Stop signal task	Food intake[15]	Significant

[15]Total calories and non-snack calories as measured in study dismissed from meta-analysis.

Patrick et al. (2008)	Correlational; n=80 students (72 females included in analysis), ages 19-24 (mean 21.09)	n-back Task and GNG	Alcohol consumption and drug use	Mixed results
Pavlik, de Moraes, Szklo, Knopman, Mosley, and Hyman (2003)	Prospective; n=15,792 adults (11,444 included in analysis), ages 48-67	Delayed Word Recall Test, Digit Symbol Substitution Test, COWAT (Word Fluency Test)	Mortality	Mixed results
Pentz and Riggs (2013)	Longitudinal; n=1,005 fourth grade children; mean age 9.27	BRIEF	Alcohol consumption, smoking and exercise	Significant
Pharo, Sim, Graham, Gross, and Hayne (2011)	Cross-sectional; n=136 adolescents; ages 13-17 (mean 15.86) and n=57 young adults; ages 18-22 (mean 19.8)	COWAT, Mental Control, Backward Digit Span, Mental Arithmetic, WCST and the Stroop Test[16]	Alcohol, smoking and drug use	Significant
Pieters, Burk, Van der Vorst, Wiers, and Engels (2012)	Longitudinal, n=238 adolescents; mean age 13.82	Self-ordered pointing task	Alcohol consumption	Non-significant

[16]Composite neuropsychological functioning measure used in meta-analysis.

Primozic, Tavcar, Avbelj, Dernovsek, and Oblak (2012)	Cross-sectional; n=114 adults diagnosed with type 2 diabetes; ages 40-80 (mean 63.74)	TOL and the Stroop Task	Diabetes self-management[17]	Mixed results
Ready, Stierman, and Paulsen (2001)	Correlational study; n=61 undergraduates; mean age 19.32	COWAT, Trail-Making test (Part B), the WCST and the Frontal Lobe Personality Scale (FLOPs)[18]	Smoking, alcohol consumption and drug use	Mixed results
Riggs, Spruijt-Metz, Chou, and Pentz (2012)	Cross-sectional; n=1,587 fourth grade students; mean age 9.30	BRIEF	Smoking, alcohol consumption, fruit, vegetable, and snack consumption and exercise[19]	Significant
Riggs, Chou, Spruijt-Metz, and Pentz (2010)	Pre-post design; n=224 fourth grade children; mean age 9.38	BRIEF	Food intake and exercise	Mixed results

[17]Only 60 participants used insulin, thus this subset was included in the meta-analysis, with the final diabetes self-management score being calculated form diet, exercise and foot care. In addition, only the colour-word condition of the Stroop task was included in the meta-analysis, with word and colour conditions being dismissed.

[18] Only the executive dysfunction scale of the FLOPs included in the meta-analysis, the apathy and disinhibition scales dismissed.

[19]Sedentary behaviour dismissed from the meta-analysis.

Riggs, Spruijt-Metz, Sakuma, Chou, and Pentz (2010)	Cross-sectional survey; n=353 children (107 included in analyses); mean age 9.4	BRIEF	Fruit, vegetable and snack consumption[20]	Mixed results
Romer et al. (2011)	Longitudinal; n=387 children, ages 10-12	Digit span backwards, Visual spatial working memory, Corsi block tapping, Letter two-back	Smoking and alcohol consumption	Significant
Romer, Betancourt, Giannetta, Brodsky, Farah, and Hurt (2009)	Multi-cohort longitudinal study; n=387 children; ages 10-12	Corsi Block-Tapping, Letter Two-back, DS, Spatial Working Memory, Counting Stroop, and a Flanker Task	Smoking, alcohol consumption and drug use	Non-significant
Solomon and Halkitis (2008)	Longitudinal; n=300 HIV positive males who had relations with other men (213 included in analyses), ages 20-70 (mean 42)	Trail Making Test A and B	Medication adherence	Mixed results

[20]Discrepancy between description of correlational data and correlation matrix presented in paper. This was resolved based on an email from the author.

Spinella and Lyke (2004)	Correlational; n=112; ages 15-55	The Frontal Systems Behavior Scale (FrSBe)[21]	Eating behaviour[22]	Mixed results
Todd and Mullan (2013)	Prospective; n= 190 students (137 included in analyses), mean age 19.7	TOL, IGT, WCST, GNG and the Stroop task.	Sleep hygiene behaviours	Mixed results
Veling et al. (2013b)	Study 1: 2 x 2 between-subjects design; n=79 young adults; mean age 21.38 Study 2: 2 x 2 between-subjects design; n=44 young adults, mean age 21.50	Go/No-go manipulation	Snack consumption	Significant
Veling, Aarts, and Papies (2011)	Experimental; Study 2: n=46 undergraduates	Go/No-go manipulation	Candy consumption	Mixed results

[21]Only executive dysfunction scale used, apathy, disinhibition and total score scales dismissed.

[22]Only eating inventory disinhibtion scale used.

Waldrop-Valverde, Jones, Gould, Kumar, and Ownby (2010)	Cross-sectional; n=191 HIV positive adults; age 18+	Colour Trails Test and TOL	Medication adherence	Mixed results
Wong and Mullan (2009)	Prospective; n=96 psychology undergraduates, ages 17-30 (mean 19.46)	GNG and the TOH	Breakfast consumption	Mixed results

Note: DEX = Dysexecutive Questionnaire, GNG = Go/No-go task, TOL = Tower of London, TOH = Tower of Hanoi, WCST = Wisconsin Card Sorting Task, IGT = Iowa Gambling Task, BRIEF = Behavior Rating Inventory of Executive Functioning, BRI = Behavior Regulation Index, MI = Metacognition Index, SSRT = Stop Signal Reaction Time, RT = Reaction time, COWAT = Controlled Oral Word Association Test, AUI = Alcohol Use Index, AUDIT = Alcohol Use Disorders Identification Test, DSMP = Diabetes Self-Management Profile, TRI CEP = Temptation and Restraint Inventory Cognitive and Emotional preoccupation, TRI CBC = Temptation and Restraint Inventory Cognitive and Behavioral Control, PAR T1 = Physical Activity Recall Time 1, NCI T1 = NCI Fruit & Vegetable Screener Time 1.

Table 2.2

Relationship between executive control and health behaviour and impact of moderators

	k	n	R	95% CI	Q
Overall	52	11,335	.145***	.106—.183	176.785***
<u>Behaviour</u>					
Fruit and vegetable consumption	7	2,498	.097***	.051 - .143	9.188
Exercise	5	3,081	.097***	.055 - .140	3.768
Medication adherence	8	1,327	.264***	.211 - .317	5.946
Snack consumption	14	2,881	.187***	.112 - .261	30.195**
Alcohol consumption	16	1,932	.088*	.014 - .160	38.068***
<u>Approach versus avoid behaviours</u>					
Approach	22	5,771	.164***	.107 - .220	74.140***
Avoid	36	8,737	.137***	.089 - .185	140.511***
<u>Habitual versus non-habitual behaviours</u>					
Habitual (frequent performance and consistent context)	12	2,018	.221***	.152-.287	43.979***

Non-Habitual		37	8,748	.108***	.066-.150	83.976***
Addictive versus non-addictive behaviours						
Addictive		17	4,081	.078*	.012 - .143	41.352***
Non-addictive		31	6,484	.173***	.128 - .219	85.460***
Type of EC measure						
Response inhibition:	Overall	28	5,093	.129***	.070 - .187	117.036***
	Approach behaviours	7	784	.162*	.031 - .287	25.272***
	Avoidance behaviours	22	4,358	.109**	.034 - .183	78.727***
Planning:	Overall	11	1,416	.082	-.010 - .172	30.341***
	Approach behaviours	8	1,129	.051	-.057 - .158	25.661***
	Avoidance behaviours	4	336	.190*	.023 - .346	2.787
Working memory:	Overall	11	3,811	.021	-.069 - .110	16.978
	Approach behaviours	2	310	.115	-.015 - .241	7.635**
	Avoidance behaviours	10	3,702	.007	-.045 - .060	7.503
Other:	Overall	12	3,645	.123**	.039 - .206	40.518***

	Approach behaviours	6	973	.158**	.050 - .263	21.610***
	Avoidance behaviours	7	2,721	.095	-.012 - .199	9.514
Objective		43	7,735	.120***	.077 - .162	141.675***
Self-report		11	3,725	.242***	.166 - .315	16.403
Sample						
Children/Adolescents		14	7,122	.127***	.062 - .191	59.250***
Students/Adults		36	3,908	.142***	.093 - .190	96.762***
Methodology						
Cross-sectional design		37	7,172	.163***	.119 - .206	90.344***
Prospective design		15	4,163	.102**	.033 - .169	58.414***
Objective		9	701	.160**	.054 - .262	15.970*
Self-report		43	10,283	.138***	.096 - .180	155.392***

*p<.05, **p<.01, ***p<.001. Note. k = Number of studies, n = sample size of studies combined, *r* = correlation coefficient, 95% CI = 95% confidence interval, Q = Heterogeneity

Systematic review: Moderation effects

Fourteen studies investigated EC as a moderator. Eight studies showed significant moderation effects, with four studies showing EC to be a moderator of the intention-behaviour relationship for behaviours such as fruit and vegetable consumption (Allom & Mullan, 2012; Hall et al., 2008b), exercise (Hall et al., 2008a; Hall et al., 2008b) and alcohol consumption (Mullan et al., 2011). Three studies showed EC to be a significant moderator of the relationship between implicit attitudes/affect on alcohol consumption (Houben & Wiers, 2009) and unhealthy eating behaviour (Hofmann et al., 2009; Hofmann et al., 2008). The final significant study showed EC to be a moderator of the IQ-mortality relationship (Hall et al., 2009). Three studies showed mixed results in relation to EC being a moderator of the intention-behaviour relationship for breakfast, fruit, vegetable and snack consumption (Allan et al., 2011; Wong & Mullan, 2009), and sunscreen use/protective sun behaviour (Allom et al., 2013). One other study showed mixed results in relation to EC as a moderator of the relationship between approach sensitivity, emotional decision making and alcohol/drug use (Patrick et al., 2008). Two studies did not find EC to be a moderator of the relationship between intention and sleep behaviour (Kor & Mullan, 2011), and between approach tendencies and alcohol consumption (Pieters et al., 2012).

Systematic review: Interventions

Four health behaviour change intervention studies found significant direct effects. Four used a Go/No-go or Stop Signal Task as their mode of intervention on behaviours including alcohol consumption (Jones et al., 2011), and unhealthy food consumption (Houben, 2011; Houben & Jansen, 2011; Veling et al., 2013b). The latter finding these effects were particularly evident for highly restrained eaters (Houben & Jansen, 2011) and those with a high appetite and habitual consumption of the food in question (Veling et al., 2013b). One other study showed direct effects using an implementation intention intervention on exercise participation (Hall et al., 2012). One study did not show any significant direct effects on calorie intake using the Go/No-go or Stop Signal Task intervention (Guerrieri et al., 2012). Only four studies were eligible for inclusion in the meta-analysis showing a non-significant effect.

Three intervention studies showed direct effects using the Go/No-go or Stop Signal Task intervention while controlling for covariates such as gender, body mass index (BMI) and chronic dieting for behaviours including alcohol consumption (Houben et al., 2011a) and caloric intake (Guerrieri et al., 2009; Veling et al., 2011). The latter finding reduced intake was present in both low and highly restrained eaters, but not those currently on a diet (Guerrieri et al., 2009) and that intake was only reduced in chronic dieters, but not non-dieters (Veling et al., 2011).

One study found moderation effects training working memory, with the moderation effect of working memory on subsequent alcohol consumption being further moderated by implicit preferences (Houben et al., 2011b). However, another study found no such moderating effects of EC on alcohol consumption (Houben et al., 2012).

Discussion

This is the first meta-analytic and systematic review to examine the published research examining the influence of EC on health behaviours in healthy populations. Both components revealed that EC has an impact on multiple health behaviours.

Meta-analytic review

Fifty-two tests of this relationship were included in the meta-analysis. Results revealed that EC has a statistically significant but small sized average effect on health behaviour, such that greater EC proficiency was associated with greater performance of healthy behaviours and reduced performance on unhealthy behaviours. Trim and fill analyses showed that this effect was not biased by unpublished studies.

Moderation analyses indicated that EC had a significant impact on both approach and avoidance health behaviours. While the effects were in opposite directions, the absolute size of effect did not differ between the two. Nevertheless, moderation effects revealed significant variations in the impact of EC on health behaviour among some of the health behaviours subsumed under approach and avoid behaviours. The strongest relationship emerged between EC and medication adherence, equating to a moderate effect size. This is an

important finding, as EC proficiency can be compromised by illness (Stern et al., 1995; Waldstein et al., 2003); thus this finding highlights the importance of EC as a means of helping individuals monitor and persist with their medication adherence goals. Furthermore, it highlights the importance of protecting EC functioning from deterioration during illness, especially long-term illnesses, such as diabetes and HIV. Indeed, it is most likely that the relationship is reciprocal, with better EC being associated with greater medication adherence/management, which in turn protects EC functioning. Although EC was a significant predictor of each group of health behaviours, its impact was significantly stronger for medication adherence compared to exercise, fruit and vegetable consumption, and alcohol consumption, but not significantly different from snack consumption. This finding that EC is significantly linked to numerous health behaviours, both encouraging more approach behaviours and discouraging performance of avoid behaviours is important. Future research might usefully examine the extent to which EC is also predictive of additional health behaviours such as dental hygiene, health screening and safe sex practices.

In addition to establishing whether a significant relationship existed between EC and health behaviour and establishing which health behaviours EC impacted on, the current meta-analysis also sought to identify the theoretical underpinnings of this relationship. In particular we examined characteristics of the behaviour, type of EC measured, sample, and methodological factors. With regard to characteristics of the behaviour, results revealed significant differences attributable to the habitualness of behaviour and addictiveness of health behaviours. Contrary to predictions, EC was a stronger predictor of habitual than non-habitual behaviours. This points to the interesting possibility that in contrast to some suggestions (Wong & Mullan, 2009) targeting EC may be a particularly effective means to change habitual behaviours. More consistent with predictions, a significant difference was also revealed between addictive and non-addictive behaviours, with stronger relationships emerging for non-addictive health behaviours. Although it is worth noting that it was significant for both.

In relation to type of EC we distinguished four types of EC types: response inhibition, planning ability, working memory and other (predominantly cognitive flexibility was measured in this category). Significant effects on health behaviour were revealed for response inhibition and the other category, with significant effects for planning ability and working memory. However, no significant differences between these four types of EC were found. Future research could usefully further test for significant differences among these different EC types in their relationship with health behaviour. Our research also failed to support the greater power of different EC measures in relation to approach versus avoidance health behaviours. In particular we had predicted that response inhibition measures might be more predictive of lower engagement with risk behaviours because of the need to resist temptation involved in avoiding such behaviours. Response inhibition measures of EC have been the focus of the majority of the literature in this area, whereas planning; working memory and cognitive flexibility have received less attention. The present findings suggest that even when examining risk behaviours, there is value in examining a range of EC types rather than exclusively focusing on response inhibition. One significant difference that did emerge for EC types was between objective and self-report measures with larger effects emerging for self-report measures. Whether self-report measures of EC accurately reflect the true nature of a person's EC is debatable. For example, in the current review, one study utilized a self-report EC measure aimed at assessing EC as a personality trait (Spinella & Lyke, 2004). It is not clear whether these measures would match the results of objective neuropsychological tests, thus the validity and reliability of this particular self-report measure comes into question. Nonetheless, objective measures may be lacking in relation to reliability (Lowe & Rabbitt, 1998; Luciana & Nelson, 2002). In this review, the Go/No-go task was a commonly used objective measure of EC. A problem with this task is that participants tend to be highly accurate in their performance, so that it is not sensitive enough as a measure of between-subject variation in EC. Indeed, in Patrick et al. (2008) it appears a ceiling effect occurred, as the vast majority of participants made virtually no errors, with 15% achieving perfect performance. Overall, the reliability of objective EC measures is a cause for concern. Some have argued for use of a combination

of objective and self-report measures of EC in order maximize predictive power (Allan et al., 2011).

In relation to sample type we found no significant difference between adolescent and adult samples. In the literature it has been argued that the relationship between EC and health behaviour may be attenuated in children/adolescent samples because EC functions have not yet fully matured (Eshel et al., 2007; Lyon & Krasnegor, 1996; Romine & Reynolds, 2005; Rubia, Smith, Woolley, Nosarti, Heyman, Taylor et al., 2006; Stoet & Lopez, 2011; Stoet & López, 2013; Ward, Shum, McKinlay, Baker-Tweney, & Wallace, 2005). However, the significant effect that emerged for children/adolescent samples and the finding that this relationship does not significantly differ from the relationship for student/adult samples shows that this argument is not borne out. One reason could be that our samples did not include sufficient numbers of young participants. For example, in the Bagner et al. (2007) study that was included in the children/adolescent grouping included participants with an age range of 8-19 years. The older adolescents included may be too similar to the adult samples examined. Future research needs to systematically explore such age effects both among younger and much older groups to find out if this is indeed the case. Nevertheless, the current review highlights that EC has a significant impact on health behaviour for a wide range of ages.

Finally in relation to methodological factors we observed no significant differences between studies employing cross-sectional or prospective designs. Most studies used a cross-sectional design. Although it is encouraging to find similar sized links between EC and health behaviours even in prospective designs, most of the prospective studies included in the review had relatively short follow-ups, with some notable exceptions (Castellanos-Ryan et al., 2011; Fernie et al., 2013; Hall et al., 2009; Khurana et al., 2013; Romer et al., 2011; Solomon & Halkitis, 2008). Future studies could usefully systematically examine the impact of length of the follow-up and also of controlling for baseline levels of health behaviour (i.e., focusing on the impact of EC on behaviour change). We did observe significant differences between studies employing self-report versus objective measures of health behaviour with stronger impacts of EC being

observed in the former. Self-report measures of health behaviour are generally considered more open to bias and therefore it would be useful to see future studies focusing on more objective measures of health behaviour (Hall et al., 2008b; Hinkin et al., 2004; Kor & Mullan, 2011; Ready et al., 2001). Self-report measures of health behaviours may be particularly open to bias when respondents are required to recall behaviour retrospectively over a prolonged period (Kor & Mullan, 2011; Ready et al., 2001). An option to remedy these issues while still using self-report measures is to use diary methods, as these have been used effectively by other researchers to investigate health behaviours (O'Connor, Conner, Jones, McMillan, & Ferguson, 2009).

Systematic review

Seventy-one tests of the relationship between EC and health behaviour were included in the systematic review. Numerous moderation effects emerged from the systematic review of the literature. Eight studies out of fourteen showed EC to be a moderator of intentions, implicit attitudes, IQ and behaviour (Allom & Mullan, 2012; Hall et al., 2009; Hall et al., 2008a; Hall et al., 2008b; Hofmann et al., 2009; Hofmann et al., 2008; Houben & Wiers, 2009; Mullan et al., 2011). In particular, EC was found to moderate the relationships between intention and behaviour and between implicit attitudes and behaviour. With regards to the intention-behaviour relationship it emerged that intentions were more likely to be translated into behaviour in those with high EC. This indicates EC is important in the translation of intentions into action. Furthermore, implicit attitudes towards the health behaviour had a weaker effect on behavioural performance in those with high EC. This indicates EC may also help individuals to overcome their strong implicit desires for unhealthy items, thus suggesting high EC can to some extent override automatic processes.

On the other hand, the two studies that examined approach sensitivity/tendencies in relation to EC yielded mixed results (Patrick et al., 2008; Pieters et al., 2012). The relationship between low inhibitory control, high approach sensitivity and alcohol consumption/drug use makes intuitive sense, for if an individual is heavily drawn to alcohol/drugs and does not have

adequate ability to resist the temptation to drink or take drugs then the likely outcome is the individual will consume alcohol/take drugs. However, the relationship between good working memory, high approach sensitivity and drug use is not so easily explained. Patrick et al. (2008) offer the explanation that individuals with good working memory are simultaneously better equipped to regulate their behaviour such that they reduce the risk of experiencing the negative consequences of their behaviour. This, therefore, raises the possibility that high EC could not only be conducive, but also detrimental to health behaviour performance under certain circumstances (Hofmann et al., 2012).

In addition, the systematic review explored the intervention literature emerging in this field. Ten interventions found significant effects both directly and while controlling for other influences. Nine of which employed a Go/No-go or Stop Signal task manipulation. This paradigm involves the presentation of pictures of alcohol or high-calorie food items, which are paired with a no-go response. This consequently encourages inhibition towards these foodstuffs, which results in less being consumed at a subsequent bogus taste test. This highlights the importance of one aspect of EC in particular: response inhibition. However, the precise definition of response inhibition is unclear in the literature. For instance, is response inhibition, the ability to ignore irrelevant stimuli, or is it the ability to ignore interfering stimuli that normally elicit an automatic response? This is an issue that will need to be addressed in order to ensure the reliability and validity of response inhibition measures. The remaining two studies explored implementation intentions (Hall et al., 2012) and working memory training (Houben et al., 2011b) as interventions. Implementation intentions are ‘if-then’ plans that aid the automatic production of behaviour by pairing an external stimulus with an appropriate behavioural response (Gollwitzer, 1999). The evidence for the efficacy of implementation intention interventions is strong with meta-analytical evidence showing them to have a moderate-to-large effect size (d=.65) on health behaviour (Gollwitzer & Sheeran, 2006). Furthermore, the study included in the present review demonstrated that implementation intentions can be particularly effective in adverse conditions (Hall et al., 2012). Houben et al. (2011b) embarked on a different intervention that trained working memory over a period of twenty-five

days using three tasks tapping working memory, which increased in difficulty as performance improved. The training not only improved working memory, but led to a decrease in alcohol consumption that persisted for over a month. Furthermore, the moderation effect of working memory on alcohol consumption was further moderated by implicit preferences, such that improved working memory particularly benefitted individuals with high implicit preferences for alcohol. The results of this study are promising, however, although this type of intervention has been effectively used in other domains (Holmes, Gathercole, & Dunning, 2009; Holmes, Gathercole, Place, Dunning, Hilton, & Elliott, 2010), the evidence for working memory training as a health behaviour change intervention is still in its infancy. Only four studies were available for inclusion in the meta-analysis, thus it is unsurprising no significant effect of EC emerged. However, there appears to be a small trend effect ($r = -.139$, $p = .065$), and with more data it is possible that a significant effect would emerge. This is encouraging, as taking account of the promising narrative reading of intervention findings and the trend emerging from the meta-analysis; it suggests EC as a target of health-based intervention is a worthwhile endeavour.

Limitations

There were three main limitations to the current systematic review and meta-analysis. First, a concern for a meta-analysis is the possibility of publication bias. However, steps were taken to contact key authors to establish if there were key papers that needed including and analyses were undertaken to assess publication bias with no issues emerging. Second, the search strategy employed generated a large number of articles for potential selection. This suggests the search terms were too broad and could have been refined to produce a smaller pool of relevant articles. However, given that such a large number of articles were examined it is more likely the current review includes the majority of relevant tests of the EC-health behaviour relationship. Third, although sixty-six articles were eligible for inclusion in the review, sufficient data was available for only forty-nine articles, covering fifty-two tests. Therefore, the current meta-analysis could not represent the findings of all the literature available on EC and health behaviour in healthy samples. Nevertheless, the

trim and fill procedure found in the current meta-analysis suggest the findings from these missing studies would be unlikely to negate the present findings.

Conclusions

The present meta-analysis indicates that EC has a statistically significant but small overall effect on health behaviour. This overall effect size is significantly moderated by health behaviour group, EC function, measurement type, design and sample. The challenge is that the correlational nature of the tests examined precludes any causal conclusions and future studies might usefully test the impact of interventions designed to change EC on subsequent health behaviour. To deal with this challenge, the manipulation of EC variables in an attempt to exact health behaviour change is beginning to emerge (Houben et al., 2012; Houben & Jansen, 2011; Houben et al., 2011b).

Chapter 3
Study 1: Executive control, conscientiousness and health behaviour: Are they related?

Introduction

Most individuals strive for good health; yet, the health of the general population is failing; largely due to poor health behaviour performance (Knoops et al., 2004; van Dam et al., 2008). As a result, encouraging performance of positive health behaviours, such as healthy eating and exercise participation; as well as discouraging performance of negative health behaviours, such as smoking and excessive alcohol consumption is a priority for health psychologists. However, achieving such health behaviour change is not an easy matter, as there are numerous variables that have an impact on health behaviour performance, such as the environment, cognition, personality and stress. Additionally, health psychologists must contend with the fact that although individuals may have the best intentions to perform a health behaviour, these intentions are not always successfully translated into action (Conner & Armitage, 1998). Therefore, it is imperative to investigate the variables believed to have an impact on health behaviour performance to establish those variables predictive of health behaviour performance and the nature of the relationship so that effective health behaviour change interventions can be developed.

Cognition, especially in terms of IQ, already has established links with health behaviour performance and mortality (Deary & Der, 2005). However, recently attention has shifted onto another aspect of cognition as a potential predictor of health behaviour, this being “executive control” (EC). Indeed, research to date that has investigated EC as both a direct predictor of health behaviour and as a moderator of the intention-behaviour relationship have provided promising results (Allan et al., 2011; Hall et al., 2008b; Mullan et al., 2011). Nevertheless, there are still many questions that remain for investigation, including: what other variables are important in this relationship? This is the question the present research aims to explore, with a particular focus being placed on the potential role of personality.

Similar to cognition, research suggests personality is a key determinant of health behaviour performance. The present study particularly explores the personality trait of conscientiousness; the reasons for which being twofold. Firstly, conscientiousness already has established links with health behaviour performance (Bogg & Roberts, 2004). Secondly, there is considerable overlap between the processes that underlie EC and the characteristics of conscientiousness, for example, the construct of self-control and planning (DeYoung & Gray, 2009). Yet, to our knowledge, only two studies have investigated the relationship between EC and conscientiousness on health behaviour in tandem (Edmonds et al., 2009; Hall et al., 2013); and only two studies have assessed whether EC and conscientiousness are related constructs, finding opposing results (Edmonds et al., 2009; Matthews & Zeidner, 2012). Furthermore, these studies have considered only a narrow range of EC tasks, specifically focussing on the inhibitory aspects of EC. For those reasons, a major aim of the current study is to explore whether EC and conscientiousness are related constructs through the use of correlational and factor analysis.

Stress is another variable that warrants investigation within the relationship of EC, conscientiousness and health behaviour. It can have a significant impact on health both directly through physical changes in biological systems (O'Connor, O'Connor, White, & Bundred, 2000)and indirectly through health behaviour performance, with stress increasing the likelihood of negative health behaviours being performed such as between-meal snacking (O'Connor, Jones, Conner, McMillan, & Ferguson, 2008). The potential impact of stress on EC is twofold. Stress could directly have a detrimental effect on EC or due to connections between the neuroanatomical regions where EC is located (e.g., the prefrontal cortex) and the limbic system, there could be a relationship between EC and the regulation of the stress response. As of yet, however, no research has investigated the relationship between EC, conscientiousness, stress and health behaviour, with the exception of O'Connor et al. (2009) who investigated conscientiousness, daily stressors and health behaviours. Moreover, there are different types of stressors/hassles, and it could be the case that there is a complex interplay between EC, conscientiousness, health

behaviour and stress that is dependent on the type of stress experienced. Indeed, other researchers have highlighted differences in health behaviour as a consequence of experiencing an ego-threatening, physical, interpersonal or work-related hassles, though these studies have only investigated eating behaviour to date (Heatherton, Herman, & Polivy, 1991; O'Connor et al., 2008; Tanofsky-Kraff, Wilfley, & Spurrell, 2000).

Consequently, the current study was also designed to examine a range of potential relationships between EC, conscientiousness, behaviour specific cognitions (intentions), stress and health behaviour in an attempt to gain a better understanding of the links between these important variables. Additionally, the current study was designed to explore a range of health behaviours, with seven categories of health behaviours being investigated: dental (teeth brushing and flossing), sleep, healthy eating, caffeine consumption, alcohol consumption, smoking and exercise. Furthermore, previous research on EC has tended to use predominantly Stroop and Go/No-go tasks, especially when assessing response inhibition (the ability to ignore irrelevant stimuli), with other EC tasks being rarely used. For instance, task-switching tasks have been largely overlooked by previous research (Hofmann et al., 2012), despite serving as both a measure of response inhibition and cognitive flexibility and been extensively used within cognitive psychology to assess EC in older adult samples (Kray & Lindenberger, 2000). Consequently, the current study aimed to explore EC using measures not regularly used, specifically a task-switching task and a flanker task, in an attempt to explore whether different tasks find similar results. As such, establishing the reliability of these measures will be important, especially as to become proficient in these tasks there is an element of learning that takes place during the first time a task is encountered. Also, the current study will employ a daily diary design to measure daily intentions and behaviour over a two week period. Once more, although this design has been used previously (Allan et al., 2011), the earlier work was on a smaller scale, as data was only recorded over three days and only one health behaviour was assessed. Therefore, by having a longer diary period and asking questions about seven health behaviours it is hoped that a

better understanding will be gained of the daily variation in intentions and behaviour and how EC, conscientiousness and stress influence these variables.

Accordingly, Study 1 was undertaken to explore the relationships between EC and multiple health behaviours, while taking into consideration conscientiousness and stress. The main aims of the study were to assess:

(1) The possible direct effects of EC and conscientiousness on health behaviour performance controlling for behaviour specific cognitions (intentions).
(2) The possible moderating effect of EC and conscientiousness on the relationship between behaviour specific cognitions and behaviour (i.e., the intention-behaviour and stress-behaviour relationship).
(3) Whether EC and conscientiousness are related in a meaningful way.
(4) The potential moderating effect of EC and conscientiousness on the relationship between stress and health behaviours.
(5) The reliability of EC measures.

The present study had a number of hypotheses:

(1) EC and health behaviour performance are related, such that individuals with high EC will be more likely to perform positive health behaviours and less likely to perform negative health behaviours. Individuals with lower executive functioning will show the opposite pattern of results. It is predicted conscientiousness will show the same pattern of results.

(2) EC will moderate the intention-behaviour relationship, such that depending upon their intentions, individuals with higher EC will be more likely to translate behavioural intention into behavioural performance. Once again, individuals with lower EC will show the opposite pattern of results. It is predicted conscientiousness will show the same pattern of results.

(3) EC and conscientiousness will moderate the relationship between stress and health behaviours, with the effect on health behaviour being dependent on the type of hassle experienced.

(4) There will be a positive relationship between EC and conscientiousness.

Pilot work

In order to develop strong hypotheses for the current PhD research, pilot work was conducted assessing the theoretical and empirical underpinnings for a relationship between EC, conscientiousness and health behaviour; such that, research predictions were derived from both theoretical and empirical knowledge. Theoretically, numerous health behaviours were rated by three academics and a PhD student with expertise in cognitive and health psychology as to whether it was a positive or negative health behaviour, the degree to which they believed the health behaviour would be influenced by EC and conscientiousness, and which aspects of EC and conscientiousness they believed would be particularly influential over each health behaviour (a completed form can be seen in Table 3.1). Empirically, a similar table was created (Table 3.2) showing examples of literature that has demonstrated an association between EC, conscientiousness and each health behaviour measured in this study. Both sources of information were used to establish clear predictions about the inter-relationships between EC, conscientiousness and health behaviour.

Table 3.1

Health behaviour rating form

Health Behaviour	Positive or negative health behaviour?	Influenced by EC (1 (Not at all) – 5 (Very much)?	Influenced by conscientiousness (1 (Not at all) – 5 (Very much)?	Possible mechanism of influence
Dental appointment attendance	Positive	3.0	3.5	Planning, Orderliness, Responsibility, Traditionalism
Brushing your teeth	Positive	1.0	1.0	Orderliness, Habit
Flossing	Positive	3.5	3.5	Planning, Orderliness
Doctor appointment attendance	Positive	3.0	3.5	Planning, Orderliness, Responsibility, Traditionalism
Self-examination behaviours	Positive	3.5	4.0	Planning, Orderliness, Responsibility, Traditionalism, Self-efficacy

Vaccination attendance	Positive	3.5	4.0	Planning, Orderliness, Responsibility, Traditionalism
Health screening attendance	Positive	3.5	4.0	Planning, Orderliness, Responsibility, Traditionalism
Medication adherence	Positive	3.0	4.0	Planning, Habit, Orderliness, Self-control, Traditionalism
Illicit drug usage	Negative	3.5	3.5	Response inhibition, Self-control, Traditionalism, Virtue
Sun protection	Positive	2.5	3.0	Planning, Habit, Orderliness, Traditionalism, Self-control, Responsibility

Going to bed at a set time	Positive	3.5	3.5	Planning, Habit, Traditionalism, Orderliness, Self-control, Responsibility
Waking up at a set time	Positive	2.5	2.5	Planning, Habit, Orderliness
Hours slept	Positive	1.5	2.0	Habit
Eating breakfast	Positive	2.5	2.5	Planning, Habit, Orderliness, Traditionalism
Eating a healthy breakfast	Positive	3.5	3.5	Planning**,** Response inhibition**,** Orderliness**,** Self-control**,** Traditionalism
Eating snacks	Negative	3.0	3.0	Response inhibition, Habit, Self-control, Orderliness, Responsibility

Eating healthy snacks	Positive	4.0	4.0	Planning, Orderliness, Traditionalism
Eating unhealthy snacks	Negative	3.5	4.0	Response inhibition, Self-control, Responsibility
Fruit consumption	Positive	3.0	3.5	Planning, Orderliness, Traditionalism
Vegetable consumption	Positive	3.0	3.5	Planning, Orderliness, Traditionalism
Caffeine consumption	Negative	1.5	2.0	Habit
Alcohol consumption	Negative	3.5	3.5	Response inhibition, Habit, Self-control, Responsibility, Virtue
Smoking	Negative	2.5	3.5	Response inhibition, Habit, Self-control, Responsibility, Virtue

Exercise	Positive	3.5	4.0	Planning, Self-control, Industriousness, Orderliness, Traditionalism

Table 3.2

Empirical evidence supporting a link between health behaviours and EC/Conscientiousness

Health behaviour	Linked with EC/conscientiousness	Mechanism	Examples	Evidence
Sleep behaviours	EC	Response inhibition	Sleep hygiene	Kor and Mullan (2011)
Unhealthy eating	EC	Response inhibition, working memory, attention, emotional regulation	Candy consumption	Hofmann, Friese, and Roefs (2009), Hofmann. Gschwendner, Friese, Wiers, and Schmitt (2008); Houben and Wiers (2009), Veling, Aarts, and Papies (2011)

		Response inhibition, cognitive flexibility	Chocolate consumption	Allan, Johnston, and Campbell (2010); Houben and Jansen (2011)
	Conscientiousness	Orderliness	Avoidance of high-calorie foods	Booth-Kewley and Vickers (1994)
		Industriousness, responsibility, traditionalism		Bogg and Roberts (2004)
Fruit and vegetable consumption	EC	Response inhibition, cognitive flexibility		Allan et al. (2011); Hall et al. (2008b)
Caffeine consumption	EC	Memory	Soft drink consumption	Junger and van Kampen (2010)
	Conscientiousness	Orderliness		Booth-Kewley and Vickers (1994)

Alcohol consumption	EC	Response inhibition		Houben, Nederkoorn, Wiers, and Jansen (2011), Jones et al. (2011), Murphy and Garavan (2011), Patrick, Blair, and Maggs (2008)
			Consumption and reasons for excessive consumption	Colder and O'Connor (2002)
			Age first consumed alcohol, drinking intentions	Deckel, Bauer, and Hesselbrock (1995)
		Response inhibition, planning	Binge-drinking	Mullan et al. (2011)
		Working memory		Houben, Wiers, and Jansen (2011)

	Conscientiousness	Responsibility, orderliness, industriousness, self-control, virtue, traditionalism	Bogg and Roberts (2004); Cook, Young, Taylor, and Bedford (1998)
Smoking	EC	Response inhibition	Hall, Elias, and Crossley (2006); Pharo et al. (2011)
	Conscientiousness	Responsibility, industriousness, orderliness, self-control	Bogg and Roberts (2004)
Physical activity	EC	Response inhibition	Hall et al. (2008a), Hall et al. (2008b), Hall et al. (2012)

	Conscientiousness	Responsibility, orderliness, industriousness, self-control, traditionalism	Bogg and Roberts (2004); Booth-Kewley and Vickers (1994); Hogan (1989)

Note. Dental and breakfast behaviour not included as there is no evidence of a link or the research is non-significant.

Method

Participants

The current study was undertaken between January and June 2012. Participants were recruited using a variety of methods including: posters, flyers, the University of Leeds participant databases and email. All advertisements took the same form by providing an outline of what participants were required to do, the inclusion criteria and a website address for them to register their interest. After registering their interest on the website, potential participants were contacted via email by the researcher. The inclusion criteria specified that individuals could only participate if they: (i) were a student, (ii) were aged between 18-30 years (iii) did not suffer from any neurological problems (e.g., dyslexia, ADHD, autism, brain injury), as this study specifically focused on a 'healthy' sample, (iv) had access to a computer with internet access (required for the daily diary component of the study), (v) were committed to participate in two separate laboratory sessions. Seventy-three individuals (11 males, 62 females) participated in the study aged between 18-28 years (mean 21.75, SD 2.758) with complete data available for sixty-nine participants (i.e., completed both laboratory sessions and a satisfactory amount of diary entries). Excluded and included participants were analysed for differences in terms of EC and conscientiousness using independent t-tests, which revealed no significant differences. For their participation, participants were reimbursed with course credits, entered into a prize draw or received a £10 Love2shop voucher. This study received ethical approval (ethics reference number 11-0265) from the University of Leeds Ethics Committee, and followed the British Psychological Society (BPS) ethical recommendations.

Design

A multilevel diary design (Appendix 3.5) was adopted to assess the within-person effects of EC, personality (particularly conscientiousness, however, the Big Five personality factors -openness to experience,

extraversion, agreeableness, neuroticism were also measured), and stress on multiple health behaviours (dental, sleep, breakfast consumption, snacking, fruit and vegetable consumption, caffeine consumption, alcohol consumption, smoking and exercise) over a fourteen day period. An interval-contingent method was employed with participants being required to complete the diary at the end of the day (between 4pm and 2am). Such a design and method was chosen due to its proven reliability in psychological domains such as health and social psychology (Bolger, Delongis, Kessler, & Schilling, 1989; Feldman, Downey, & Schaffer-Neitz, 1999; Green, Rafaeli, Bolger, Shrout, & Reis, 2006). Furthermore, interval-contingent diaries have the advantage of reducing participant burden, which promotes motivation and compliance, especially when studies are undertaken over long durations (Green et al., 2006; Tennen, Affleck, Coyne, Larsen, & DeLongis, 2006). In addition, it allows researchers to combine within and between participant variables. Thus it provides detailed data on not only the differences that can be seen between participants, but also the day-to-day fluctuations in, for instance in the current research, behavioural intentions and actual behaviour.

Measures

EC measures

Both EC tasks were completed on a computer with a Linux operating system using the experimental software PsyToolkit (Stoet, 2010). Stimuli were presented on a 17” colour monitor and response to stimuli was measured using a Cedrus USB keyboard (model RB-834) with only three keys being used across both tasks (Figure 3.1). The Task-switching task was completed first, followed by the Flanker task. Instructions were presented on the computer, which were navigated using either the space bar, the up/down arrows or the ‘q’ key on the keyboard. Participants had the option to browse through the instructions repeatedly and were free to ask questions at any time as the experimenter remained in the room throughout the sessions. Diagrams and examples were included within the instructions to aid participant understanding of the tasks. In addition, after each block of trials for the two EC tasks

participants were presented with feedback on their mean response time and accuracy rate (presented as a percentage). Additionally, participants were informed to turn off any mobile or electronic devices to reduce possible distractions, and were required to wear earplugs during the non-training blocks of trials for both EC tasks in order to cancel out any noise distractions.

