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Goal orientation is a key determinant of healthy dietary behaviour change in European adults receiving personalised *vs.* non-personalised nutrition advice

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Although personalised nutrition is more effective than generic approaches to dietary health promotion, effect sizes tend to be small. Behaviour change theory implies the importance of goal setting to successful health intervention. This secondary analysis of the Food4Me personalised nutrition intervention study (N = 1480) sought to understand the role of goal orientation and habit strength in determining dietary change. Latent class analysis (LCA) identified three groups distinguished by degree of goal orientation (low; moderate; high) at baseline. Data were analysed using multigroup binary channel coding (BCH) models with auxiliary variables. Differences in healthy eating indices (HEI) between treatment (randomised to personalised nutrition advice) and control (generic dietary advice) groups at 6-months post-intervention were compared within latent classes distinguished by goal orientation. A second model included habit strength, measured by the self-report habit index (S-RHI), as an outcome and compared treatment and control groups within classes defined on goal orientation. The results indicated that HEI increased significantly in response to treatment (compared with controls) post-intervention only among those participants with high baseline goal orientation (P < 0.0001). S-RHI at baseline was associated with higher HEI at 6-months within all three classes defined on goal orientation but did not alter the initial result indicating higher HEI only in the high goal-oriented group. These findings indicate the importance of goal orientation to success of personalised nutrition and reinforce previous research linking habit strength to dietary behaviour change. Personalised interventions should include goal setting at the outset, monitor progress towards goals and encourage strong healthy eating habits.

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1. Introduction

Personalised, digitally delivered intervention is considered important to the successful promotion of population dietary health now and in the future.[1] Systematic reviews[2,3] and narrative literature reviews[4,5] of Randomised Control Trials (RTCs) have concluded that participants in intervention groups who receive personalised nutrition advice are more likely to increase consumption of fruit and vegetables[2,6] and to be at lower risk of being overweight or of developing type 2 diabetes.[4] Personalised nutrition may also be more effective than generic advice (which is the same for all participants) in bringing about long-term dietary changes.[7] Despite evidence to suggest that genetic testing for personalised nutrition elicits healthy dietary behaviour change,[5] genotype-based dietary advice appears to be no more effective than phenotype and/or lifestyle-based advice in changing dietary behaviours.[8,9] This implies that it is the *personalised* nature of advice rather than the *type* of advice offered that influences dietary responses. Effect sizes, however, tend to be small.[10] To explain these results, and to improve the efficacy of personalised advice, recent research has focussed upon understanding how psycho-

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logical factors determine behaviour change in personalised nutrition interventions.[3,6,11–13]

Individual characteristics associated with behaviour change may be important to the success of personalised healthy eating interventions,[14–16] yet few intervention studies have considered individual differences in psychology and responses to personalised nutrition interventions.[10,13] Psychological characteristics may influence how different types of advice impact upon behavioural responses to personalised nutrition.[12,17] Psychological factors that motivate behaviour change such as goal orientation may also influence the success of personalised nutrition interventions.[18,19] Goal setting is considered important to adapting personalised nutrition to individual psychological needs and in determining responses to different types of personalised advice.[19,20] There is growing interest in adaptive personalised nutrition advice systems (APNASs) that incorporate goal preferences into personalised nutrition advice, monitoring, feedback and service delivery.[10,21,22] Goal setting as part of nutrition counselling has been associated with healthy dietary behaviour change.[23,24]

Habit is another influential psychological motivating factor associated with food choice and dietary behaviour. Habits are cognitive structures that preserve responses to recurring situations[25] and responses to dietary health intervention have been linked to habit strength.[14] Habit strength (related to eating behaviour) has been associated with greater improvement in healthy eating indices (HEI),[18] more frequent intake of fruit and vegetables[26] and less consumption of unhealthy snack foods.[27–29] Habit is thought to mediate intention to make dietary changes as well as actual change in behaviour.[26,30] Although goals and habit both explain behaviour and may be related, it has been argued that they represent different underlying processes and mechanisms.[25] Ideally habits should align with the goals driving behaviour so that, once established, habits can keep goals on track.[31] The formation of strong habit may be crucial where a behaviour serves an important goal.