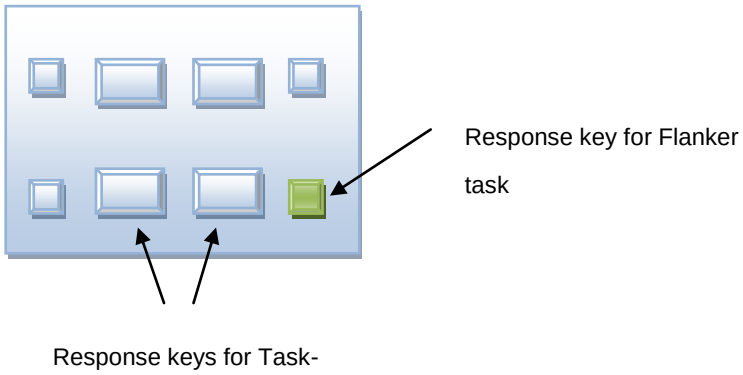


Figure 3.1: Diagram of the Cedrus keyboard used for the EC tasks.

Task-switching task. Participants were initially informed that the task would measure their response precision and speed; therefore they must respond quickly, but accurately. Should participants make an error or respond too slowly, a message would appear informing them. Subsequently, participants were presented with a large rectangle across the computer screen split in half horizontally. The top half of the rectangle related to the 'Shape' task, which was labelled above the rectangle. The bottom half of the rectangle related to the 'Filling' task, which was labelled below the rectangle. Participants were presented with three types of task that required responding to stimuli in the shapes of diamonds and rectangles with a filling of two or three dots. In the 'Shape' task, either a diamond or a rectangle would appear at random in the top half of the rectangle. The diamond required a left button press and the rectangle required a right button press. The filling of these shapes was to be ignored. Similarly, in the 'Filling' task, diamond and rectangle shaped stimuli would appear randomly in the bottom half of the rectangle, but the outer shape was to be ignored, and participants must only respond to the number of dots filling the shape. A filling of two and three dots required a left and right button press

respectively. The ‘Mixed’ task was simply the ‘Shape’ and ‘Filling’ task combined (Figure 3.2), such that participants were required to respond to shape and filling randomly within the same block of trials. Firstly, participants completed three practise blocks of the ‘Shape’, ‘Filling’ and ‘Mixed’ task comprising of ten trials each, except the ‘Mixed’ practise which was twenty trials (10 ‘Shape’, 10 ‘Filling’). Afterwards, participants completed the real test blocks. The ‘Shape’ and ‘Filling’ tasks comprised of 48 trials each and the ‘Mixed’ task was a total of 96 trials (48‘Shape’, 48 ‘Filling’). Participants had 1000ms in which to respond to the stimuli.

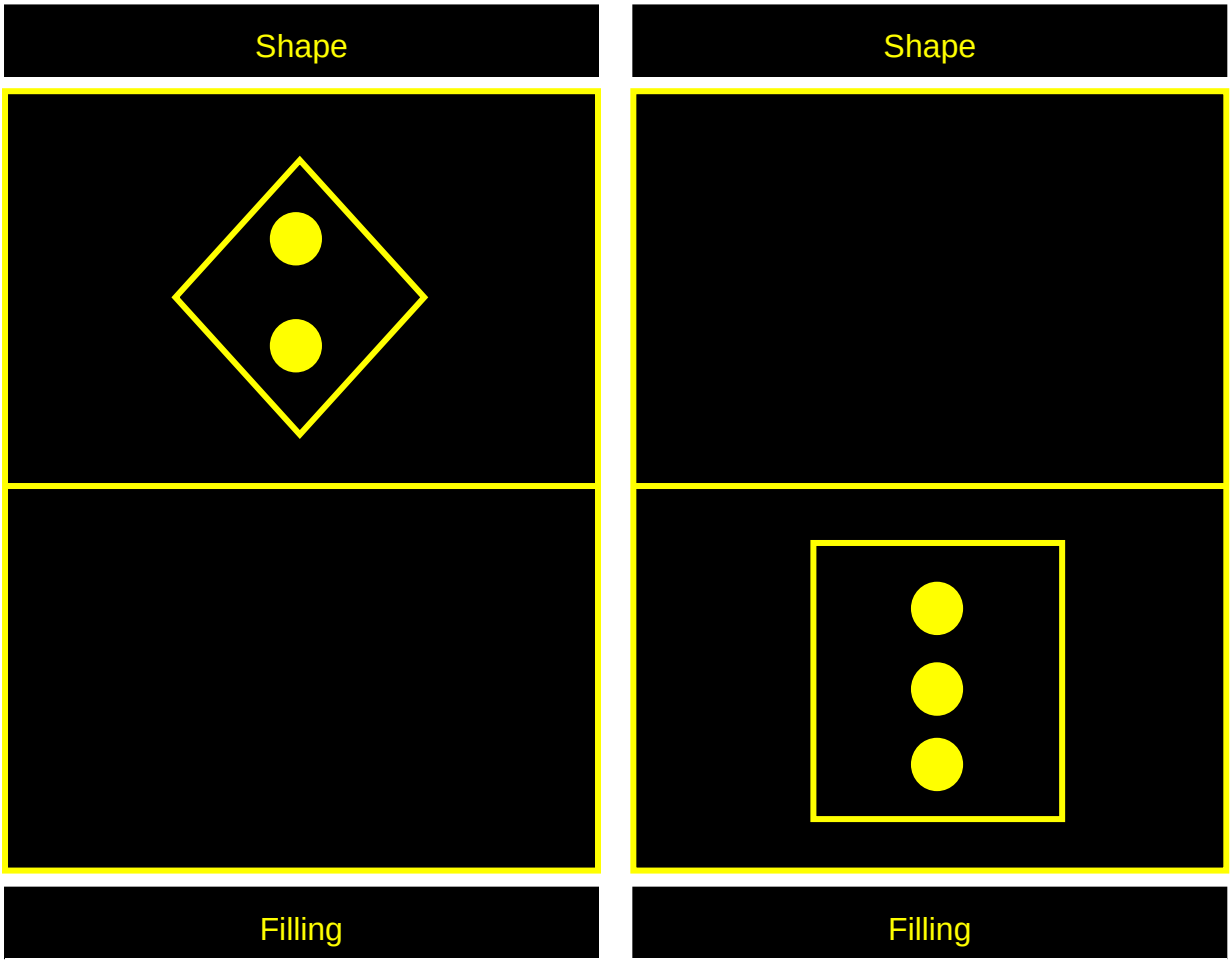


Figure 3.2: The Task-switching task. The left panel shows a diamond shape with a filling of two dots in the top half of the rectangle. When stimuli appears in the top half of the rectangle only the shape of the stimuli is to be responded to and the filling is to be ignored. The right panel shows a rectangle shape with a filling of three dots in the bottom half of the rectangle, therefore only the filling is to be responded to and the shape should be ignored.

Flanker task. Participants were informed that this task was going to measure their ability to ignore irrelevant information and they were to respond quickly and accurately. If participants made an error or were slow at responding a message would appear informing them. Participants were then presented with a 3x3 square grid and instructed to press the green button only when they saw a green ball in the centre grid position. Otherwise, they must not press any button, thus the other grid positions were to be ignored and red balls were to be ignored (Figure 3.3). A 3-2-1 countdown was used at the beginning of each block to focus participants' attention on the screen. This technique was also used in the task-switching task. First, participants completed a practise block of 10 trials, followed by two further blocks of 128 trials each. Once more, participants had 1000ms to respond.

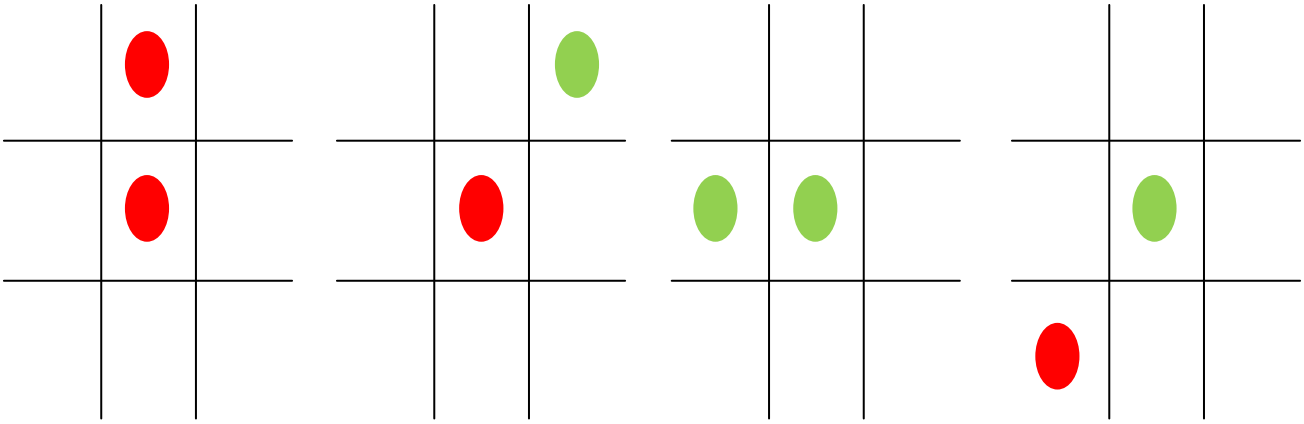


Figure 3.3: The Flanker task. The four grids above display the four possible combinations of balls the participant could see. The two panels on the left show the red ball in the centre of the grid, therefore the correct response is to ignore the red ball and press nothing. The two panels on the right show the green ball in the centre of the grid; therefore the correct response is to press the designated button.

Personality measures

60-item conscientiousness questionnaire (Hill & Roberts, 2011). The six facets of conscientiousness (virtue, traditionalism, self-control, responsibility, orderliness and industriousness) are represented by ten items each and participants must indicate how accurately each statement applies to them on a 5-point Likert scale ranging from *Very accurate (1) – Very inaccurate (5).* For

this questionnaire, the lower score suggests the individual is higher in conscientiousness. For the statistical analyses, this was changed so a high score reflected higher conscientiousness, thus allowing easier comparisons to be made between the scales. Before answering any questions, participants had to click a button to confirm they understood the instructions and when answering the questions they had to press a button saying “Click here for next question”. This was to ensure all questions were answered. Due to the considerable length of the questionnaire participants were presented with a screen halfway through the questionnaire to provide a break and inform them of their current position within the questionnaire. In order to continue, participants were to click on a button when they were ready to complete the second half of the questionnaire.

50-item set of International Personality Item Pool (IPIP) Big-Five Factor Markers (Goldberg, 1992). This self-report questionnaire measures the Big-Five personality dimensions (Agreeableness, Conscientiousness, Emotional stability, Extraversion and Intellect/Imagination) by asking participants to indicate the extent to which each of the fifty statements describe them on a 5-point Likert scale (*Very Inaccurate (1), Moderately Inaccurate (2), Neither Accurate Nor Inaccurate (3), Moderately Accurate (4), Very Accurate (5)*). For this questionnaire, higher scores indicate higher levels of these personality traits.

Health behaviour measures

Daily diary. The diary was structured into three distinct blocks of questions: daily hassles/stressors, intentions to perform multiple health behaviours and actual behavioural performance of the multiple health behaviours. This structure was adopted in an attempt to reduce respondent burden. Based on the work of Conner, Fitter, and Fletcher (1999) and O'Connor et al. (2008) the daily hassles/stressors items asked participants to briefly describe the hassles they had experienced and indicate the intensity of each stressful event on a 5-point Likert scale (*‘Not stressful’ (1) – ‘Very Stressful’ (5)*). Hassles/stressors are defined as “events, thoughts or situations which, when they occur produce negative feelings such as annoyance, irritation, worry or frustration, and/or

make you aware that your goals and plans will be more difficult or impossible to achieve" (O'Connor et al., 2008 p.20). Using the definitions of hassles outlined by O'Connor et al. (2008), each hassle was coded as being ego-threatening, interpersonal, physical, work-related or other. Hassles were coded as "other" if they failed to match the definitions used for the other four hassle types. Common examples of hassles coded as other include financial troubles, damage to possessions and waking up early or oversleeping. Additionally, the hassles types are not necessarily mutually exclusive; therefore a hassle may be coded as more than one hassles type. Coding was undertaken by three individuals trained to PhD level with percentage of agreement ranging between 88-100%. Cohen's k was also used to assess inter-rater reliability (see Table 3.3 for results).

Behavioural intentions to perform each health behaviour was measured in turn with most items taking the format of "To what extent do you intend to/avoid [health behaviour] tomorrow? *(Not at all (1) – Very much (7))*", although some questions required a free response. Intentions were framed so that they adhered to health guidelines, such that for dental behaviours participants expressed the extent to which they intended to brush and floss their teeth at least twice and once a day respectively, for sleep it was eight hours, for breakfast and snacks it was how much they intended to eat healthy breakfasts and snacks, for fruit and vegetables it was five portions a day, and for exercise it was at least thirty minutes of moderate and strenuous activity respectively.

Actual behaviour was measured primarily by free response questions, however participants were asked about each health behaviour in turn as with the intention measures. With regards to questions about snacking, all snacks were coded as high-fat, high-sugar or high in both. Coding was undertaken by one individual trained to PhD level. If a snack was low in both fat and sugar it was included within the snack total only. Definitions of high-fat and high-sugar were established using NHS recommendations. High-fat was defined as more than 20 grams of fat per 100 grams. High-sugar was defined as more than 15 grams of sugar per 100 grams. Using these values each snack had its fat and sugar content evaluated using the McCance and Widdowson (2002) food composition tables. Again, inter-rater reliability was high with a 97-98%

percentage of agreement. Cohen's k results can be seen in Table 3.3. With regards to exercise, the minutes of moderate and strenuous exercise were added together to create a total exercise measure. Accordingly, a matching intention measure was created for total exercise, which was the mean of the moderate and strenuous exercise intention ratings.

Table 3.3

Cohen's k for coding of hassles and snacks

	K	CI (95%)	*p*
		Hassle type	
Ego-threatening	.265	-.152 - .682	.002
Physical	.873	.701 - 1.045	<.001
Interpersonal	1.000	-	<.001
Work-related	.944	.870 - 1.018	<.001
Other	.767	.616 - .918	<.001
		Snack type	
High-fat	.969	.908 - 1.030	<.001
High-sugar	.951	.884 - 1.018	<.001
High fat and sugar	1.000	-	<.001

k = Cohen's kappa; CI (95%) = 95% confidence interval

Procedure

Firstly, participants were required to attend a laboratory-based session within the Institute of Psychological Sciences, University of Leeds. At this first session, participants were provided with an information sheet (Appendix 3.1), and informed written consent was gained (Appendix 3.2). Although strict exclusion criteria had been advertised during recruitment, participants were screened for neurological impairment, colour vision deficiency (using the

Ishihara colour blindness test) and whether they were taking medication that could affect performance. Demographics such as age and gender were recorded, as well as their email address so they could receive reminder emails to complete the diary (Appendix 3.3). Additionally, participants were required to create a unique identification code, as this would be needed to match the laboratory session and diary data anonymously. After this information had been collected, participants completed two computer-based EC tasks: a task-switching task and a Flanker task; and a conscientiousness questionnaire (Appendix 3.4). This session lasted 30 minutes.

The day after attending the laboratory session, participants began their online 14-day diary (Appendix 3.5). An automatic reminder was sent via email at 5pm every day containing the web link (www.psyc.leeds.ac.uk/14daydiary) for the diary and could be completed anytime onwards up to 2am when the diary would close for the day to prevent participants from retrospectively completing the diary. Diary entries took approximately 5-10 minutes to complete each day and were date and time stamped.

The day after participants had finished their last diary entry, they returned to the laboratory for a second session. In this session the same computer-based EC tasks as in the first session were completed, and an additional questionnaire was completed on the Big Five personality dimensions (Appendix 3.6). Although it was only the conscientiousness dimension of the Big Five questionnaire that was of interest. See Figure 3.4 for a schematic of the study's procedure.

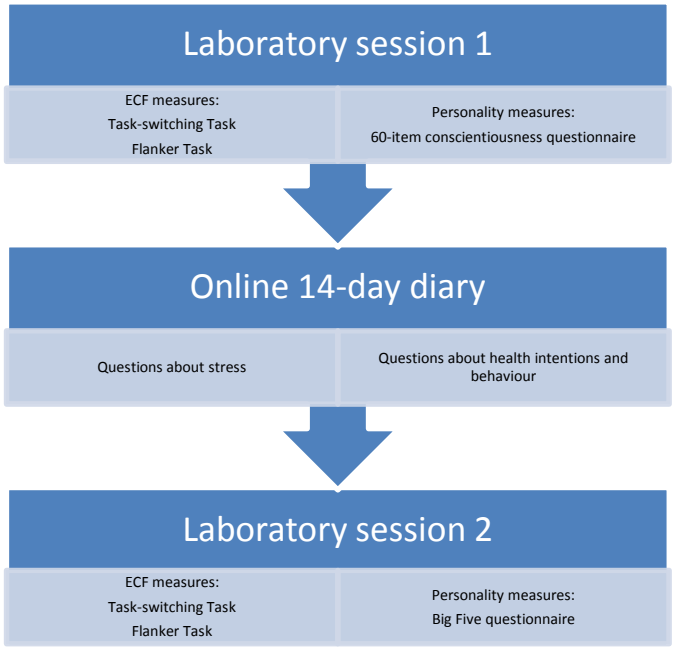


Figure 3.4: Schematic representation of the study.

Results

Reliability of measures

Due to the lack of research employing task-switching tasks as a measure of EC in health behaviour research, this measure was assessed for its reliability. The EC measures' reliability was assessed in terms of whether participants' performance on these tasks was consistent at session 1 and session 2. A significant positive correlation was found between switch costs in the Task-switching task between session 1 and 2 (r= .47, $p < .05$, see Figure 3.5). As a result of the strong reliability between performance at session 1 and 2, in subsequent analyses the data were combined.

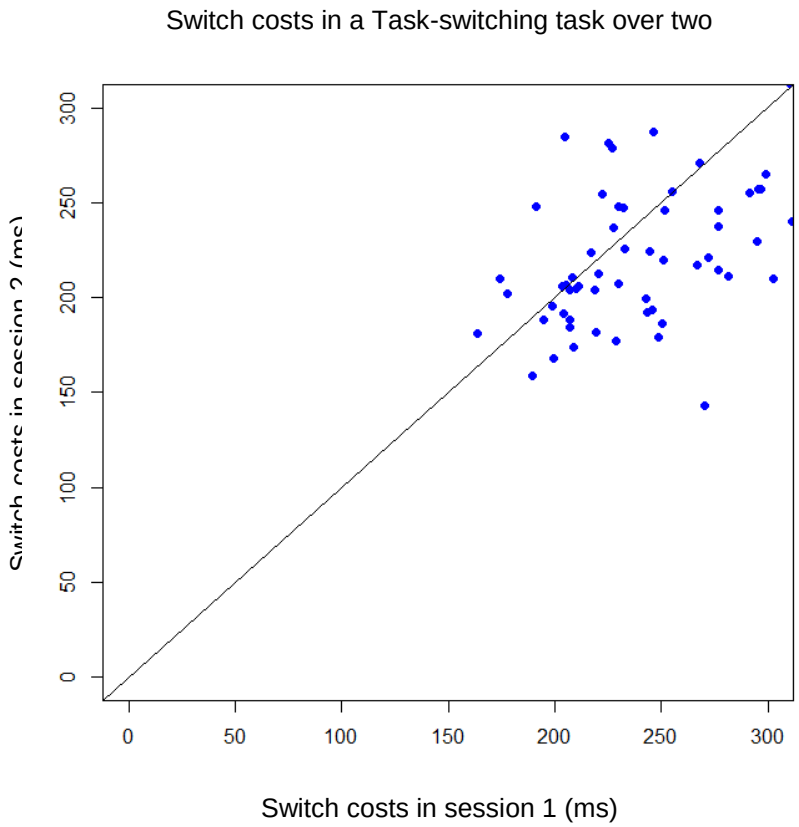


Figure 3.5: Switch costs in two sessions two weeks

EC and conscientiousness

A correlational analysis was undertaken on the EC and conscientiousness measures used in the current study to assess whether they were related. The analysis revealed no significant relationship between switch costs; switch task inhibition and flanker task inhibition and conscientiousness (see Table 3.4). However, switch costs and the conscientiousness facet of industriousness were statistically significantly related, such that high switch costs were associated with lower industriousness. On the other hand, switch costs and flanker task inhibition were marginally correlated (r =.22 p = .075).

Table 3.4

Pearson Product Moment correlations between EC and conscientiousness

	1	2	3	4	5	6	7	8	9	10
1 Switch Cost	-	.028	.216	-.162	-.034	-.157	.073	-.077	-.237*	-.251*
2 Switch task inhibition		-	.152	-.141	-.106	.038	-.079	-.136	-.153	-.100
3 Flanker task inhibition			-	.053	.245*	.006	.150	-.039	-.177	-.101
4 Conscientiousness (60-item)				-	.734**	.441**	.611**	.664**	.756**	.601**
5 Orderliness					-	.058	.318**	.461**	.428**	.307**
6 Virtue						-	.324**	-.017	.348**	.186
7 Traditionalism							-	.266*	.399**	.115
8 Self-control								-	.403**	.262*
9 Responsibility									-	.484**
10 Industriousness										-

**p < .05 **p < .01*

Data Analysis

The data was analysed using multilevel modelling (hierarchical linear modelling [HLM]) (Raudenbush, Bryk, Cheong, & Congdon, 2004). Forming a two level hierarchical structure, level-1 (within-subject variation) contained the daily hassles, health behaviour intentions and actual health behaviour (intentions and behaviour were lagged, such that intentions for day 1 predicted behaviour for day 2 and so on); level-2 (between-subject variation) contained the EC and conscientiousness data. The majority of the level-1 and 2 variables were continuous; therefore they were entered into the model group centred. In the instances where variables were dichotomous they were entered into the model uncentered (Raudenbush et al., 2004). Due to the decision to only include participants who had provided a minimum of seven diary entries, four participants were excluded from analysis by manually removing their diary data from the SPSS data files leaving the final participant total of sixty-nine providing 7-14 diary entries. Missing diary data from the remaining 69 participants was removed using the "Delete missing level-l data when making mdm" function on the HLM software. A lagged analysis was undertaken, such that the behavioural intentions made were for the following day's behaviour. Descriptive statistics for all the level-1 and level-2 variables are shown in Tables 3.5 and 3.6.

Table 3.5

Means and standard deviations for the level-1 variables

Level-1 Variables	*M*	*SD*
Hassle total	1.60	1.32
Hassle intensity total	5.09	4.67
Ego-threatening hassle total	0.07	0.27

Ego-threatening hassle intensity	0.29	1.12
Physical hassle total	0.25	0.59
Physical hassle intensity	0.85	2.02
Interpersonal hassle total	0.21	0.53
Interpersonal hassle intensity	0.63	1.59
Work-related hassle total	0.51	0.76
Work related hassle intensity	1.71	2.76
Other hassle total	0.56	0.77
Other hassle intensity	1.61	2.44
Brush intentions (brush teeth)*	6.57	1.17
Floss intentions (floss teeth)*	2.65	2.22
Number of hours of sleep intentions*	5.60	1.98
Healthy breakfast consumption intentions*	5.12	2.03
Healthy snack consumption intentions*	4.32	2.01
Fruit and vegetable consumption intentions*	4.75	1.86
Caffeine consumption intentions*	3.06	2.42
Alcohol consumption intentions*	4.95	2.43
Smoking intentions*	6.22	1.97
Moderate exercise intentions*	3.05	2.15

Strenuous exercise intentions*	2.42	2.13
Total exercise intentions*	2.73	1.85
Brush behaviour	1.88	0.59
Floss behaviour	0.29	0.60
Bedtime intentions fulfilled (coded yes or no)	0.72	0.45
Wake up time intentions fulfilled (coded yes or no)	0.75	0.43
Number of hours slept	7.76	1.73
Healthy breakfast consumption*	4.59	2.26
Snack total	2.15	1.80
High fat snack total	0.36	0.67
High sugar snack total	0.66	0.98
High in fat and sugar snack total	0.40	0.94
Healthy snack consumption*	3.00	2.31
Fruit consumption	1.59	1.28
Vegetable consumption	1.89	1.36
Caffeine consumption	1.52	1.57
Alcohol consumption**	0.80	0.40
Total alcohol	0.69	1.97
Smoking**	0.93	0.25

Total number of cigarettes smoked	0.23	1.37
Moderate exercise (in minutes)	7.41	18.69
Strenuous exercise (in minutes)	5.03	16.30
Total exercise (moderate and strenuous in minutes)	12.44	26.58

**Rated on a scale from 1(Not at all) – 7(Very much) **Yes/No answer format*

Table 3.6

Means and standard deviations for the level-2 variables

Level-2 Variables	*M*	*SD*
Age	21.80	2.83
Switch cost (as measured in the Task-switching task)	198.62	91.54
Switch task inhibition (Response inhibition as measured in the Task-switching task)	49.75	45.53
Flanker task inhibition (Response inhibition as measured in the Flanker task)	11.92	11.68
Conscientiousness total (60-item questionnaire)	150.20	22.45
Orderliness †	33.83	7.81
Virtue †	33.20	5.33
Traditionalism †	32.71	5.42
Self-control †	33.62	6.80

Responsibility †	38.43	4.10
Industriousness †	38.41	5.72
IPIP Big Five conscientiousness	34.83	7.44

†*Facets of conscientiousness*

Main effects of EC and conscientiousness

The relationships between behavioural intentions and health behaviour performance and the possibility of EC and conscientiousness being moderators of the intention-health behaviour relationship were assessed using the following model:

Level-1: y_{ij} (Behaviour) = β_{0j} + β_{1j}*(Intentions) + r_{ij}

Level-2: β_{0j} = γ_{00} + γ_{01}*(Gender) + γ_{02}*(Switch costs) + γ_{03}*(Switch task inhibition) + γ_{04}*(Flanker task inhibition) + γ_{05}*(Conscientiousness) + u_{0j}

β_{1j} = γ_{10} + γ_{11}*(Switch costs) + γ_{12}*(Switch task inhibition) + γ_{13}*(Flanker task inhibition) + γ_{14}*(Conscientiousness total) + u_{1j}

where γ_{00} denotes the health behaviour mean, γ_{01}-γ_{05} signify the influence EC (comprising switch costs for the task-switching task, response inhibition from the task-switching task and response inhibition from the flanker task respectively) and conscientiousness (as measured by the 60-item conscientiousness questionnaire) has on the mean, γ_{10} represents the average size of the intention-behaviour relationship, and γ_{11} – γ_{14} indicates the degree to which the intention-behaviour relationship is moderated by each of the EC and conscientiousness variables. Similar models were used to assess EC and conscientiousness as moderators of the stress-behaviour relationship. Due to the disproportionate ratio of females to males in the sample, gender was controlled for in all the analyses.

Switch cost calculations

Switch costs are defined as the difference in accuracy and response speed when performing a repetition of a task compared to switching to a new task (Monsell, 2003). Switch costs were calculated using the statistical package R (R Core Team, 2014), as were all the EC variables using the following calculation: the mean of the switch trials minus the mean of the repeat trials. Switch task inhibition was calculated as the mean of incongruent switch trials (where the correct response for the 'shape' and 'filling' tasks is not the same, e.g., the shape is a diamond but the filling is three dots, requiring a left and right button press respectively, therefore the same response button does correctly match both tasks) minus the mean of congruent switch trials (where the correct response for the 'shape' and 'filling' tasks is the same, e.g., the shape is a diamond and the filling is two dots, both stimuli require a left button press to be answered correctly). Flanker task inhibition (i.e., ignoring flanker stimuli) was similarly calculated as the mean of incongruent go trials (where the flanker was a different colour to the target stimuli, i.e., red) minus the mean of congruent go trials (where the flanker was the same colour as the target stimuli, i.e., green). For the sake of brevity, only significant findings are reported below, due to the large number of variables analysed. It also must be acknowledged that as two models were used which included the same variables (EC measures), but included a different measure of conscientiousness, many of the same variables remained significant, therefore only the relationships that were different to the model including the 60-item measure of conscientiousness are reported under the IPIP Big Five measure of conscientiousness.

Main effect of gender

The results showed there was no significant effect of gender on most health behaviours. However, there was an effect of gender on teeth flossing and

on whether an individual smoked, with females showing increased performance of both of these health behaviours (Table 3.7).

Table 3.7

Main effects of gender on health behaviour performance

MRCM Effect	γ	B	*SE*	β	*p*
Intercept: Flossing	γ_{00}	0.069687	0.050496	1.380	0.172
Gender – Flossing	γ_{01}	0.263910	0.078287	3.371	0.001
Intercept: Smoking	γ_{00}	1.849074	1.105915	1.672	0.099
Gender – Smoking	γ_{01}	3.194256	1.217982	2.623	0.011

MRCM=Multilevel random coefficient model; γ=Hierarchical multivariate linear modelling symbol; B=Unstandardized coefficients; *SE*=Standard error; β=Standardized coefficients.

Main effect of EC on health behaviour

A number of significant results emerged revealing EC as a direct predictor of health behaviour. Specifically, switch task inhibition was revealed to predict teeth flossing, whether bedtime intentions were fulfilled (went to bed at the time they intended), and the number of hours slept. The direction of these relationships indicated slower performance in trials that required inhibition (in this case, inhibiting performance of a conflicting task rule) was associated with less flossing, being more likely to go to bed at the intended time, as well as sleeping for a longer number of hours.

On the other hand, Flanker task inhibition was found to predict the number of high fat snacks consumed and moderate exercise performance.

Slower performance in trials that required inhibition (in this case, inhibiting interfering information from the flanker stimuli) was associated with less engagement in moderate exercise and reduced consumption of high fat snacks (see Table 3.8).

Table 3.8

Main effects of EC on health behaviour performance

MRCM Effect	γ	B	*SE*	β	*p*
Intercept: Flossing	γ_{00}	0.069687	0.050496	1.380	0.172
Switch task inhibition – Flossing	γ_{03}	-0.002050	0.000880	-2.329	0.023
Intercept: Bedtime intentions fulfilled	γ_{00}	0.808560	0.254390	3.178	0.002
Switch task inhibition - Bedtime intentions fulfilled	γ_{03}	-0.003105	0.001554	-1.999	0.050
Intercept: Hours slept	γ_{00}	7.183790	0.371776	19.323	<0.001
Switch task inhibition – Hours slept	γ_{03}	0.004944	0.002046	2.416	0.019
Intercept: High fat snack consumption	γ_{00}	0.406252	0.095542	4.252	<0.001
Flanker task inhibition – High fat snacks	γ_{04}	-0.006122	0.002758	-2.220	0.030
Intercept: Moderate exercise	γ_{00}	8.321736	2.950731	2.820	0.006
Flanker task inhibition - Moderate exercise	γ_{04}	-0.217270	0.087051	-2.496	0.015

MRCM=Multilevel random coefficient model; γ=Hierarchical multivariate linear modelling symbol; B=Unstandardized coefficients; *SE*=Standard error; β=Standardized coefficients.

Main effect of conscientiousness on health behaviour

As with EC, data analysis revealed conscientiousness as measured by the 60-item questionnaire to be a significant predictor of healthy breakfast eating rating and fruit consumption. Higher conscientiousness was related to increased attempts to eat a healthy breakfast and higher fruit consumption (Table 3.9).

Table 3.9
Main effects of conscientiousness on health behaviour performance

MRCM Effect	γ	B	*SE*	β	*p*
Intercept: Healthy breakfast eating rating	γ_{00}	3.973856	0.440523	9.021	<0.001
Conscientiousness total – Healthy breakfast rating	γ_{05}	0.018700	0.008027	2.330	0.023
Intercept: Fruit consumption	γ_{00}	1.477106	0.317820	4.648	<0.001
Conscientiousness total – Fruit consumption	γ_{05}	0.014417	0.003381	4.264	<0.001

Main effects of the six facets of conscientiousness

Industriousness. A significant positive relationship was revealed between industriousness and healthy breakfast eating rating and fruit consumption, such

that the more industrious the individual was the more likely they were to attempt to eat a healthy breakfast and to consume more fruit (see Table 3.10 for full results).

Orderliness. High orderliness was revealed to be significantly associated with being more likely to wake at the intended time and being more likely to eat snacks high in fat and sugar.

Responsibility. High responsibility was revealed to be significantly associated with reduced snack consumption and fewer hours slept.

Self-control. High self-control was significantly related to increased consumption of snacks, particularly those high in fat and high in both fat and sugar.

Traditionalism. High traditionalism was significantly associated with being more likely to go to bed at the intended time.

Virtue. A number of significant main effects emerged in relation to virtue, such that high virtue was associated with reduced alcohol consumption and being more likely to smoke, as well as being less likely to wake up at the intended time.

Table 3.10

Main effects of the facets of conscientiousness on health behaviour performance

MRCM Effect	γ	B	*SE*	β	*p*
			Industriousness		
Intercept: Healthy breakfast rating	γ_{00}	4.265092	0.413260	10.321	<0.001
Industriousness – Healthy breakfast rating	γ_{07}	0.057660	0.028285	2.039	0.046
Intercept: Fruit	γ_{00}	1.510515	0.313356	4.820	<0.001
Industriousness – Fruit	γ_{07}	0.034465	0.016886	2.041	0.046
			Orderliness		
Intercept: Wake up intentions fulfilled	γ_{00}	1.360764	0.253595	5.366	<0.001
Orderliness – Wake up intentions fulfilled	γ_{02}	-0.030538	0.013505	-2.261	0.027
Intercept: High fat and sugar snacks	γ_{00}	0.390829	0.160604	2.433	0.018

Orderliness – High fat and sugar snacks	γ_{02}	0.016394	0.007375	2.223	0.030
			Responsibility		
Intercept: Snack total	γ_{00}	1.939637	0.195368	9.928	<0.001
Responsibility – Snack total	γ_{06}	-0.083390	0.041468	-2.011	0.049
Intercept: Hours slept	γ_{00}	7.323227	0.380368	19.253	<0.001
Responsibility – Hours slept	γ_{06}	-0.061821	0.024271	-2.547	0.013
			Self-control		
Intercept: Snack total	γ_{00}	1.939637	0.195368	9.928	<0.001
Self-control – Snack total	γ_{05}	0.047084	0.015762	2.987	0.004
Intercept: High fat snacks	γ_{00}	0.417118	0.080410	5.187	<0.001
Self-control – High fat snacks	γ_{05}	0.013292	0.006085	2.184	0.033

Intercept: High fat and sugar snacks	γ_{00}	0.390829	0.160604	2.433	0.018
Self-control – High fat and sugar snacks	γ_{05}	0.013987	0.006140	2.278	0.026
			Traditionalism		
Intercept: Bedtime intentions fulfilled	γ_{00}	0.653505	0.259843	2.515	0.015
Traditionalism – Bedtime intentions fulfilled	γ_{04}	-0.038815	0.018388	-2.111	0.039
			Virtue		
Intercept: Total alcohol	γ_{00}	0.737372	0.216529	3.405	0.001
Virtue – Total alcohol	γ_{03}	-0.030399	0.012925	-2.352	0.022
Intercept: Smoking	γ_{00}	1.112536	1.114059	0.999	0.322
Virtue - Smoking	γ_{03}	-0.219847	0.076215	-2.885	0.005
Intercept: Wake up intentions fulfilled	γ_{00}	1.360764	0.253595	5.366	<0.001

Virtue – Wake up intentions fulfilled	γ_{03}	0.035199	0.016810	2.094	0.040

MRCM=Multilevel random coefficient model; γ=Hierarchical multivariate linear modelling symbol; B=Unstandardized coefficients; *SE*=Standard error; β=Standardized coefficients.

The intention-health behaviour relationship

As expected behavioural intentions were found to be significant predictors of numerous health behaviours (Table 3.11). These behaviours included teeth flossing, the number of hours slept at night, healthy breakfast rating, fruit and vegetable consumption, alcohol consumption as well as the amount of alcohol consumed, and finally the minutes of moderate and strenuous exercise performed as well as total exercise. In each of these cases, with the exception of the amount of alcohol, these relationships were in a direction that suggested the stronger the behavioural intention the more likely the behaviour was performed. In regards to alcohol, the greater the intention to avoid alcohol the more likely the individual would avoid consuming large amounts of alcohol over the study period.

Table 3.11

Within-person associations of behavioural intentions and health behaviour performance

MRCM Effect	γ	B	*SE*	β	*p*
Intercept: Flossing	γ_{00}	0.069687	0.050496	1.380	0.172
Level-1 slope: Flossing intentions – Flossing behaviour	γ_{10}	0.043105	0.019365	2.226	0.030
Intercept: Hours slept	γ_{00}	7.183790	0.371776	19.323	<0.001
Level-1 slope: Number of sleep hours intended –Hours slept	γ_{10}	0.380510	0.042707	8.910	<0.001
Intercept: Healthy breakfast rating	γ_{00}	3.973856	0.440523	9.021	<0.001
Level-1 slope: Healthy breakfast intentions – Healthy breakfast rating	γ_{10}	0.361444	0.052549	6.878	<0.001
Intercept: Vegetables	γ_{00}	1.950305	0.349943	5.573	<0.001
Level-1 slope: Fruit and vegetable intentions – Vegetable consumption	γ_{10}	0.089525	0.039069	2.291	0.025
Intercept: Alcohol consumption	γ_{00}	1.618131	0.382132	4.234	<0.001
Level-1 slope: Avoiding alcohol intentions – Alcohol consumption	γ_{10}	0.229794	0.060781	3.781	<0.001

Intercept: Total alcohol	γ_{00}	0.724955	0.251027	2.888	0.005
Level-1 slope: Avoiding alcohol intentions – Total alcohol	γ_{10}	-0.195490	0.050534	-3.869	<0.001
Intercept: Moderate exercise	γ_{00}	8.321736	2.950731	2.820	0.006
Level-1 slope: Moderate exercise intentions - Moderate exercise behaviour	γ_{10}	1.401584	0.421346	3.326	0.001
Intercept: Strenuous exercise	γ_{00}	6.048347	2.053076	2.946	0.005
Level-1 slope: Strenuous exercise intentions - Strenuous exercise behaviour	γ_{10}	2.693271	0.504618	5.337	<0.001
Intercept: Total exercise	γ_{00}	12.419285	1.568275	7.919	<0.001
Level-1 slope: Total exercise intentions – Total exercise behaviour	γ_{10}	5.596450	0.649594	8.615	<0.001

MRCM=Multilevel random coefficient model; γ=Hierarchical multivariate linear modelling symbol; B=Unstandardized coefficients; *SE*=Standard error; β=Standardized coefficients.

Moderation (cross-level interaction) Analysis

In order to decompose cross-level interactions, moderator variables were dichotomised into low and high (e.g., switch costs, conscientiousness and the six facets of conscientiousness) or slow and fast (e.g. switch task inhibition and flanker task inhibition) by performing a median split on the data. This was done to aid interpretation of the cross-level interactions so that it could be seen what influence high EC and conscientiousness and low EC and conscientiousness were having on the intention-behaviour, and stress-behaviour relationships. Then the same Level-1 analysis was completed for both low and high or slow and fast with the behaviour being entered as the outcome variable and either intention or hassle being entered group centred.

EC as a moderator of the intention-behaviour relationship.

Analysing the potential moderation effects of EC on the intention-behaviour relationship only one significant moderation emerged. Switch costs were found to moderate the relationship between individuals' intentions to brush their teeth and actual brushing, such that strong intentions to brush their teeth unexpectedly did not translate into brushing behaviour for individuals with low switch costs (β = -4.278, $p < .001$).

Conscientiousness as a moderator of the intention-behaviour relationship.

Exploring the potential moderation effects of conscientiousness (60-item measure) on the intention-behaviour relationship; conscientiousness moderated the relationship between intentions to engage in moderate levels of exercise and how many minutes of moderate exercise were performed with once more low conscientious individuals' better translating strong intentions into behaviour. Exploring the potential moderation effects of conscientiousness (Big Five

measure) on the intention-behaviour relationship, conscientiousness significantly moderated the relationships between intention and brushing your teeth and moderate exercise. Similarly, for low conscientious individuals a strong relationship was found between intentions to engage in moderate exercise and actual engagement in moderate exercise, but low conscientious individuals were also less likely to enact their intentions to brush their teeth (see Table 3.12 for results).

Table 3.12

Conscientiousness as a moderator of the intention-behaviour relationship

Moderator	γ	B	*SE*	β	*p*
		Moderate exercise			
Cross-level interaction					
Conscientiousness* x Moderate exercise intentions - Moderate exercise	γ_{14}	-0.041069	0.013377	-3.070	0.003
Decomposition of cross-level interaction					
Low conscientiousness* x Moderate exercise intentions - Moderate exercise	γ_{10}	2.272807	0.764903	2.971	0.005
High conscientiousness* x Moderate exercise intentions - Moderate exercise	γ_{10}	0.819473	0.510705	1.605	0.118

		Brushing			
Cross-level interaction					
Conscientiousness** x brushing intentions – brushing behaviour	γ_{14}	0.005835	0.002126	2.744	0.008
Decomposition of cross-level interaction					
Low conscientiousness** x brushing intentions – brushing behaviour	γ_{10}	-0.071570	0.025377	-2.820	0.008
High conscientiousness** x brushing intentions – brushing behaviour	γ_{10}	0.036296	0.052381	0.693	0.494

MRCM=Multilevel random coefficient model; γ=Hierarchical multivariate linear modelling symbol; B=Unstandardized coefficients; *SE*=Standard error; β=Standardized coefficients.

**60-item conscientiousness measure*

*** Big Five conscientiousness measure*

Moderations of the six facets of conscientiousness on the intention-health behaviour relationship

Industriousness. Industriousness moderated the relationship between smoking intention and actual smoking, such that smoking was not avoided as intended for those low in industriousness.

Orderliness. Orderliness was found to moderate the intention-behaviour relationship for the health behaviours of the numbers of hours slept and whether an individual smokes. Low orderliness was found to be associated with smoking. However, low and high orderliness were associated with intentions to sleep for eight hours a night and sleeping longer hours.

Self-control. Self-control was found to moderate the relationship between intentions to smoke and actual smoking with low self-control being associated with being less likely to avoid smoking.

Traditionalism. Traditionalism was found to significantly moderate the intention-behaviour relationship for smoking with individuals' low in traditionalism being less likely to avoid smoking.

Virtue. Virtue was found to moderate the number of hours slept and healthy breakfast rating. Similar to orderliness, both low and high virtue was associated with sleeping for longer, as well as greater attempts to eat a healthy breakfast ($p<.001$; see Table 3.13 for full results for each facet).

Table 3.13

The six facets of conscientiousness as moderators of the intention-behaviour relationship

Moderator	γ	B	*SE*	β	*p*
			Smoking		
Cross-level interaction					
Low industriousness x Intentions to avoid smoking – smoking	γ_{10}	-0.216410	0.063344	-3.416	0.002
Low orderliness x Intentions to avoid smoking – smoking	γ_{10}	-0.325076	0.053892	-6.032	<0.001
Low self-control x Intentions to avoid smoking – smoking	γ_{10}	-0.193869	0.063799	-3.039	0.005
Low traditionalism Intentions to avoid smoking –	γ_{10}	-0.034278	0.009936	-3.450	0.001

smoking

		Hours slept			
Cross-level interaction					
Low orderliness x Number of sleep hours intended – Hours slept	γ_{10}	0.286642	0.042724	6.709	<0.001
High orderliness x Number of sleep hours intended – Hours slept	γ_{10}	0.493420	0.069411	7.109	<0.001
Low virtue x Number of sleep hours intended – Hours slept	γ_{10}	0.330966	0.048333	6.848	<0.001
High virtue x Number of sleep hours intended – Hours slept	γ_{10}	0.405990	0.055982	7.252	<0.001
		Healthy breakfast rating			

Cross-level interaction					
Low virtue x Healthy breakfast intentions – Healthy breakfast rating	γ_{10}	0.459723	0.086262	5.329	<0.001
High virtue x Healthy breakfast intentions – Healthy breakfast rating	γ_{10}	0.299343	0.074254	4.031	<0.001

MRCM=Multilevel random coefficient model; γ=Hierarchical multivariate linear modelling symbol; B=Unstandardized coefficients; *SE*=Standard error; β=Standardized coefficients.

Effects of EC and conscientiousness on the stress-health behaviour relationship

Stress as a whole and the different types of stress individuals experience has been shown to have a detrimental effect on health behaviour performance, as such the current study sought to explore if and how EC and conscientiousness played an influential role in the stress-health behaviour relationship. The possibility of EC and conscientiousness being moderators of the stress-health behaviour relationship was assessed using models similar to those looking at the intention-behaviour relationship, with the total number of hassles and the different types of hassles replacing intentions.

The stress-health behaviour relationship

Stress emerged as a predictor of a number of health behaviours across the different models used. The total number of daily hassles was associated with less hours slept. Ego-threatening hassles were associated with less high fat and high sugar snacks being consumed, as well as reduced caffeine consumption, and greater attempts to consume more vegetables. However, ego-threatening hassles were also associated with being less likely to go to bed at the intended time, greater alcohol consumption. Physical hassles were associated with a decreased likelihood of smoking. Work hassles were associated with sleeping for less and being more likely to smoke. Finally, interpersonal and other hassles were not associated with any of the health behaviours directly (Table 3.14).

Table 3.14

Within-person associations of stressors/hassles and health behaviour performance

MRCM Effect	γ	B	*SE*	β	*p*
			Total hassles		
Intercept: Hours slept	γ_{00}	7.347417	0.385025	19.083	<0.001
Level-1 slope: Total hassles – Hours slept	γ_{10}	-0.105427	0.051621	-2.042	0.045
			Ego-threatening hassles		
Intercept: High fat snacks	γ_{00}	0.345980	0.084187	4.110	<0.001
Level-1 slope: Ego-threatening hassles – High fat snacks	γ_{10}	-0.159519	0.049797	-3.203	0.002
Intercept: High sugar snacks	γ_{00}	0.745101	0.184124	4.047	<0.001
Level-1 slope: Ego-threatening hassles – High sugar snacks	γ_{10}	-0.160925	0.068029	-2.366	0.021
Intercept: Vegetable consumption	γ_{00}	1.896933	0.329808	5.752	<0.001

Level-1 slope: Ego-threatening hassles – Vegetable consumption	γ_{10}	-0.288594	0.111931	-2.578	0.012
Intercept: Caffeine consumption	γ_{00}	1.259724	0.320875	3.926	<0.001
Level-1 slope: Ego-threatening hassles – Caffeine consumption	γ_{10}	-0.420563	0.124464	-3.379	0.001
Intercept: Total alcohol	γ_{00}	0.520401	0.161211	3.228	0.002
Level-1 slope: Ego-threatening hassles – Total alcohol	γ_{10}	0.894594	0.375050	2.385	0.020
Intercept: Bedtime intentions fulfilled	γ_{00}	0.839682	0.262980	3.193	0.002
Level-1 slope: Ego-threatening hassles – Bedtime intention fulfilled	γ_{10}	0.827007	0.347793	2.378	0.020
		Physical hassles			
Intercept: Smoking	γ_{00}	2.515572	1.442801	1.744	0.086
Level-1 slope: Physical hassles – Smoking	γ_{10}	1.524244	0.443566	3.436	0.001
		Work hassles			

Intercept: Hours slept	γ_{00}	7.209348	0.340233	21.189	<0.001
Level-1 slope: Work-related hassles – Hours slept	γ_{10}	-0.162270	0.081385	-1.994	0.050
Intercept: Smoking	γ_{00}	1.195435	1.424214	0.839	0.405
Level-1 slope: Work-related hassles – smoking	γ_{10}	-1.367288	0.430253	-3.178	0.002

MRCM=Multilevel random coefficient model; γ=Hierarchical multivariate linear modelling symbol; B=Unstandardized coefficients; *SE*=Standard error; β=Standardized coefficients.

EC as a moderator of the stress-health behaviour relationship

Due to the number of health behaviours and types of hassles/stressors investigated, similar health behaviours are grouped together and discussed in turn below. Furthermore, although many significant cross-level interactions emerged, most after further decomposing were found to be non-significant, therefore only the significant moderations are reported (See Table 3.15 for full results of each health behaviour).

Dental. Cross-level interactions emerged between physical hassles and teeth brushing. The more physical hassles experienced the less likely individuals who performed slowly on the Flanker task (poor inhibition) were to brush their teeth ($p = .011$).

Sleep. Poor flanker task inhibition was found to be associated with being more likely to go to bed at the intended time when physical hassles were experienced ($p=.006$). Additionally, poor flanker task performance was associated with sleeping longer when physical hassles were encountered ($p = .009$). The more hassles experienced in general, however, was associated with sleeping less for those with good flanker task inhibition ($p = .026$). On the other hand, poor switch task inhibition was associated with being more likely to wake up at the intended time when encountering ego-threatening hassles ($p = .035$).

Diet. With regards to ego-threatening hassles, low switch costs were associated with reduced consumption of high sugar snacks ($p = .005$). Low switch costs were also associated with reduced consumption of snacks high in both fat and sugar in relation to physical ($p < .001$), and total hassles ($p = .050$). Good switch task inhibition was associated with consuming more snacks ($p = .033$) in relation to work threats. However, good switch inhibition was associated with reduced consumption of high sugar snacks in relation to ego-threatening hassles ($p = .011$). Good flanker inhibition, on the other hand, was associated with consuming more snacks, particularly high sugar snacks in relation to work

hassles and total hassles. Additionally, both poor and good switch task inhibition was associated with consuming fewer vegetables in relation to ego-threatening ($p = .005$) and physical ($p = .040$) hassles respectively.

Smoking. High switch costs were associated with being less likely to smoke when experiencing a higher frequency of hassles in total ($p < .001$), interpersonal ($p = .013$), work-related ($p = .011$) and other ($p = .003$) hassles. In contrast, low switch costs were associated with being more likely to smoke when experiencing work-related hassles ($p = .012$). Good switch task inhibition was associated with being more likely to smoke when experiencing a higher frequency of hassles in total ($p = .002$) and other hassles ($p = .011$).

Exercise. For total exercise, it was revealed that when experiencing interpersonal hassles, those performing poorly in the switch task performed less moderate and strenuous exercise generally ($p = .029$).

Table 3.15

EC as a moderator of the stress-health behaviour relationship

Moderator	γ	B	*SE*	β	*p*
			Dental behaviours		
Cross-level interaction					
Poor flanker task inhibition x Physical hassles – Brushing	γ_{10}	-0.080827	0.030184	-2.678	0.011
			Sleep behaviour		
Poor flanker task inhibition x Physical hassles – Bedtime intentions fulfilled	γ_{10}	-0.522783	0.176155	-2.968	0.006
Poor switch task inhibition x Ego-threatening hassles – Wake up intentions fulfilled	γ_{10}	1.268064	0.578263	2.193	0.035
Good flanker task inhibition x Total hassles – Hours slept	γ_{10}	-0.184094	0.079294	-2.322	0.026

Poor flanker task inhibition x Physical hassles – Hours slept	γ_{10}	0.375457	0.136110	2.758	0.009
			Diet		
Good switch task inhibition x Work-related hassles – Snack total	γ_{10}	0.209024	0.094001	2.224	0.033
Good flanker task inhibition x Work-related hassles – Snack total	γ_{10}	0.256108	0.097344	2.631	0.013
Low switch costs x Ego-threatening hassles – High sugar snacks	γ_{10}	-0.336017	0.110766	-3.034	0.005
Good switch task inhibition x Ego-threatening hassles – High sugar snacks	γ_{10}	-0.292561	0.108080	-2.707	0.011
Good flanker task inhibition x Total hassles – High sugar snacks	γ_{10}	0.113788	0.047492	2.396	0.022
Low switch costs x Total hassles – High fat and sugar snacks	γ_{10}	-0.168122	0.082905	-2.028	0.050
Low switch costs x Physical hassles – High fat and sugar snacks	γ_{10}	-0.168978	0.043157	-3.915	<0.001
Poor switch task inhibition x Ego-threatening hassles – Vegetable consumption	γ_{10}	-0.364642	0.120932	-3.015	0.005

Good switch task inhibition x Physical hassles – Vegetable consumption	γ_{10}	-0.201764	0.094330	-2.139	0.040
			Smoking		
High switch costs x Total hassles - Smoking	γ_{10}	1.435371	0.387779	3.702	<0.001
High switch costs x Interpersonal hassles – Smoking	γ_{10}	0.806934	0.305804	2.639	0.013
Low switch costs x Work-related hassles – Smoking	γ_{10}	-0.828700	0.312190	-2.654	0.012
High switch costs x Work-related hassles – Smoking	γ_{10}	0.895811	0.333497	2.686	0.011
High switch costs x Other hassles - Smoking	γ_{10}	1.564477	0.482817	3.240	0.003
Good switch task inhibition x Total hassles – Smoking	γ_{10}	-0.551414	0.168486	-3.273	0.002
Good switch task inhibition x Other hassles – Smoking	γ_{10}	-0.694303	0.259404	-2.677	0.011
			Exercise		
Poor switch task inhibition x Interpersonal hassles - Total exercise	γ_{10}	-5.180270	2.275706	-2.276	0.029

MRCM=Multilevel random coefficient model; γ=Hierarchical multivariate linear modelling symbol; B=Unstandardized coefficients; *SE*=Standard error; β=Standardized coefficients.

Conscientiousness as a moderator of the stress-health behaviour relationship

Similar to EC, health behaviours are grouped and discussed in turn below, with only statistically significant results presented (See Table 3.16).

Dental. It was revealed that highly conscientious (60-item measure) individuals brushed their teeth less as the number of hassles they experienced increased ($p = .046$), especially other hassles ($p = .046$). Furthermore, highly conscientious individuals were flossing less also in response to ego-threatening ($p = .004$) as measured by the 60-item conscientiousness measure and work hassles ($p = .015$, 60-item measure; $p = .021$, big five measure). Although, high conscientiousness as measured by the big five measure was associated with increased flossing in response to physical threats ($p = .032$).

Sleep. In relation to interpersonal hassles, low conscientiousness (big five) was associated with being more likely to wake up at the intended time ($p = .029$). In contrast, high conscientiousness (60-item) was associated with sleeping fewer hours in response to other threats ($p = .045$).

Diet. With regards to the 60-item measure of conscientiousness, low conscientiousness was associated with reduced consumption of high fat snacks when experiencing a greater number of interpersonal hassles ($p = .049$). With regards to the big five measure of conscientiousness, in relation to the total number of hassles experienced, low conscientiousness was associated with greater consumption of high sugar snacks ($p = .039$). Finally, both low ($p < .001$) and high ($p = .016$) conscientiousness (60-item measure) were associated with decreased caffeine consumption in relation to ego-threatening hassles.

Alcohol consumption. Low conscientiousness (big five measure) was associated with consuming fewer alcoholic beverages in relation to interpersonal hassles ($p = .047$). Contrastingly, high conscientiousness (big five measure) was associated with consuming more alcoholic beverages in total in relation to other threats ($p = .014$).

Smoking. Low conscientiousness was associated with being more likely to smoke when experiencing a higher frequency of hassles in total ($p = .003$), other ($p = .035$) and work-related ($p = .022$, 60-item measure; $p = .025$, big five measure). However, both low ($p = .045$) and high ($p < .001$) conscientiousness were associated with being less likely to smoke when experiencing physical hassles.

Table 3.16

Conscientiousness as a moderator of the stress-health behaviour relationship

Moderator	γ	B	*SE*	β	*p*
Cross-level interaction			Dental behaviours		
High conscientiousness* x Total hassles - Brushing	γ_{10}	-0.031637	0.015229	-2.077	0.046
High conscientiousness* x Other hassles - Brushing	γ_{10}	-0.048040	0.023199	-2.071	0.046
High conscientiousness* x Ego-threatening hassles – Flossing	γ_{10}	-0.099204	0.032210	-3.080	0.004
High conscientiousness** x Physical hassles – Flossing	γ_{10}	0.051470	0.022778	2.260	0.032
High conscientiousness* x Work-related hassles – Flossing	γ_{10}	-0.098817	0.038503	-2.566	0.015
High conscientiousness** x Work-related hassles – Flossing	γ_{10}	-0.072762	0.029684	-2.451	0.021
			Sleep behaviour		
Low conscientiousness** x Interpersonal hassles – Wake up	γ_{10}	-0.508592	0.225016	-2.260	0.029

intentions fulfilled					
High conscientiousness* x Other hassles – Hours slept	γ_{10}	-0.188901	0.090557	-2.086	0.045
			Diet		
Low conscientiousness** x Total hassles – High sugar snacks	γ_{10}	0.109139	0.051181	2.132	0.039
Low conscientiousness* x Interpersonal hassles – High fat snacks	γ_{10}	-0.072516	0.035551	-2.040	0.049
Low conscientiousness* x Ego-threatening hassles – Caffeine consumption	γ_{10}	-0.721968	0.169171	-4.268	<0.001
High conscientiousness* x Ego-threatening hassles – Caffeine consumption	γ_{10}	-0.361698	0.142832	-2.532	0.016
			Alcohol consumption		
Low conscientiousness** x Interpersonal hassles – Total alcohol	γ_{10}	-0.219337	0.107066	-2.049	0.047
High conscientiousness** x Other hassles – Total alcohol	γ_{10}	0.432849	0.165330	2.618	0.014

		Smoking			
Low conscientiousness* x Total hassles – Smoking	γ_{10}	-0.850047	0.264872	-3.209	0.003
Low conscientiousness* x Physical hassles – Smoking	γ_{10}	0.899213	0.432387	2.080	0.045
High conscientiousness* x Physical hassles – Smoking	γ_{10}	1.255874	0.282816	4.441	<0.001
Low conscientiousness* - Work-related hassles- Smoking	γ_{10}	-1.405688	0.585868	-2.399	0.022
Low conscientiousness** x Work-related hassles – Smoking	γ_{10}	-1.053053	0.453004	-2.325	0.025
Low conscientiousness* x Other hassles - Smoking	γ_{10}	-0.549902	0.250765	-2.193	0.035

MRCM=Multilevel random coefficient model; γ=Hierarchical multivariate linear modelling symbol; B=Unstandardized coefficients; *SE*=Standard error; β=Standardized coefficients.

*60-item conscientiousness **Big Five conscientiousness

The six facets of conscientiousness as moderators of the stress-health behaviour relationship

Similar to EC and conscientiousness as a whole, health behaviours are grouped and discussed in turn below, with only statistically significant results presented (see Tables 3.17).

Dental. Low traditionalism was found to be associated with less likely to floss when experiencing a higher frequency of physical hassles ($p = .028$). Low and high industriousness were associated with being less likely to floss when experiencing a higher frequency of work ($p = .015$) hassles respectively.

Sleep. Low orderliness was associated with being less likely to go to bed at the intended time in relation to ego-threatening hassles ($p = .009$). A higher frequency of hassles was associated with sleeping for a fewer number of hours for those low in orderliness ($p = .041$), with this same relationship also being found with regards to work hassles ($p = .012$), and those high in responsibility ($p = .009$). With regards to physical hassles, individuals who were high in orderliness ($p = .032$) and industriousness ($p = .025$), slept for a longer number of hours.

Diet. The total number of hassles was associated with greater attempts to eat a healthy breakfast for those low in traditionalism ($p = .046$). Less attempts to eat a healthy breakfast were made by those low in responsibility when facing ego-threatening hassles ($p = .044$). A number of cross-level interactions emerged between hassles and snack eating behaviour. Higher consumption of snacks was associated with a higher frequency of hassles for those low in responsibility ($p = .013$). High fat snacks were consumed less by those low ($p = .045$) and high ($p = .014$) in virtue when experiencing ego-threatening hassles. Furthermore, reduced consumption of high fat snacks was related to ego-threatening hassles for those low in traditionalism ($p = .014$), but high in industriousness ($p = .013$). High sugar snacks were consumed more when experiencing a higher frequency of hassles by those low in responsibility ($p =$

.042), but consumed less by those high in responsibility (p = .011) when experiencing interpersonal hassles. Regarding vegetable consumption, high traditionalism (p = .004) and low responsibility (p < .001) were both associated with consuming fewer vegetables in response to ego-threatening hassles. Low virtue (p = .002), high virtue (p = .023), low self-control (p = .001), high self-control (p = .009) and low traditionalism (p < .001) were all associated with consuming fewer caffeinated beverages in relation to ego-threatening hassles. The relationship between high self-control and reduced caffeine consumption was also demonstrated in relation to other hassles.

Alcohol consumption. High responsibility and high orderliness were both associated with alcohol consumption when experiencing ego-threatening (p = .047) and other (p = .038) hassles respectively. The total amount of alcohol consumed was moderated by virtue and orderliness with a higher frequency of other hassles and high orderliness being associated with increased alcohol consumption (p = .038).

Smoking. Low virtue was associated with being more likely to smoke when experiencing a higher frequency of hassles (p < .001) and other (p = .009) hassles, but in relation to physical hassles both low (p = .011) and high (p < .001) virtue were associated with being less likely to smoke. Low responsibility was associated with being more likely to smoke when experiencing work-related hassles (p = .028). Lastly, low self-control was associated with being more likely to smoke when experiencing work-related hassles (p = .022)

Exercise. Regarding total exercise, high industriousness was associated with less engagement in exercise when experiencing a higher frequency of ego-threatening hassles (p = .002). In comparison, high responsibility was associated with more engagement in exercise (p = .048). Focussing on moderate exercise, a higher frequency of hassles was associated with more moderate exercise for those low in orderliness (p = .050), but less moderate exercise for those high in orderliness (p = .015). Similarly, high orderliness was associated with less moderate exercise in relation to other hassles (p = .016).

Focussing on strenuous exercise, a higher frequency of interpersonal and ego-threatening hassles was associated with less engagement in strenuous exercise for those low in traditionalism ($p = .025$) and high in industriousness ($p = .001$) respectively.

Table 3.17

The six facets of conscientiousness as moderators of the stress-health behaviour relationship

Moderator	γ	B	*SE*	β	*p*
Cross-level interaction			Dental behaviours		
High industriousness x Work-related hassles – Flossing	γ_{10}	-0.085112	0.033093	-2.572	0.015
Low traditionalism x Physical hassles – Flossing	γ_{10}	-0.018557	0.008124	-2.284	0.028
			Sleep		
Low orderliness x Ego-threatening hassles – Bedtime intentions fulfilled	γ_{10}	1.336409	0.485098	2.755	0.009
Low orderliness x Total hassles – Hours slept	γ_{10}	-0.198329	0.093255	-2.127	0.041
Low orderliness x Work-related hassles – Hours slept	γ_{10}	-0.320037	0.120080	-2.665	0.012
High orderliness x Physical hassles – Hours slept	γ_{10}	0.308606	0.137961	2.237	0.032

High responsibility x Total hassles – Hours slept	γ_{10}	-0.203314	0.072828	-2.792	0.009
High industriousness x Physical hassles – Hours slept	γ_{10}	0.275630	0.117348	2.349	0.025
			Diet		
Low traditionalism x Total hassles – Healthy breakfast rating	γ_{10}	0.274883	0.133134	2.065	0.046
Low responsibility x Ego-threatening hassles – Healthy breakfast rating	γ_{10}	-0.825497	0.395112	-2.089	0.044
Low responsibility x Total hassles – Snack total	γ_{10}	0.171198	0.065544	2.612	0.013
Low virtue x Ego-threatening hassles – High fat snacks	γ_{10}	-0.205320	0.098971	-2.075	0.045
High virtue x Ego-threatening hassles – High fat snacks	γ_{10}	-0.172114	0.066218	-2.599	0.014
High industriousness x Ego-threatening hassles – High fat snacks	γ_{10}	-0.246303	0.093128	-2.645	0.013
Low traditionalism x Ego-threatening hassles – High fat snacks	γ_{10}	-0.237849	0.091625	-2.596	0.014
Low responsibility x Total hassles – High sugar snacks	γ_{10}	0.117308	0.055704	2.106	0.042

High responsibility x Interpersonal hassles – High sugar snacks	γ_{10}	-0.181136	0.067313	-2.691	0.011
Low responsibility x Ego-threatening hassles – Vegetable consumption	γ_{10}	-0.634568	0.132381	-4.793	<0.001
High traditionalism x Ego-threatening hassles – Vegetable consumption	γ_{10}	-0.535670	0.172468	-3.106	0.004
Low self-control x Ego-threatening hassles – Caffeine consumption	γ_{10}	-0.572146	0.163358	-3.502	0.001
High self-control x Ego-threatening hassles – Caffeine consumption	γ_{10}	-0.431293	0.154160	-2.798	0.009
Low Virtue x Ego-threatening hassles – Caffeine consumption	γ_{10}	-0.567385	0.170711	-3.324	0.002
High virtue x Ego-threatening hassles – Caffeine consumption	γ_{10}	-0.284471	0.118280	-2.405	0.023
Low traditionalism x Ego-threatening hassles – Caffeine	γ_{10}	-0.690431	0.164194	-4.205	<0.001

consumption					
High self-control x Other hassles – Caffeine consumption	γ_{10}	-0.132649	0.063927	-2.075	0.046
		Alcohol consumption			
High responsibility x Ego-threatening hassles - Alcohol consumption	γ_{10}	-0.600938	0.290639	-2.068	0.047
High orderliness x Other hassles – Alcohol consumption	γ_{10}	-0.415117	0.167189	-2.483	0.018
High orderliness x Other hassles – Total alcohol	γ_{10}	0.277909	0.128657	2.160	0.038
		Smoking			
Low virtue x Total hassles – Smoking	γ_{10}	-0.449456	0.118989	-3.777	<0.001
Low virtue x Physical hassles - Smoking	γ_{10}	1.101336	0.410587	2.682	0.011
High virtue x Physical hassles - Smoking	γ_{10}	2.230777	0.459425	4.856	<0.001
Low virtue x Other hassles - Smoking	γ_{10}	-0.909536	0.330994	-2.748	0.009

Low responsibility x Work-related hassles - Smoking	γ_{10}	-1.134881	0.494886	-2.293	0.028
Low self-control x Work-related hassles - Smoking	γ_{10}	-0.956408	0.397289	-2.407	0.022
			Exercise		
Low orderliness x Total hassles – Moderate exercise	γ_{10}	2.572082	1.268425	2.028	0.050
High orderliness x Total hassles – Moderate exercise	γ_{10}	-1.480923	0.575020	-2.575	0.015
High orderliness x Other hassles – Moderate exercise	γ_{10}	-1.870949	0.736382	-2.541	0.016
High industriousness x Ego-threatening hassles - Strenuous exercise	γ_{10}	-7.071748	2.000675	-3.535	0.001
Low traditionalism x Interpersonal hassles – Strenuous exercise	γ_{10}	-3.553579	1.520316	-2.337	0.025
High industriousness x Ego-threatening hassles – Total exercise	γ_{10}	-7.842574	2.323770	-3.375	0.002
High responsibility x Other threat – Total exercise	γ_{10}	5.381226	2.614731	2.058	0.048

MRCM=Multilevel random coefficient model; γ=Hierarchical multivariate linear modelling symbol; B=Unstandardized coefficients; *SE*=Standard error; β=Standardized coefficients.

Discussion

The current study aimed to explore the relationships between EC, conscientiousness and health behaviour performance, with a view to assess whether EC and conscientiousness both directly predicted health behaviour performance and indirectly predicted health behaviour performance through moderation of the intention-behaviour and stress-behaviour relationships. Additionally, this study aimed to investigate the reliability of the measures being used to measure EC and conscientiousness. Broadly three main findings emerged: Firstly, EC and conscientiousness measures did not measure the same construct. Secondly, EC and conscientiousness (including the six separate factors of conscientiousness) directly predicted a variety of health behaviours; however, the findings were mixed. Thirdly, EC and conscientiousness (including the six separate factors of conscientiousness) moderated the intention-behaviour and stress-behaviour relationships; once more, however, these findings were mixed.

Reliability and validity of measures

Firstly, due to task-switching tasks not being used extensively in the existing health behaviour literature, it was thought prudent to assess the reliability of this EC measure. It was strongly indicated that the measures used were highly reliable ($r = .47$). Participants performed at a consistent level in both session 1 and 2 in the task-switching task, exhibiting a high degree of switch costs at both times, thus indicating the measure was reliable. This is important to establish as with any novel task, a learning process must take place. The current study provides evidence to suggest this learning takes place quickly, thus allows individuals to perform at a consistent level even when separated by a fourteen day gap. However, further research is needed to establish the nature of this finding.

The relationship between EC and conscientiousness

Although the constructs of EC and conscientiousness at a conceptual level seem to overlap considerably, a significant correlation between the three measures of EC (switch costs, switch task inhibition and flanker task inhibition) and the two measures of conscientiousness (60-item and Big Five) was not achieved ($r = -.162, -.141, .053$ and $r = -.082, -.112, .053$ respectively). This suggests that although similar, EC and conscientiousness are two distinct entities, which is in line with the findings of Edmonds et al. (2009). This finding poses an interesting scenario, as it suggests people could have low EC, but be high in conscientiousness and vice versa. Therefore, this presents health psychologists with a dilemma when developing health interventions as it highlights the need to tailor interventions accordingly to ensure the most appropriate construct is being targeted. Nevertheless, the current study, Edmonds et al. (2009) and Matthews and Zeidner (2012) did not look at EC tasks that assess planning, which is also a key component of conscientiousness. Therefore, it could be that a relationship lies within these key aspects of EC and conscientiousness. Furthermore, this highlights the value of exploring EC and conscientiousness when do and do not correspond.

The intention-behaviour relationship

Main effects

Similar to other studies (Hall, 2012; Hall et al., 2006; Kor & Mullan, 2011; Mullan et al., 2011; Wong & Mullan, 2009) EC was found to be related to sleep, high fat snack consumption, moderate exercise, breakfast consumption and alcohol consumption. With other studies, the general conclusion has been that poor EC is associated with greater performance of negative health behaviours and reduced performance of positive health behaviours, whereas high EC is associated with the opposite pattern of results. Subsequently, with regards to flossing and moderate exercise, the current findings are in line with previous findings such that poor EC, specifically poor response inhibition, is linked to

reduced performance of positive health behaviour. However, although the current study has found relationships between EC and health behaviour not all the findings are similar to those found in other studies.

Unexpectedly, it was found that poor switch task inhibition was associated with a reduced likelihood of flossing; as well as with being more likely to fulfil bedtime intentions, and sleeping more; and poor flanker task inhibition was found to be associated with being less likely to eat high fat snacks and engage in moderate exercise. Slow performance in these variables reflects poor performance, thus lower EC, as it suggests that when switching between tasks the individual is struggling to inhibit the interference from the previous tasks rules and that they are being distracted by the incongruent flanker stimuli respectively. The associations with bedtime intentions, the number of hours slept, and high fat snack consumption seem to conflict with research in this field, though other research investigating sleep has not considered the same variables as the current study, and have focussed on sleep hygiene behaviours instead (Kor & Mullan, 2011; Todd & Mullan, 2013, 2014). With regards to high fat snack consumption, however, the findings of the current study are in stark contrast to other research (Allan et al., 2010, 2011; Hall, 2012). The main reason for this is most likely due to the nature of the tasks used to measure EC in the current study compared to other research. The literature in this area tends to focus on measures that exclusively tap response inhibition, such as Go/No-go and Stroop task, but the present study chose to explore the task-switching and flanker tasks due to their current under-representation in the literature. These tasks, however, do not exclusively tap response inhibition. They also tap another function of EC known as cognitive flexibility.

Considering conscientiousness, it was found in relation to healthy breakfast eating rating and fruit consumption that higher conscientiousness predicted increased consumption of these foodstuffs. This is in line with the established findings that highly conscientious individuals are more predisposed to perform healthy behaviours, such as the ones found in our study (Bogg & Roberts, 2004). Focussing on the six facets of conscientiousness, although these generally seem to be following a pattern of the lower an individual is in these conscientiousness traits the less likely they are to perform positive

behaviours and the more likely they are to perform negative behaviours there are some spurious findings. The explanation could be that some behaviours rely more heavily on these factors for influence than others. Indeed, the meta-analysis of Bogg and Roberts (2004) highlights that self-control and traditionalism are more consistent predictors of health behaviours than the other facets, particularly industriousness and order, which were the poorest predictors of health behaviour. In addition, Bogg and Roberts (2004) highlighted that not all health behaviours are highly correlated with conscientiousness, particularly presenting exercise behaviour as one of the weaker predictive relationships. Yet, others have found that the responsibility facet of conscientiousness is associated with greater exercise participation (Arai & Hisamichi, 1998; Hogan, 1989). Consequently, this demonstrates that the relationship between conscientiousness and its underlying facets with health behaviour is not clear cut, and different effects can emerge depending on the facet and health behaviour in question, which may explain why unexpected findings emerged in relation to orderliness, self-control and virtue, particularly with regards to snacking behaviour. Further research is thus needed to explain the mechanisms underlying these relationships.

EC and conscientiousness as moderators of the intention-behaviour relationship

A similar pattern emerged when looking at EC and conscientiousness as moderators of the intention-behaviour relationship. Largely, it appears individuals with poor EC and/or low conscientiousness tend to be less successful at translating their health intentions into health behaviour. Meanwhile, individuals with good EC and/or high conscientiousness tend to be better able to translate strong intentions into actual behaviour. However, unexpectedly it emerged that high switch costs, which would traditionally be viewed as poor EC performance, were more conducive to health behaviour performance, with individuals with high switch costs generally having a stronger relationship between intentions and behaviour than those with low switch costs. Although, this could be interpreted as poor EC, is this necessarily true? With

this type of task, individuals are faced with a speed-accuracy trade-off - do they respond quickly but risk being incorrect, or do they take their time to make the correct decision albeit a slower decision? In relation to these findings it is possible that the individuals with high switch costs are more considered in their approach therefore take their time in order to execute what they believe to be the sensible decision. Furthermore, it has been suggested that high task switching ability may be detrimental as well as facilitative to goal pursuit, as it may allow successful balancing of incongruous goals (Hofmann et al., 2012). Yet again, further research is needed to elucidate this issue.

In addition, there are a number of other possible reasons for such mixed findings in relation to both EC and conscientiousness. As already alluded to EC and conscientiousness may not be influential factors for all health behaviours. Indeed, Table 3.2 highlights that empirical support for each of the health behaviours included within this study has not been found. It may be the case that they are more and less important for the performance of certain behaviours; which is once more indicated in Table 3.2. For instance, specifically considering response inhibition; not all behaviours will require an inhibitory reaction, for example brushing and flossing your teeth, as it simply does not make sense to inhibit performing these behaviours. Alternatively, some behaviour may be habitual, for example, bedtimes and wakeup times. Due to these behaviours being habitual, EC may not need to be relied upon, as the behaviour can be performed automatically without calling upon any cognitive resources. Indeed, the idea of habit being a more important determinant over certain behaviours than EC has been proposed by a number of researchers (Fulham & Mullan, 2011; Wong & Mullan, 2009). On the other hand, specifically concentrating on the six facets of conscientiousness, all the moderating relationships were in the expected direction. This suggests when considered as a whole entity, conscientiousness obscures moderating relationships with health behaviour, and to establish clearer moderator relationships, the individual facets should be considered.

The stress-behaviour relationship

With regards to the stress-behaviour relationship, similar to the intention-behaviour findings the results were mixed. Broadly speaking, the results follow the pattern of the intention-behaviour results. The frequency of hassles (in total and different types) were positively associated with the performance of negative health behaviours while the performance of positive health behaviours decreased for those low in EC and conscientiousness. Individuals with high EC and conscientiousness showed the opposite pattern. Nonetheless, the direction of the results was not completely clear cut. However, it must be taken into account that this is the first study to explore the stress-behaviour relationship with regards to EC and conscientiousness, including conscientiousness' six separate facets. Consequently, there is no precedent for this research, and at present there is no specific literature available for comparison. Nevertheless, it is hoped this study will provide the first foothold into this research to enable further study of this area. Furthermore, research that has investigated daily stressors and health behaviour has demonstrated that the different stressors can interact with even the same health behaviour in opposing ways (Heatherton et al., 1991; O'Connor et al., 2008). Indeed, similar to the present study, O'Connor et al. (2008) and Heatherton et al. (1991) found that physical hassles differed in their effect on eating behaviour to ego-threatening, interpersonal and work-related hassles. Thus, it is likely that such differences will carry over into other health behaviours, such as sleep for instance.

Other remarks

Overall, the current study has widened the number of health behaviours EC is related to by finding links to dental behaviours, as well as measuring health behaviour variables in greater detail than in other studies. For instance, although other studies have investigated sleep behaviours, none to our knowledge have assessed whether people go to bed at the time they intend and the number of hours slept. In a similar vein, the present study assessed the different types of snacks consumed in order to assess whether EC was related

to a specific type of snack. Subsequently, this suggests EC exerts some influence over a broader range of behaviours than previously known.

As with other studies investigating the effects of EC on health behaviours, response inhibition has been highlighted as a prominent aspect of EC that is particularly predictive of health behaviour performance. Within this study, two different measures of response inhibition have been shown to exert significant influence over health behaviour performance. This is especially important to emphasise as the two measures of response inhibition used in this study were derived from tasks that are not commonly used in other studies of this type, which instead tend to employ tasks such as the Stroop or a Go/No-go task (Allan et al., 2011; Hall et al., 2008b). Thus, this exemplifies the need to broaden the types of EC tasks used within studies of this nature in order to obtain a comprehensive picture of the nature of EC, and particularly response inhibition on health behaviour. Furthermore, this suggests response inhibition is perhaps a more complicated construct than previously believed. As such, it may be the case that what response inhibition actually represents needs to be assessed and a more thorough definition developed. Additionally, this study has highlighted another task of predictive value: the task-switching task. The present study has found that switch costs, which are an indicator of cognitive flexibility, exerts some influence over health behaviour performance. As a result, in future studies investigating EC and health behaviour, task-switching paradigms should be further explored.

Finally, the current study has demonstrated that EC is a multi-faceted construct, and different aspects of EC are associated with different health behaviours. Consequently, subsequent research will need to be aware of these nuances and investigate them further, as they will be especially important when developing effective health behaviour change interventions.

Limitations

The current study aimed to explore a wide range of health behaviours, employing measures not currently commonly used in the health behaviour literature. Subsequently, the current findings are unprecedented; hence there is

a need for replication of these results. Replication of the current findings would not only serve to clarify the findings of the current study, but also provide new avenues for research.

Conclusions

The current study aimed to explore the relationships between EC, conscientiousness (including the underlying six facets) and multiple health behaviours in a healthy sample. Two main findings emerged: Firstly, EC and conscientiousness are independent constructs. Secondly, a number of EC and conscientiousness measures are directly related to health behaviour and moderate a number of intention-health behaviour and stress-health behaviour relationships, but a number of EC measures are not significantly related to health behaviour and indeed, in some instances demonstrate relationships contrary to predictions. The current findings suggest the relationships between EC, conscientiousness and health behaviour are complex, thus further research is needed to provide a clearer picture of the mechanisms underlying these relationships.

Chapter 4
Study 2: An exploration of the relationships between executive control and conscientiousness

Introduction

Study 1 explored the relationships between EC, conscientiousness and health behaviour. Findings revealed that EC and conscientiousness were not significantly related, but EC and conscientiousness variables independently predicted health behaviour performance over a 14-day period both directly and moderated the intention-behaviour and stress-behaviour relationships. The finding that EC and conscientiousness were not strongly related concepts was unexpected due to the substantial conceptual similarities they share, especially in terms of impulse control (inhibition) and planning. However, Study 1 only employed two measures of EC both primarily tapping inhibition. It may be the case that these particular tasks fail to adequately reflect the underlying characteristics of conscientiousness. Therefore, it was decided to explore EC further in Study 2 by employing a broader range of EC tasks while also further exploring the tasks used in Study 1 (task-switching and flanker tasks).