The Food4Me intervention trial established that personalised advice was more effective than generic advice in producing healthy dietary change but did not establish why individualised advice was better than generic. Previous research[16] which considered the potential impact of psychological factors in explaining the Food4Me results found that although neither self-efficacy nor health locus of control had any effect upon HEI, habit strength was stronger in the treatment (personalised) group than the control (generic advice) group at six months post intervention. Another factor not considered in the Food4Me intervention study's primary analysis was the impact of individual dietary goals upon behaviour[32] and could explain the small effect sizes observed. This study will therefore seek to establish how goal orientation at baseline determined change in overall healthiness of the diet, measured as the healthy eating index (HEI), among participants in the Food4Me study in response to generic *versus* personalised nutrition advice. Given the previous finding that habit strength determined HEI in those who received personalised advice, habit strength has been considered as part of a second model, along with goal orientation, as a potential co-determinant of progress toward individual dietary goals. Given current theory[25] we hypothesised that goals and habit strength will both explain behaviour, but independently of each other. This analysis will consider if dietary related goals and habit strength at baseline determine change in HEI in response to either generic dietary advice (controls) or personalised nutrition advice (treatment) derived from information on individual lifestyle, phenotypic and/or genetic factors. Our research question is, given individual goal orientation (the degree to which dietary goals are considered important), which type of nutrition advice produces the greatest improvement in overall diet? Based on previous research on goal setting and dietary behaviour change, it is predicted that clusters of consumers defined on their goal orientations will differ in HEI in response to personalised *versus* generic nutrition advice and that goal orientation and/or habit strength will determine individual responses to personalised dietary intervention.

2. Method

2.1. Ethical statement

Secondary analysis was conducted using anonymised data collected previously as part of the Food4Me four-arm, web-based, randomised controlled trial (RCT) (NCT01530139) conducted across seven European countries.[32] The protocol for this secondary analysis was pre-registered on the Open Science Framework https://doi.org/10.17605/OSF.IO/KRH4P. The original trial, which was conducted according to the guidelines laid down in the declaration of Helsinki, compared the effects of different levels of personalised nutrition upon eating behaviour. Ethical approval was granted by the research ethics committee of each recruiting centre (University College Dublin; Maastricht University; University of Navarra; Harokopio University; University of Reading; National Food and Nutrition Institute; Technische Universität München). For a detailed account of the recruitment, sampling and procedure and the original CONSORT document, please see Celis-Morales and colleagues (2015).[32]

2.2. Sampling

Volunteers aged 18+ years were recruited to the 6-month online nutrition intervention study. Exclusion criteria were being pregnant or lactating; following a prescribed diet; having a dietary-related metabolic condition; or having no or limited internet access. Volunteers completed a screening questionnaire which enquired on biological sex which has been referred to throughout using the terms 'male/s' and 'female/s'. Following screening,[33] eligible volunteers were stratified by biological sex (at birth), age and country (UK, Greece, Spain, Poland, Ireland, Germany and Netherlands) so that the resultant sample (N = 1607) comprised slightly more females (61%) than males, with a spread in age range and nationality.[32,34]

2.3. Procedure

All participants were required to provide written informed consent before being randomly allocated to one of four treatment conditions using an urn randomisation scheme. In randomising individuals to condition, it was assumed that individual characteristics would be evenly distributed across conditions. Treatment conditions were personalised on the type of advice issued and based on: (i) current diet assessed on healthy eating guidelines and anthropometry (n = 414); (ii) current diet and anthropometry plus phenotype (blood glucose, total serum cholesterol, carotenes and n-3 index) (n = 404); (iii) current diet and anthropometry plus phenotype plus genotype (specific variants of the following genes: *MTHFR*, *FTO*, *TCF7L2*, *APOE ε4* and *FADS1*) (n = 402). The control group (n = 387) received non-personalised healthy eating advice based upon European recommendations to reduce fat and salt intake and encouraging consumption of fish, fruit and vegetables. The trial was single-blinded so that participants were unaware of the treatment group to which they had been allocated.

2.4. Measures

At baseline, participants were requested to provide demographic details and to complete a questionnaire *via* an email link. Questionnaire content included psychological measures of behaviour change the selection of which was informed by prior qualitative research.[19,35]

2.4.1. Goal orientation. Goals were assessed using seven items which asked what motivated participants to volunteer to take part in the personalised nutrition intervention study: "prevent illness"; "improve sport performance"; "improve wellbeing"; "improve their health"; "improve their family's health"; or, "to know what foods were best for them". Responses were dichotomous (yes/no) with positive responses assigned 1 and negative responses 0.