Further exploration of the task-switching task is particularly important because the literature in this field to date has not explored this task in a meaningful way. Furthermore, Study 1 revealed that switch costs, which are the decrements in performance (reaction times) seen when performing two different tasks consecutively compared to repeating the same task were related to health behaviour performance; albeit, not in the expected direction (with the intention-behaviour relationship being weaker for those with low switch costs). Therefore, examining the relationships between task-switching performance and other measures of EC, as well as conscientiousness, may provide insight into why this finding occurred. On another note, the main reason for identifying the predictors of health behaviour is to ultimately attempt to use these predictors as targets to change health behaviour by means of interventions. With Study 2, it was decided to explore how quickly individuals' performance improves on a task-switching task. This offers the opportunity to potentially use the task-switching task as a form of EC training whereby improvements in EC may

translate into better performance of health behaviours. Indeed, such training methodologies have been used as health behaviour change interventions (Houben et al., 2011b). However, previous research has only shown that working memory training, specifically, improves working memory, but it did not examine the actual learning process. The current study aims to explore the learning curve that takes place over two laboratory sessions block by block not only to attempt to pin-point how quickly individuals learn this task, but also to explore the nature of the task in a meaningful way to provide information to other researchers on how this tool can be used effectively.

In addition to a task-switching task, a flanker task was once more employed in this study as it also provides a switch cost measure, as individuals must switch between congruent and incongruent trials. Therefore, it was expected that the switch costs from the flanker tasks would be correlated with the switch costs from the task-switching tasks, but this has not been previously examined, therefore this potential relationship was considered worth exploring. Furthermore, similarly to performance on the task-switching task, in Study 1, flanker task performance was significantly associated with a number of health behaviours, thus deeper investigation into the nature of this measure is warranted.

In addition, a number of other measures of EC were employed in the current study; including memory, reasoning, and Go tasks. The rationale for looking at a broader range of EC measures in the second study was to explore the nature of the relationships between different components and measures of EC. The three particular measures were chosen here due to their established links to mortality (Murray, Pattie, Starr, & Deary, 2012; Shipley et al., 2006). The Go task specifically provides an indication of information processing speed, therefore identifies how quickly an individual can respond to stimuli. This information can be used to assess whether slow reaction time performance is purely due to participants generally responding slowly or if these decrements in performance are a result of the difficulties of the task. Additionally, previous research suggests that information processing is a particularly strong predictor of mortality (Shipley et al., 2006), therefore was worth exploring in respect to our interest in the relationship between EC and health. Another EC function

receiving increasing interest in terms of being linked to health behaviour is memory, with promising results particularly arising for working memory (Hofmann et al., 2008; Houben et al., 2011b; Romer et al., 2011), thus the inclusion of a memory task was considered a sensible decision considering the current direction of research in this area. On the other hand, although reasoning ability is not normally considered an EC function, it nevertheless has important implications in terms of justifying health behaviour. Thus it was included as though the current study does not measure health behaviour it was interested in exploring potential predictors and moderators of health behaviour, therefore it was worthwhile exploring the relationship between these underlying variables.

Each of the above tasks are objective measures of EC and work on the principle that if an individual exhibits difficulties with these tasks then it can be assumed that they may have difficulties with everyday life that require the same executive resources (Burgess, Alderman, Evans, Emslie, & Wilson, 1998). The Dysexecutive questionnaire (DEX) is a self-report measure of the everyday life symptoms of dysexecutive syndrome (previously referred to as 'frontal lobe syndrome') and is used as part of the Behavioural Assessment of the Dysexecutive Syndrome test battery (BADS). Though this measure is traditionally used to assess the executive deficits experienced in real life by patients with brain-injury or neurological impairment (Wilson, Evans, Emslie, Alderman, & Burgess, 1998), there is nothing to suggest that this measure could not be used to assess the executive function of 'healthy' individuals. Indeed, the DEX has been used in studies investigating the relationship between EC and health behaviours with promising results (Allan et al., 2011). Although other research has investigated the relationship between the DEX and health behaviour, only one study has looked at whether the DEX was related to other measures of EC producing non-significant findings (Burgess et al., 1998). This study also only looked at whether the DEX was related to other measures within the BADS; therefore whether the DEX correlates with more general measures of EC is unknown. Consequently, the current study aims to broaden this research by examining whether self-report and objective measures of EC are related, therefore establishing the convergent validity of these measures. In

addition, the current study aimed to explore the DEX to establish if it can be used as a valid and easy to administer measure of EC.

Apart from EC another key part of this research is personality and the question of whether EC and personality are related. A major personality trait of interest in the first study and of this programme of research is conscientiousness due to the large conceptual overlap between the concepts of conscientiousness and EC. Only one study has investigated the possible relationship between EC, conscientiousness and health behaviour, finding that there was no relationship between EC and conscientiousness (Edmonds et al., 2009). Study 1 also confirmed this non-significant relationship. However, Edmonds et al. (2009) only looked at three measures of EC: the GoStop task, the Iowa Gambling task and an objective measure of impulsivity. It could therefore be argued that important measures of EC were missing, for example, other objective measures of EC, including a task-switching task and self-report measures, such as the DEX. Although, Study 1 did include a task-switching paradigm, which did not correlate with conscientiousness; it is still worthwhile to look at this relationship within the broader context of EC tasks in an attempt to provide a definitive answer to the question of whether these two variables are related.

In summary, the current study had two main aims. First, to explore how quickly individuals could improve at an EC task and examine the nature of this learning. Second, to explore the inter-relationships between EC and conscientiousness. Accordingly, the current study had three main hypotheses:

1) Individuals will learn the task-switching task quickly, exhibiting distinct improvements in session 2 compared to session 1.
2) EC and conscientiousness will be significantly related, such that individuals with higher levels of trait conscientiousness would display higher EC.

3) There will be an interaction between EC and conscientiousness that will impact on the performance of EC measures.

Method

Participants

The current study was carried out between June and October 2012. Participants were recruited via posters, flyers, and the University of Leeds participant databases. Advertisements for the study provided information regarding what the study entailed, the incentive for participation and directed them to a website address that contained additional information about the study (e.g., inclusion/exclusion criteria and how to sign up). The inclusion/exclusion criteria stated that participants were eligible to participate if: (i) they were aged between 18-30 years, (ii) English was their native language, (iii) they did not suffer from any neurological disorder (e.g., language (dyslexia), motoric, sensory or attentional (ADHD, autism). Seventy-four individuals (17 males, 57 females) aged between 18-29 years (mean 21.15 years, SD 2.87, median 20 years old) participated in the study for either course credit or £12. The study followed the British Psychological Society (BPS) ethics recommendations, and was approved by the IPS Ethics Committee (ethics reference number 11-0265)[23].

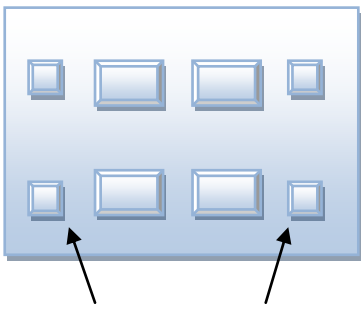
Design

A correlational repeated-measures design was employed in the current study. Such a design was adopted to assess the relationships between EC and conscientiousness over time. In particular, this study aimed to assess the relationships between self-reported executive dysfunction, information processing speed, switch costs (average and per block), incongruency costs, reasoning, memory and conscientiousness. The predictor variables were EC and conscientiousness. Due to the correlational design, reaction times and scores of each of the predictor variables were also the outcome variables.

[23] Under ethical procedures at the time similar study procedures were covered under the same ethical license. Any changes to documentation were approved prior to study commencement.

Apparatus

All EC tasks and questionnaires were created using the experimental software PsyToolkit (Stoet, 2010) and were completed on a Linux operating computer. Task stimuli and questionnaires were displayed on a 17” colour monitor. Participants navigated through the instructions presented on screen using the space bar of the computer keyboard with the exception of the last instruction before beginning the task. In these instances, the participant had to consult with the experimenter to see if they could continue. After ensuring the participant understood the task and answering all participants’ questions the 'q' key on the keyboard was pressed to continue. Instructions included colour diagrams and examples to enhance participants understanding of the tasks. Responses to EC tasks were recorded on a Cedrus USB keyboard (model RB-834) with only two keys being used for all the tasks (Figure 4.1). After each block a feedback screen was displayed showing participants their accuracy (percentage) and mean reaction time (ms). Responses to questionnaires were recorded by using the computer mouse to click options provided on screen. In an attempt to reduce extraneous variables participants were required to turn off any mobile devices and wear earplugs. Furthermore, the experimenter was present in the room at all times to answer questions and ensure standardised experimental procedures were followed.



Response keys for Task-switching task, Go Task and Flanker Task

Figure 4.1: Diagram of the showing keys used on Cedrus keyboard for the EC tasks.

Measures

EC Measures

Go Task. This task measured simply how quickly participants could respond to stimuli. After being presented with a 3-2-1 countdown to focus participants' attention and promote concentration a blue circle with the word "GO" within it was presented randomly in the centre of the screen. As soon as participants saw the blue circle they were required to press as quickly as possible either the left or right button on the Cedrus keyboard depending on which was their preferred hand. Participants initially completed 10 practice trials followed by 50 real trials.

Flanker task. In this task, participants were required to respond to the direction of a triangle presented in the centre of the screen (Figure 4.2). The triangle in the centre randomly faced right or left and participants had to quickly, but as accurately as possible indicate using the corresponding right and left buttons on the Cedrus keyboard which direction the triangle was facing. The centre triangle was surrounded either side by two flankers, either congruent with the centre triangle (e.g., centre triangle facing right, flankers facing right), incongruent (e.g., centre triangle facing right, flankers facing left) or neutral (the flankers were squares). First, participants completed one block of 10 practice trials followed by two blocks of 180 real trials. Participants had 500ms to respond. If participants' responses were wrong or too slow a message appeared on screen informing the participant.

Figure 4.2: *Flanker Task*. Participants were instructed to only attend to the direction of the triangle positioned in the centre and to ignore the surrounding triangles. The panels above depict (i) congruent, (ii), incongruent and (iii) neutral trials.

Task-switching task. Participants were presented with a square split into four quadrants on the computer screen. A letter/number combination (e.g., A2) was presented in each quadrant in a clockwise direction (Figure 4.3). If the letter/number combination was presented in the top two quadrants participants were required to respond to the letter. If the letter presented was a consonant (G, K, M, R) participants were to press the left button of the Cedrus keyboard. If the letter presented was a vowel (A, E, I, U) participants were to press the right button. If the letter/number combination was presented in the bottom two quadrants participants were required to respond to the number. If the number was odd (3, 5, 7, 9) participants were to press the left button. If the number was even (2, 4, 6, 8) participants were to press the right button. Initially, participants completed three blocks of practice trials. The first block of eight practice trials was purely focussed on the upper two quadrants; therefore participants just had to attend to the letter. The second block of eight practice trials was purely focussed on the lower two quadrants, therefore participants just had to attend to the number. The third block of 48 practice trials saw the letter/number combination move around the quadrants in a clockwise fashion; therefore participants had to respond to both the letter and number. Participants then completed 34 blocks of 50 trials each, one block where the focus was purely on the letters, one block where the focus was purely on the numbers and the remainder a mixture of the two. Participants had 1000ms to respond and if they provided the incorrect response a message was appeared on screen informing the participant.

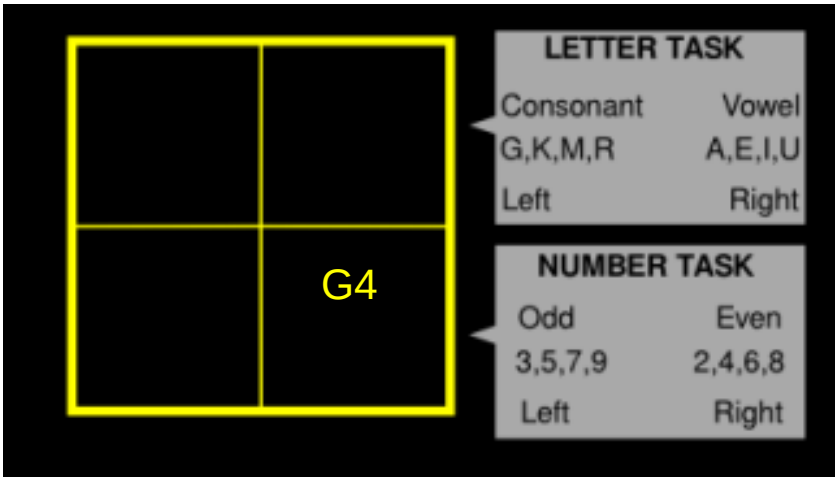


Figure 4.3: *Task-switching task*. A letter/number combination moved around the grid in a clockwise fashion, always beginning in the top left hand corner. When in the upper part of the grid participants were to respond only to the letters. When in the lower part of the grid participants were to respond to the number.

Dysexecutive Questionnaire (DEX, Wilson et al, 1996). This study employed the 20-item self-report measure of daily behavioural symptoms associated with dysexecutive syndrome (Appendix 4.1). The questions probe four areas of potential executive dysfunction: emotional/personality, motivational, behavioural and cognitive (the specific characteristics of dysexecutive syndrome targeted by each of the DEX questions can be seen in Burgess et al. (1998)). Participants are required to indicate on a 5-point Likert scale (0 (Never) – 4 (Often)) the extent they have problems with daily tasks (e.g., “I act without thinking, doing the first thing that comes to mind”). The DEX was originally intended for qualitative analysis, but recently has been used in a more quantitative capacity (Bodenburg & Dopslaff, 2008). As such, it has only been of late that it has been attempted to clinically classify the scores in order to identify the level of executive impairment. Bodenburg and Dopslaff (2008) achieved this by splitting

the DEX into three quartile limits (25%, 50% and 75%), thus scores of 20, 28 and 36 indicate mild, moderate and strong levels of executive dysfunction respectively. The DEX has been shown to be an ecologically valid (Burgess et al., 1998) and reliable measure with a Cronbach's alpha of .8 (Bennett, Ong, & Ponsford, 2005; Bodenburg & Dopslaff, 2008).

Reasoning task (Ekstrom, French, & Harman, 1976). This task was the diagramming relationships test from the validated Kit of Factor Referenced tests (Ekstrom et al., 1976). The reasoning task required participants to use diagrams to explain the relationships between three different objects. Participants were presented with three objects (e.g., cutlery, forks, spoons) and provided with five different diagrams (A-E) which consisted of overlapping circles. Participants had to decide which diagram correctly depicted the relationship between the specified objects. For instance, taking the previous example, forks and spoons could be represented by two separate circles inside a larger circle representing cutlery. This is because although all forks and spoons are cutlery, forks and spoons are not the same piece of cutlery (See Figure 4.4 for diagram). Fifteen of these items were presented on screen and participants had four minutes to complete all the items, after which the items would automatically be removed from the screen. After completion of the first set of fifteen items, participants had to complete another fifteen items, which once more had a time limit of four minutes. Participants were discouraged from guessing as they were informed that their score was derived from the number of correct answers minus a fraction of their incorrect answers, therefore guessing would provide no advantage.

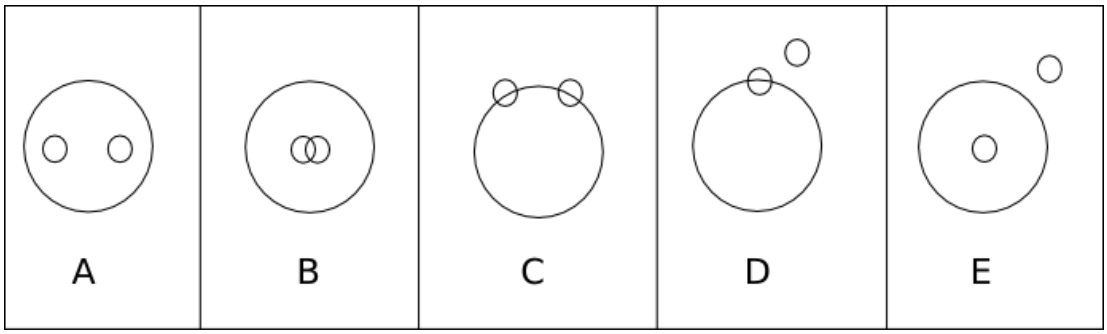


Figure 4.4: *Reasoning task*. In the reasoning task participants were presented with three items and had to choose from the options above which diagram of circles accurately depicted the relationship between those three items. Given cutlery, forks, spoons the correct answer would be A, as all spoons and forks are cutlery, but spoons and forks are not the same.

Memory task (Ekstrom et al., 1976). This task was the visual number span test from the validated Kit of Factor Referenced tests (Ekstrom et al., 1976). Digit span tasks are a commonly employed measure of working memory (Houben et al., 2011b; Romer et al., 2009; Romer et al., 2011). In this task, single-digits numbers (1-9) were presented at the centre of the computer screen sequentially, creating a random sequence of numbers ranging from 3-13 digits in length. Participants were required to memorise these sequences in the order they were presented. After each sequence, the word “WRITE” appeared on screen, which signalled to participants that they were now able to write down the sequence presented on a piece of paper provided by the experimenter. The experimenter remained sat adjacent to the participant at all times during this task to ensure participants did not start to write down the sequences of numbers before they were explicitly instructed to do so. The experimenter also had full control of when to proceed with the next sequence to ensure the procedure was standardised for each participant. Two practice trials were completed initially, followed by 24 trials.

Personality Measures

50-item set of IPIP Big-Five Factor Markers (Goldberg, 1992). This is a self-report measure of the Big-Five personality dimensions (Agreeableness, Conscientiousness, Emotional stability (similar to neuroticism), Extraversion and Intellect/Imagination (similar to openness)). Participants were asked to indicate the extent to which each of the fifty statements describe them on a 5-point Likert scale (*Very Inaccurate (1), Moderately Inaccurate (2), Neither Accurate Nor Inaccurate (3), Moderately Accurate (4), Very Accurate (5)*); with higher scores indicating higher levels of these personality traits. Although, all five measures were assessed only conscientiousness was used in the analysis.

Barratt Impulsiveness Scale-11 (BIS-11; (Patton, Stanford, & Barratt, 1995). The BIS-11 is a revised version of the BIS-10 comprising of 30 self-report items of impulsiveness (Appendix 4.2). The BIS was included within the study procedure, however, due to a change in the direction of the research it was not included in subsequent analyses.

Procedure

Participants were required to attend two 50 minute laboratory sessions occurring within seven days of each other at the Institute of Psychological Sciences, University at Leeds. All instructions, tasks and questionnaires were primarily run on the computer, with the exception of the reasoning task where paper instructions were provided and the memory task where answers were recorded on paper. At the first session, participants completed a number of demographic questions. Completion of the questions indicated consent to participate in the study. Afterwards, participants completed a series of EC tasks (the go task, flanker task, and task-switching task). Finally, participants completed a series of personality measures (Five Factor model questionnaire and BIS) and the DEX. At the second session, participants once more completed a series of demographic questions followed by the task-switching task. Lastly, participants completed the reasoning and memory tasks.

Results

Data Analysis

Data was analysed using correlational methods (Pearson's product moment correlations) using SPSS 19. Each individual's data for the EC measures was visually analysed using plots to assess errors and variability. As expected, there was much variability in the data with some participants having small variance in their data and few errors and some participants having large variance in their data and many errors, with the remainder showing variations in these extremes. For the flanker and task-switching tasks, switch costs were calculated (mean performance (i.e., reaction time) for switch trials minus the mean performance for repetition trials) and used in the correlation analyses (Rogers & Monsell, 1995). Additionally, incongruency costs were calculated for the task-switching task as the mean performance of incongruent trials minus the mean performance for congruent trials. Incongruency costs serve as an indication of how well individuals deal with task-irrelevant stimulus features, such as the type of response inhibition that is taking place. Due to the large number of variables analysed only significant results are reported.

Descriptive statistics

Examination of the descriptive statistics for the EC variables (Table 4.1) reveals that participants were generally extremely fast at simply responding to stimuli with participants responding within 251ms to the Go task. However, reaction times were considerably slower in the flanker and task-switching task with the most prominent decrement in reactions times being evident for the task-switching task (617ms compared to 316ms). Nevertheless, a switch cost was demonstrated in both tasks with the task-switching task producing the largest switch cost (149ms), with participants incurring a switch cost of 21ms per block. The task-switching task also displayed a relatively large incongruency cost of 66ms. Performance on the reasoning and memory tasks was generally poor on average, and scores on the DEX were relatively high on average indicating poorer EC.

Table 4.1

Descriptive statistics for EC and conscientiousness measures

	M	SD	Range
DEX	27.65	12.16	1-61
Go Task (ms)	251.26	29.13	205.04-345.58
Flanker Task (ms)	315.87	-	12.02-593.48
Flanker task Switch cost(ms)	66.06	24.97	12.021-149.045
Task-switching Task (ms)	616.67	-	376.67-1082.13
Task-switching switch costs(ms)	149.18	66.81	2.53 -320.99
Task-switching task Switch cost per block(ms)	20.98	23.96	-28.96-114.99
Task-switching task incongruency costs per block(ms)	22.99	9.99	-406.12-384.94
Reasoning	20.45	5.67	3-29
Memory	10.55	3.33	2-18
Conscientiousness	34.64	7.16	20-50

Note: ms = milliseconds

Improvement in task-switching task

A major aim of the current study was to assess how quickly individuals showed improvement in tasks of EC, specifically, the task-switching task. Over two sessions consisting of 34 blocks of trials in total, it was demonstrated that individuals did display improvement in this task, displaying a strong learning curve characterized by initially high switch costs (slow reaction times) that gradually decreased (becoming faster reaction times) over session 1, then reaching asymptote in session 2 (Figure 4.5). Focussing on the improvement in switch costs over the two sessions it can be seen (Figure 4.6) that participants'

improved quickly over the course of session 1. At the beginning of session 2, this improvement was initially lost with participants performing worse than they had done at the beginning of session 1. This initial decrement, however, gives way to a steep improvement with participants performing substantially better than in session 1.

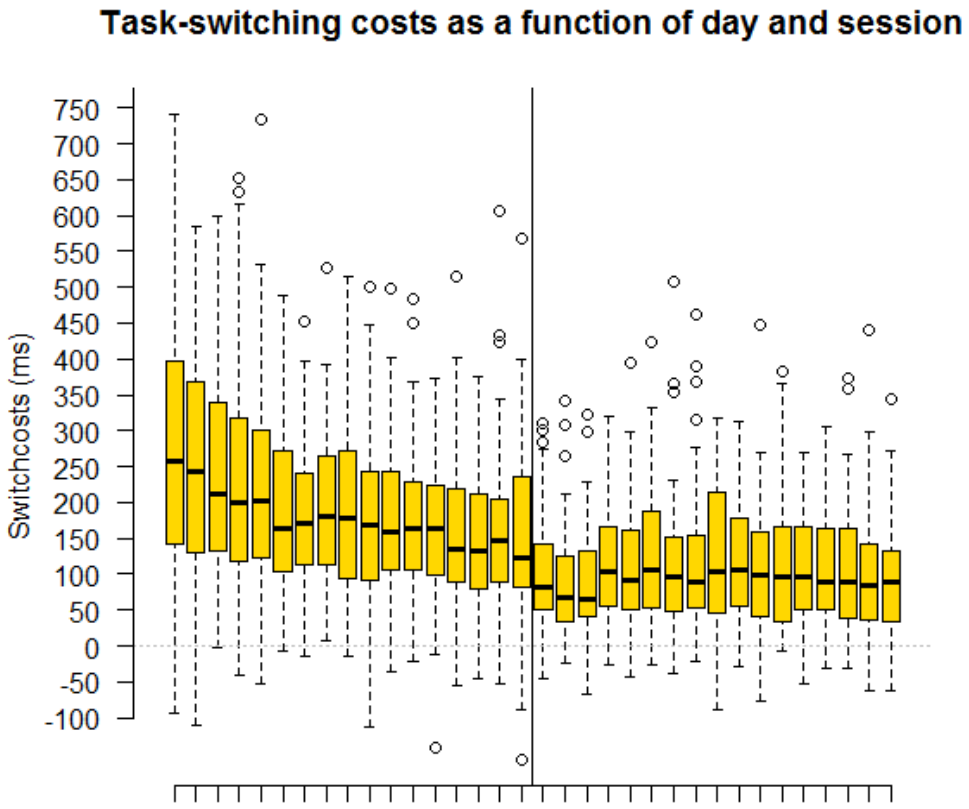


Figure 4.5: This graph shows the changes in switch costs from the task-switching task over the 34 blocks of trials over the two sessions (session 1 is before the midline, session 2 is after the midline). A clear learning curve can be seen. Switch costs are high to begin with, gradually decreasing over time and eventually plateau (see a clear asymptote).

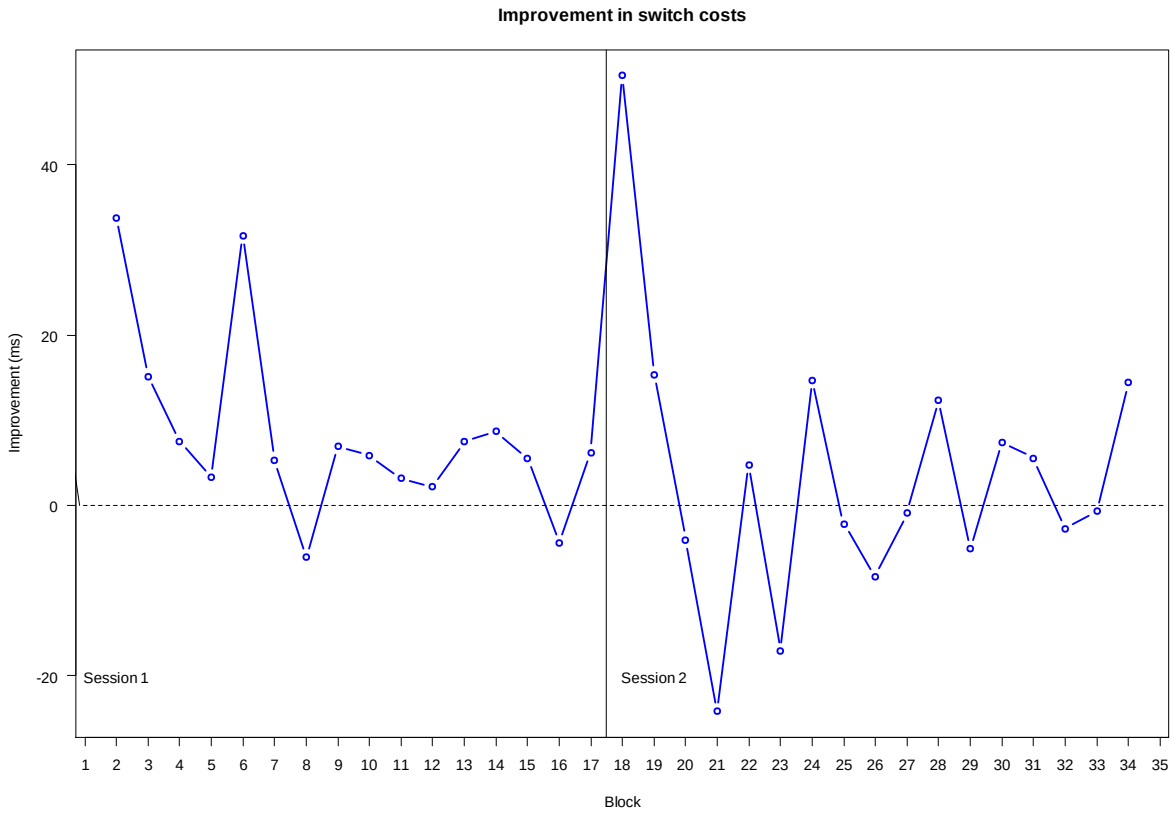


Figure 4.6: This graph shows the improvement in switch costs from the task-switching task over the 34 blocks of trials over the two sessions separated by one week. Participants improve quickly at the task producing faster switch costs than when they began with the most marked improvements in performance being visible in the second session.

Task-switching reliability

After exploring the nature of the learning process for the task-switching task, the reliability of the task over the two sessions was assessed. The switch costs of session 1 were correlated with the switch costs of session 2 using R (R Core Team, 2014). Results showed a significant correlation between task-switching performance at session 1 and session 2 ($r(74) = .72$, $p < .001$, Figure 4.7).

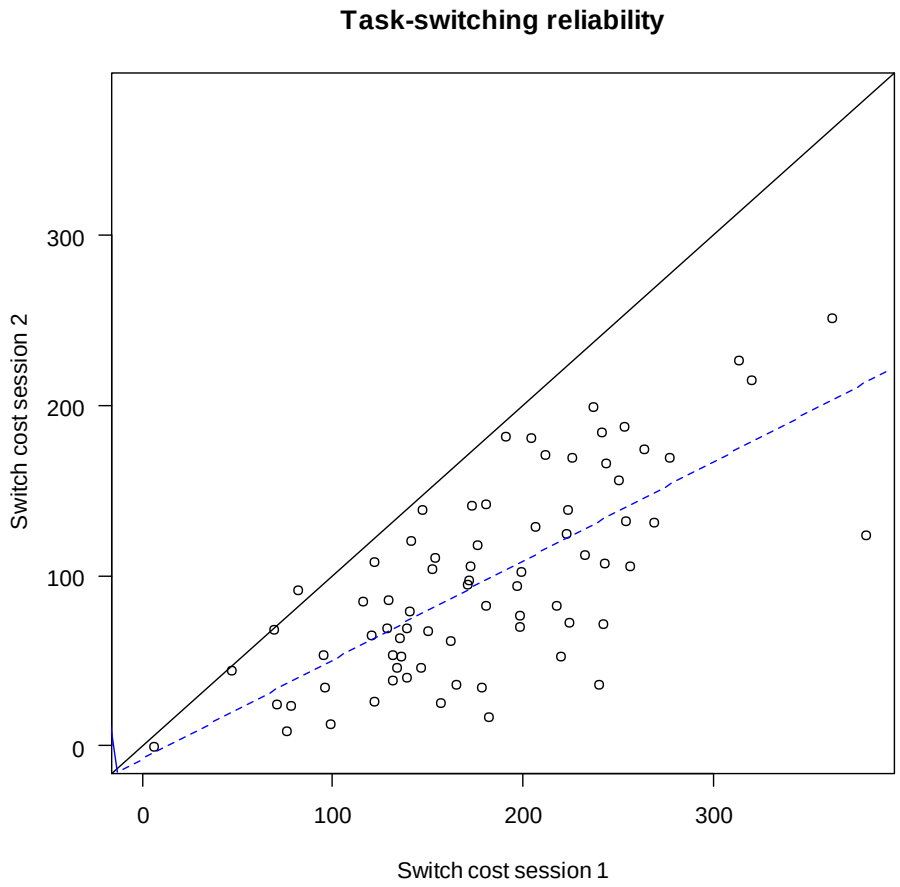


Figure 4.7: This graph shows the correlation between task-switching switch costs at session 1 and session 2. The blue line demarcates this relationship.

Correlations between EC variables and conscientiousness

A correlation matrix of the EC variables was created to assess the inter-relationships between these measures (Table 4.2). It was revealed that task-switching switch costs were positively correlated with incongruency costs, such that individuals who produced high switch costs also produced high incongruency costs. Both high task-switching switch costs and incongruency costs were marginally (r =.20, p = .09 and r = .21, p = .07 respectively) correlated to performance in the Go task with high costs being associated with slower reaction times; and negatively associated with reasoning task performance with high costs being once again associated with lower reasoning scores. The DEX was also negatively correlated to reasoning task performance

with a higher DEX score (indicating greater executive dysfunction) being associated with lower reasoning scores. Flanker task switch costs did not significantly correlate with any of the other EC measures. Although, not the focus of the current research, correlational analysis was undertaken on the Big Five measures of personality to assess an underlying correlations between conscientiousness and the other four personality measures. This revealed emotional stability to be positively correlated with conscientiousness, such that, greater emotional stability was associated with being more conscientious ($r = .27$, $p < .05$).

Table 4.2

Pearson Product Moment correlations between EC variables

	1	2	3	4	5	6	7
1 DEX	-						
2 Go Task	0.04	-					
3 Flanker Task Switch Costs	0.19	-0.14	-				
4 Task-switching switch costs	-0.01	0.02	0.07	-			
5 Task-switching Switch Costs per block	-0.03	0.20	0.13	-0.03	-		
6 Task-Switching Incongruency Costs per block	0.04	0.21	0.17	-0.01	0.96***	-	
7 Reasoning	-0.24*	-0.19	-0.14	0.01	-0.28*	-0.31**	-
8 Memory	-0.06	-0.04	-0.18	-0.19	-0.14	-0.17	0.19

*<0.05 **<0.01 ***<0.001

Note: DEX = Dysexecutive questionnaire

In addition, correlational analyses were undertaken between the EC measures and conscientiousness to assess whether relationships existed. Conscientiousness was revealed to be significantly negatively correlated with the DEX, such that high conscientiousness was associated with a lower executive dysfunction score (indicating better EC); and positively correlated with task-switching switch costs meaning high conscientiousness is associated with higher switch costs over the two sessions on average. Similarly, emotional stability was negatively correlated with the DEX; with individuals higher in emotional stability having lower executive dysfunction scores (Table 4.3).

Table 4.3

Pearson Product Moment correlations between conscientiousness, emotional stability and EC

	Personality	
	Conscientiousness	Emotional stability
EC measures		
DEX	-0.42***	-0.51***
Go Task	0.02	-0.10
Flanker task switch costs	0.12	-0.19
Task-switching switch costs	0.25*	-0.16
Task-switching task switch costs per block	0.19	0.01
Task-switching task incongruency costs per block	0.13	-0.08
Reasoning	-0.09	0.09
Memory	-0.05	0.07

*<0.05 ***<0.001*Note:* DEX = Dysexecutive questionnaire

Another main aim of this study was to assess whether EC and conscientiousness are significantly related to one another due to their strong conceptual similarities. First, the relationship between conscientiousness and task-switching was further explored by plotting conscientiousness block by block over the two experimental sessions. This served as a means to explore whether there is a specific stage in the task-switching performance that reflects the conscientious trait. Although the relationship between conscientiousness and switch costs failed to reach significance, as can be seen in Figure 4.8, the relationship came closest to approaching significance at the end of session 1 and the beginning of session 2, therefore after the initial learning phase has taken place.

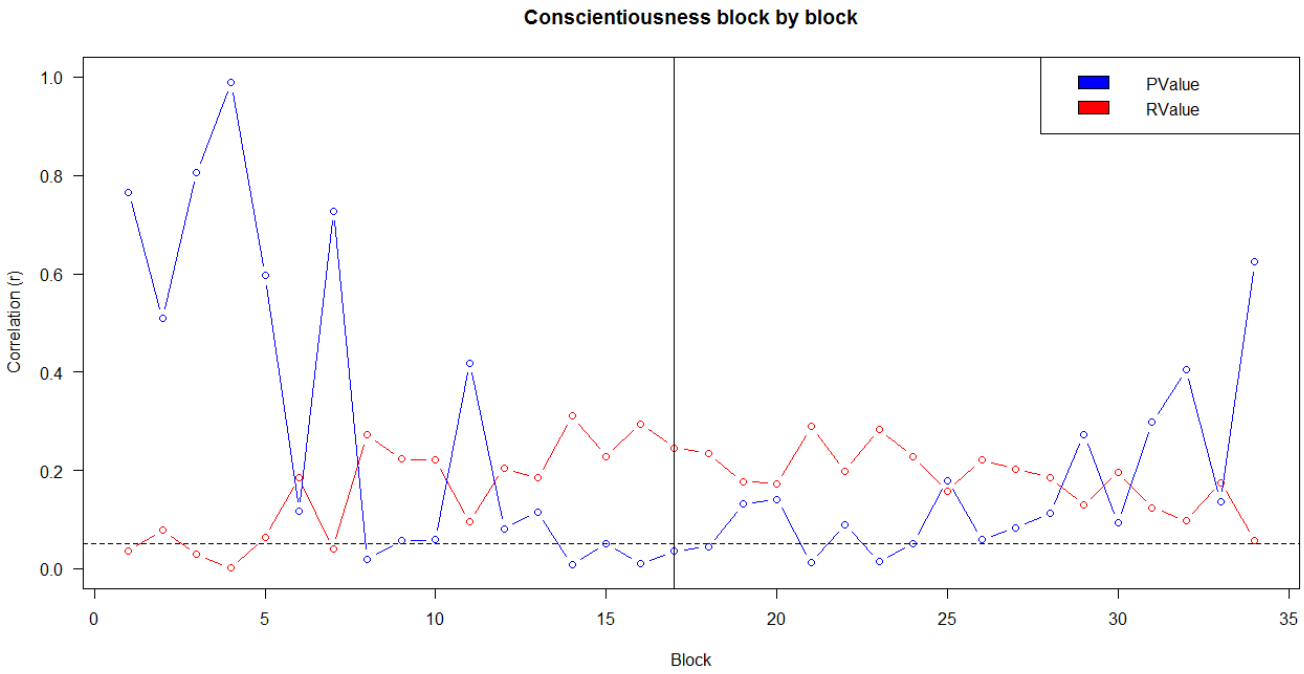


Figure 4.8: This graph shows the relationship between conscientiousness and switch costs block by block. The blue line represents the significance value (P value) and the red line represents the correlation (r value). The vertical line delineates the two sessions and the dashed line represents p = .05. It appears that the relation approaches significance at the end of session 1 and the beginning of session 2, after the initial learning phase has taken place.

The interaction between EC and conscientiousness

In Study 1, it was revealed that it could be the case that an individual could have dissociated levels of EC abilities and conscientiousness. For instance, an individual may be highly conscientious, but have poor EC and vice versa. As a result, it was decided to explore how conscientiousness and EC (specifically task-switching tasks switch costs per block) interacted on other measures of EC. Four groups were created: (1) Low conscientiousness and low switch costs, (2) High conscientiousness and high switch costs, (3) Low conscientiousness and high switch costs, and (4) High conscientiousness and low switch costs. These groups were created using median splits to separate high and low conscientiousness and switch costs per blocks[24]. In terms of the descriptive statistics, performance on the other EC tasks and the relation to emotional stability were mixed, though it seems the individuals high in conscientiousness and producing low switch costs were the most consistent in their performance and personality; generally performing quite well across the board (Table 4.4). Subsequently, a 2x2 MANOVA was undertaken on the data to ascertain if there were discernable differences between the four groups on EC performance and personality. There were no statistically significant differences in EC performance and personality based on divergent levels of conscientiousness and switch costs (F (18,162) =.995, p >.05; Wilk's Λ =.743, partial η^2=.094).

[24] Switch costs per block were chosen over average switch costs due to producing better comparable sample sizes between groups.

Table 4.4

Descriptive statistics (means and standard deviations) of the four groups separated by conscientiousness and switch costs.

	Low in both group	High in both group	Low conscientiousness, high switch cost group	High conscientiousness, low switch cost group
N	17	17	15	17
			EC measures	
DEX	33.94 (10.55)	22.47 (16.25)	30.07 (9.98)	25.29 (9.67)
Go task	246.46 (30.47)	252.85 (27.19)	255.84 (38.66)	247.77 (21.95)
Flanker task switch costs	68.32 (33.21)	71.60 (21.42)	62.09 (22.77)	65.62 (26.42)
Reasoning	21.59 (5.39)	18.88 (4.86)	19.33 (7.07)	22 (4.65)
Memory	11.24 (3.38)	10.76 (3.99)	10.80 (3.36)	10.35 (2.45)
			Personality	
Emotional stability	26.35 (8.09)	30.53 (8.66)	27.33 (7.10)	29.82 (6.01)

Note: Participants who equalled the median of conscientiousness (n= 8) were excluded from analysis as they could not be accurately placed within a group.