2.4.2. Habit strength. Habit strength was assessed using four items previously employed by Honkanen and colleagues[36] and taken from the Self-Report Habit Index (S-RHI).[37] Answers were on a 5-point Likert scale ranging from 1 = 'completely disagree' to 5 = 'completely agree', in response to the following statements: "Eating healthily is something I do frequently"; "I eat healthily without having to consciously think about it"; "I feel weird if I don't eat healthily"; "Eating healthily is something I do without having to think about it". Each item was scored and summed on four dimensions: frequency of behaviour; awareness; lack of control; and mental efficiency. Reliability was satisfactory Cronbach's α = 0.73.

2.4.3. Healthy eating index (HEI). Dietary quality was assessed using a 157-item food frequency questionnaire (FFQ) developed and validated for the study[38–40] completed on-line to assess dietary intakes at baseline and 6-months post-intervention. The healthy eating index (HEI) updated (2010) version[41] was computed from FFQ responses as reported previously[9] and used as a measure of overall healthiness of habitual diet. The HEI-2010 comprises 12 food groups, 9 of which assess adequacy of the diet, including (1) total fruit; (2) whole fruit; (3) total vegetables; (4) greens and beans; (5) whole grains; (6) dairy; (7) total protein foods; (8) seafood and plant proteins; and (9) fatty acids. The remaining 3 items assessed refined grains, sodium, and empty calories (*i.e.*, energy from solid fats, alcohol, and added sugars), which were reverse scored. Scores on the 12 components were summed to yield a total score ranging from 0–100 so that higher HEI scores reflected better diet quality. The HEI (2010) has been shown to have good validity.[41]

2.5. Data analysis

Given evidence that it is the personalised nature of advice rather than the type of information used to personalise content that determines response,[7,9,18] the treatment (personalised) groups were combined and compared with the control group (generic advice) in the subsequent analysis.

2.5.1. Goal orientation: latent class analysis (LCA). LCA was undertaken on dichotomous (yes/no) data relating to goals that were collected at baseline and prior to randomisation (N = 1607). Taking the diagonal probability value of 0.8 for class membership, it was assumed that there was sufficient distinction between the groups. The three latent class model provided a good description for these data as shown by the model fit statistics. The VUONG-LO-MENDELL-RUBIN ADJUSTED LRT TEST was significant for 3 classes = 113.012; P < 0.001 but not for 4 classes = 26.969; P = 0.3041). Three groupings were established using LCA which showed good model strength. The indicator means were computed and estimates on a probability scale plotted graphically to determine the pattern of scores between the classes. The LCA clearly distinguished between three latent classes of individuals. Descriptive labels reflecting the pattern of scores on the goal items between groups were then agreed by the authors (BS-K; MA; BPB) and assigned to the classes. The three-class solution indicated three clear latent classes of individuals who were highly likely (high goal orientation), moderately likely (moderate goal orientation) or less likely (low goal orientation) to have selected each of the goals (Fig. 1). Individuals in the high goal orientation group were those who selected more personal and health goals from the available list of options in comparison to those who fell into the low goal orientation group. All three classes rated 'knowing what foods are best for me' highest among the goals. A large proportion of those in the high goal orientation class also selected 'prevent illness', 'improve my health' and 'improve my wellbeing'. None of those in the low orientation class (class 1) selected 'improve my health' and only a very few selected 'improve my family's health' or 'improve my wellbeing' (see SI file 1).

Goal orientation was inferred from latent class membership and used as the main independent variable in this analysis. The three latent classes distinguished by their goal orientation then served as independent variables in subsequent analyses to determine differences in healthy eating indices (HEI) and habit strength (S-RHI) following intervention, both between latent classes (defined on goal orientation) and between treat-

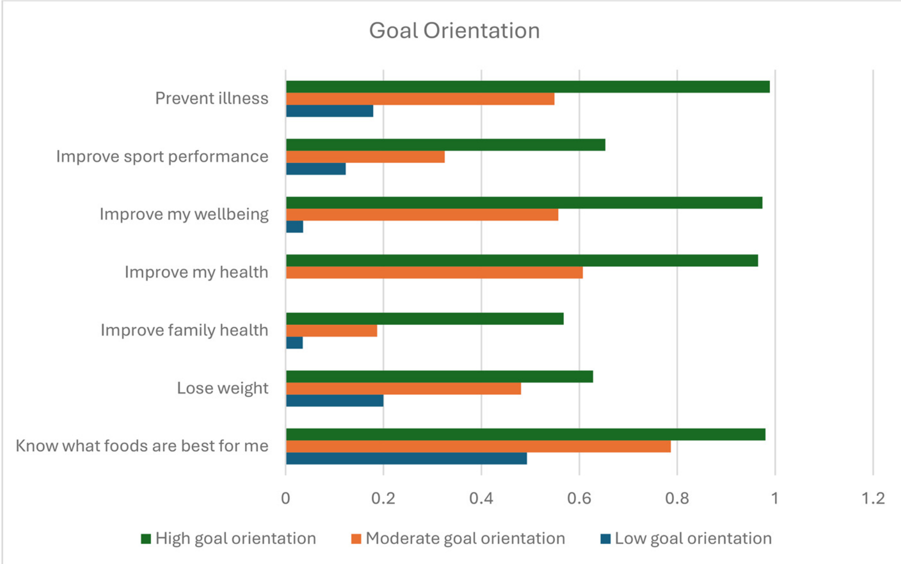

Fig. 1 Latent class membership on goals selected at baseline (goal orientation) (N = 1607).

ment *versus* control groups within the classes. HEI and S-RHI scores were continuous variables taken as the outcomes in the analyses. Treatment and control conditions were then compared within and between clusters (defined on motivations/goals) taking HEI and S-RHI at 6 months as outcomes and compared between clusters taking $P < 0.05$ significance level. Data were analysed using Mplus.[42]

2.5.2. Goal orientation, habit strength and healthy eating indices. To establish relationships between the latent classes and the distal outcome measure of HEI, a multigroup binary channel BCH coding strategy with auxiliary variables was implemented using Mplus version 8.11.[42,43] The procedure was undertaken in two steps to estimate a distal outcome model[44] of HEI. In the first stage, estimates were obtained for the LCA solution and auxiliary variables saved. BCH latent class weights were included in the revised dataset. Data use was maximised by adopting a full information maximum likelihood strategy. Missing data (non-completers) were treated using listwise deletion. An intention-to-treat approach was adopted.

2.5.3. Model 1. Goal orientation (latent class) and healthy eating indices (HEI). Multigroup regression analyses (distal outcome models) were undertaken to determine the degree to which goal orientation (low/moderate/high) was associated with HEI scores between the treatment and control groups within the latent classes post intervention. The outcome was HEI at 6 months post-intervention. This was conducted in the context of a 3-class multi-group model. The parameters related to HEI at baseline and at 6-months were constrained to be equal across latent classes and this provided a parsimonious description of these data. HEI at 6-months were regressed onto their baseline values. The regressions with effects from the baseline were employed as statistical controls, before undertaking an examination of the interventions. HEI scores for the treatment *versus* control conditions were entered into the model as an interaction. A BCH strategy[42] was then employed to determine associations between the three latent classes (high, moderate and low goal orientation) and the HEI outcome and any interaction between conditions (treatment/control) within classes.

2.5.4. Model 2. Goal orientation (latent classes), healthy eating indices (HEI) and self-reported habit strength (S-RHI). A secondary hypothesis was tested to determine if nutritional habit strength provided an explanation for any association between goal orientation and healthy eating indices (HEI) within the goal orientated latent classes in the context of the intervention. An indirect 'effect' was introduced as a separate (mediator) variable from baseline to six-months post intervention. Multigroup regression analyses (distal outcome models) were then undertaken for each latent class to determine the degree to which goal orientation (low/moderate/high) was associated with HEI and self-reported habit (S-RHI) in response to the intervention, whilst randomised to a treatment or control group. The outcomes were HEI and S-RHI at 6 months post intervention. Missing data (non-completers) were treated using listwise deletion. Relationships between HEI at baseline and HEI at 6-months and between S-RHI at baseline and S-RHI at six-months, were constrained to be equal across latent classes and this provided a parsimonious description of these data. An indirect effect was introduced from the baseline score on S-RHI to healthy eating indices at 6-months post intervention. In the next step HEI and S-RHS at 6-months were regressed onto their baseline values. An indirect effect was introduced from the baseline HEI on S-RHS at 6-months (Fig. 2). Direct effects were then introduced from baseline HEI and S-RHI to these measures at 6 months. To optimise the relationships, a BCH strategy[42] was employed to examine the effect of the three latent classes (goal orientation) on the healthy eating (HEI) and habit (S-RHI) outcomes.