Discussion

The current study aimed to explore how quickly individuals improved at an EC task and to examine the nature of this learning; as well as exploring the inter-relationships between EC and conscientiousness. It was hypothesised that: (i) individuals would learn the task-switching task quickly, exhibiting more improvement in session 2 compared to session 1; (ii) EC and conscientiousness would be significantly related, such that higher conscientiousness would be associated with higher EC; (iii) the interaction between EC and conscientiousness would impact on performance of EC measures. The findings are discussed in turn below.

EC measures

Purely focussing on the task-switching task, it was found that participants exhibited a clear learning curve. Participants showed substantial improvements in their switch costs, particularly in the second session where performance reached a plateau. This has important implications in terms of developing health behaviour change interventions. If EC can be manipulated and trained, this improvement in EC may transfer not only to other aspects of EC, but also into positive health behaviour performance. Such interventions have already been utilised (Houben et al., 2011b). In the Houben et al. (2011b) study, participants received training on three working memory tasks over a 25-day period with the tasks gradually increasing in difficulty as participants' performance improved. However, to date, no studies have investigated the learning process as a whole and none have looked at the switch costs, especially within a task-switching paradigm. This finding thus provides additional important information about the task-switching task as a measure in itself, which is of interest to cognitive psychologists and health psychologists alike.

The current study also explored the relationships between EC measures. Although other measures of EC were correlated with each other; unexpectedly, task-switching switch costs and flanker switch costs were not significantly related. From a common sense perspective it would seem reasonable that switch costs, irrespective of the task they are derived from, would be related. Therefore, the finding that they were not related in this study was surprising. In

an attempt to make sense of this finding, it could be argued that despite both tasks producing switch costs the tasks do have unique qualities that perhaps alter the nature of the switch costs. The key difference being that in the flanker task, the individual is explicitly instructed to not respond to the flankers, but in the task-switching task, individuals are instructed to respond to both types of stimuli, but not consistently. Another reason could be attributed to the origin of the switch cost, for the source may be different for the two tasks. There are two explanations of why the switch cost occurs: task-set reconfiguration and task-set inertia (Monsell, 2003). Task-set reconfiguration is the proposal that between tasks the brain must reconfigure the cognitive set of rules/skills it uses to perform the task, whereas task-set inertia refers to the interference of the previous task rules on the subsequent task (Monsell, 2003). However, it has also been suggested that EC is not a unified construct. Over the past few years, Miyake and colleagues (Miyake & Friedman, 2012; Miyake et al., 2000) have proposed EC functions are not necessarily identical constructs, but are dissociable; thus emphasising the complex nature of EC.

EC and conscientiousness

A primary goal of the last two studies has been to establish whether a relationship exists between EC and conscientiousness. Previous findings from our own research (Study 1) and others (Edmonds et al., 2009) have found no such association despite the links the variables have conceptually and empirically to health behaviour. The current study has, however, reversed this trend by revealing conscientiousness to be significantly correlated with the DEX and significantly correlated with task-switching switch costs. Considering the relationship between conscientiousness and the DEX, it was found that higher conscientiousness was associated with a lower executive dysfunction score. This relationship is therefore in the expected direction, as it was hypothesised that individuals with higher conscientiousness would have better EC. The reasoning behind this being that the underlying characteristics of conscientiousness include control, planning, competence, deliberation and being achievement-orientated (McCrae & Costa, 1987); all of which are important attributes to have to perform executive tasks in daily life (Edmonds et al., 2009). The link to daily life is a key point to make, as it is this link to

everyday executive tasks that appears to most strongly link conscientiousness and EC rather than objective neuropsychological tests separate from daily life. This is possibly the reason why Study 1 and Edmonds et al. (2009) failed to find a relationship as both focussed on objective EC measures rather than self-report EC measures, such as the DEX. Objective measures are not necessarily accurate reflections of individuals EC performance within daily life. It can only be assumed that performance on these tasks reflects real life performance, and to an extent this is most likely achieved, but the DEX precisely pin-points executive dysfunction in real life.; although, it too has its weaknesses in terms of self-report measures being open to under/over-estimation of dysexecutive symptoms and socially desirable answers. This consequently brings into question the ecological validity of EC measures. Significant relationships may be found in relation to the DEX because it taps real life behaviour, thus has high ecological validity. In contrast, ecological validity is an attribute that objective measures, which are separate from real life scenarios, may lack.

However, the current study did reveal a significant relationship between average switch costs (derived from the task-switching task) and conscientiousness, although in the unexpected direction. The positive correlation indicates that higher conscientiousness was associated with higher switch costs. Although, initially this seems a surprising finding there is an intuitive reason for this result. The task requires individuals to respond quickly while maintaining accuracy, thus the individual is faced with the speed-accuracy trade-off. They can respond rapidly, but there is a higher likelihood they will make more errors or they can respond at a slower rate to increase their likelihood of being more accurate. The latter, more cautious approach, may be the preferred position of highly conscientiousness individual who are achievement-orientated and characterized by caution and discipline (McCrae & Costa, 1987). A similar argument was proposed in study 1, as it was found high switch costs were associated with higher performance of positive health behaviours, namely teeth brushing. It was proposed that these findings emerged because individuals with higher switch costs might not have low EC, but instead purposely choose to be more cautious in their performance of the task, which results in a sacrifice in reaction time speed to improve accuracy.

Conscientious individuals are cautious and disciplined and to maximise their task performance may respond slower to reduce the chances of making an error, which may serve as a disadvantage in performing the task to a high standard both in terms of accuracy and speed, but may serve as an advantage when faced with executive challenges in daily life, such as health behaviour performance. The findings of the current study appear to bear out this argument.

The idea that conscientiousness and EC may work within a complex interplay within everyday life was further borne out when the analysis split participants into four groups based on EC performance level and conscientiousness level. Individuals high in conscientiousness and low in switch costs (arguably the ideal configuration of these two variables) broadly produced the most consistent overall performance with these individuals having good EC performance and being emotionally stable, but the other configurations hint that perhaps some compensation is taking place. However, when placed in a 2x2 MANOVA no significant main effects of interactions between groups emerged. The implications of these findings are that there appears to be a complicated interplay of personality and EC within individuals, but further research is needed to assess if significant differences exist between these groups. Nevertheless, these variables will need careful consideration when developing health behaviour change interventions. A decision would need to be made as to whether to tackle both variables in tandem or target them independently. With regards to personality, there are no established tools to alter personality at present; therefore manipulation of conscientiousness will be a challenge for future research.

Referring back to the task-switching task, the relationship between conscientiousness was plotted block by block. Despite not reaching significance, it did reveal that conscientiousness approached significance in the learning process when the task had been learnt. It would have been expected that conscientiousness would have played more of a role in the initial learning of the task, as the characteristics of being disciplined, for example, would seemingly help task performance. However, there did appear to be a peak in

conscientiousness at the beginning of the second session, thus suggesting although conscientiousness does not play a significant role in the learning process, once the task has been learnt to successfully perform again, a conscientious approach is needed. On another note, the current study revealed emotional stability correlated highly with conscientiousness; therefore it is unsurprising that it shows the same pattern of relations with EC. A possible explanation for why both personality traits have these relationships may be because of their similarities in the characteristics they possess in terms of control. Being conscientiousness entails being disciplined and organized in order to achieve goals, and emotional stability entails having control over ones impulses. In EC tasks that require the successful inhibition of responses it is clear such characteristics would confer an advantage.

Limitations

There are two significant limitations to the current study. Firstly, all the personality measures (Five Factor model and BIS), and the DEX are self-report measures. It may be the case that participants underestimated or overestimated their cognitive abilities and personality through lack of insight or social desirability bias. For example, with regards to the DEX specifically, patients with dysexecutive syndrome do tend to underestimate the executive difficulties they experience (Burgess et al., 1998; Wilson et al., 1998). Nevertheless, a strength of this study was its use of a wide range of objective EC tasks in conjunction with the self-report measure of the DEX, but none of the other EC measures with the exception of reasoning task performance was significantly correlated with DEX scores. The reason for this finding may be as previously mentioned that participants overestimated the executive difficulties they experience in the self-report measure or objective measures may not adequately reflect the executive challenges faced in real everyday life or reflect how individuals actually feel about their cognitive abilities.

Secondly, this study is correlational in nature; therefore causal inferences cannot be drawn. The current study can state that these variables are linked, but it is limited in the predictions it can make, as the study cannot reliably infer

that one variable occurs because of another. However, it is important to uncover these relationships first before attempting to manipulate these variables, as it allows a knowledge base to be built about what variables are related to each other and how they are related. This study is the first to find a significant relationship between EC and conscientiousness and explore the learning process involved when undertaking such EC tasks. These findings can therefore be used to pursue not only research that directly influences these variables and uncovers the causal mechanisms, but also research that manipulates these variables in order to exert a change in other related variables (e.g., health behaviour change interventions).

Recommendations for further research

There are a number of possible directions this research could take. A major finding of this study was that EC and conscientiousness were related when using the self-report measure of EC (the DEX) and with switch costs. However, planning is a key component of both EC and conscientiousness, but both studies 1 and 2 did not include an EC measure of planning, thus a reasonable next step to take would be to replicate the findings of studies 1 and 2 while using a planning task.

Another recommendation for further research would be to attempt to manipulate some of the variables in this study, for instance, EC and conscientiousness, to develop a health behaviour change intervention. Study 1 highlighted that both EC and conscientiousness independently predicted health behaviour performance, although it must be acknowledged this did not apply to all the health behaviours included within the study; whereas Study 2 highlighted that these important variables are linked to a certain extent and individuals show improvements in EC performance quickly. Although, there is the argument that EC is not being improved, instead, participants are simply getting better at the task itself. This is a question for further research to explore. These findings open up the possibility that not only could individuals' EC be trained, but also that to effectively enhance the chances of this training leading to health behaviour change other related variables, such as conscientiousness, could be manipulated in parallel.

Conclusions

The current study aimed to explore the relationship between EC conscientiousness and explore the learning process for an EC task. Two main findings emerged. Firstly, dependent on the measure, EC and conscientiousness are significantly related. Secondly, individuals quickly improve their performance on a task-switching task, with performance being maintained one week later, although conscientiousness does not significantly play a role in the learning process. Consequently, the findings indicate EC could be trained, which may lead to improvements in other EC functions and potentially behaviour. However, the findings also hint at the complexity of EC as a construct, and issues of ecological validity.

Chapter 5
Study 3: The relationship between executive control, conscientiousness, healthy eating and exercise

Introduction

Two important findings emerged from studies 1 and 2. First, there are weak relationships between objective measures of EC and conscientiousness, but subjective measures of EC, such as the DEX, yield a stronger relationship. Second, independently there is evidence to suggest EC and conscientiousness are both directly associated with health behaviour and indirectly through moderation of the intention-behaviour and stress-behaviour relationships. However, this second finding is rather less conclusive, with opposing results emerging depending on the type of EC measure used and the health behaviour measured. As a result, it was decided to attempt to replicate a previous study that found clear relationships between EC and health behaviour and build upon it, particularly by investigating the potential impact of conscientiousness.

The study chosen was by Allan et al. (2011), who over two studies investigated the extent to which EC accounted for the size of the intention-behaviour gap for high-calorie snack consumption and fruit and vegetable consumption. In their first study fifty students completed a number of objective (a subset of the DKEFS battery of tests and a Go/No-go task based on the work of Hall et al. (2008b) and self-report (DEX) measures of EC along with measures of behavioural intentions for fruit, vegetable and high-calorie snack consumption. Actual dietary behaviour was then measured over a three day period by means of a computerised diary. The study revealed that EC accounted for 16-23% of the variance in the intention-behaviour gap; however, the Go/No-go task did not significantly contribute. In the second study, therefore, focus was placed entirely on measures of response inhibition with participants completing a Go/No-go task and the Stroop colour-word interference task. Once more, the discrepancy between intentions and behaviour for consuming high-calorie snacks over a 24 hour period was accounted for by the Stroop task, but not for the Go/No-go task. The novelty of

this study was that the researchers focussed primarily on whether EC could explain the size of the gap specifically, but to build upon this study it would be worthwhile to explore potential mediator and moderator effects.

As previously mentioned, although this study aims to replicate the work of Allan et al. (2011), it also aims to build upon it and a number of important changes have been made. For instance, the diary component has been extended from three days to seven days, thus it has the advantage of gaining an insight into how the variables of interest influence a full week. This design also allows the measurement of behaviour over the weekdays and weekend, which is important as it may be the case that health behaviour changes over the course of a week. For example, people may indulge in more unhealthy behaviours over the weekend when they are free from work restrictions. Additionally, although Allan et al. (2011) included questions about exercise in their study exercise data were not presented. As exercise is an important health-enhancing behaviour, it was decided to include this variable in the current study. Another substantial change was the addition of a new predictor variable: conscientiousness. Conscientiousness was added to this study as it shares conceptual similarities to EC, but as of yet, no definitive link between the two variables has been revealed. Therefore, the current study was designed to explore the possible relationship between the two variables in more detail. The aim of the current study was to replicate and extend the study conducted by Allan et al. (2011), and had two main hypotheses:

1) EC and conscientiousness will moderate the intention-behaviour relationship, such that intention will be a stronger predictor of behaviour for those with high EC and high conscientiousness compared to those with low EC and low conscientiousness.
2) EC and conscientiousness will be significantly related to one another when using the DEX measure of EC.

Method

Participants

The present study was carried out between January and March 2013. Participants were recruited using posters and the University of Leeds participant databases. Advertisements for the study were distributed around the University campus and provided information regarding what the study entailed, the incentive for participation and the contact details of the researcher. The inclusion/exclusion criteria was the same as previous studies, such that participants were eligible if: (i) they were aged 18-40 years old, (ii) they were proficient English speakers, and (iii) they did not suffer from any neurological disorder. Eighty-two individuals (8 males, 71 females) aged between 18-35years (mean 21.30 years, SD 3.43) participated in the study for course credit or a £5 Love2Shop voucher. The current study was approved by the University of Leeds Ethics Committee (ethics reference number 11-0265)[25] and abided by British Psychological Society (BPS) guidelines.

Design

A multilevel diary design was adopted to assess the within-person effects of EC and conscientiousness on four health behaviours (high-calorie snack consumption, fruit and vegetable consumption, and exercise) over a seven day period. An interval-contingent method was adopted with participants completing the diary at the end of the day (between 4pm and 2am). The online diary was accessible before the end of standard work hours to accommodate participants who did not have computer/internet access at home. This method was chosen due to its reliability and high rate of participant compliance over long study durations(Bolger et al., 1989; Feldman et al., 1999; Green et al., 2006; Tennen et al., 2006).The predictor variables were intentions, EC and conscientiousness. The dependent variables were performance of the health behaviours (high-calorie snack consumption, fruit and vegetable consumption, and exercise) as measured by the online daily diary over seven days.

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[25] Under ethical procedures at the time similar study procedures were covered under the same ethical license. Any changes to documentation were approved prior to study commencement.

Apparatus

The Go/No-go task and questionnaires were created using the experimental software PsyToolkit (Stoet, 2010) and were completed on a Linux operating laptop. Participants navigated through the on-screen instructions using the space bar on the keyboard. Responses were recorded on a Cedrus USB keyboard (model RB-834), with only one key being used. Responses to questionnaires were recorded by using the laptop mouse to click options provided on screen. The other EC tasks used formed part of the Delis-Kaplan executive functioning system (DKEFS) battery of tests (Delis, Kaplan, & Kramer, 2001), which included a book with all the test materials, as well as pegs and disks for the tower task. Thus, instructions were provided verbally and responses were recorded using the appropriate record sheet and a stopwatch by the experimenter.

Measures

Objective EC measures

*Trail-making task (TMT, Delis et al., 2001).*Split into five conditions the basic principle behind this task is to connect as quickly as possible numbers and letters randomly arranged on a piece of paper, alternating between numbers and letters in the correct numerical and alphabetical order (i.e., 1-A-2-B-3-C). With participants having a maximum of between 150-240 seconds to complete each condition, faster completion times indicate good attentional switching/cognitive flexibility.

*Verbal fluency test (VFT, Delis et al., 2001).*This task is split into three conditions. Condition 1 assesses letter fluency. This entails participants naming as many words as they can within 60 seconds (s) that begin with the letters F, A and S over three trials. The words cannot be people, places or numbers. Condition 2 assesses category fluency. Over two trials participants must name as many animals and boys names as they can within 60s. Condition 3 assesses category switching. This requires participants to switch back and forth from naming fruits and pieces of furniture over 60s. Higher scores indicate good cognitive flexibility.

Stroop task (Delis et al., 2001). Split into four conditions, the basic principle behind this task is to name the colour of the ink the colour word is printed in rather than name the word itself which can be congruent (i.e., the colour word and the colour of the ink it is printed in match; e.g., the word 'RED' printed in red ink) or incongruent (i.e., the colour word and the colour of the ink it is printed in do not match; e.g. the word 'RED' printed in blue ink). Condition 1 involves naming the colour of square patches and condition 2 involves reading colour words printed in black ink. Although participants must name the patches/words as quickly as possible there is a time limit of 90s for the first 2 conditions. Conditions 3 and 4 have a time limit of 180s and involve naming the colour of the ink the colour words are printed in and switching between naming the colour of the ink the colour word is printed in and naming the word itself respectively. Faster completion times indicate good response inhibition.

Tower task (Delis et al., 2001). Over nine trials increasing in difficulty (ranging from 1-26 moves) participants had to move a set of five disks one at a time from a predefined start position to a predefined end position in the fewest number of moves possible and without placing larger discs over smaller discs. Participants' had a time limit of 30s to complete the first trial gradually increasing to a maximum of 240s as the task increased in difficulty. Scores were out of 30 based on the number of moves required to complete each trial with higher scores indicating better planning ability.

*Go/No-go task (based on Hall et al., 2008b).*In this task, participants were presented with a fixation point in the centre of the laptop screen and a randomized mixture of upper and lower case letters of the alphabet to which they were required to respond. In response to lower case letters participants had to press as quickly as possible a key on the Cedrus keyboard (a 'Go' response). In response to upper case letters participants had to withhold responding (a 'No-go' response). The first block of twelve training trials had an equal likelihood of presenting upper and lower case letters. The following eight blocks of 60 trials each did not have an equal likelihood of upper and lower case letters. In half the blocks more 'Go' responses were required, whereas in the other half more 'No-go' responses were required (a 20/40 split). Subtraction of

the reaction time taken to provide a 'Go' response when there were more 'No-go' trials from the time taken to make a 'Go' response when there were more 'Go' trials provides the time cost related to inhibiting an automatic, but in this instance incorrect response. A smaller time cost indicates better response inhibition.

Self-report EC measures

Dysexecutive Questionnaire (DEX, Wilson et al., 1996). Items and scoring were the same as in Study 2.

Personality Measures

60-item conscientiousness questionnaire (Hill & Roberts, 2011). Items and scoring were the same as Study 1.

Barratt Impulsiveness Scale-11 (BIS-11, (Patton et al., 1995). Items and scoring were the same as study 2, but variable was not included in data analysis.

Health behaviour measures

Behavioural intentions. Behavioural intentions to perform six daily behaviours were measured via six questionnaire items at the end of the laboratory session (Appendix 5.1). Similar to Allan et al's (2011) study, distracter questions about studying, shopping, and T.V. viewing were included in order to disguise the health behaviours of interest. These were fruit and vegetable consumption ("To what extent do you intend to eat at least 5 portions of fruit and vegetables each day?"), high-calorie snack consumption ("To what extent do you intend to avoid high-calorie snacks each day (High-calorie snacks include: crisps, savoury snacks (such as Cheddars and Twiglets), chocolate, sweets, cakes, biscuits, pies and pastries)?"), and exercise ("To what extent do you intend to engage in a minimum of 30 minutes of mild-to-vigorous exercise each day?"). The questions were phrased in line with health recommendations and were measured on a 5-point Likert scale ranging from 1 (*Not at all*) – 5 (*Very much*).

7-day diary. The diary measured actual self-reported behaviour over a seven day period (Appendix 5.2). Fruit and vegetable consumption was measured separately using the items: "How many portions of fruit did you eat today?" and

“How many portions of vegetables did you eat today?” Snacking was measured with a single item: “How many high-calorie snacks have you eaten today? (High-calorie snacks include: crisps, savoury snacks (such as Cheddars and Twiglets), chocolate, sweets, cakes, biscuits, pies and pastries).” Finally, exercise was measured with 3 items: “How many minutes of mild exercise (e.g., walking) did you engage in today?”, “How many minutes of moderate exercise (e.g., carrying light loads, bicycling at a regular pace, or doubles tennis) did you engage in today?”, and “How many minutes of vigorous exercise (e.g., heavy lifting, digging, aerobics, or fast bicycling) did you engage in today?” Free responses were required for answers, and these raw scores were used in the analysis. These scores were used to create an overall health behaviour index. This entailed collapsing the seven days worth of behavioural data into one mean score for each health behaviour, creating six behavioural intentions and actual behaviour scores for each participant. It was attempted to create the health behaviour index by combining the measures for each day, but this resulted in multicollinearity that could not be analysed using the HLM software. Due to creating an overall health behaviour index, the intention ratings for high-calorie snack consumption were reverse scored so all the behaviours followed the same directional pattern, such that higher scores indicated healthier behaviours.

Procedure

Firstly, participants were required to attend a one hour laboratory session at the Institute of Psychological Sciences, University of Leeds. Participants initially were presented with an information sheet and a consent form. Once consent was obtained a number of details about the participant, such as age, gender and email address (required for the participant to receive reminder emails about the diary) were taken. Afterwards, participants completed the DKEFS battery of tests (specifically, the trail-making task, the verbal fluency task, the Stroop task and the tower task). The order of these tasks was counterbalanced in order to reduce any adverse effects on task performance caused by variables such as fatigue. The rest of the experiment was completed on a laptop computer with participants completing the Go/No-go task first and

ending with the questionnaire measures (i.e., the DEX, the 60-item conscientiousness questionnaire, the BIS, and the behavioural intentions questions). The following day the 7-day daily diary began. Participants received reminder emails everyday at 4pm providing the link to access the online diary (www.psyc.leeds.ac.uk/7-day-diary). By clicking on this link participants could then answer questions about their daily behaviour. The diary was only accessible between 4pm-2am, and took approximately five minutes to complete.

Factor analysis

Allan et al. (2011) conducted a factor analysis on the measures of the Go/No-go, verbal fluency, trail-making and tower task they used. A similar factor analysis was conducted in the current study, using a principal components analysis with an oblique rotation (direct oblimin) using PASW 19. Items with eigenvalues of 0.7 and above were identified as loading on a factor. Following Allan et al. (2011) DEX and Stroop measures were kept separate. Unlike, Allan et al. (2011) whose verbal fluency, trail-making and tower task measures loaded onto one factor, these measures in the current study did not load onto a single factor, but were identified as independent measures, thus were analysed as such.

There are, however, a number of individual components that make up these tasks that were measured in the current study, thus a separate factor analysis using the same criteria was applied to the other components of the trail-making, verbal fluency and Stroop tasks. A five factor solution emerged with factors 1-5 accounting for 30.36%, 18.39%, 15.12%, 10.13% and 7.54% of the variance respectively, cumulatively accounting for 81.54% of the variance (Table 5.1). Factor 1 comprised of the colour naming and word reading components of the Stroop task, thus representing ‘processing speed’. Factor 2 comprised of the number and letter sequencing components of the trail-making task, thus representing ‘processing speed/flexibility’. Factor 3 encompassed the category switching (total correct responses and total switching accuracy) components of the verbal fluency task, henceforth represents ‘Switching’. Factor 4 encompassed the inhibition and inhibition switching components of the Stroop task, henceforth represents ‘response inhibition’; and finally factor 5 was

trail-making task motor speed. High scores on factors 1, 2, 4, 5 indicate low EC, whereas high scores on factor 3 indicate high EC. Subsequent correlational, mediation and moderation analysis were undertaken using the EC measures outlined above. Due to the large number of variables assessed only significant results and non-significant results of relevance are reported. The individual scores for these measures were converted into z scores and the mean score of the combined scores were used in the analyses.

Table 5.1

Factor loadings for additional EC variables used in current study

	Factor				
	1	2	3	4	5
TMT Visual scanning	.470	.603	.178	-.348	.283
TMT Number sequencing	.272	**.837**	-.158	.115	.206
TMT Letter sequencing	-.048	**.856**	-.090	.090	.179
TMT Motor speed	.243	.252	.015	.044	**.950**
VFT Category switching totalcorrectresponses	-.184	-.098	**.969**	-.204	-.005
VFT Category switching totalswitchingaccuracy	-.117	-.097	**.978**	-.157	-.011
ST Colour naming	**.873**	.081	-.215	.366	.111
ST Word reading	**.750**	.127	-.249	.299	.376
ST Inhibition	.527	.156	-.157	**.784**	-.182
ST Inhibition switching	.299	.171	-.199	**.845**	.223

Note. Factor loadings in bold highlight the factor that loaded onto each factor. Due to only minor differences between the pattern and structure matrix, structure matrix values are reported.

TMT=Trail-making task; VFT=Verbal fluency task; ST=Stroop task

Results

Data Analysis

Although eighty-two individuals participated in the study, three were excluded from the data analysis due to two producing an extremely large percentage of errors on the Go/No-Go task, which may have been due to technical error and the other participant failing to complete any diary entries. Thus, seventy-nine participants' data was analysed. Any missing diary data from the remaining 79 participants was removed using the "Delete missing level-l data when making mdm" function on the HLM software.

Correlational and mediation analysis was undertaken using SPSS 19, whereas main effects and moderated effects were analysed using multilevel modelling (hierarchical linear modelling [HLM]) (Raudenbush et al., 2004). Forming a two level hierarchical structure, level-1 (within-subject variation) contained the health behaviour intentions and health behaviour index; Level-2 (between-subject variation) contained the EC and conscientiousness data. The Level-1 variables were entered group-mean centred and the level-2 variables were entered grand-mean centred. The possibility of EC and conscientiousness being moderators of the intention-health behaviour relationship was assessed using models similar to the example below:

Level-1: y_{ij} (Health behaviour index) = β_0+ β_1*(Intentions) + r

Level-2: $\beta_0 = \gamma_{00} + \gamma_{01}$*(Conscientiousness) + u_0

$\beta_1 = \gamma_{10} + \gamma_{11}$*(Conscientiousness) + u_1

Where γ_{00} denotes the health behaviour mean, γ_{01} signifies the influence EC and/or conscientiousness has on the mean, γ_{10} represents the average size of the intention-behaviour relationship, and γ_{11} indicates the degree to which the intention-behaviour relationship is moderated by each of the EC and conscientiousness variables.

Descriptive statistics for both the current study and Allan et al.'s (2011) study can be seen in Table 5.2 (Allan et al's (2011) study has been included in this table to allow a comparison of results).

Table 5.2

Descriptive statistics (mean (SD)) for Allan et al. (2011) and current study

	Allan et al. 2011	Gray-Burrows et al. 2013
n	49	79
Age in years*	22 (4.9)	21.30 (3.43)
Gender*	19 M, 30 F	8 M, 71F
Go/No-Go task RT (cost of effortful initiation, in ms)*	57.2 (59.7)	32.20 (13.56)
Trail making switch condition completion time*	62.4 (17.4)	55.22 (18.21)
Stroop task (Inhibition vs. Colour naming)*	N/A	17.75 (7.90)
Tower task overall score (/30)*	17.9 (4.7)	18.67 (2.99)
Verbal fluency score*	77.8 (16.7)	89.11 (14.50)
DEX score (/80)*	24.8 (11.9)	28.53 (8.38)
Intended portions of fruits and vegetables	9.5 (4.6)	3.41 (1.23)
Portions of fruits and vegetables consumed	9.0 (5.6)	1.62 (.73)
Intended number of snacks	3.3 (2.7)	2.99 (1.31)
Number of snacks consumed	5.5 (3.7)	1.56 (.90)
Intended exercise participation	-	3.22 (1.37)
Minutes of exercise participation	-	20.12 (10.23)
Intention–behaviour gap for fruits and vegetables	0.5 (3.9)	-
Intention–behaviour gap for snacks	2.2 (3.8)	-
Intention–behaviour gap for exercise	-	-

**Directly comparable variables. However, it must be acknowledged that the large difference in reaction times of the Go/No-go task could be due to a difference in time allowed to make a response. In the current study this was set at 500ms.*

The intention-behaviour relationship

Behavioural intentions were found to be significant predictors of actual behavioural performance, both for the overall health behaviour index (r (79) =.15, p<0.01) and each health behaviour (i.e., fruit and vegetable consumption, high-calorie snack consumption and exercise). This took the form of higher intentions to perform the behaviour being associated with greater performance of that behaviour; whereas for high-calorie snack consumption, higher intentions to avoid snacking was associated with consuming less high-calorie snacks. Each individual intention was moderately associated with its corresponding behaviour also (Table 5.3).

Further to assessing the intention-behaviour relationship it was decided to assess whether intentions for different types of health behaviour were inter-related. Correlational analysis found that fruit and vegetable consumption, high-calorie snack consumption and exercise intentions were moderately positively correlated with one another. Similar analyses were conducted on actual performance of the health behaviours of interest to assess whether performance on one behaviour was associated with an increased or decreased likelihood of performing other health behaviours. Correlational analyses revealed that only fruit consumption and high-calorie snack consumption were moderately negatively correlated, such that greater fruit consumption was associated with lower consumption of high-calorie snacks. The remaining health behaviours were not significantly related (Table 5.3).

Additional correlational analyses were undertaken to ascertain if EC and conscientiousness were correlated with the behavioural intentions and the health behaviours themselves. Firstly, focussing on the EC variables used by Allan et al. (2011), fruit and vegetable and high-calorie snack intentions were small-to-moderately negatively correlated with the DEX (r = -.29, p< .05 and r = -.25, p< .05 respectively), such that stronger intentions were associated with a lower, thus better EC score. On the other hand, the total achievement score from the tower task was small-to-moderately positively correlated with exercise intentions (r = .24, p< .05), with higher scores, thus better EC being associated with stronger intentions; but in relation to actual behaviour a higher tower task total achievement score was associated with eating less high-calorie snacks (r

= .23, *p*< .05). Secondly, focussing on the EC factors created in the current study there was only a small-to-moderate negative correlation between high-calorie snack consumption and factor 2 ('Processing speed/flexibility', *r* = -.23, *p*< .05), such that slower performance was associated with eating less high-calorie snacks (Table 5.3).

Conscientiousness and a subset of the six facets (orderliness, virtue and responsibility) were found to be small-to-moderately positively related to fruit, vegetable and high-calorie snack consumption intentions. The direction of the relationship being that higher conscientiousness, and specifically being higher in the underlying facets of orderliness, virtue and responsibility were associated with higher intentions to consume more fruit and vegetables and less high-calorie snacks (Table 5.3). These same conscientiousness variables were related to actual behaviour with high conscientiousness being associated with eating more fruit and vegetables, whereas eating more high-calorie snacks and low engagement in exercise was associated with low conscientiousness.

The relationship between EC and conscientiousness

Due to the extensive range of EC tasks used in the current study only a general overview of the results will be given here, however, the results in full can be seen in Table 5.3. Overall, a large number of small-to-high inter-correlations were revealed between the EC variables. The direction of these relationships being that poor EC performance in one task in terms of slower reaction time performance or low accuracy was associated with a similarly poor performance in other tasks.

With regards to the EC-conscientiousness relationship, only the DEX showed a moderate-to-high negative relationship with conscientiousness and the underlying facets of virtue, self-control, responsibility and industriousness. The nature of this relationship being the higher DEX scores (poorer EC) was associated with lower conscientiousness.

Table 5.3

Pearson Product Moment correlations between behavioural intention, EC, conscientiousness and health behaviour.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Fruit & vegetable intentions													
2. High-calorie snack intentions	.380**												
3. Exercise intentions	.382**	.316**											
4. Fruit & Vegetable consumption	.712**	.394**	.210										
5. High-calorie snack consumption	-.207	-.390**	.008	-.384**									
6. Exercise behaviour	.099	.045	.497**	.122	.096								
7. Go/No-go task time cost***	-.017	-.026	-.158	-.073	.083	-.214							
8. TT Total achievement score***	-.082	.061	.239*	-.169	.229*	.146	.048						
9. TMT Number-letter switching***	.161	.062	.083	.045	-.202	-.104	-.104	-.022					
10. DEX***	-.285*	-.246*	-.070	-.157	.133	.011	.163	-.025	.091				
11. Stroop (Inhibition vs. colour naming)***	-.017	-.010	-.085	.021	-.107	-.058	-.016	-.201	.132	.155			
12. Verbal fluency***	.098	.146	.071	.202	-.082	.070	.047	.088	-.272*	-.165	-.093		
13. Factor 1 ('Processing speed')	-.173	-.127	.006	-.057	-.090	-.162	-.077	-.028	.123	-.070	.005	-.242*	
14. Factor 2 ('Processing speed/flexibility')	.084	-.020	.085	.043	-.225*	-.023	-.070	-.057	.549**	.020	.135	-.356**	.156

	1	2	3	4	5	6	7	8	9	10	11	12	13
15. Factor 3 ('Switching')	.191	-.065	.005	.122	.150	.049	.043	.068	-.196	-.017	-.059	.341**	-.256*
16. Factor 4 ('Inhibition')	-.104	-.129	-.109	-.095	-.065	-.178	.042	-.178	.270*	.194	.723**	-.259*	.502**
17. Factor 5 ('Motor speed')	-.023	-.010	.060	.094	-.062	-.029	-.106	-.063	.353**	.086	-.136	-.262*	.283*
18. Total conscientiousness	.362**	.215	-.023	.313**	-.249*	.014	.020	-.063	-.074	-.497**	.041	.016	.021
19. Orderliness†	.329**	.198	.000	.274*	-.227*	-.223*	.102	.040	.067	-.123	.016	-.084	.032
20. Virtue†	.252*	.092	-.004	.195	.021	.084	.043	-.189	-.071	-.436**	-.020	.085	.103
21. Traditionalism†	-.015	.154	-.067	.050	-.063	.010	-.161	.003	-.017	-.202	-.114	.048	-.016
22. Self-control†	.112	-.019	-.153	.075	-.217	.040	.008	-.044	-.117	-.340**	.065	-.033	.012
23. Responsibility†	.462**	.307**	.162	.467**	-.338**	.162	.029	-.022	-.031	-.403**	.130	.057	-.064
24. Industriousness†	.183	.090	.002	.116	-.071	.094	-.006	-.061	-.133	-.428**	.059	.050	-.003

	14	15	16	17	18	19	20	21	22	23
15. Factor 3 ('Switching')	-.160									
16. Factor 4 ('Inhibition')	.196	-.211								
17. Factor 5 ('Motor speed')	.248*	.003	.102							
18. Total conscientiousness	-.028	-.089	.019	.065						
19. Orderliness†	.072	-.121	.041	.219	.577**					

	14	15	16	17	18	19	20	21	22	23
20. Virtue†	-.194	-.020	.149	-.033	.506**	.039				
21. Traditionalism†	.012	.025	-.167	.013	.404**	-.099	.065			
22. Self-control†	.014	-.138	-.006	.002	.753**	.333**	.201	.344**		
23. Responsibility†	.084	-.006	.041	.000	.744**	.303**	.426**	.210	.462**	
24. Industriousness†	-.122	-.016	-.006	-.040	.720**	.208	.340**	.239*	.426**	.481**

*p<0.05 **p<0.01

***Allan et al. (2011) EC variables †Conscientiousness facets

TMT=Trail-making task, VFT=Verbal fluency task, ST=Stroop task, TT=Tower task

Intention as a mediator of the relationships between EC, conscientiousness and behaviour

A multiple regression analysis was performed to assess whether intention mediated the relationship between EC, conscientiousness and health behaviours. For this analysis to be undertaken, two new behavioural intention and health behaviour index scores were computed to reduce the number of comparisons, which was a mean score, thus creating one behavioural intention and one health behaviour score for each participant. The behavioural intention score was the average of the combined fruit and vegetable intention, high-calorie snack intention and combined exercise intention ratings. To keep the specificity of the behavioural intention and health behaviour score the same, fruit and vegetable consumption was averaged as was mild, moderate and vigorous exercise, which created three behavioural variables: fruit and vegetable consumption, high-calorie snack consumption and exercise participation. It was then these three behavioural variables that were averaged to create the health behaviour score. In the first step of the multiple regression, all the EC variables relating to Allan et al.'s (2011) study, and conscientiousness were entered into the analysis. In the second step, behavioural intention was entered into the analysis. Step 1 failed to significantly predict variability in health behaviour (R^2= .24, F (12, 66) = 1.750, p>.05), but Step 2 did significantly predict the variability in health behaviour (R^2= .39, F(13,65) = 3.247, p = .001). Intention significantly partially mediated the relationship between EC, conscientiousness and health behaviour (β = .438, p < .001), with the Go/No-go task time cost (β = -.207, p = .050), DEX (β = .251, p = .047) and orderliness (β = -.329, p = .004) also making significant contributions to the model (Table 5.4).

Table 5.4

Regression analyses testing the mediating effects of EC and conscientiousness on health behaviour

	Step 1 (excluding intention)		Step 2 (including intention)		
	β	ΔR^2 for step	β	ΔR^2 for step	Total R^2
Predictor		.103		.273	.376
Go/No-go task time cost	-.106*		-.079*		
TT Total achievement score	.310		.222		
TMT Number-letter switching	-.020		-.037		
DEX	.152		.155*		
Stroop task (Inhibition vs. Colour naming)	-.075		-.040		
Verbal fluency	.014		.003		
Orderliness	-.197*		-.207**		
Virtue	.080		.083		
Traditionalism	-.169		-.091		

Self-control	.074	.136
Responsibility	.312*	.131
Industriousness	.080	.077
Behavioural intention	-	2.633***

*$p<0.05$ **$p<0.01$ ***$p<0.001$ β= Unstandardised coefficient, ΔR^2 = Adjusted r-squared, Total R^2 = sum of ΔR^2 for Step 1 and 2

The same multiple regression analysis was conducted replacing Allan et al's (2011) EC variables with the EC factors created in the current study. Step 1 failed to significantly predict variability in health behaviour (R^2=.168, F(11,67) = 1.232, p>.05), but Step 2 did significantly predict the variability in health behaviour (R^2= .342, F(12,66) = 2.861, p = .003). Intention significantly partially mediated the relationship between EC, conscientiousness and health behaviour (β= .460, p<.001), with orderliness (β= -.375, p = .002) also making a significant contribution to the model (See Table 5.5 for full results).

Table 5.5

Regression analyses testing the mediating effects of EC and conscientiousness on health behaviour

	Step 1 (excluding intention)		Step 2 (including intention)		
	B	ΔR^2 for step	β	ΔR^2 for step	Total R^2
Predictor		.032		.223	.255
Factor1 ('Processing speed')	-.529		-.733		
Factor2 ('Flexibility')	.057		-.300		
Factor3 ('Switching')	-.154		-.386		
Factor4 ('Inhibition')	-1.041		-.516		
Factor5 ('Motor speed')	.497		.507		
Orderliness	-.219**		-.236**		
Virtue	.021		.006		
Traditionalism	-.153		-.084		
Self- control	.043		.118		

Responsibility	.259	.084
Industriousness	.046	.044
Behavioural intention	-	2.762***

*p<0.05 **p<0.01 ***p<0.001 β= Unstandardised coefficient, ΔR^2 = Adjusted r-squared, Total R^2 = sum of ΔR^2 for Step 1 and 2

Main effects of EC on health behaviour

The results of hierarchical linear modelling revealed only one main effect of EC on health behaviour performance. Higher scores on factor 1 ('Processing speed'), indicating slower EC performance, therefore poorer EC, were associated with lower performance of the health behaviours, specifically eating less fruit and vegetables and lower engagement in exercise, and eating more high-calorie snacks (see Table 5.6). There were no significant main effects of conscientiousness on health behaviour.