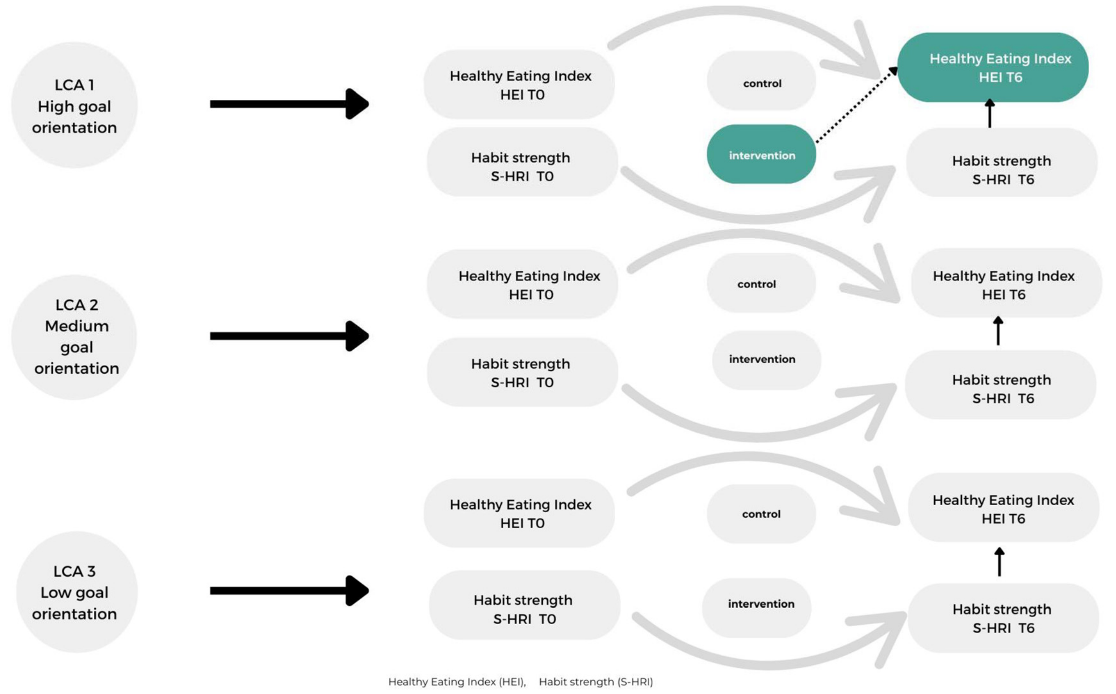

Fig. 2 Association between each of the three latent classes defined on goal orientation (high/moderate/low) depicted as three layers with habit strength (S-RHI), healthy eating indices (HEI) and treatment *versus* control condition at baseline *versus* six-months post-intervention (N = 1476). The figure illustrates that HEI in response to the intervention increased in the treatment (personalised) arm of the high goal-oriented group. The figure also shows that HEI at baseline was associated with HEI at 6 months post-intervention, that Habit strength (S-RHI) at baseline was associated with S-RHI at 6 months and that S-RHI at 6 months was associated with HEI at 6 months (for output see SI file 2). Abbreviations: LCA = latent class analysis; CONvsINT = control *vs.* intervention; Habit0 (habit strength at baselines); Habit6 (habit strength at 6-months); HEISCOT0 = healthy eating index at baseline; HEISCOT6 = healthy eating index at 6 months.

3. Results

3.1. Composition of latent classes

The characteristics of participants in each of the three latent classes at baseline (N = 1480) are shown in Table 1.

3.2. Model 1. Goal orientation (latent class) and healthy eating index (HEI)

3.2.1. Latent class 1 (high goal orientation). HEI at baseline was positively associated with HEI at 6 months (Est: 0.588; SE: 0.024; P < 0.001). There was an interaction between latent class and dietary (HEI) response within LC 1 (high goal orientation) among the treatment group within the high goal-oriented class. This one modification, which was the key test for the implicit potential role of goal orientation, indicated a relationship between the intervention condition and higher HEI only in those with a high goal orientation. The intervention group within the high goal orientation class showed a significantly greater increase in HEI at 6-months post-intervention compared with controls (Est: 4.588; SE: 1.315; P < 0.001) (Fig. 2).

3.2.2. Latent class 2 (moderate goal orientation). HEI scores at baseline were positively associated with HEI scores at 6-months post-intervention in latent class in LC 2 – moderate goal orientation (Est: 0.589; SE: 0.024; P < 0.001). There was no difference in HEI between the control and intervention group within LC 2 – moderate goal orientation at 6-months post-intervention (Est: 0.199; SE: 0.783; P = 0.799).

3.2.3. Latent class 3 (low goal orientation). HEI scores at baseline were positively associated with HEI scores at

Table 1 Characteristics of the latent classes at baseline (N = 1480)

	LC1, high goal orientated			LC2, moderate goal orientated			LC3, low goal orientated		
	N	Mean	SD	*N*	Mean	SD	*N*	Mean	SD
HEI	439	48.33	10.27	796	49.23	9.78	245	50.59	9.45
S-RHI	476	3.19	0.79	865	3.32	0.756	266	3.44	0.76
Age years	476	40.01	12.03	865	39.17	13.13	266	40.18	14.45
Female	293	—	—	514	—	—	147	—	—

HEI, healthy eating index; S-RHI, self-reported habit index LC, latent class.

6-months post-intervention in latent class in LC 3 – low goal orientation (Est: 0.589; SE: 0.024; $P < 0.001$). The experimental intervention (CONVSINT) was not statistically significant and there was no difference in HEI between the control and intervention group within LC 3 – low goal orientation at 6-months post-intervention (Est: −0.206; SE: 1.516; $P = 0.892$).

3.3. Model 2. Goal orientation (latent class), healthy eating index (HEI) and habit strength (S-RHI)

Having established the effectiveness of the intervention in the presence of higher goal orientation, a secondary hypothesis was tested to determine if nutritional habit strength contributed independently and/or additionally to change within the goal-oriented latent classes and between treatment *versus* controls within classes.

A higher score on the HEI was observed at six months post-intervention among the high goal orientation group within the intervention (treatment) condition. This interaction within the relationship between the HEI and the treatment/control group, only showed statistically when the subpopulation (latent class) of scores on goal orientation was brought into the model (see SI file Table 2).

3.3.1. Latent class 1 (high goal orientation). HEI at baseline was positively associated with HEI at 6 months (Est: 0.548; SE: 0.026; $P < 0.001$) and S-RHI at 6-months post-intervention (Est: 1.640; SE: 0.366; $P < 0.001$) in LC 1 (high goal orientation) S-RHI at baseline was positively associated with S-RHI at 6-months (Est: 0.519; SE: 0.030; $P < 0.0001$). Baseline HEI was positively associated with S-RHI at 6 months (Est: 0.012; SE: 0.002; $P < 0.001$).

Latent class 1 (high goal orientation) differed from both the other classes (low and moderate goal orientation) in that the intervention group showed a greater increase than controls in HEI at 6-months post-intervention. There was an interaction between latent class and dietary (HEI) response within LC 1 (high goal orientation), whereby the control group scored significantly lower than the treatment group on HEI at 6-months post-intervention (Est: 4.638; SE: 1.297; $P < 0.001$) (Fig. 2).

3.3.2. Latent class 2 (moderate goal orientation). HEI scores at baseline were positively associated with HEI scores at 6-months post-intervention in latent class in LC 2 – moderate goal orientation (Est: 0.548; SE: 0.026; $P < 0.001$). HEI at baseline was positively associated with S-RHI at 6-months (Est: 0.012; SE: 0.002; $P < 0.001$) in LC 2 – moderate goal orientation. S-RHI at baseline was positively associated with S-RHI at 6-months (Est: 0.519; SE: 0.030; $P < 0.001$) in LC 2 – moderate goal orientation.