Table 5.6

Within-person associations of EC on health behaviour performance

MRCM Effect	γ	B	*SE*	β	*p*
Intercept: Health behaviour index	γ_{00}	12.048133	1.647557	7.313	<0.001***
Factor 1 ('Processing speed') - Health behaviour index	γ_{01}	-1.170965	0.548496	-2.135	0.036*

*<0.05 **<0.01 ***<0.001

Level-1 *n* =79. MRCM=Multilevel random coefficient model; γ=Hierarchical multivariate linear modelling symbol; B=Unstandardized coefficients; *SE*=Standard error; β=Standardized coefficients.

Moderators of the intention-behaviour relationship

Firstly, none of the moderation effects reported by Allan et al. (2011)were found to be significant in the current study, with the exception of the total achievement score for the tower task which formed part of a composite 'Switching/flexibility' score in their study. None of the EC factors created in the current study demonstrated any moderation effects either. Similarly, conscientiousness did not moderate the intention-behaviour relationship. However, the tower task total achievement score was revealed to be a significant moderator of the intention-behaviour relationship (Table 5.7). This cross-level interaction was decomposed by performing a simple slopes analysis on the data (Preacher, Curran, & Bauer, 2006). Results showed that behavioural intentions were significantly associated with health behaviour performance ($\beta = 10.695$, $p < .01$), with the intention-behaviour relationship being stronger for those with higher total achievement scores on the tower task, thus good EC planning skills compared to those with lower total achievement scores (Figure 5.1).

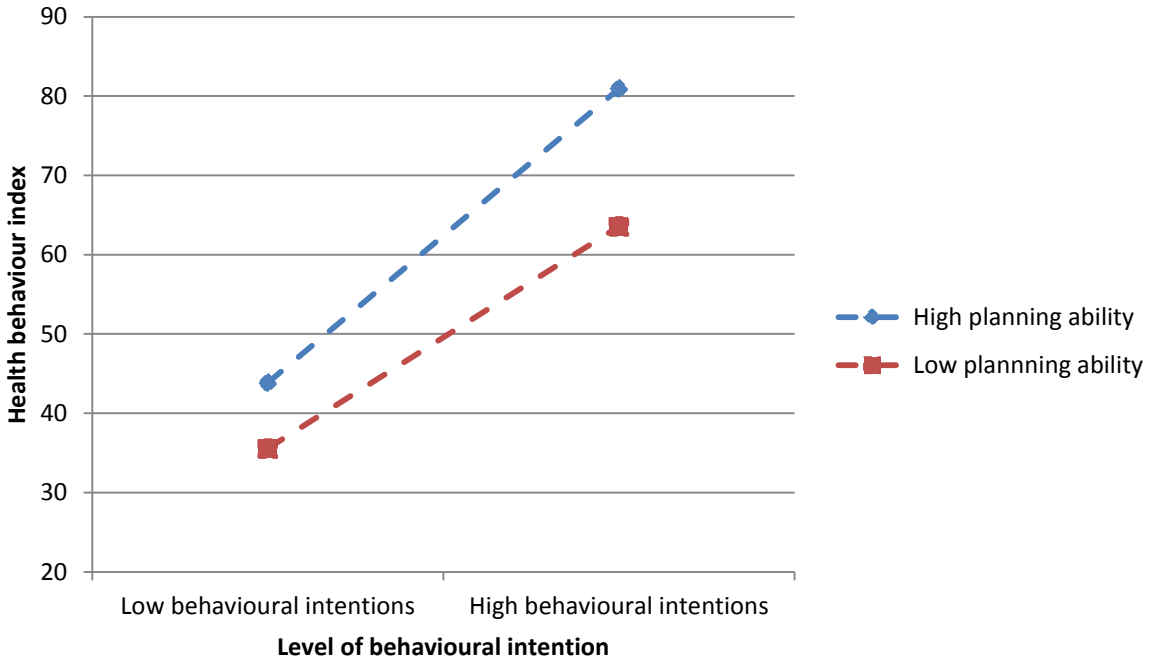

Figure 5.1: The relationship between behavioural intentions and health behaviour performance as moderated by high and low planning ability (1 SD above or below the mean tower task total achievement score respectively). Higher health behaviour index scores indicate greater performance of positive health behaviours, including eating less snacks, eating more fruit and vegetables and greater exercise participation.

Table 5.7

Individual moderators of the within-person effects of behavioural intention on health behaviour

MRCM effect	γ	B	*SE*	β	*p*
Intercept: Health behaviour index	γ_{00}	10.78074	0.570907	18.884	<0.001***
Level-1 slope: Intention-Health behaviour index	γ_{10}	1.603592	0.741713	2.162	0.034*
Main effect					
Tower task Total achievement score-Health behaviour index	γ_{01}	0.270386	0.173754	1.556	0.124
Cross-level interaction with EC					
Tower task Total achievement score x Intention-Health behaviour index	γ_{11}	0.57981	0.221927	2.613	0.011*

*<0.05 ***<0.001Level-1 *n* =79. MRCM=Multilevel random coefficient model; γ=Hierarchical multivariate linear modelling symbol; B=Unstandardized coefficients; *SE*=Standard error; β=Standardized coefficients

Discussion

The current study aimed to replicate the findings of Allan et al. (2011), and to build on this work by incorporating more variables, including exercise intentions and behaviour, and conscientiousness. In addition the study modified the methodology to include a longer daily diary element and analysed the intention-behaviour relationship using multilevel modelling. It was predicted that EC and conscientiousness would significantly moderate of the intention-behaviour relationship; with higher EC and higher conscientiousness being associated with less consumption of high-calorie snacks and more consumption fruit and vegetables, and greater participation in exercise. Furthermore, in light of our previous studies, it was expected that conscientiousness and EC would be significantly related when using the DEX measure of EC. Overall, the findings of the present study fall into four main categories: (1) Intention-behaviour relationships and intention as a mediator, (2) Relationship between EC and conscientiousness, (3) Main effects of EC and conscientiousness on health behaviour, and (4) Moderating effects of EC and conscientiousness on the intention-behaviour relationship. Each of these categories will now be discussed in turn.

Intention-behaviour relationships and intention as a mediator

First, the backbone of the current research is that behavioural intentions are vital for health behaviours to be actualised. Therefore, the finding that intention predicted all the health behaviours assessed affirms the study's theoretical foundations. As part of the data analysis, it was assessed whether behavioural intentions and the actual behaviours were inter-correlated. It was found that all the behavioural intentions significantly correlated with each other, such that stronger intentions to eat at least five portions of fruit and vegetables a day were associated with higher intentions to avoid eating high-calorie snacks and higher intentions to engage in exercise. However, regarding actual behaviour, only fruit consumption and high-calorie snack consumption were significantly related, such that higher fruit consumption was associated with eating less high-calorie snacks. This indicates that performance of one health behaviour does not necessarily facilitate performance of other health behaviours, which suggests health behaviour change interventions may have to

tackle health behaviours individually rather than holistically. In this case, the behaviours that correlated were dietary behaviours. Nevertheless, further research will be needed to confirm and elaborate on these findings. On the other hand, it is suggested that intentions do influence each other, therefore, health behaviour change interventions, perhaps need to focus on the motivational aspect of behaviour in parallel to directly attempting to change health behaviour. This highlights the issue of motivational versus volitional intervention strategies. Gollwitzer (1990) defined two phases of self-regulation. The motivational phase is the intention and the cost/benefit analysis that is associated with deciding to enact behaviour, but as already mentioned this motivation does not always necessarily translate into direct action, thus the volitional phase is the development of plans and action strategies to aid intention enactment, a particularly popular strategy being the development of implementation intentions (Gollwitzer, 1993, 1999; Gollwitzer & Sheeran, 2006). Therefore, both phases need to be considered carefully when trying to promote health behaviour change, and indeed, some researchers are combining these approaches to provide comprehensive behaviour change interventions (Milne, Orbell, & Sheeran, 2002). The importance of intentions is further underlined by the results indicating EC and conscientiousness have an influence over behavioural intentions. The direction of the relationship being broadly that low EC is associated with weaker intentions and high EC is associated with stronger intentions. Similarly, high conscientiousness is associated with higher intentions. In addition, it was revealed that intention significantly mediated the relationship between EC, conscientiousness and health behaviour, thus this further emphasises their pivotal role in the performance of numerous health behaviours.

Relationships between EC and conscientiousness

Firstly, there were a range of inter-correlations found between the different EC measures; however, not all the EC tasks were significantly associated. This is similar to our findings in previous studies, and once more seems to follow the ideas set out by Miyake and colleagues (Miyake & Friedman, 2012; Miyake et al., 2000); the premise being that EC is both unified and diverse. Nonetheless, Miyake and colleagues have attempted to bring

some structure to the concept of EC, proposing that it can be split into three broad domains: "*updating* (constant monitoring and rapid addition/deletion of working memory contents), *shifting* (switching flexibly between tasks or mental sets), and *inhibition* (deliberate overriding of dominant or pre-potent responses)" (Miyake & Friedman, 2012 p.9). Other researchers have pointed to evidence showing generally poor correlation between neurocognitive measures (see Vainik et al., 2013).

Secondly, a primary aim of the present study was to establish whether a relationship existed between EC and conscientiousness. Similar to our first study, it was found that conscientiousness was highly related to the DEX. The DEX also highly correlated with all of the underlying facets of conscientiousness, but this was the only EC variable to correlate with conscientiousness. This appears to confirm the findings of Edmonds et al. (2009) who found no relationship between conscientiousness and laboratory measures of EC, and highlights the possibility of ecological validity being an issue in this relationship. Moreover, it has been pointed out by other researchers that self-report measures are more likely to be correlated than objective neurocognitive measures (Vainik et al., 2013).

An unexpected finding was that the tower task was not significantly related to conscientiousness. The tower task is a measure of planning, and with planning and organisation being key characteristics of conscientiousness it could be argued that conceptually a relationship ought to exist. However, it is important to note that the tower task is only one measure of planning and further research is needed attempting to replicate this result. Also, it is important to acknowledge that although planning is a key characteristic of both conscientiousness and the tower task (Delis et al., 2001; McCrae & Costa, 1987), they tap different elements of planning. For instance, the tower tasks tap the ability to plan, whereas conscientiousness taps whether an individual engages in planning. Indeed, Matthews and Zeidner (2012) highlighted that conscientiousness is more generally associated with task engagement rather than task performance. Therefore, there is an issue of specificity of measures that needs to be addressed, as it could explain the current non-significant findings.

Main effects of EC and conscientiousness on health behaviour

Significant main effects were only found for EC, with conscientiousness exhibiting no direct effects on health behaviour. Slower information processing speed was associated with eating less fruit and vegetables, and eating more high-calorie snacks and engaging in less exercise. Traditionally, simple processing speed and EC have been treated as separate entities, but this is not necessarily the case as there is evidence suggesting reaction time variability may reflect lapses in EC (Stuss, Murphy, Binns, & Alexander, 2003; West, Murphy, Armilio, Craik, & Stuss, 2002). Therefore, this finding highlights that even the more basic aspects of not only EC, but cognition overall, exert an influence over our behaviour. Indeed, the importance of processing speed has been previously demonstrated when examining the relationship between IQ, health and mortality (Deary & Der, 2005). Greater reaction time variability has also been found to be indicative of neurological disorders (Anstey, Mack, Christensen, Li, Reglade-Meslin, Maller et al., 2007; Walhovd & Fjell, 2007), and mental illnesses (Carroll, O'Donnell, Shekhar, & Hetrick, 2009; Kaiser, Roth, Rentrop, Friederich, Bender, & Weisbrod, 2008). Furthermore, the relationship between reaction time variability and health is reciprocal as performance of health-damaging behaviours; for instance alcohol consumption, can have detrimental effects on processing speed (Simmons, Levy, Riley, Madra, & Mattson, 2009).

Moderating effects of EC and conscientiousness on the intention-behaviour relationship

The main aim of the current study was to replicate the findings of Allan et al. (2011), and the current study has to some extent partially replicated those findings. The present study replicated two of Allan et al.'s (2011) results, finding a non-significant effect of time costs in the Go/No-go task on the intention-behaviour relationship, and yet, finding the total achievement score on the Tower task to moderate the intention-behaviour relationship. However, in the current study the tower task components were assessed as individual entities, whereas Allan et al. (2011) combined the tower task with the verbal fluency and trail-making tasks to create an overall 'switching/flexibility' score. This serves to

highlight an important issue with the current research that may explain why the results were not completely replicated. That being said, this was not the purest replication of Allan et al.'s (2011) work, as the methodology and analysis were modified to include other variables of interest to the researchers and to build on previous work. Another reason why this study may have failed to fully replicate Allan et al.'s (2011) results could be due to the differential performance of the samples on the EC tasks. Generally, the standard deviation for our samples performance on the EC tasks is much smaller, which means there is less variance within the data.

The rather unusual result that did emerge from the current study was that conscientiousness did not significantly moderate the intention-behaviour relationship. This was an unexpected result considering our previous work finding such a relationship and the wealth of literature linking conscientiousness to fruit and vegetable consumption (de Bruijn, 2013), snacking (Booth-Kewley & Vickers, 1994) and exercise (Rhodes & Dickau, 2013). A potential reason for this result could be due to the main limitation of this study: the sample consisted of students and was modest in size. A student sample was chosen because Allan et al. (2011) used a student sample and the current study was devised to serve as a model to assess whether such relationships existed within a subset of the population before applying it to the wider population. Nevertheless, it is widely documented that conscientiousness is associated with academic achievement (Paunonen & Ashton, 2001), therefore the sample may be particularly high in conscientiousness, and in other research investigating the relationship between action planning and academic achievement, it has been found high conscientiousness exerts no effect, with significant effects only emerging for those with moderate and low conscientiousness (Webb, Christian, & Armitage, 2007). Though this may have affected the current results, once again, caution must be exerted before drawing any definite conclusions as this result would need to be replicated. Consequently, the current study highlights that future studies should employ a sample from the wider more representative population. On the other hand, the internal consistency of conscientiousness was weak in places. Although the questionnaire as a whole and the subscales of orderliness, self-control, and industriousness had a Cronbach's alpha ranging

from .845 - .894; virtue, traditionalism and responsibility only had a Cronbach's alpha ranging from .641 - .674. Therefore, the low reliability in these three subscales may have influenced the results.

Conclusions

In conclusion, the present study revealed five main findings: (1) intentions are important predictors of behaviour that are influenced not only by each other but by EC and conscientiousness variables, (2) EC and conscientiousness are only related when the DEX measure of EC is used, (3) processing speed has a direct effect on health behaviour, and (4) planning ability moderates the intention-behaviour relationship, (5) conscientiousness did not significantly predict or moderate health behaviour relationships. Overall, these results have important implications for further research. They suggest wider more representative population samples should be used in order to gain a broader insight into the nature of these relationships and attempt to replicate these findings. On another note, the findings of the current study serve to highlight the importance of intentions and what variables can influence them. Together this could be vital information to consider when developing health behaviour change interventions.

Chapter 6
Study 4: The relationship between executive control, conscientiousness, dietary and exercise behaviour: A replication study

Introduction

Study 3 aimed to replicate and build upon the work of Allan et al. (2011).To some extent the previous study was successful in terms of replicating the significant effects for tower task performance on subsequent health behaviour and the non-significant findings for the Go/No-go task. Nonetheless, despite the partial replication, Study 3 notably did not re-produce the significant Stroop task findings produced in Allan et al.'s (2011) study. With regards to our specific interest in the relationship between conscientiousness, EC and health behaviour; once again, conscientiousness and EC were found to not be significantly related, except when the self-report DEX measure of EC was used. Once more, this highlights issues regarding the independence of these two constructs, and raises questions about ecological validity. Another more unexpected result was that conscientiousness had no significant direct or indirect effects on health behaviour. This finding was in stark contrast to findings from our own research (e.g., Study 1), and other research linking conscientiousness to dietary (de Bruijn, 2013; O'Connor et al., 2009) and exercise (Rhodes & Dickau, 2013) behaviours.

The main reason for these mixed findings may have been due to the sample used. Although both Allan et al. (2011) and Hall et al. (2008b), whom the Go/No-go task was replicated from used student samples of a moderate size, there are problems with both smaller sample sizes and using students as participants. Smaller sample sizes reduce the variability in the sample, therefore making it harder to distinguish significant differences, and potentially leaving the study underpowered. The problem with using students is two-fold. First, students are relatively highly educated and it could be argued that because these individuals are most likely highly intelligent then they perhaps naturally have higher EC. Nevertheless, due to EC not being an entirely unitary construct, not every function subsumed under the construct of EC is related to

intelligence (Friedman, Miyake, Corley, Young, DeFries, & Hewitt, 2006). Furthermore, it is worth acknowledging that EC does not fully develop until we reach our early twenties (Eshel et al., 2007; Lyon & Krasnegor, 1996; Romine & Reynolds, 2005; Rubia et al., 2006; Ward et al., 2005), thus the executive skills of younger students is still maturing. Second, academic achievement is associated with higher conscientiousness (Paunonen & Ashton, 2001), thus the previous study may have elicited non-significant findings because of ceiling effects; an effect that has been seen in other studies investigating conscientiousness using student samples (Webb et al., 2007). Nevertheless, it was still sensible to use a predominantly student sample for our previous studies. The reasons being that key research in this field and particularly the research we set out to replicate used a student sample. Furthermore, it served as a useful model to test whether these relationships existed within a large sub-set of the population before undertaking this research with the wider population, especially when other literature in this area has yielded significant results from student populations (Allan et al., 2011; Hall et al., 2012; Mullan et al., 2011).

As a result of the mixed findings, not only found in Study 3, but previous studies also (e.g., Study 1), it seemed most prudent to attempt to replicate Study 3, but with a larger and more diverse sample (i.e., larger age range and fewer students). This was to allow the researchers to ascertain whether the sample was having an impact on the results and help to provide more definitive answers on the relationships between EC, conscientiousness and health behaviour, which can subsequently be used to inform potential future health behaviour change interventions.

However, there is still room for innovations in a replication study, particularly when in some instances they improve upon the limitations of the previous study. For instance, Study 3 only took one initial measure of behavioural intentions as this was in line with Allan et al.'s (2011) study, but as there are daily fluctuations in our behaviour this may reflect daily fluctuations in our intentions also. Therefore, in the current study behavioural intentions were measured everyday to account for this possible fluctuation, in order to provide more accurate and powerful results, and to allow the full within and between-person measures analysis to be explored using hierarchical linear modelling

(Raudenbush et al., 2004). In line with this idea of exploring intentions and behaviour on a more day-to-day basis the follow-up period was also longer. This was particularly important as most studies in this area tend to have short follow-ups. Indeed, the Allan et al. (2011) paper had follow-ups of 24 hours and three days.

A further addition to the current study was the measurement of explicit attitudes towards the health behaviours. As well as the relationship between intentions and behaviour it may be that there is an important relationship between attitudes and health behaviour that is potentially moderated by EC and conscientiousness. It is particularly worth exploring these inter-relationships as although implicit attitudes have been investigated (Houben et al., 2011a), to date there is no research in this area investigating explicit attitudes.

Finally, changes have been made to the measures of exercise behaviour. In previous studies, measures of mild, moderate and vigorous exercise were taken. However, the current study has removed the mild exercise measure and retained only the moderate and vigorous exercise measures. The reason for this change is namely due to NHS health recommendations and the subjectivity of what constitutes mild exercise. Health recommendations promote at least 30 minutes of moderate exercise. Thus, although mild exercise is worthwhile, as this study is interested in health benefits and the other intention/behavioural questions were framed in terms of the health recommendations, it was decided to exclude the mild exercise measure to be consistent. Furthermore, there are problems with the definition of mild exercise as it is unclear what constitutes mild exercise compared to moderate and vigorous exercise. Our research has based its definitions on those set out in the Godin Leisure-time exercise questionnaire (Godin & Shephard, 1985), which defines mild exercise as activities requiring minimal effort, including easy walking. However, what constitutes as easy walking will be subjective to the individual engaging in the activity, and will likely depend on factors such as fitness level. In addition, it is likely that people will naturally engage in more mild intensity exercise (e.g., easy walking) than moderate and particularly vigorous exercise (e.g., running), especially as engaging in such exercise may entail planning a gym visit. Furthermore, the current study employed an objective

measure of exercise; this being a GENEActiv device, which worn on the wrist provides daily data on movement frequency, thus will allow a more accurate picture of physical activity to be gained that can be compared to self-reported exercise (Esliger, Rowlands, Hurst, Catt, Murray, & Eston, 2011). In addition, high-calorie snack consumption will be more objectively measured than the previous study for instead of participants reporting how many high-calorie snacks they have consumed, participants will be required to specifically state the snacks they have consumed and this list will be independently evaluated by a trained researcher to negate problems with knowing what snacks are high in fat and sugar as this is not always clear (Adriaanse, de Ridder, & de Wit, 2009).

Consequently, the present study aims to replicate the findings of Study 3 with a larger and more diverse sample, while incorporating innovations in terms of utilising objective measures of behaviour and including additional measures, such as behavioural attitudes. As such, the current study has two main hypotheses:

1) Planning ability will significantly moderate the intention-behaviour relationship.
2) Conscientiousness and the DEX measure of EC will be significantly related.

Method

Participants

The current study was carried out between September 2013 and April 2014. Participants were recruited using poster and email advertisements distributed around the University of Leeds campus as well as using the University of Leeds participant databases. These advertisements provided information about the study procedure, eligibility criteria, reimbursement for participation and researcher contact details. The inclusion/exclusion criteria were similar to previous studies, but with notable differences to address the current study aims, henceforth participants were eligible if: (i) they were aged 18-60 years, (ii) they were proficient English speakers, (iii) they did not suffer from any neurological disorder, and (iv) they were not a student (this

recruitment protocol was later changed to include a small proportion of students in order to create an accurate reflection of the general population). A total of 118 individuals (20 males, 98 females) aged between 18-59 years (mean 34.18 years, SD 10.89) participated in the study for a £10 Love2Shop voucher. The current study was approved by the University of Leeds Ethics Committee (ethics reference number 13-0142) and abided by British Psychological Society (BPS) guidelines.

Design

A multilevel diary design was adopted to assess the within-person effects of EC and conscientiousness on four health behaviours (high-calorie snack consumption, fruit and vegetable consumption and exercise (moderate/vigorous) over a fourteen day period. An interval-contingent method was adopted with participants completing the daily diary online at the end of the day (between 5pm and 2am). The diary was only accessible at the specified times, and each entry was date and time stamped. This method was chosen due to its reliability and high rate of participant compliance over long study durations (Bolger et al., 1989; Feldman et al., 1999; Green et al., 2006; Tennen et al., 2006). The predictor variables were EC and conscientiousness. The dependent variables were performance of the health behaviours (high-calorie snack consumption, fruit and vegetable consumption, and exercise) as measured by the diary over fourteen days. In addition, exercise was measured objectively using GENEActiv devices (see below for more details).

Apparatus

The Go/No-go task and questionnaires were created using the experimental software PsyToolkit (Stoet, 2010) and were completed on a Linux operating laptop. Participants navigated through on-screen instructions using the space bar of the computer keyboard. Responses were recorded on a Cedrus USB keyboard (model RB-834) with only one key being used. Responses to questionnaires were recorded using the laptop mouse to click options provided on-screen. The other EC tasks used formed part of the DKEFS (Delis et al., 2001) battery of tests, which included a book with all the test

materials, as well as pegs and disks for the tower task. Instructions were provided verbally and responses were recorded using the appropriate record sheet and a stopwatch by the experimenter. A GENEActiv device was also used to measure exercise over the fourteen day diary period.

Measures

Objective EC measures

Due to the replication nature of this study the same objective EC measures used in Study 3 were utilised in the current study. These were the Trail-making, Verbal fluency, Stroop and Tower tasks from the DKEFS (Delis et al., 2001) and the Go/No-go task.

Subjective EC measures

Dysexecutive Questionnaire (DEX, Wilson et al., 1996). Items and scoring were the same as Studies 2 and 3.

Personality Measures

60-item conscientiousness questionnaire (Hill & Roberts, 2011). Items and scoring were the same as Studies 1 and 3.

50-item set of IPIP Big-Five Factor Markers (Goldberg, 1992). Only the ten items measuring conscientiousness were used in the current study, with participants being asked to indicate the extent to which each statement described them on a 5-point Likert scale (*Very Inaccurate (1), Moderately Inaccurate (2), Neither Accurate Nor Inaccurate (3), Moderately Accurate (4), Very Accurate (5)*). Higher scores indicate higher levels of conscientiousness. Due to the high correlation between this measure of conscientiousness and the 60-item measure (r = .727, p <.01), this measure was not used in subsequent analyses.

Barratt Impulsiveness Scale-11 (BIS-11, (Patton et al., 1995). Items and scoring were the same as Study 2 and 3. This measure was not included in subsequent analyses.

Health behaviour measures

Subjective measures

14-day diary. The diary was structured into three distinct blocks of questions: behavioural intentions for the next day, attitude towards the behaviour, and behavioural performance (Appendix 6.1). This structure was adopted in an attempt to reduce respondent burden by easing the flow between questions.

Behavioural intentions to perform each health behaviour were measured in turn with items taking the format of "To what extent do you intend to/avoid [health behaviour] tomorrow?*(Not at all (1) – Very much (7))*". All the behavioural intentions were framed to be in line with health recommendations; for instance, five portions of fruit and vegetables a day and 30 minutes of moderate/vigorous exercise a day. Examples of each behaviour were provided to promote accurate reporting of behaviour.

Behavioural attitudes were also framed in terms of health recommendations, taking the form of "For me to/avoid [health behaviour] tomorrow would be...(*Harmful (-3) – Beneficial (3), Pleasant (-3) – Unpleasant (3)*)".

Behavioural performance was measured by free response questions, with participants reporting individually how many fruits and vegetables they had consumed that day, as well as reporting how many minutes of moderate and vigorous exercise they had engaged in. With regards to high-calorie snack consumption, participants were required to list all the snacks they had eaten that day, and these were independently coded as either high-fat, high-sugar or high in both by two individuals trained to PhD level with a 98% percentage of agreement. Cohen's k results can be seen in Table 6.1. If a snack was low in both fat and sugar it was included within the snack total only. Definitions of high-fat and high-sugar were established using NHS recommendations. High-fat was defined as more than 20 grams of fat per 100 grams. High-sugar was defined as more than 15 grams of sugar per 100 grams. Using these values each snack had its fat and sugar content evaluated using the McCance and Widdowson (2002) food composition tables.

Table 6.1

Cohen's k for coding of snacks

	K	CI (95%)	*p*
High-fat	.976	.929 – 1.023	<.001
High-sugar	.976	.929 – 1.023	<.001
High fat and sugar	.981	.944 - 1.018	<.001

k = Cohen's kappa; CI (95%) = 95% confidence interval

Objective measures

GENEActiv devices. These devices are lightweight tri-axial accelerometers worn on the wrist of the non-dominant hand and serve as a means of non-invasively measuring movement frequency (60 hertz). The devices are waterproof, thus can be worn 24 hours a day, including while asleep. Within the context of the current study, this device was used to objectively measure moderate and vigorous physical activity. This data was initially analysed using the openly available physical activity macro accessible at open.geneactiv.org. This macro splits the data into day and night by recording out of bed and going to bed time (before watches issued to participants they are calibrated with the correct date and time), level of physical activity (mild/moderate/vigorous) and indicates the amount of non-wear time. The devices have been shown to be valid and reliable (Esliger et al., 2011; Zhang, Murray, Zillmer, Eston, Catt, & Rowlands, 2012; Zhang, Rowlands, Murray, & Hurst, 2012), with the devices being used effectively in longitudinal studies of physical activity (Hamer, Lavoie, & Bacon, 2014).

Procedure

Firstly, participants were required to attend a laboratory session in the Institute of Psychological Sciences at the University of Leeds lasting 1 hour 15 minutes. Participants initially were presented with an information sheet and a consent form. Once consent was obtained a number of details about the participant, such as age, gender, education level, profession and email address (required for the participant to receive reminder emails about completing the

diary) were taken. Additionally, participants were required to create a unique identification code that would be used to match the laboratory, diary and GENEActiv data anonymously. Afterwards, participants completed the trail-making, verbal fluency, Stroop and tower tasks from the DKEFS battery of tests. The order of these tasks was counterbalanced in order to reduce any adverse effects on the task caused by variables such as fatigue. The rest of the experiment was completed on a laptop computer with participants completing the Go/No-go task first and ending with the questionnaire measures (i.e., the DEX, the 60-item conscientiousness questionnaire, the 10-item conscientiousness questionnaire, and the BIS). At the end of the session, participants were fitted with a GENEActiv device. It was explained to participants that they must wear the device continuously over the next fourteen days, and any queries participants had were answered. The following day, the 14-day daily diary began. Participants received reminder emails everyday at 5pm providing the link to click on to access the online diary (www.psyc.leeds.ac.uk/14dailydiary). By clicking on this link participants could then answer questions about their daily behavioural intentions, attitudes and behaviour. The diary took approximately five minutes to complete each day.

Results

Data analysis

A total of 118 participants took part in the study, with all available data being used. However, due to technical faults with the GENEActiv devices, objective exercise datasets with at least six days of data was only available for 103 participants. Missing data was removed using the “Delete missing level-l data when making mdm” function on the HLM software.

Correlational analysis was undertaken using IBM SPSS Statistics 21, whereas main effect and moderation analysis was undertaken using multilevel modelling (hierarchical linear modelling [HLM]) (Raudenbush et al., 2004). Forming a two level hierarchical structure, Level-1 (within-subject variation) contained the health behaviour intentions and actual health behaviour (diary data); Level-2 (between-subject variation) contained the EC and

conscientiousness data. The Level-1 variables were entered group-mean centred and the Level-2 variables were entered grand-mean centred. A lagged analysis was undertaken, such that the behavioural intentions made were for the following day's behaviour. Due to the imbalance of the genders in the sample, gender was controlled for in preliminary analyses. As gender did not significantly impact on any of the behaviours measured, it was not included in subsequent analyses. Furthermore it was attempted to create an overall motivation variable comprising of behavioural intentions and behavioural attitudes, however, the attitude measures did not scale, thus were excluded from the subsequent analyses. Separate models were built to assess:

1) Behavioural intentions as a predictor of health behaviour. For example:
   Level-1: y_{ij} (Behaviour) = β_{0j} + β_{1j}*(Intentions) + r_{ij}

2) EC and conscientiousness as direct predictors of health behaviour. For example:
   Level-1: y_{ij} (Behaviour) = β_{0j} + r_{ij}
   Level-2: β_{0j} = γ_{00} + γ_{01}* (Conscientiousness total) + u_{0j}

3) EC and conscientiousness as moderators of the intention-behaviour relationship. For example:
   Level-1: y_{ij} (Behaviour) = β_{0j} + + β_{1j}*(Intentions) + r_{ij}
   Level-2: β_{0j} = γ_{00} + u_{0j}
   β_{1j} = γ_{10} + γ_{11}*(Conscientiousness total) + u_{1j}

Where γ_{00} denotes the health behaviour mean, γ_{01} signifies the influence EC and/or conscientiousness has on the mean, γ_{10} represents the average size of the intention-behaviour relationship, and γ_{11} indicates the degree to which the intention-behaviour relationship is moderated by each of the EC and conscientiousness variables. For reasons of brevity only significant findings are reported. Descriptive statistics for all the Level-1 and Level-2 variables are shown in Tables 6.2 and 6.3 respectively.

Table 6.2

Descriptive statistics for Level-1 measures

	M	*SD*	Range
Snack intention rating	5.07	1.84	0 – 7
Fruit & vegetable intention rating	5.39	1.61	0 – 7
Moderate exercise intention rating	5.13	1.95	0 - 7
Strenuous exercise intention rating	3.54	2.32	0 – 7
Unhealthy snacks	1.52	1.62	0 – 11
High-fat snacks	0.30	0.65	0 – 5
High-sugar snacks	0.42	0.76	0 – 7
Fruit & vegetable consumption	4.05	2.16	0 – 12
Self-reported moderate exercise (in minutes)	32.07	41.37	0 - 600
Self-reported strenuous exercise (in minutes)	12.80	27.89	0 – 360
Objectively recorded moderate exercise (in minutes)	164.34	86.60	0 – 736
Objectively recorded strenuous exercise (in minutes)	12.63	22.97	0 - 262

Table 6.3

Descriptive statistics for Level-2 measures

	M	SD	Range
Trail-making switch condition completion time	59.74	17.92	24.98 – 127.90
Verbal fluency score	90.40	16.58	49 - 144
Stroop task (Inhibition vs. Colour naming)	21.30	7.24	7.22 – 49.60
Tower task overall score (/30)	18.12	3.26	11 - 26
Go/No-Go task RT (cost of effortful initiation, in ms)	20.80	15.95	-31.62 – 73.28
DEX score (/80)	25.78	9.02	4 – 45
Total conscientiousness (60-item measure)	213.66	22.35	166 – 269
Orderliness	34.85	7.54	18 – 50
Virtue	33.84	4.84	20 - 45
Traditionalism	31.63	5.08	15 – 45
Self-control	35.18	6.32	20 – 48
Responsibility	38.87	4.54	29 – 49
Industriousness	39.27	5.47	23 - 50

Note: n = 103 (mean age 34.07 years, SD 10.78, range 18-59 years) for Level-2 variables.

EC and conscientiousness

Correlational analysis was undertaken on the EC and conscientiousness variables using IBM SPSS Statistics 21 (See Table 6.4). First, it is important to

acknowledge that age was moderate-to-largely significantly positively correlated with trail-making, Stroop task (i.e., inhibition vs. colour naming), and verbal fluency. As age increased reaction times were slower for trail-making and the Stroop task, but verbal fluency improved with age.

With regards to the inter-relationships between EC measures, a number of significant correlations emerged. Slower reaction times on the trail-making task were moderately correlated with similarly slow reaction time performance on the Stroop task. Furthermore, poor performance on these tasks was associated with similarly poor performance on the tower task.

With regards to the relationship between EC and conscientiousness, numerous relationships emerged between self-report and objective measures of EC and conscientiousness, including its underlying facets. The self-report DEX measure of EC was moderately-to-largely negatively associated with all conscientiousness measures, such that poorer EC was associated with lower conscientiousness. In relation to objective EC scores, greater verbal fluency was small-to-moderately positively associated with higher self-control. In relation to objective reaction time EC measures, greater time costs in the Go/No-go task were small-to-moderately associated with lower conscientiousness, including being lower in responsibility and industriousness. In contrast, slower reaction times on the trail-making task were small-to-moderately associated with higher self-control, and slower reaction times on the Stroop task were moderately positively associated with higher total conscientiousness, including being higher in virtue, self-control, and industriousness (see Table 6.4 for full results).

Table 6.4

Pearson Product Moment correlations between EC and conscientiousness measures

	1	2	3	4	5	6	7	8	9	10	11	12	13
1.Age													
2.Trail-making task	.259**												
3.Verbal fluency	.261**	-.181											
4.Stroop (Inhibition vs. Colour naming)	.413**	.362**	.008										
5.Tower task	-.087	-.281**	-.011	-.365**									
6.Go/No-go task (RT)	-.127	.123	-.068	-.106	.143								
7.DEX	-.167	-.052	-.132	-.098	.073	.131							
8.Total conscientiousness (60-item)	.125	.139	-.007	.263**	-.139	-.189*	-.598**						
9.Orderliness	.008	.084	-.054	.069	-.124	-.008	-.343**	.689**					
10.Virtue	.032	.099	-.060	.245**	-.094	-.147	-.338**	.647**	.235*				
11.Traditionalism	.053	-.048	-.035	.127	-.020	-.149	-.355**	.608**	.259**	.397**			
12.Self-control	.157	.186*	.192*	.243**	-.091	-.083	-.623**	.654**	.291**	.373**	.275**		

	1	2	3	4	5	6	7	8	9	10	11	12	13
13.Responsibility	.131	.044	.030	.122	-.038	-.185*	-.459**	.722**	.365**	.418**	.333**	.367**	
14.Industriousness	.136	.157	-.114	.266**	-.164	-.250**	-.274**	.696**	.393**	.315**	.305**	.255**	.553**

*Note: n= 118 in all measures with exception of Go/No-go task due to exclusion of two outliers (n = 116). *p<.05 **p<.01*

The intention-behaviour relationship

Multilevel modelling revealed behavioural intentions to be a significant predictor of all the health behaviours with the exception of snack consumption. This was irrespective of the type of snack (i.e., high-fat or high-sugar). Nevertheless, significant positive correlations between behavioural intention and actual health behaviour performance were found for fruit and vegetable consumption ($\beta = 4.075$, $p < .001$), self-reported moderate and vigorous exercise ($\beta = 7.579$, $p < .001$, and $\beta = 7.367$, $p < .001$ respectively), and moderate and vigorous exercise as objectively assessed by the GENEActiv devices ($\beta = 2.219$, $p = .029$, and $\beta = 5.057$, $p < .001$ respectively). These relationships all took the direction of stronger behavioural intentions to perform these behaviours were associated with greater behavioural performance (i.e. eating more fruit and vegetables and engaging in more moderate and vigorous exercise).

Main effects of EC and conscientiousness

Hierarchical linear modelling revealed direct main effects of EC and conscientiousness on health behaviour. With regards to EC, higher tower task and verbal fluency scores were associated with less consumption of high-fat snacks and greater self-reported engagement in vigorous exercise respectively. On the other hand, higher tower task scores were also associated with less engagement in self-reported moderate exercise. With regards to conscientiousness, a higher level of traditionalism was associated with less engagement in objectively assessed moderate exercise as measured by the GENEActiv devices (see Table 6.5 for full results).

Table 6.5

Within-person associations of EC and conscientiousness on health behaviour performance

MRCM Effect	γ	B	*SE*	β	*p*
Intercept: High-fat snack consumption	γ_{00}	0.306508	0.034601	8.858	<0.001
Tower task – High-fat snack consumption	γ_{01}	-0.021356	0.010645	-2.006	0.048
Intercept: Self-reported vigorous exercise	γ_{00}	12.218897	1.559488	7.835	<0.001
Verbal fluency – Self-reported vigorous exercise	γ_{01}	0.142104	0.068777	2.066	0.041
Intercept: Self-reported moderate exercise	γ_{00}	32.192237	2.426300	13.268	<0.001
Tower task – Self-reported moderate exercise	γ_{01}	-1.518927	0.647723	-2.345	0.021
Intercept: Objectively measured moderate exercise	γ_{00}	162.946015	6.317086	25.794	<0.001
Traditionalism - Objectively measured moderate exercise	γ_{01}	-2.471780	1.243189	-1.988	0.049

MRCM=Multilevel random coefficient model; γ=Hierarchical multivariate linear modelling symbol; B=Unstandardized coefficients; *SE*=Standard error; β=Standardized coefficients.

Moderation effects of EC and conscientiousness

Hierarchical linear modelling revealed a number of moderating effects of EC and conscientiousness on snack, fruit and vegetable consumption and moderate and vigorous exercise. These cross-level interactions were decomposed by performing simple slopes analysis on the data (Preacher et al., 2006). In order to test the moderation effects, main and moderation effects were added to the existing models. For example:

Level-1: y_{ij} (Health behaviour) = β_{0j} + β_{1j}*(Behavioural intentions) + r_{ij}

Level-2: β_{0j} = γ_{00} + γ_{01}*(Conscientiousness) + u_{0j}

β_{1j} = γ_{10} + γ_{11}*(Conscientiousness) + u_{1j}

The following cross-level interactions were significant, whilst controlling for the main effects EC and conscientiousness (See Table 6.6 for full results).With regards to snack consumption, simple slopes analysis found that the DEX score moderated the intention-behaviour relationship (Figure 6.1), such that the association between intention and high-fat snack consumption was negative for individuals with a low DEX score (β = -0.0408, *p*> .05), and positive for individuals with a high DEX score (β = 0.0351, *p* = .0285).

With regards to fruit and vegetable consumption, the intention-behaviour relationship was moderated by virtue (Figure 6.2), such that the association between intention and fruit and vegetable consumption was positive and strongest for individuals low in virtue(β = 0.3926, *p*< .001) compared to individuals high in virtue (β = .0.1282, *p*> .05).