S-RHI at 6-months was positively associated with HEI scores at 6-months in LC 2 – moderate goal orientation (Est: 1.640; SE: 0.366; $P < 0.001$). There was no difference (at the $P < 0.05$ level) in HEI scores between the control and intervention group within LC 2 – moderate goal orientation at 6-months post-intervention (Est: 0.111; SE: 0.784; $P = 0.887$).

3.3.3. Latent class 3 (low goal orientation). HEI scores at baseline were positively associated with HEI scores at 6-months post-intervention in latent class in LC 3 – low goal orientation (Est: 0.548; SE: 0.026; $P < 0.0001$). HEI at baseline was positively associated with S-RHI at 6-months (Est: 0.012; SE: 0.002; $P < 0.001$) in LC 3 – low goal orientation. S-RHI at baseline was positively associated with S-RHI at 6-months (Est: 0.519; SE: 0.030; $P < 0.001$) in LC 3 – low goal orientation.

S-RHI at 6-months was positively associated with HEI at 6-months in LC 3 – low goal orientation (Est: 1.640; SE: 0.366; $P < 0.001$). There was no difference in HEI scores between the control and intervention group within LC 3 – low goal orientation at 6-months post-intervention (Est: −0.268; SE: 1.508; $P = 0.859$).

4. Discussion

Previous research has underlined the importance of goal setting in personalised nutrition in bringing about healthy dietary change.[10,19,23] Accordingly, knowing people's goals in relation to why they enlisted in the study has potential to enrich our understanding and explanation of the Food4Me intervention results. LCA of responses to goal items at baseline indicated that people recruited to the study were well-differentiated with respect to goal orientation. This secondary analysis therefore compared responses to either the personalised intervention or control at 6-months post-intervention among participants grouped according to their goal orientation at baseline. Given the initial Food4Me intervention study found that those who received personalised advice (irrespective of content/level) showed greater increase in HEI than controls,[9] we compared HEI between the control and the treatment groups combined within each of the three classes defined on goal orientation.

The results indicated that the effect of the intervention (treatment *vs.* control) upon HEI was only significant within the class of people who had a high goal orientation. That provision of personalised nutrition advice increased HEI compared to controls within the high goal-oriented class, upholds our non-directional hypothesis that goal orientation would be associated with HEI indices. It could be argued that those who were more highly goal orientated were already more motivated to establish healthy eating habits when exposed to the intervention. Individual differences in goal orientation at baseline could also explain why there was no differential response in the primary intervention to advice based on the various types of personalisation (lifestyle, phenotypical or genotypical).[9] Those with a high goal orientation may have responded irrespective of the type of advice provided. That there were no differences in HEI between the three goal-oriented groups at baseline, however, implies that neither was the case, and that goal orientation operated independently of initial HEI. These results agree with previous qualitative research[19] implying the importance of goals in motivating people to adopt personalised nutrition and add to a growing body of literature suggesting the importance of goal setting in motivating healthy dietary behaviour change.[10,21–23,45] Our findings concur with previous research that suggests that goal setting could be an effective tool for promoting healthy dietary change.[46]

Previous analysis of the Food4Me intervention dataset indicated that habit strength was important in determining response to the individualised intervention.[18] This analysis therefore also sought to determine if differences in response to the intervention between the three classes defined on goal orientation was related to their habit strength. The results showed that both HEI and habit strength (S-RHI) at baseline were associated with HEI at six-months post-intervention in all three classes. Habit strength, however, only influenced the relationship between treatment groups *versus* controls and HEI at six months among those with a high goal orientation. The addition of habit to the model, while potentially strengthening theoretical understanding of healthy dietary change, therefore, had little effect upon the healthy eating indices between the different latent classes.