With regards to moderate exercise, the intention-behaviour relationship was moderated by orderliness (Figure 6.3), such that the association between intention and objectively measured moderate exercise was positive and strongest for individuals low in orderliness (β = 9.4588, *p*<.001) compared to individuals high in orderliness (β = 0.3183, *p*> .05).

With regards to vigorous exercise, the intention-behaviour relationship was moderated by responsibility, such that the association between intention and self-reported vigorous exercise was positive and strongest for individuals high in responsibility (β = 5.9897, *p*< .001) compared to individuals low in

responsibility (β = 3.1447, *p*< .01, Figure 6.4). Similarly, the association between intention and objectively measured vigorous exercise was positive and strongest for individuals high in responsibility (β = 3.4044, *p*< .001) compared to individuals low in responsibility (β = 0.9214, p > .05, Figure 6.5).

Table 6.6

Individual moderators of the within-person effects of behavioural intention on health behaviour

MRCM effect	γ	B	*SE*	β	*p*
Intercept: High-fat snack consumption	γ_{00}	0.306206	0.035168	8.707	<0.001***
Level-1 slope: Intention- High-fat snack consumption	γ_{10}	-0.003303	0.014896	-0.222	0.825
Main effect					
Self-control - High-fat snack consumption	γ_{01}	0.000468	0.005787	0.081	0.936
Cross-level interaction with conscientiousness					
Self-control x Intention- High-fat snack consumption	γ_{11}	-0.004911	0.002036	-2.412	0.018*
Intercept: High-fat snack consumption	γ_{00}	0.306079	0.035075	8.726	<0.001***
Level-1 slope: Intention- High-fat snack consumption	γ_{10}	-0.002886	0.014346	-0.201	0.841
Main effect					
DEX - High-fat snack consumption	γ_{01}	-0.002033	0.004892	-0.416	0.679

Cross-level interaction with EC					
DEX x Intention- High-fat snack consumption	γ_{11}	0.004206	0.001903	2.210	0.029*
Intercept: High-sugar snack consumption	γ_{00}	0.423008	0.037806	11.189	<0.001***
Level-1 slope: Intention- High-sugar snack consumption	γ_{10}	-0.000299	0.017496	-0.017	0.986
Main effect					
Orderliness - High-sugar snack consumption	γ_{01}	-0.008284	0.004717	-1.756	0.082
Cross-level interaction with conscientiousness					
Orderliness x Intention- High-sugar snack consumption	γ_{11}	0.003906	0.001651	2.365	0.020*
Intercept: High-sugar snack consumption	γ_{00}	0.423865	0.038110	11.122	<0.001***
Level-1 slope: Intention- High-sugar snack consumption	γ_{10}	0.002765	0.017457	0.158	0.874
Main effect					
Total conscientiousness - High-sugar snack consumption	γ_{01}	-0.001374	0.001787	-0.769	0.444

Cross-level interaction with conscientiousness					
Total conscientiousness x Intention- High-sugar snack consumption	γ_{11}	0.001385	0.000707	1.958	0.053
Intercept: Fruit and vegetable consumption	γ_{00}	4.006292	0.163884	24.446	<0.001***
Level-1 slope: Intention- Fruit and vegetable consumption	γ_{10}	0.260406	0.066164	3.936	<0.001***
Main effect					
Virtue - Fruit and vegetable consumption	γ_{01}	0.023709	0.035666	0.665	0.508
Cross-level interaction with conscientiousness					
Virtue x Intention- Fruit and vegetable consumption	γ_{11}	-0.027313	0.013654	-2.000	0.048*
Intercept: Self-reported moderate exercise	γ_{00}	32.173549	2.455591	13.102	<0.001***
Level-1 slope: Intention-Self-reported moderate exercise	γ_{10}	5.979509	0.767209	7.794	<0.001***
Main effect					
Industriousness-Self-reported moderate exercise	γ_{01}	0.104741	0.539844	0.194	0.847

Cross-level interaction with conscientiousness					
Industriousness x Intention-Self-reported moderate exercise	γ_{11}	-0.258667	0.140035	-1.847	0.068
Intercept: Objectively measured moderate exercise	γ_{00}	162.819198	6.302087	25.836	<0.001***
Level-1 slope: Intention – Objectively measured moderate exercise	γ_{10}	4.888535	1.797111	2.720	0.008**
Main effect					
Orderliness – Objectively measured moderate exercise	γ_{01}	-1.644356	1.015768	-1.619	0.109
Cross-level interaction with conscientiousness					
Orderliness x Intention – objectively measured moderate exercise	γ_{11}	-0.606134	0.202596	-2.992	0.003**
Intercept: Self-reported vigorous exercise	γ_{00}	12.135201	1.564393	7.757	<0.001***
Level-1 slope: Intention – Self-reported vigorous exercise	γ_{10}	4.567229	0.637405	7.165	<0.001***
Main effect					

Responsibility – Self-reported vigorous exercise	γ_{01}	0.284634	0.343475	0.829	0.409
Cross-level interaction with conscientiousness					
Responsibility x Intention – Self-reported vigorous exercise	γ_{11}	0.313322	0.120952	2.590	0.011*
Intercept: Objectively measured vigorous exercise	γ_{00}	12.158213	1.394473	8.719	<0.001***
Level-1 slope: Intention – Objectively measured vigorous exercise	γ_{10}	2.239080	0.453762	4.934	<0.001***
Main effect					
Traditionalism – Objectively measured vigorous exercise	γ_{01}	0.004195	0.313835	0.013	0.989
Cross-level interaction with conscientiousness					
Traditionalism x Intention – Objectively measured vigorous exercise	γ_{11}	0.148485	0.077591	1.914	0.058
Intercept: Objectively measured vigorous exercise	γ_{00}	12.135600	1.381558	8.784	<0.001***
Level-1 slope: Intention – Objectively measured vigorous	γ_{10}	2.162909	0.447614	4.832	<0.001***

exercise					
Main effect					
Responsibility – Objectively measured vigorous exercise	γ_{01}	0.369787	0.310353	1.192	0.236
Cross-level interaction with conscientiousness					
Responsibility x Intention – Objectively measured vigorous exercise	γ_{11}	0.273464	0.089568	3.053	0.003*

*<0.05**<0.01 ***<0.001Level-1 *n* =79. MRCM=Multilevel random coefficient model; γ=Hierarchical multivariate linear modelling symbol; B=Unstandardized coefficients; *SE*=Standard error; β=Standardized coefficients

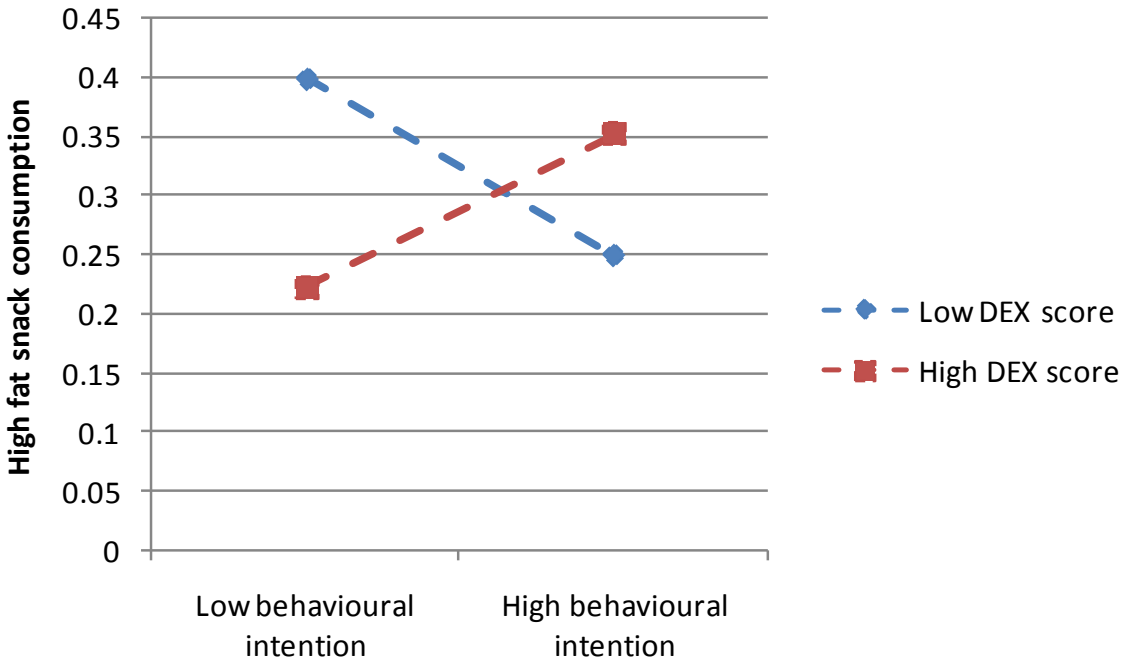

Figure 6.1: The relationship between behavioural intentions and high-fat snack consumption as moderated by the DEX. The association between intention and high-fat snack consumption was negative for individuals with a low DEX score and positive for individuals with a high DEX score.

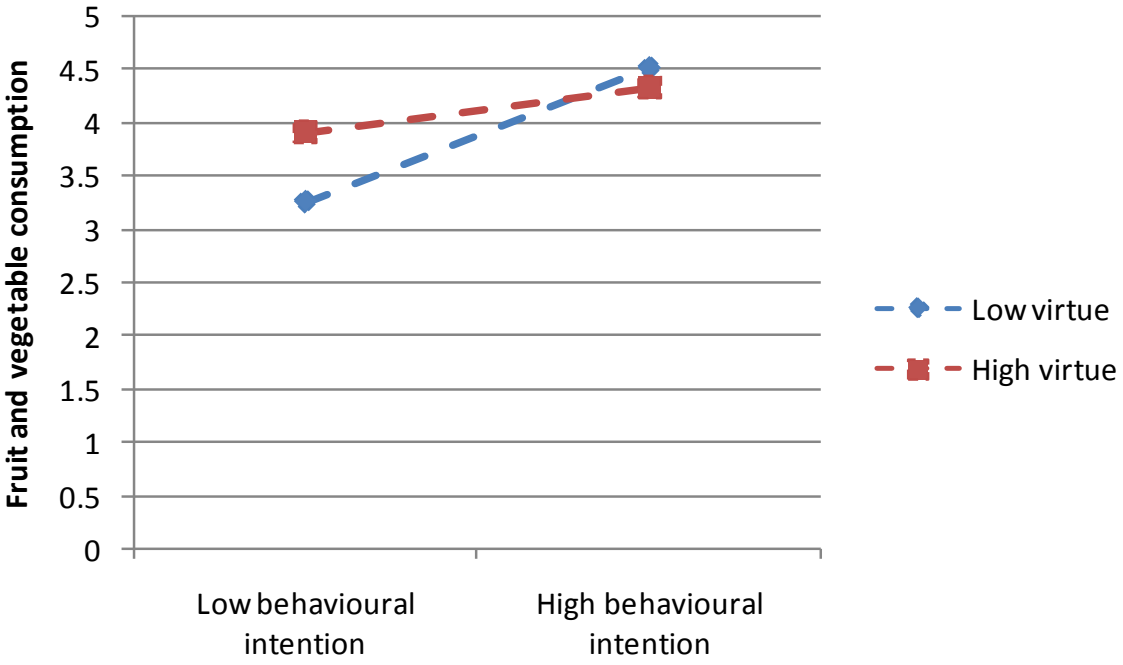

Figure 6.2: The relationship between behavioural intentions and fruit and vegetable consumption as moderated by virtue. The association between intention and fruit and vegetable consumption was positive and strongest for individuals low in virtue compared to individuals high in virtue

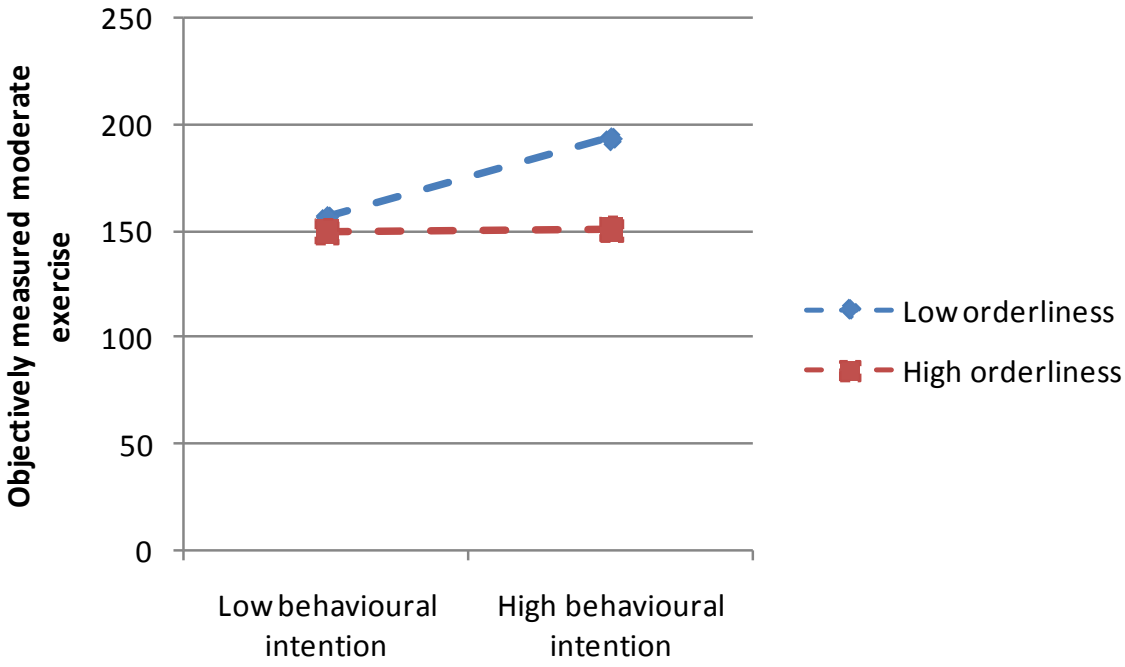

Figure 6.3: The relationship between behavioural intentions and objectively measured moderate exercise as moderated by orderliness. The association between intention and objectively measured moderate exercise was positive and strongest for individuals low in orderliness compared to individuals high in orderliness.

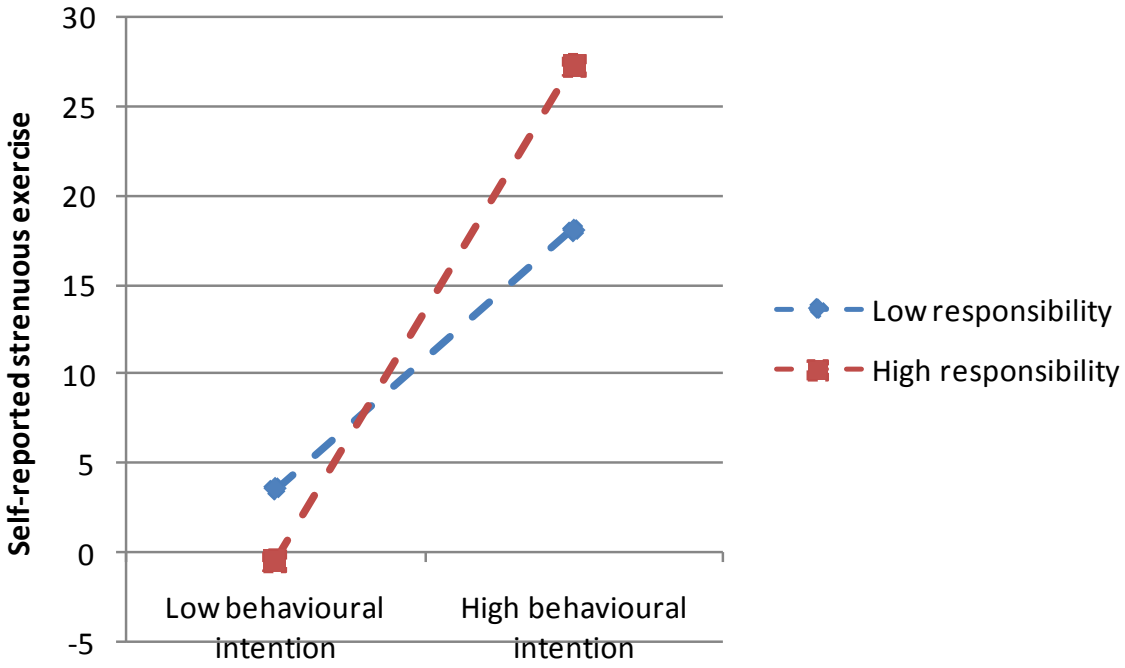

Figure 6.4: The relationship between behavioural intentions and self-reported vigorous exercise as moderated by responsibility. The association between intention and self-reported vigorous exercise was positive and strongest for individuals high in responsibility compared to individuals low in responsibility.

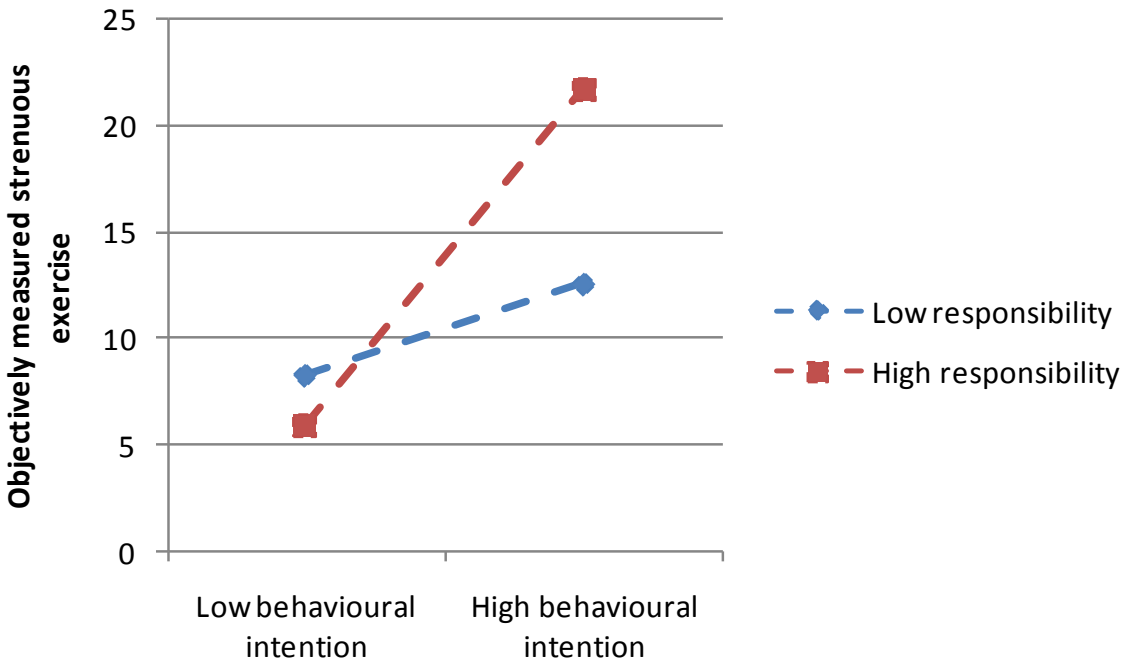

Figure 6.5: The relationship between behavioural intentions and objectively measured strenuous exercise as moderated by responsibility. The association between intention and objectively measured vigorous exercise was positive and strongest for individuals high in responsibility compared to individuals low in responsibility.

Discussion

The present study aimed to replicate the findings of Study 3 with a larger and more diverse sample. It was hypothesised that the current study's findings would replicate the findings of Study 3, such that EC and conscientiousness would only be correlated when a self-report measure of EC was used, and that only planning ability would moderate the intention-behaviour relationship. Three main findings emerged from the current study. First, conscientiousness and EC are significantly related to one another, though this is dependent on the EC measure used. Second, certain types of EC and conscientiousness have direct effects on health behaviour performance. Third, stronger evidence was found that conscientiousness moderated the intention-behaviour relationship compared to EC; each of which will be discussed in turn.

EC and conscientiousness

The current study assessed numerous relationships between not only EC and conscientiousness, but also the inter-relationships within these variables and how these variables were associated with age. Greater sample diversity was an important advance in the current study in an attempt to avoid possible restrictions in variability as a result of using student samples. Thus exploring the correlations between EC, conscientiousness and age served as a first step in assessing these possible differences. Although age was not associated with all EC measures, broadly, it appears that increased age was associated with a slowing of reaction times, but verbal fluency improved with age. Cognitive decline is a normal part of the aging process, thus it is unsurprising to see a decline in EC functioning as age increases (Grigsby, Kaye, Shetterly, Baxter, Morgenstern, & Hamman, 2002). However, the finding that verbal fluency improves with age suggests that not all EC functions decline with age. The possible reasons for a distinct improvement in verbal fluency specifically are twofold. First, for the trail-making task participants must physically draw a line from one answer to the next, thus this particular task requires good motor function as well as good cognitive flexibility, but as with cognition, motor functions decline with age (Seidler, Bernard, Burutolu, Fling, Gordon, Gwin et al., 2010). However, it must be pointed out that none of the participants in the current study suffered from motor-based problems. Second, it is likely that older individuals will have more years of education and experience of different environments, which may be conducive to building a broader vocabulary. In contrast, conscientiousness was not significantly correlated with age in the current study. The stability of conscientiousness is debateable and normally correlated with age. Nevertheless, the correlation is positive, so although not statistically significant it does point to a slight increase in conscientiousness with age (Roberts, Walton, & Viechtbauer, 2006; Srivastava, John, Gosling, & Potter, 2003).

Furthermore, the current study explored the inter-relationships between the different EC measures. Similar to our previous studies, only a small number of the EC measures were significantly related. Specifically, slower reaction times on the trail-making task were correlated with similarly slow reaction time

performance on the Stroop task, which in turn was associated with poor performance on the tower task. Such findings add to the evidence base of weak correlations largely occurring between neurocognitive measures (Vainik et al., 2013), and also highlight the complexity of EC as a construct. Although the trail-making task and Stroop task fit well with the shifting and inhibition domains of Miyake and colleagues (Miyake & Friedman, 2012; Miyake et al., 2000) proposed structure of EC; other measures of EC that tap these domains which were used in the study were not definitively linked, and planning ability was distinctly missing from this structure. This is an important omission considering the recent evidence from our own studies (i.e., Study 3) and other researchers (Allan et al., 2013) highlighting planning ability as a significant determinant of health behaviour.

The major aim of the current study, however, was to establish the nature of the relationship between EC and conscientiousness now sample diversity had been increased. In line with previous studies (Study 2 and 3), a significant relationship was revealed between the self-report EC measure of the DEX and conscientiousness, including all of its underlying six facets. The direction of this relationship was such that poorer EC was associated with lower conscientiousness. Previously, the lack of a relationship between objective measures of EC and conscientiousness has pointed to the independence of these constructs and highlighted potential issues with ecological validity. However, the current study has revealed significant relationships between objective EC measures and conscientiousness. Indeed, with regards to verbal fluency and the Go/No-go task, these were in the expected direction, such that higher EC performance on the verbal fluency task was associated with higher conscientiousness, whereas poor EC performance on the Go/No-go task was associated with lower conscientiousness. Therefore reflecting the conceptual overlap that has been expounded in our previous studies. On the other hand, the trail-making task and the Stroop task produced the opposite finding, such that slower reaction times on these were associated with higher conscientiousness. This is an unexpected finding, but it does point to two important possibilities to consider. First, in our previous work it has been suggested that when individuals are faced with a reaction time task they are

presented with a speed-accuracy dilemma, and although longer reaction times are normally seen as poorer EC performance; perhaps the individual is actually just approaching the task more cautiously, thus sacrificing speed to gain accuracy. As a result, the finding that longer reaction times were associated in some cases with higher conscientiousness seems to add weight to the argument, as highly conscientiousness individuals are characterised by qualities including cautiousness (McCrae & Costa, 1987). Second, it is interesting that the Go/No-go task and Stroop task show opposing relationships with conscientiousness considering both purport to measure response inhibition. Yet again, this highlights the complexity of EC, and begs the question – are these tasks measuring different aspects of response inhibition? Does this suggest a more precise definition of response inhibition is required? Indeed, it has recently been suggested that there are two distinct types of response inhibition: active versus passive (Hofmann et al., 2012), and in empirical research it has been suggested that to effect health behaviour change manipulating overall response inhibition is not as effective as manipulating responses with the targeted behaviour in mind (Houben, Nederkoorn, & Jansen, 2014).

Main effects of EC and conscientiousness

Significant main effects were found primarily for EC, with only one direct relationship emerging between conscientiousness and health behaviour. With regards to EC, higher tower task and verbal fluency scores were associated with less consumption of high-fat snacks and greater self-reported engagement in vigorous exercise. This accords with other literature evidencing better EC is associated with greater performance of positive/approach behaviours and decreased performance of negative/avoid behaviours (Hall, 2012; Hall et al., 2008b). The current findings also further add weight to the findings of Allan et al. (2011) whose study we originally aimed to replicate in Study 3, as they also yielded significant findings in relation to the tower task and verbal fluency task in relation to dietary behaviour. In addition, the current findings further corroborate the importance of planning ability in the performance of health behaviours. This was demonstrated in the previous study (i.e., Study 3), and recently by Allan et al. (2013).

Alternatively, it also emerged that better EC as indicated by the tower task was associated with less engagement in self-reported moderate exercise. A higher level of the traditionalism facet of conscientiousness also provided the same result. These are unexpected findings as we would expect to find the opposite pattern of results, which would be in line with the findings of other researchers and ourselves. However, there are three reasons why these findings could have emerged. First, it is interesting that these findings emerge for the tower task and conscientiousness, as one of the major conceptual overlaps between these variables is planning ability. Therefore, it could be argued although this relationship appears detrimental, that these individuals are actively bypassing engagement in moderate exercise to engage in more vigorous exercise instead. Indeed, the health recommendations advise participating in 30 minutes of *at least* moderate exercise, thus leaves open the option to progress into more strenuous forms of exercise. Second, self-reported levels of moderate exercise were substantially lower than objectively measured moderate exercise, with participants reported an average of 32.07 minutes of moderate exercise, whereas the GENEActiv devices recorded an average of 164.34 minutes of moderate exercise. This shows that participants in the current study underestimated the levels of moderate exercise they were engaging in, thus indicating that individuals to some extent may lack awareness of what constitutes moderate exercise and serves to highlight this as an area for improvement in educating the general population about health. Third, it has been suggested, albeit with working memory rather than planning ability, that EC can be a hindrance to health behaviour performance (Patrick et al., 2008), and other influential variables, for instance, action tendencies can overwhelm EC abilities even EC function is high(Sharbanee, Stritzke, Wiers, Young, Rinck, & MacLeod, 2013). This last point emphasises that health behaviour is influenced by a variety of variables that will work in a complex interplay to impact behaviour, which is why exploring EC and conscientiousness as moderating variables is a valuable endeavour.

Moderation effects of EC and conscientiousness

A number of significant moderation effects were revealed in the current study in relation to diet and exercise. EC function was found to significantly moderate one intention-behaviour relationship, that being that the association between intentions and high-fat snack consumption was negative for participants with a low DEX score, but rather unexpectedly positive and strongest for participants with a high DEX score. The findings for the low DEX score fall in line with the current study's predictions, however, the finding for the high DEX score is unexpected as it suggests that irrespective of how high behavioural intentions are to avoid high-calorie snacks poorer EC is associated with greater snack consumption. However, it must be acknowledged that in the current study behavioural intentions to avoid high-calorie snacks did not significantly predict snack consumption. The self-report measure of the DEX is more commonly used with clinical populations (Wilson et al., 1998), however, there is one other study that has used the DEX to assess EC function with healthy populations (Allan et al., 2011) who also found the DEX to play a similarly significant role between behavioural intentions and snack consumption. The DEX is a useful measure of EC as it provides a general overview of EC functioning and due to its self-report nature allows an insight into the individuals awareness of their EC difficulties. On the other hand, as it provides a general overview of EC, it is not possible to identify the specific EC functions, such as response inhibition, that are potentially having an effect, henceforth why it is also important to incorporate objective measures into studies. Objective measures of EC are useful in that they purport to specifically measure certain aspects of EC, for example the Go/No-go task measures response inhibition, therefore can highlight relationships between health behaviours and specific functions of EC. However, they may lack the ecological validity gained through self-report measures, thus again to balance these issues and achieve the most comprehensive results a combination of measures is recommended.

With regards to fruit and vegetable consumption, it was revealed that the intention-behaviour was strongest for those individuals low in virtue. It would be expected that high virtue would be more conducive to fruit and vegetable consumption, thus this finding appears a little surprising at first, but a further

look at the data provides a reason for this finding. Even with low behavioural intentions, individuals high in virtue already consumed close to the recommended health guidelines (approximately 4 portions of fruit and vegetables) and with high behavioural intentions individuals low and high in virtue were eating a similar amount. The difference is that the trajectory between low and high behavioural intentions and fruit and vegetable consumption is much steeper for individuals low in virtue. This suggests that strong behavioural intentions are more important for those who are lower in a trait to achieve their goal, whereas those individuals high in a trait may be more naturally predisposed to achieve their goals/follow guidelines, which in this case is to eat more fruit and vegetables.

In contrast, only conscientiousness was found to moderate any of the intention-exercise relationships with distinct differences emerging between moderate and vigorous exercise. With regards to moderate exercise it was revealed that the intention-behaviour relationship was stronger for those individuals low in orderliness. Again this seems a surprising finding, but as previously mentioned it is unclear when engagement in moderate exercise progresses into engagement in strenuous exercise. It is possible that those individuals higher in conscientiousness purposely engage in less moderate exercise to engage in more vigorous forms of exercise. Indeed, this is shown by our findings in relation to vigorous exercise. It was revealed in the current study that responsibility moderated the intention-behaviour relationship, with the association stronger for those individuals high in responsibility, with this relationship emerging for both self-report and objective measures of vigorous physical activity. The clear findings linking conscientiousness and exercise are particularly significant as establishing links has been difficult in the past(Bogg & Roberts, 2004), the only exception being responsibility(Arai & Hisamichi, 1998; Hogan, 1989). The importance of this facet being further corroborated with the current study's findings, most significantly for the first time using objective measures of exercise. The use of objective measures within this area of research is still in its infancy, with only one study apart from our research employing such measures (Hall et al., 2008a). The current findings, however,

demonstrate the usefulness of using such objective measures to measure behavioural outcomes, and encourages their use in future research.

Conclusions

The current study aimed to replicate the findings of Study 3, in terms that EC and conscientiousness would only be correlated when a self-report (DEX) measure of EC was used, and planning ability would moderate the intention-behaviour relationship. These findings were partially replicated as the DEX and conscientiousness were significantly related. However, a number of significant correlations between objective EC measures and conscientiousness were also revealed. Furthermore, planning ability had a main effect on health behaviour, but not a moderating effect. Numerous main and moderation effects were revealed between EC, conscientiousness and an array of health behaviours; however these relationships were not always in the expected direction. In addition, significant relationships failed to emerge in relation all EC and conscientiousness measures. The difference in findings can be accounted for by the use of a more diverse sample, and suggests future research should be conducted with a more varied sample in mind.

Chapter 7
General discussion

Aims and objectives

"To date, the study of the relationship between executive functions and self-regulation is in its infancy, and it is possible that executive functions are the outcome, predictor, moderator or mediator of self-regulation" (Meule, Lutz, Vögele, & Kübler, 2014, p. 104).

The above quote highlights the challenge faced by the current research, that although the literature has begun to flourish in the area of EC and health behaviour performance, it is still at an early stage and the nature of ECs impact on health behaviour remains unclear. In parallel, the personality trait of conscientiousness has also received increasing attention as a determinant of health behaviour; a variable that appears to have considerable conceptual overlap with EC. As such, this PhD aimed to explore the relationships between EC, conscientiousness and health behaviour. The main objectives were to:

(1) Undertake a comprehensive review of the literature to establish a current consensus of findings and identify issues warranting address.
(2) Establish the nature of the relationship between EC and conscientiousness.
(3) Assess EC and conscientiousness as direct predictor, mediator and moderator variables on health behaviour.

These objectives were to be attained by not only replicating the findings of other researchers (e.g., Allan et al. 2011), but by building upon this work by applying various innovations to this area. For instance, in terms of measurement and statistical analysis of intentions, attitudes and health behaviour. Broadly, the current PhD research found the relationship between EC and conscientiousness is dependent on the EC measure used; and both EC and conscientiousness serve as direct predictors and moderators, but not mediators of health behaviour. These findings and the subsequent issues that have arisen during this research will now be discussed in turn.

Importance of intentions

Chronic diseases related to negative health behaviors are on the rise (Cervone, Shadel, Smith, & Fiori, 2006). As a result, promoting health behaviour change is an important concern for researchers and governments, particularly in the Western world. This is evident from the increasing prevalence of health behaviour change campaigns launched in recent years targeting both diet and exercise. Regardless of these efforts, the majority of individuals, even with the best intentions do not act on these intentions; a phenomenon known as the intention-behavior gap (Sniehotta, Scholz, & Schwarzer, 2005). For instance, only 30-40% of intentions to have a healthy lifestyle are successfully translated into behaviour (Sheeran, 2002). As a result, a key aim of the PhD was to establish whether EC and conscientiousness moderated the intention-behaviour relationship and so help bridge the intention-behaviour gap. Nevertheless, the underlying principle that behavioural intentions are vital for behavioural performance has formed a strong backbone to the current research, and indeed the findings with regards to intentions confirms their importance for performance. Behavioural intentions to perform one health behaviour were associated with similar intentions to perform other health behaviours, and with actual behavioural performance. Furthermore, behavioural intentions significantly mediated the relationship between EC, conscientiousness and health behaviours. Simply, EC and conscientiousness do influence health behaviour, but principally through generating a strong motivation to perform the behaviour. Indeed a recent study by Tahaney, Kantner, and Palfai (2014) has also highlighted the importance of motivational constructs in relation to EC, as they found the trail-making task was predictive of alcohol consumption only in those individuals with high restraint goals.

The current research revealed a number of significant moderations of the intention–behaviour relationship by EC and conscientiousness across an array of positive and negative health behaviours. Broadly, these relationships indicated that those individuals with higher EC and higher conscientiousness were more successful in translating their behavioural intentions into actual performance. On the other hand, the current research also found that EC and conscientiousness appear to influence behavioural intentions themselves, with

higher EC and higher conscientiousness being associated with higher behavioural intentions. Furthermore, a number of direct (unmediated) relationships emerged between EC, conscientiousness and various health behaviours, predominantly in the direction that higher EC and higher conscientiousness were associated with greater performance of positive health behaviours and decreased performance of negative health behaviours. Together the direct, mediated and moderating relationships, although there are notable exceptions that will be discussed below, corroborate the research of others linking EC and conscientiousness to snacking (Allan et al., 2011; Booth-Kewley & Vickers, 1994), fruit and vegetable consumption (Allom & Mullan, 2012; de Bruijn, 2013), and exercise (Hall et al., 2012; Rhodes & Dickau, 2013). In addition, the current research provided the first evidence of the relationship between these variables and dental behaviours (i.e., brushing and flossing), and expanded the research on sleep, which to date had only focused on sleep hygiene behaviours (Kor & Mullan, 2011; Todd & Mullan, 2013, 2014).

Overall, these findings have important implications to the future development of health behaviour change interventions. In particular, they suggest that the motivational and volitional aspects of self-regulation should be targeted to bring about more effective health behaviour change (Gollwitzer, 1990), and certainly this approach appears to be gaining momentum (Milne et al., 2002). However, with regards to both EC and conscientiousness there are issues that need careful consideration, for example, construct complexity, before implementing an intervention manipulating these variables.

Complexity of EC

The challenging nature of EC has been recognised by a number of researchers (Baddeley, 1998; Levine, Stuss, & Milberg, 1995) with Baddeley (1998) referring to EC functions as "…probably the most complex aspects of human cognition" (p.525).This complexity arises due to issues regarding construct definition, structure and measurement. However, Miyake and colleagues (Miyake & Friedman, 2012; Miyake et al., 2000) have undertaken extensive work to address the challenge of the structure of EC. They state EC encompasses three broad domains: "*updating* (constant monitoring and rapid

addition/deletion of working memory contents), *shifting* (switching flexibly between tasks or mental sets), and *inhibition* (deliberate overriding of dominant or pre-potent responses)" (Miyake & Friedman, 2012 p.9). Overall, this is a good representation of EC that covers most of the key functions subsumed under the umbrella term of EC, including response inhibition, working memory and cognitive flexibility. However, a key omission from the current structure definition is planning. Planning is a key part of EC (Stoet & Snyder, 2009) that is recognised as an important determinant of health behaviour (Allan et al., 2013). Thus there is room for further development to encompass a four rather than three domain structure. Furthermore, through their work on the structure of EC, Miyake and colleagues have identified that despite attempts to simplify the construct of EC it is not entirely unitary, and displays considerable diversity (Miyake & Friedman, 2012; Miyake et al., 2000). Indeed, the research reported in this thesis has revealed that not all EC measures are correlated with each other, which corroborates the findings that neurocognitive measures generally show poor correlations (Salthouse, Atkinson, & Berish, 2003; Vainik et al., 2013). This highlights the next major challenge with EC: measurement.

The struggle to provide a universal definition of EC and connections to other cognitive capacities (Suchy, 2009) coupled with the lack of a "gold standard" task (Royall et al., 2002) leaves the measurement of EC fraught with difficulties. Nevertheless, there are many reliable EC measures, particularly for response inhibition (Congdon, Mumford, Cohen, Galvan, Canli, & Poldrack, 2012; Friedman, Miyake, Young, DeFries, Corley, & Hewitt, 2008), which is one of the most commonly investigated EC functions, especially recently with regards to health behaviour (Allan et al., 2011; Hall et al., 2008b). Some of the most widely used response inhibition tasks include the Stroop, Go/No-go and Stop signal tasks. However, it is worth highlighting the current research also attested to the reliability of a less commonly used task, this being a task-switching task. Despite the high reliability of these tasks, a common problem is that they are easy to perform leading in many cases to ceiling effects (Meule, Lutz, Krawietz, Stuetzer, Voegele, & Kuebler, 2014; Patrick et al., 2008; Veling & Aarts, 2011). As a result, variability could be reduced, therefore making it harder to make distinctions between individuals. Although, Study 2 showed that

individuals are adept at learning a task very quickly, albeit for a task-switching task rather than a response inhibition task. For after an initially steep learning curve individuals performance plateaued with individuals demonstrating equally good performance a week later. Thus learning capacity must be taken into consideration when administering EC tasks.

Another problem faced when assessing EC, is that it is often unclear which EC function is being tapped (Friedman et al., 2006). This was an issue faced in the current research. In Study 4 two correlations emerged between objective measures of EC (the Stroop task, and the Go/no-go task) and conscientiousness. Yet, the correlations were in opposing directions. This was an unexpected finding considering both tasks are purported to tap response inhibition, and consequently raises questions about the definition of response inhibition. This question has recently received attention with it being argued there are two types of response inhibition: active versus passive (Hofmann et al., 2012). In terms of goal-achievement, active inhibition is characterized by a 'avoid that behaviour' mind set, whereas passive inhibition is characterized by an 'approach that behaviour' mind set, and has links to working memory capacity. Furthermore, empirically it has been shown that targeting behaviour-specific response inhibition is more effective for behaviour change than targeting overall response inhibition (Houben et al., 2014). Subsequently, there is a need to address the definition and measurement of the underlying functions of EC, particularly response inhibition. This will be especially important to consider when developing health behaviour change interventions to ensure the most effective means of manipulation are being appropriately utilised. The suitability of measures becomes even more vital when you add the further complication that EC is not necessarily always advantageous for health behaviour.

EC, specifically high EC can be both advantageous and disadvantageous to health behaviour. For instance, in Study 1 it was found that individuals with low switch costs, thus better task-switching performance were less likely to translate their dental behaviour intentions into actual behavioural performance. Indeed, task-switching ability is one EC function that has been recently highlighted as potentially facilitative and detrimental to behavioural

performance (Hofmann et al., 2012). High task-switching ability (i.e., low switch costs) can be facilitative to behavioural performance through 'means-shifting', such that highly able individuals are better equipped to switch from suboptimal means of reaching their goals to alternative routes that are more optimal to goal pursuit. Conversely, high task-switching ability can be detrimental to behavioural performance through 'goal-shifting', such that highly able individuals are better able to balance incongruous goals, whereby these individuals are better able to cope with temporarily abandoning their goal to pursue short term gratification. For example, dieters who occasionally allow themselves to indulge in a tempting treat (Fishbach, Zhang, & Koo, 2009).

Similarly, working memory capacity has been also highlighted as having facilitative and detrimental effects on health behaviour performance. Again, it has been suggested that better working memory can be detrimental to health behaviour performance; as such individuals are better able to downplay the negative consequences of performing a risky health behaviour (Patrick et al., 2008). Alternatively, Allan and Allan (2013) have shown that better memory can mean enhanced memory for tempting stimuli, for example, the location of high-calorie food. On the other hand, others have suggested that irrespective of whether an individual has good working memory, if the action tendency to perform the behaviour is strong enough, working memory capacity may be insufficient to overcome the temptation (Sharbanee et al., 2013).

Together this could suggest that in some instances higher EC may lead to self-regulation failure, and this may be as a result of such individuals being better able to justify their behaviour. De Witt Huberts, Evers, and De Ridder (2014) have recently proposed that individuals justify their self-regulation failures by making excuses for performing a behaviour that is incongruent with their intentions in advance of performing the behaviour to allow them to fulfil the short-term gratification without experiencing unacceptable conflict. Therefore it could be argued that individuals with better abilities to switch between goals and downplay the negative consequences of behaviour are more susceptible to this maladaptive justification process. However, empirical research is needed to provide evidence for this argument. This especially needs to be taken into consideration when De Witt Huberts et al. (2014) cite negative emotional events

as a common justification for discrepant behaviour; and indeed, in Study 1 the relationship between EC, conscientiousness, stress and health behaviours was mixed. Though broadly, the findings suggested individuals with higher EC and higher conscientiousness were better able to manage the impact of daily hassles on subsequent health behaviour. The scope for research into the emotional influences on EC and in turn health behaviour is growing, with of late, the proposal of 'hot' versus 'cool' EC. In contrast to the emotionally-neutral, abstract situations where 'cool' EC is elicited, 'hot' EC is elicited in emotionally-salient, motivationally significant situations, thus there is a difference in the importance attached to the problem with much more care given in the latter situation (Zelazo & Carlson, 2012). Therefore, it is clear to see how this distinction between 'hot' and 'cool' EC may be important to future health behaviour research.

Clearly, there are multiple variables interacting with each other, hence it is unsurprising that the nature of the relationships between EC and health behaviour is complicated. This relationship is further complicated by evidence demonstrating that the relationship between EC and health behaviour is reciprocal, with negative health behaviours such as alcohol consumption (Peeters, Monshouwer, Janssen, Wiers, & Vollebergh, 2014) being associated with decrements in EC functioning and positive health behaviours, such as exercise being associated with enhancing EC functioning (Joseph et al., 2011). This by no means suggests the nature of the relationship between conscientiousness and health behaviour is less complicated. Conscientiousness is comprised of six underlying facets: *orderliness* (the propensity to be prepared), *industriousness* (to be hardworking and determined),*self-control* (response inhibition), *responsibility* (to be dependable), *virtue* (acting with decorum) and *traditionalism* (to be rule-abiding and uphold societal conventions)(Roberts et al., 2014), and the facets differ in their consistency as predictors of health behaviour (Bogg & Roberts, 2004). Furthermore, not all health behaviours are strongly associated with conscientiousness, with exercise being pointed out as particularly problematic (Bogg & Roberts, 2004). Although, responsibility has been shown to have strong links with exercise participation (Arai & Hisamichi, 1998; Hogan, 1989), and this was corroborated by the strong

moderation effect of responsibility on the intention-behaviour relationship for self-reported and objectively measured strenuous exercise in Study 4. Overall, both EC and conscientiousness are complex constructs; yet, this is not the only similarity they share, which is why a major component of the current PhD was to explore the relationship between EC and conscientiousness.

The relationship between EC and conscientiousness

EC and conscientiousness conceptually (Vainik et al., 2013) and empirically (Hall et al., 2013) overlap. Yet, to date, correlations between EC and conscientiousness have been inconsistent (Edmonds et al., 2009; Matthews & Zeidner, 2012), with it generally being concluded that there is no meaningful relationship between the two variables (Vainik et al., 2013). Initially, findings (i.e., Study 1 and 3) appeared to support this general conclusion, although Study 1 did yield some marginally significant results. The only clear exception was the consistent finding that the DEX measure of EC and conscientiousness were significantly related, such that poorer EC was associated with lower conscientiousness. Consequently, this pointed to EC and conscientiousness broadly being independent constructs, with the idea of individuals having differing levels of EC and conscientiousness being explored in Study 2. However, the finding that the strongest relationship between EC and conscientiousness emerged when a self-report measure of EC was used highlighted possible issues with ecological validity. Conscientiousness encompasses many characteristics that are important for the successful performance of executive tasks in daily life (Edmonds et al., 2009), but objective measures of EC tend to be abstract in nature, and thus are unrelated to real life. In contrast, the DEX was specifically designed to assess executive dysfunction in real life. This indicates that the ecological validity of measures needs to be taken into careful consideration in order to gain the most accurate reflection of individual abilities. Self-report measures do have their weaknesses, however. For instance, individuals may not accurately report their executive difficulties (Burgess et al., 1998; Wilson et al., 1998). Moreover, it is important to acknowledge that self-report measures, which both the DEX and

conscientiousness questionnaires were, are more likely to be correlated than objective neurocognitive measures (Vainik et al., 2013).

A surprising finding of the current research was that the Tower task (a measure of planning) was not correlated with conscientiousness. Planning is a key characteristic of both EC and conscientiousness, and one of the main points of conceptual overlap between the two variables. However, this finding may be the result of measurement specificity rather than a lack of a relationship. Tower tasks assess an individual's ability to plan, whereas conscientiousness assesses whether an individual actively engages in planning; therefore two different aspects of planning are being targeted by these measures. This was further emphasised by the findings of Study 2, which showed conscientiousness to have no significant effect on task performance, but it is more likely that conscientiousness was associated with task engagement (Matthews & Zeidner, 2012), though this was not investigated in the current research. Subsequently, this highlights the need to explore the relationship between EC performance and conscientiousness with a broad range of measures in mind.

Studies 2 and 4, however, did reveal objective measures of EC to significantly correlate with conscientiousness. The go/no-go task showed a similar relationship with EC as the DEX, such that poor EC performance was associated with lower conscientiousness. In addition, better EC performance as indicated by the verbal fluency task was associated with higher conscientiousness. Conversely, the current research also revealed that longer reaction times on the task-switching task, trail-making task and the Stroop task, indicating poorer EC, was associated with higher conscientiousness. These latter tasks present the individual with the dilemma of responding quickly and accurately - the speed-accuracy trade-off. Thus successful task completion will likely be at the expense of either accuracy or speed, which one is sacrificed, will depend on the individual. It could be argued that highly conscientiousness individuals with their achievement-orientation and cautious and disciplined attributes (McCrae & Costa, 1987) actively adopt a more cautious approach to the task, thus purposely take longer to respond to ensure accuracy, and indeed, this is what the results seem to suggest. Moreover, although such an approach

may be disadvantageous to the performance of these specific tasks, it may be advantageous when faced with executive challenges in daily life, such as health behaviour performance. For example, in Study 1 it was found that high switch costs were associated with greater performance of positive health behaviours, including teeth brushing.

Finally, it must be acknowledged that the majority of the significant relationships between objective measures of EC and conscientiousness were found in Study 4. The reason for this could be due to, as previously alluded to, greater sample diversity in this study. In Study 4 a wider distribution of participants were recruited, which is important to increase variability in both EC and conscientiousness measures. Moreover, the increased age range takes into account the developmental trajectories of EC and conscientiousness. EC develops over time, reaching full functionality in the early-to-mid twenties (Eshel et al., 2007; Lyon & Krasnegor, 1996; Romine & Reynolds, 2005; Rubia et al., 2006). Therefore, in studies using student samples it is likely that their EC is still maturing, which may have been an issue in the previous studies. Similarly, although personality is thought to be stable, and remains relatively unchanged, there is evidence demonstrating that conscientiousness does increase over the lifespan (Roberts et al., 2006; Srivastava et al., 2003). In addition, the facets of conscientiousness appear to mature at different rates. Industriousness, self-control and reliability (i.e., responsibility) develop between early adulthood through to middle age, whereas self-control, reliability and conventionality (i.e., traditionalism) develop in late adulthood (Jackson, Bogg, Walton, Wood, Harms, Lodi-Smith et al., 2009). Genetic and environmental explanations are given for these differing rates of maturation (Jackson et al., 2009). All of which may contribute to health behaviour. As a result, the developmental trajectories of both EC and conscientiousness will need to be considered in future research, especially in the cases of those researchers that wish to target EC and/or conscientiousness for intervention, as the age of the target population could dictate the EC function or conscientiousness facet manipulated.

Objective versus self-report measures

The current PhD utilised numerous objective and self-report measures of EC and health behaviour. A combination of these measures were used to compensate for the relative strengths and weaknesses exhibited by both types of measurement and thus gain as accurate a measure of EC and health behaviour as possible. With regards to EC, traditionally objective neuropsychological measures have been most commonly used to assess EC function with a plethora of objective tests tapping specific EC function being available. In contrast, there are few self-report measures of EC (e.g., DEX, BRIEF). However, self-report measures focus on the everyday real life executive difficulties individuals' experience, which is in stark contrast to the abstract nature of neuropsychological tests. This consequently raises the question of ecological validity, and suggests that objective measures of EC may be lacking. However, self-report measures are open to inaccurate reporting and it may even be the case that EC function influences how individuals report. The issue of inaccurate reporting and providing particularly socially desirable answers is a potential problem when assessing health behaviour, but objectively measuring health behaviour is not always possible, especially over long durations. Attempts are being made to rectify this problem, and indeed, the current PhD used an objective measure of health behaviour that can be used over long periods of time (i.e., GENEActiv devices to measure physical activity). At present, however, a combination of measures is optimal in order to obtain the most accurate results.

Limitations

There were three main limitations to the current research. First, the meta-analysis was not conducted at the same time as the systematic review. The systematic review was undertaken before conducting any empirical research whereas the meta-analysis was conducted subsequent to the empirical studies. As a result, the information gleaned from the meta-analysis could not be used to conduct power calculations and thus inform the design of the studies in the current PhD. This means the statistical power of the findings may be limited, though sample sizes were recruited that were similar in size to previous

research conducted in this area (e.g., Allan et al., 2011). In addition, the systematic review did not include an assessment of the quality of the included papers. Therefore, it is unclear whether all the papers included in the review are of the same methodological quality. However, due the limited literature base it was decided to include any relevant papers irrespective of their quality in order to gain a comprehensive understanding of the research conducted to date. Nevertheless, any future reviews should consider an examination of study quality.

Second, the studies within this PhD were largely correlational in nature, with notable exceptions, for example the MANOVA analysis in Study 2. The issue with correlational data is that although it can demonstrate a relationship exists between variables, it cannot establish causality. However, as has been recently argued by Mullan, Todd, Chatzisarantis, and Hagger (2014), despite this drawback correlational research is an invaluable starting point in terms of uncovering what variables are related and how they are related, for without a sufficient preliminary evidence base health behaviour change interventions may be ineffective or lack knowledge of why an intervention strategy is effective. As such, the current research serves a useful role in ascertaining the relationships that exist between EC, conscientiousness and various health behaviours in healthy populations that can henceforth be used to inform future health behaviour change interventions.

Third, the initial studies comprised largely of student samples. This decision was made to be in line with present research in this area (e.g., Allan et al, 2011) and to serve as a model to assess whether such relationships existed within a subset of the population before applying it to the wider population. Nevertheless, using such a sample may have its complications. For example, there were no significant effects of conscientiousness on health behaviour in Study 3, which may have been due to a ceiling effect as a result of the academic achievement level of students (Paunonen & Ashton, 2001; Webb et al., 2007). However, this issue was addressed in Study 4, and allowed our research to provide findings on both specific (i.e., student) and wider samples.

Future recommendations

There is a growing literature demonstrating links between health behaviour and conscientiousness (de Bruijn, 2013; Hall et al., 2013; Mottus, McNeill, Jia, Craig, Starr, & Deary, 2013; Reeves, Halsey, McMeel, & Huber, 2013; Rhodes & Dickau, 2013) and EC (Allan et al., 2011; Hall et al., 2013; Hall et al., 2008b; Mullan et al., 2011). As a result of the emerging literature base there seems to be sufficient evidence to begin to consider developing health behaviour change interventions that manipulate EC and conscientiousness in an attempt to exact health behaviour change. Indeed, other researchers in this field have begun to develop and implement intervention strategies in relation to palatable food, alcohol consumption and exercise with promising results. The intervention methods they have developed mainly target EC, and provide three intervention options.

Option 1: Stop signal task

The stop signal task is a version of the Go/No-go task that involves pairing visual stimuli with either a 'go' or 'no-go' response. A 'no-go' response tends to be signalled by the presentation of a tone. In the studies utilising such a methodology to attempt health behaviour change, pictorial stimuli of palatable food (Guerrieri et al., 2012; Guerrieri et al., 2009; Houben, 2011; Houben & Jansen, 2011; Veling et al., 2011; Veling et al., 2013b) or alcohol (Houben et al., 2011a; Jones & Field, 2013; Jones et al., 2011) has been paired with the 'no-go' response to encourage inhibitive actions towards behaviours that can be detrimental to health through their association with serious illnesses; and indeed have yielded promising results with less palatable food and alcohol being consumed after this type of manipulation. However, there are two limitations to using the stop signal task as an intervention. First, the studies using this task have only demonstrated immediate effects, therefore there is to date no evidence that these effects are maintained beyond a laboratory setting. Second, Chiu and Aron (2014) have highlighted that as of yet, it is unclear whether the effect of this training on health behaviour is the result of motor inhibition or cognitive reappraisal, which could have significant implications on achieving the best behavioural outcome. To date, there is evidence to support both the

argument for a change in motor inhibition (Chiu, Aron, & Verbruggen, 2012) and de-valuation of palatable stimuli (Veling, Aarts, & Stroebe, 2013a).

Option 2: working memory

Another intervention option involves training working memory. Although working memory training has been successfully used to improve working memory in children with working memory impairments (Holmes et al., 2009) and ADHD (Holmes et al., 2010), only two studies have currently used working memory training as a means of tackling health behaviour change (Houben et al., 2011b; Verbeken, Braet, Goossens, & van der Oord, 2013). In the Houben et al. (2011b) study alcohol consumption was targeted by training working memory over twenty-five days using three tasks tapping working memory: a letter span task, a backward digit span task and a visuospatial task, with tasks increasing in difficulty with improvement. The training did improve working memory and participants consumed less alcohol following the intervention with the effect remaining a month later, but the effect was moderated by implicit alcohol preferences with those with high alcohol preferences particularly benefitting. In the Verbeken et al. (2013) study, a similar twenty-five sessions of EC training was undertaken, training both working memory and response inhibition. The training also incorporated game elements to assess weight loss maintenance in obese children compared to standard care. Similar to Houben et al. (2011b) the children receiving training showed improvements in working memory and meta-cognition, as well as maintaining weight loss up to eight weeks later. However, these effects diminished twelve weeks later. Thus, despite these promising results there is still a lack of evidence supporting the efficacy of working memory training as an effective health behaviour change technique that can be maintained. Indeed, to counteract the short-lived effects of these types of interventions it has been proposed that “maintenance” training may be needed, but such training is time-consuming and requires sustained concentration (Verbeken et al., 2013).

Option 3: Implementation intentions

The final option is to use implementation intentions as a means of intervening. Implementation intentions are ‘if–then’ plans that help individuals to

form a link in their memory between a situation and a response (behavioural/cognitive) (i.e. 'If I [encounter situation X], I will [perform behaviour Y]'). This improves people's chances of achieving a goal by specifying *when*, *where* and *how* an individual will perform a behaviour. By imparting control to an external stimulus, simply encountering that stimulus should trigger automatic performance of the planned behaviour (Gollwitzer, 1999; Gollwitzer & Sheeran, 2006). As such, implementation intentions work by aiding the transition between motivation/intention into volitional action (Gollwitzer, 1993).

There are three strong reasons why using an implementation intention-based intervention strategy is justifiable. First, implementation intentions cover planning as the technique requires the individual to make a precise plan of what they want to achieve and how they are going to achieve it, which is a key aspect of both EC and conscientiousness. As our research is interested in the effects of both variables on health behaviour and indeed has demonstrated links between these variables and various health behaviours, it seems prudent to use an intervention that is appropriate for both variables. Second, there is a strong evidence base for the utility of implementation intentions as an intervention. For example, in a meta-analysis of 94 studies implementation intentions were found to have a medium-to-large effect size of d=.65 on health behaviour change (Gollwitzer & Sheeran, 2006). Furthermore, there are specific examples of implementation intentions being used to change health behaviour in relation to EC (Hall et al., 2012) and conscientiousness (Webb et al., 2007). Third, implementation intentions are a practical intervention. Practical in terms of being a brief, simple intervention that can be delivered anywhere in a variety of formats and can be applied easily to any behaviour; therefore, both reducing any unnecessary burden being placed on participants and giving them greater control over their intentions and actions.

In summary, the literature linking EC, conscientiousness and health behaviour is building to such a degree that there is arguably sufficient evidence to develop health behaviour change interventions manipulating these variables, and there is literature where EC/planning interventions have already been developed and tested. This research has yielded three viable intervention

options: stop-signal task manipulation, working memory training and implementation intentions. Despite, all three having their advantages and disadvantages, an implementation intention-based intervention seems the most feasible option due to its conceptual links with EC and conscientiousness, the well-established evidence for the efficacy of implementation intentions, and the ease of delivery.

Conclusions

This PhD explored the relationships between EC, conscientiousness and health behaviour. Through a comprehensive systematic/meta-analytic review and a series of four studies it has been revealed that EC and conscientiousness are related constructs dependent on the type of EC measure used; the most consistent relationship emerging in relation to the DEX measure of EC. Also, EC and conscientiousness are related to health behaviour and serve as significant moderators of the intention-behaviour and stress-behaviour relationships; however this relationship does not emerge for all EC and conscientiousness measures and in some instances the relationship is in contradiction to expectations. Thus, the evidence shows that EC and conscientiousness have a significant impact on health behaviour performance, but these relationships are more complex than indicated by previous research. This is due to issues such as construct complexity, sample diversity, measurement and the influence of other factors. Nonetheless, the findings indicate that EC and conscientiousness are viable targets for health behaviours, and indeed, research is already beginning to progress in that direction.

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Appendix

Appendix 3.1

Information Sheet

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Professor Daryl O'Connor (d.b.o'connor@leeds.ac.uk)
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This sheet will hopefully provide you with enough information about the study to allow you to make an informed decision about participation. However, if you have any questions or would like to discuss anything with me please let me know.

You will complete two computer-based tasks and a short questionnaire asking about you in general. This will take place in the psychology laboratories and should only take 30 minutes.

Afterwards, you will be provided with a diary to complete each day for 14 days, which is available online. This diary will be recording health behaviours including snack, caffeine and alcohol intake, smoking, exercise and sleep. This will take approximately 5-10 minutes to complete and must be filled in each day. You will receive a reminder email every day at 5pm and will have between 5pm – 2am to complete your diary entry each day.

Following the 14-day diary, you will be asked to return to the psychology laboratories to complete the same two tasks you completed in the first session and a questionnaire. This will take approximately 30 minutes.

Your information will remain completely anonymous throughout the study, however if you wish to withdraw your information you are free to do so at any time, and will be fully debriefed at the end of the study.

Appendix 3.2

Consent Form

Date	Time	Name in block letters	Signature

Appendix 3.3

Participant Question Sheet

Unique Identification code (ID): Your unique code consists of the day of your birthday, the first letter of your mother's first name, and the last two numbers of your phone number (e.g. if you were born on the 14th, your mother's name was Mary, and your phone number ended in 67, your code would be: 14M67)

Participant n^{o}		ID		Age		Gender		Email address	

Comments:

Session 1:

Session2:

Participant n^{o}		ID		Age		Gender		Email address	

Comments:

Session 1:

Session2:

Appendix 3.4

60-item conscientiousness questionnaire

You will now read 60 statements. For each, say how accurate it is (1(Very inaccurate), 2 (Inaccurate), 3 (Neither accurate nor inaccurate), 4 (Accurate), 5 (Very accurate).

1. Being neat is not exactly my strength.
2. Organization is a key component of most things I do.
3. I need a neat environment in order to work well.
4. I become annoyed when things around me are disorganized.
5. For me, being organized is unimportant.
6. Half of the time I do not put things in their proper place.
7. Most of the time my room is in complete disarray.
8. Every item in my room and on my desk has its own designated place.
9. I frequently forget to put things back in their proper place.
10. I hate when people are sloppy.
11. If I could get away with it, I would not pay taxes.
12. I would lie without hesitation if it serves my purpose.
13. I could be insincere and dishonest if situation required me to do so.
14. If I find money laying around, I'll keep it to myself.
15. If a cashier forgot to charge me for an item I would tell him/her.
16. I would rather get a bad grade than copy someone else's homework and turn it in as my own.
17. It bothers me when people cheat on their taxes.
18. If I accidentally scratched a parked car, I would try to find the owner to pay for the repairs.
19. I firmly believe that under no circumstances it is okay to lie.
20. The people who know me best would say that I am honest.
21. I have the highest respect for authorities and assist them whenever I can.

22. People respect authority more than they should.

23. Even if I knew how to get around the rules without breaking them, I would not do it.

24. I believe that people should be allowed to take drugs, as long as it doesn't affect others.

25. I support long-established rules and traditions.

26. People who resist authority should be severely punished.

27. When I was in school, I used to break rules quite regularly.

28. In my opinion, all laws should be strictly enforced.

29. In my opinion, censorship slows down the progress.

30. When working with others I am the one who makes sure that rules are observed.

31. I often rush into action without thinking about potential consequences.

32. I rarely jump into something without first thinking about it.

33. I am known to make quick, hot-headed decisions.

34. I do not take unnecessary risks.

35. I am easily talked into doing silly things.

36. My friends say I am unpredictable.

37. I get into trouble because I act on impulses rather than on thoughts.

38. I am careful with what I say to others.

39. I dislike being around impulsive people.

40. Even under time pressure, I would rather take my time to think about my answer than to say the first thing that comes to mind.

41. I carry out my obligations to the best of my ability.

42. I often feel responsible for making sure that all group project assignments are completed.

43. I go out of my way to keep my promises.

44. Sometimes it is too much of a bother to do exactly what is promised.

45. I would gladly spend some of my leisure time trying to improve my community.

46. If I am running late to an appointment, I may decide not to go at all.

47. I am usually not the most responsible group member, but I will not shirk my duties either.

48. If I am running late, I try to call ahead to notify those who are waiting for me.

49. When I make mistakes I often blame others.

50. I have a reputation for being late for almost every meeting or event.

51. I have high standards and work toward them.

52. I go above and beyond what is required.

53. I do not work as hard as the majority of people around me.

54. I invest little effort into my work.

55. I demand the highest quality in everything I do.

56. I try to be the best at anything I do.

57. I make every effort to do more than what is expected of me.

58. I do what is required, but rarely anything more.

59. Setting goals and achieving them is not very important to me.

60. Getting average grades is enough for me.

Appendix 3.5
14-day diary (Study 1)

Please fill in the following details

What is your unique code?

Your unique code consists of the day of your birthday, the first letter of your mother's first name, and the last two numbers of your phone number

(E.g. if you were born on the 14th, your mother's name was Mary, and your phone number ended in 67, your code would be: 14M67)

Hassles/stressors

Please provide a brief description of each hassle/stressor you have experienced today, the time when you experienced it, and rate its intensity from 1 (Not at all Intense) to 5 (Very intense):

Hassles/stressors are events, thoughts or situations which, when they occur, produce negative feelings such as annoyance, irritation, worry or frustration and/or make you aware that your goals and plans will be more difficult to achieve (e.g., making a presentation at work, losing your keys, argument with partner, exams etc.)

Dental behaviours

To what extent do you intend to brush your teeth at least twice tomorrow?

1| 2 | 3 | 4 | 5 | 6 | 7

Not at all | Very much

To what extent do you intend to floss your teeth at least once tomorrow?

1| 2 | 3 | 4 | 5 | 6 | 7

Not at all | Very much

Sleep

What time do you intend to go to bed tonight?

What time do you intend to wake up tomorrow?

To what extent do you intend to have at least 8 hours sleep tonight?

1| 2 | 3 | 4 | 5 | 6 | 7

Not at all | Very much

Breakfast

To what extent do you intend to eat a healthy breakfast (low fat and high fibre) tomorrow? (E.g. porridge, muesli, fruit, yoghurt)

1| 2 | 3 | 4 | 5 | 6 | 7

Not at all | Very much

Snacks

If you eat snacks, to what extent do you intend to eat only healthy snacks tomorrow? (E.g. apple, banana, dried fruit)

1| 2 | 3 | 4 | 5 | 6 | 7

Not at all | Very much

Fruit and vegetables

Definition: This is a guideline to indicate portion size of fruit and vegetables, to help you fill in the diary.

You will be asked how many portions of fruit and vegetables you have eaten each day, please include fresh, canned, frozen, or dried fruit and vegetables.

Fruit: Examples of portion of fruit are half a large grapefruit, a slice of melon, two satsumas, three dried apricots, one tablespoon of raisins, or a glass of 100% juice (fruit or vegetable juice)

Please count juice as only one portion a day, no matter how much you drink.

Vegetables: Examples of portions of vegetables are three heaped tablespoons of cooked carrots (peas, sweet corn, or one cereal bowl of mixed salad).

Please count beans and other pulses (such as kidney beans) as only one portion a day no matter howmuch you eat.Please do not count potatoes.

To what extent do you intend to eat at least 5 portions of fruit and vegetables tomorrow?

1| 2 | 3 | 4 | 5 | 6 | 7

Not at all | Very much

Caffeine drinks

*drinks containing caffeine include tea and coffee, colas e.g. Pepsi or coke, energy drinks e.g. lucozade or red bull)

To what extent do you intend to avoid caffeine drinks tomorrow?

1| 2 | 3 | 4 | 5 | 6 | 7

Not at all | Very much

Alcoholic drinks

To what extent do you intend to avoid alcoholic drinks tomorrow?

1| 2 | 3 | 4 | 5 | 6 | 7

Not at all | Very much

Smoking

To what extent do you intend to avoid smoking tomorrow?

1| 2 | 3 | 4 | 5 | 6 | 7

Not at all | Very much

Exercise

To what extent do you intend to engage in at least 30 minutes of mild exercise (minimal effort) tomorrow? (e.g., yoga, archery, fishing from river bank, bowling, golf, easy walking)

1| 2 | 3 | 4 | 5 | 6 | 7

Not at all | Very much

To what extent do you intend to engage in at least 30 minutes of moderate exercise (not exhausting) tomorrow? (e.g., fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming)

1| 2 | 3 | 4 | 5 | 6 | 7

Not at all | Very much

To what extent do you intend to engage in at least 30 minutes of strenuous exercise (heart beats rapidly) tomorrow? (e.g., running, hockey, football, squash, basketball, judo, roller skating, vigorous swimming, long distance bicycling)

1| 2 | 3 | 4 | 5 | 6 | 7

Not at all | Very much

Please answer the following questions.

Dental behaviours

How many times did you brush your teeth today?

How many times did you floss your teeth today?

Sleep

What time did you go to bed last night?

What time did you wake up this morning?

How many hours sleep did you get last night?

Breakfast

To what extent do you feel you ate a healthy breakfast this morning? (E.g. porridge, muesli, fruit, yoghurt)

1 | 2 | 3 | 4 | 5 | 6 | 7

Not at all | Very much

Snacks

Please list each food that you have eaten between meals today, and the time at which you ate them (e.g. fruit, chocolate, crisps, nuts)

If you eat snacks, to what extent do you feel that you have eaten only healthy snacks today? (E.g. apple, banana, dried fruit)

1 | 2 | 3 | 4 | 5 | 6 | 7

Not at all | Very much

Fruit and vegetables

How many portions of fruit did you eat today?

How many portions of vegetables did you eat today?

Caffeine drinks

How many drinks containing caffeine* have you had today?

*drinks containing caffeine include tea and coffee, colas e.g. Pepsi or coke, energy drinks e.g. lucozadeor red bull)

Alcoholic drinks

Have you drunk any alcohol today?

How many pints of beer/lager/cider:

How many measures of spirits? (1 = single shot, 2 = double shot)

How many glasses of wine (standard glass = 175ml)?

Smoking

Do you smoke?

How many cigarettes did you smoke today?

Exercise

How many minutes of mild exercise (minimal effort) have you engaged in today? (e.g., yoga, archery, fishing from river bank, bowling, golf, easy walking)

How many minutes of moderate exercise (not exhausting) have you engaged in today? (e.g., fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming)

How many minutes of strenuous exercise (heart beats rapidly) have you engaged in today? (e.g., running, hockey, football, squash, basketball, judo, roller skating, vigorous swimming, long distance bicycling)

Thank you for completing your diary entry.

Appendix 3.6
50-item set of IPIP Big-Five Factor Markers

How Accurately Can You Describe Yourself? Describe yourself as you generally are now, not as you wish to be in the future. Describe yourself as you honestly see yourself, in relation to other people you know of the same sex as you are, and roughly your same age. So that you can describe yourself in an honest manner, your responses will be kept in absolute confidence. Indicate for each statement whether it is 1. Very Inaccurate, 2.Moderately Inaccurate, 3. Neither Accurate Nor Inaccurate, 4. Moderately Accurate, or 5.Very Accurate as a description of you.

1. Am the life of the party.

2. Feel little concern for others.

3. Am always prepared.

4. Get stressed out easily.

5. Have a rich vocabulary.

6.Don't talk a lot.

7. Am interested in people.

8. Leave my belongings around.

9. Am relaxed most of the time.

10. Have difficulty understanding abstract ideas.

11. Feel comfortable around people.

12. Insult people.
13. Pay attention to details.
14. Worry about things.
15. Have a vivid imagination.
16. Keep in the background.
17. Sympathize with others' feelings.
18. Make a mess of things.
19. Seldom feel blue.
20. Am not interested in abstract ideas.
21. Start conversations.
22. Am not interested in other people's problems.
23. Get chores done right away.
24. Am easily disturbed.
25. Have excellent ideas.
26. Have little to say.
27. Have a soft heart.
28. Often forget to put things back in their proper place.
29. Get upset easily.
30. Do not have a good imagination.
31. Talk to a lot of different people at parties.
32. Am not really interested in others.
33. Like order.
34. Change my mood a lot.
35. Am quick to understand things.
36. Don't like to draw attention to myself.
37. Take time out for others.
38. Shirk my duties.
39. Have frequent mood swings.

40. Use difficult words.

41. Don't mind being the centre of attention.

42. Feel others' emotions.

43. Follow a schedule.

44. Get irritated easily.

45. Spend time reflecting on things.

46. Am quiet around strangers.

47. Make people feel at ease.

48. Am exacting in my work.

49. Often feel blue.

50. Am full of ideas.

Appendix 4.1
Dysexecutive Questionnaire (DEX)

You will now read 20 statements. For each, say how it describes you (0 (Never), 1 (Rarely), 2 (Occasionally), 3 (Regularly), 4 (Often)).

1. I have problems in understanding what other people mean unless they keep things simple and straightforward.

2. I act without thinking, doing the first thing that comes to mind.

3. I sometimes talk about events or details that never actually happened but I believe did happen.

4. I have difficulty thinking ahead or planning for the future.

5. I sometimes get overexcited about things and can be a bit over the top at these times.

6. I get events mixed up with each other and get confused about the correct order of events.

7. I have difficulty realizing the extent of my problems and am unrealistic about the future.

8. I seem lethargic and unenthusiastic about things.

9. I do or say embarrassing things when in company of others.

10. I really want to do something one minute but could not care less about it the next.

11. I have difficulty showing emotion.

12. I lose my temper at the slightest thing.

13. I seem unconcerned about how I should behave in certain situations.

14. I find it hard to stop repeating saying or doing things once started.

15. I tend to be very restless, and I cannot sit still for any length of time.

16. I find it difficult to stop doing something even if I know I should not.

17. I will say one thing but will do something different.

18. I find it difficult to keep my mind on something and am easily distracted.

19. I have trouble making decisions or deciding what I want to do.

20. I am unaware of, or unconcerned about, how others feel about my behaviour.

Appendix 4.2
Barrett Impulsiveness Scale (BIS-11)

People differ in the ways they act and think in different situations. This is a test to measure some of the ways in which you act and think. Read each statement and please indicate the extent to which you do these things. Do not spend too much time on any statement. Answer quickly and honestly. The scale goes from 1) rarely never, 2) occasionally, 3) Often, to 4) Almost always/always.

1. I plan tasks carefully
2. I do things without thinking
3. I make-up my mind quickly
4. I am happy-go-lucky
5. I don't 'pay attention
6. I have 'racing' thoughts
7. I plan trips well ahead of time
8. I am self controlled
9. I concentrate easily
10. I save regularly
11. I 'squirm' at plays or lectures
12. I am a careful thinker
13. I plan for job security
14. I say things without thinking
15. I like to think about complex problems
16. I change jobs
17. I act on impulse

18. I get easily bored when solving thought problems

19. I act on the spur of the moment

20. I am a steady thinker

21. I change residences

22. I buy things on impulse

23. I can only think about one thing at a time

24. I change hobbies

25. I spend or charge more than I earn

26. I often have extraneous thoughts when thinking

27. I am more interested in the present than the future

28. I am restless at the theatre or lectures

29. I like puzzles

30. I am future oriented

Appendix 5.1
Behavioural intention measure (Study 3)

You will now read a number of statements about daily behaviour. For each, say what your intentions for each daily behaviour are (rating from 1 (Not at all) –5 (Very much)).

1. To what extent do you intend to eat at least 5 portions of fruit and vegetables each day?

2. To what extent do you intend to avoid high-calorie snacks (High-calorie snacks include: crisps, savoury snacks (such as cheddars and twiglets), chocolate, sweets, cakes, biscuits, pies and pastries) each day?

3. To what extent do you intend to study each day?

4. To what extent do you intend to avoid buying non-essential shopping items each day?

5. To what extent do you intend to avoid watching T.V each day?

6. To what extent do you intend to engage in a minimum of 30 minutes of mild-to-vigorous exercise each day?

Appendix 5.2
7-Day diary (Study 3)

Daily Diary

Please fill in the following details

What is your participant number?

How many portions of fruit did you eat today?

How many portions of vegetables did you eat today?

How many high-calorie snacks have you eaten today? *(High-calorie snacks include: crisps, savoury snacks (such as cheddars and twiglets), chocolate, sweets, cakes, biscuits, pies and pastries).

How many hours of study did you do today?

How many non-essential shopping items did you buy today?

How many hours of T.V. did you watch today?

How many minutes of mild exercise (e.g., walking) did you engage in today?

How many minutes of moderate exercise (e.g., carrying light loads, bicycling at a regular pace, or doubles tennis) did you engage in today?

How many minutes of vigorous exercise (e.g., heavy lifting, digging, aerobics, or fast bicycling) did you engage in today?

Appendix 6.1
14-day diary (Study 4)

Daily Diary

Please fill in the following details

What is your unique code?

Your unique code consists of the day of your birthday, the first letter of your mother's first name, and the last two numbers of your phone number (e.g. if you were born on the 14th, your mother's name was Mary, and your phone number ended in 67, your code would be: 14M67)

Please answer the following questions.

Snacks

To what extent do you intend to avoid high-calorie snacks (High-calorie snacks include: crisps, savoury snacks (such as cheddars and twiglets), chocolate, sweets, cakes, biscuits, pies and pastries) tomorrow?

Not at all 1| 2 | 3 | 4 | 5 | 6 | 7 Very much

Fruit and vegetables

Definition: This is a guideline to indicate portion size of fruit and vegetables, to help you fill in the diary.

You will be asked how many portions of fruit and vegetables you have eaten each day, please include fresh, canned, frozen, or dried fruit and vegetables.

Fruit: Examples of portions of fruit are half a large grapefruit, a slice of melon, two satsumas, three dried apricots, one tablespoon of raisins, or a glass of 100% juice (fruit or vegetable juice)

Please count juice as only one portion a day, no matter how much you drink.

Vegetables: Examples of portions of vegetables are three heaped tablespoons of cooked carrots (peas, sweet corn, or one cereal bowl of mixed salad).

Please count beans and other pulses (such as kidney beans) as only one portion a day no matter how much you eat.

Please do not count potatoes.

To what extent do you intend to eat at least 5 portions of fruit and vegetables tomorrow?

Not at all 1| 2 | 3 | 4 | 5 | 6 | 7 Very much

Exercise

To what extent do you intend to engage in at least 30 minutes of moderate exercise (not exhausting) tomorrow? (e.g., fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, carrying light loads, bicycling at a regular pace, doubles tennis)

Not at all 1| 2 | 3 | 4 | 5 | 6 | 7 Very much

To what extent do you intend to engage in at least 30 minutes of strenuous exercise (heart beats rapidly) tomorrow? (e.g., running, hockey, football, squash, basketball, judo, roller skating, vigorous swimming, long distance bicycling, heavy lifting, digging, aerobics, fast bicycling)

Not at all 1| 2 | 3 | 4 | 5 | 6 | 7 Very much

Snacks

For me to avoid eating unhealthy snacks tomorrow would be...

Harmful -3 | -2 | -1 | 0 | 1 | 2 | 3 Beneficial

Pleasant -3 | -2 | -1 | 0 | 1 | 2 | 3 Unpleasant

Fruit and vegetables

For me to eat at least 5 portions of fruit and vegetables tomorrow would be...

Harmful -3 | -2 | -1 | 0 | 1 | 2 | 3 Beneficial

Pleasant -3 | -2 | -1 | 0 | 1 | 2 | 3 Unpleasant

Exercise

For me to engage in at least 30 minutes of moderate exercise tomorrow would be...

Harmful -3 | -2 | -1 | 0 | 1 | 2 | 3 Beneficial

Pleasant -3 | -2 | -1 | 0 | 1 | 2 | 3 Unpleasant

For me to engage in at least 30 minutes of strenuous exercise tomorrow would be...

Harmful -3 | -2 | -1 | 0 | 1 | 2 | 3 Beneficial

Pleasant -3 | -2 | -1 | 0 | 1 | 2 | 3 Unpleasant

Please answer the following questions.

Snacks

How many high-calorie snacks have you eaten today? *(High-calorie snacks include: crisps, savoury snacks (such as cheddars and twiglets), chocolate, sweets, cakes, biscuits, pies and pastries).

Please list each food that you have eaten between meals today, and the time at which you ate them (e.g. fruit, chocolate, crisps, nuts)

1. Time:
2. Time:
3. Time:
4. Time:
5. Time:
6. Time:
7. Time:
8. Time:

Fruit and vegetables

How many portions of fruit did you eat today?

How many portions of vegetables did you eat today?

Exercise

How many minutes of moderate exercise (not exhausting) did you engage in today? (e.g., fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, carrying light loads, bicycling at a regular pace, doubles tennis)

How many minutes of strenuous exercise (heart beats rapidly) did you engage in today? (e.g., running, hockey, football, squash, basketball, judo, roller skating, vigorous swimming, long distance bicycling, heavy lifting, digging, aerobics, fast bicycling)

Thank you for completing your diary entry.