Our finding that habit strength was independent of goals and healthy eating indices, concurs with previous research that suggests that while goal setting can be an effective tool for promoting habit change, their impact was independent of habits and the specific behaviour targeted.[46] From the outset of the intervention, a strong healthy eating habit may have enabled people with a high goal orientation to act on the information provided. Establishing strong habits may therefore be important, even in the presence of defined goals. Meanwhile, these results support the theory that goals and habits operate independently in influencing healthy dietary behaviour change[25] and that dietary related goal setting may be more effective in changing behaviour if accompanied with the establishment of associated dietary habits. That habit strength increased with the personalised intervention substantiates previous findings indicating the need for personalised plans to seek to enhance healthy eating habit strength.[14,18] Our findings also support those of previous studies implying that habit is important to goal attainment and healthy dietary behaviour change.[25,26,30]

4.1. Strengths and limitations

This analysis used data from the Food4Me study which is one of the largest randomised controlled studies investigating personalised nutrition conducted to date. This secondary analysis is novel in that it has considered how dietary goals and habit strength distinguish between groups of people who show a differential response to personalised nutrition. The study reflects the current interest in goal setting and habit formation for dietary health improvement.

Among potential limitations of this study is that the goals from which responses were generated were all pre-defined. This approach did not allow for free responses that may have generated a wider range of goals sought in adopting personalised nutrition. The goals that were included were specific and individual ("lose weight", and "increase sport performance") as well as more generic ("improve my family's health"). Whether this may have impacted the results is not clear. Further research is required to establish how participants would prioritize the goals.

That the measures were self-reported may have affected the accuracy of the results. The employment of electronic dietary assessment, such as that employed in this study, however, tends to be more accurate and produces better compliance than 'paper and pencil' versions.[47] It is also probable that any errors in dietary assessment would be distributed randomly across treatments and so is unlikely to bias the outcomes of the current study.

Another potential limitation was that sample attrition affected the control group to a greater degree than the treatment group[33] and the dropout rate was highest in those with lower goal orientation (27%), especially among male participants. This highlights the importance of goal setting from the outset in helping people, particularly males, to commit to a personalised regimen.

Unlike previous dietary interventions that have sampled clinical populations,[48] our sample was recruited from the wider European Union (EU) population. That the volunteers were self-selected, however, may have biased the sample towards those who were more health oriented. Although the sample reflected the EU adult population on certain demographic characteristics,[33] the inherent lack of ethnic diversity, could limit the degree to which findings can be generalised to other populations.

4.2. Implications

These results support the notion that goal orientation could prove a useful tool in motivating and guiding people successfully through the personalised nutrition process to healthier eating. Those who have low goal orientation may benefit from counselling and specific dietary goal setting at the outset of the intervention and in tailoring dietary advice. Those with higher goal orientation, who bring pre-existing goals to the intervention, may benefit more from targeted adherence to these goals in the design of personalised nutritional advice. Advances in development of machine learning algorithms and greater potential utility in digital health intervention,[21,49] should facilitate taking account of individual dietary related goals and goal orientation and in matching them to the type of personalised advice that would be most effective in bringing about healthy dietary change. Habit strength, whilst similar between the classes at baseline and independent of goal orientation, may be an important mechanism in the achievement of goals. A possible implication of these results is that goal orientation and habit strength should be viewed together when setting goals at the start of a personalised nutrition plan as well as in assessing response in achieving individualised goals.

5. Conclusion

This secondary analysis illustrates how dietary goals and habit strength distinguish between groups of people who demonstrate a differential response to personalised nutrition interventions. Personalised nutrition advice compared to generic advice, was most effective in individuals with high goal orientation, which along with habit strength, may have utility in promoting healthy eating. Low effect sizes observed in previous personalised nutrition RCTs,[10] therefore, may be improved through consideration of mutually agreed individualised goals and habit strength. Although our model is strong and the sample size sufficient for a randomised controlled trial, these results will need confirmed in larger more representative population samples.

Author contributions

The analysis was conceived by MA and the plan for analysis devised by MA, BS-K and BPB. The data analysis undertaken by BPB. The intervention study was designed by JM, and KL (who was also involved in data collection). BS-K drafted the manuscript with input from MA. LF, JM and KL commented on the draft manuscript.

Conflicts of interest

The authors know of no conflict of interest that could impact upon the integrity of these results. The research funder was not involved in the study design; collection, management, analysis, and interpretation of data; writing of the report; or the decision to submit the report for publication. Materials and dataset will be made available upon publication. All authors have approved the final submitted manuscript.

Data availability

The full data set will be made available on request and with publication. Note that the raw outputs have been supplied as supplementary files along with the submitted manuscript.

Supplementary information (SI) is available. See DOI: https://doi.org/10.1039/d5fo03197d.

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