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# Maintenance of a gluten free diet in coeliac disease: The roles of self-regulation, habit, psychological resources, motivation, support, and goal priority

**Article** in *Appetite* · February 2018

DOI: 10.1016/j.appet.2018.02.023

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1 **Funding:** EPH was funded by a research grant from Coeliac Australia. The funder was not involved in  
2 the design, collection, analysis or interpretation of the data.

3 **Word count:** 8182

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5

1 **ABSTRACT**

2 **Introduction:** A strict lifelong gluten free diet (GFD) is the only treatment for coeliac disease (CD).  
3 Theory-based research has focused predominantly on initiation, rational, and motivational processes  
4 in predicting adherence. The aim of this study was to evaluate an expanded collection of theoretical  
5 constructs specifically relevant to the maintenance of behaviour change, in the understanding and  
6 prediction of GFD adherence.

7 **Methods:** Respondents with CD (N=5573) completed measures of GFD adherence, psychological  
8 distress, intentions, self-efficacy, and the maintenance-relevant constructs of self-regulation, habit,  
9 temptation and intentional and unintentional lapses (cognitive and behavioural consequences of  
10 lowered or fluctuating psychological resources and self-control), motivation, social and  
11 environmental support, and goal priority, conflict, and facilitation. Correlations and multiple  
12 regression were used to determine their influence on adherence, over and above intention and self-  
13 efficacy, and how relationships changed in the presence of distress.

14 **Results:** Better adherence was associated with greater self-regulation, habit, self-efficacy, priority,  
15 facilitation, and support; and lower psychological distress, conflict, and fewer self-control lapses  
16 (e.g., when busy/stressed). Autonomous and wellbeing-based, but not controlled motivations, were  
17 related to adherence. In the presence of distress, the influence of self-regulation and intentional  
18 lapses on adherence were increased, while temptation and unintentional lapses were decreased.

19 **Discussion:** The findings point to the importance of considering intentional, volitional, automatic,  
20 and emotional processes in the understanding and prediction of GFD adherence. Behaviour change  
21 interventions and psychological support are now needed so that theoretical knowledge can be  
22 translated into evidence-based care, including a role for psychologists within the multi-disciplinary  
23 treatment team.

24

25 **KEYWORDS:** Gluten free diet adherence; coeliac disease; maintenance; self-regulation; habit;  
26 distress; theory

## 1 INTRODUCTION

2           The sole treatment for coeliac disease (CD) is lifelong adherence to a strict gluten free diet  
3 (GFD; Hardy & Tye-Din, 2016). Failure to achieve this, even due to trace amounts of gluten, can  
4 result in the persistence of gastrointestinal symptoms and place individuals at risk of long-term  
5 health complications such as cancer, infertility, and osteoporosis (Green & Jabri, 2003). There is an  
6 assumption within the medical and dietetic fields that giving a patient information about their  
7 condition and the associated risks, and providing information about its treatment, will be sufficient  
8 to prompt good adherence (e.g., Ciacci et al., 2015). The reality of behaviour change is, however, far  
9 more complex than the provision of knowledge and instruction alone (Hornik, 1989; Sainsbury,  
10 Mullan, & Sharpe, 2013b), and many patients with CD struggle to meet the strict but necessary  
11 standards for adherence (Hall, Rubin, & Charnock, 2009).

12           GFD adherence is the outcome of a series of complex patient behaviours, including the  
13 reading of food labels and ingredient lists, ensuring safe food preparation at home, telling the  
14 people who are responsible for preparing food about your CD and need for a GFD, and asking  
15 questions about food preparation and the risk of contamination when eating away from home,  
16 among others. Understanding the modifiable determinants of poor adherence is essential for the  
17 design of evidence-based strategies to improve dietary adherence and health. We and others have  
18 shown that a range of patient factors including food label-reading skills, degree of symptomatology  
19 to gluten exposure (Halmos et al., 2017), and depressive symptoms (Sainsbury & Marques, 2018),  
20 are associated with, and likely to influence, both behaviour and dietary adherence, but ultimately  
21 patient behaviour is the most important and modifiable determinant. One means to the  
22 development of interventions is the use of health behaviour change theory (e.g., Craig et al., 2008).  
23 The successful application of theory to a behavioural problem, such as GFD adherence, provides a  
24 blueprint or logic model for intervention efforts by suggesting the mechanisms via which changes in  
25 behaviour may be achieved (Bartholomew Eldredge et al., 2016; Glanz & Bishop, 2010; Michie &  
26 Prestwich, 2010). Theory-based behaviour change interventions are potentially more effective than

1 those without a theoretical basis, and have the advantage of giving insight into why an intervention  
2 does or does not work (Glanz & Bishop, 2010; Michie, Johnston, Francis, Hardeman, & Eccles, 2008;  
3 Webb, Joseph, Yardley, & Michie, 2010).

4 Few studies have applied theory to the understanding and prediction of GFD adherence in  
5 CD, and only one intervention designed specifically to improve adherence has been published  
6 (Sainsbury et al., 2013b; Sainsbury, Mullan, & Sharpe, 2015b). Using the theory of planned behaviour  
7 (TPB), attitudes and perceived behavioural control (PBC) predicted significant variance in both the  
8 intention to follow a strict GFD and GFD adherence (Sainsbury & Mullan, 2011; Sainsbury, Mullan, &  
9 Sharpe, 2013a). The presence of an intention-behaviour gap, however, suggested that additional  
10 factors are needed to explain why some individuals struggle to remain gluten free despite having  
11 strong intentions (Sainsbury et al., 2013a). Extending the TPB, it was found that the interaction  
12 between intention, habit, and PBC predicted GFD adherence, such that individuals with both low  
13 habit and low PBC had the worst adherence, regardless of their level of intention; whereas for  
14 people with high habit and low PBC, adherence did increase as a function of intention (Kothe,  
15 Sainsbury, Smith, & Mullan, 2015). It was acknowledged that habit may be a better predictor if  
16 applied to the separate behaviours that comprise adherence, as differences in the likelihood and  
17 desirability of automaticity for these may differ.

18 Protection motivation theory (PMT) was recently applied to GFD adherence, differentiated  
19 based on whether gluten consumption was intentional or accidental (Dowd, Jung, Chen, &  
20 Beauchamp, 2016). Intentions (or protection motivation) were a direct predictor of intentional but  
21 not unintentional gluten consumption. Additional, indirect predictors (via intention) of intentional  
22 consumption were greater symptom severity, lower perceptions of the costs of following a GFD  
23 (distress, barriers, and stigma), greater self-regulatory efficacy, more frequent planning, and better  
24 knowledge. In contrast, self-regulatory efficacy, or having the confidence to regulate one's  
25 behaviour to maintain a strict GFD, was the only predictor of less frequent *unintentional* gluten  
26 consumption, and this exerted a direct rather than indirect effect (Dowd et al., 2016).

1           A similar pattern of results was found by Hall, Rubin, and Charnock (2013), whereby the only  
2 correlates of unintentional consumption were related to self-efficacy (perceived difficulty, control,  
3 and confidence), whereas intention, attitudes, symptoms (experienced and perceived tolerance),  
4 and social support were additionally related to intentional gluten consumption. By definition,  
5 unintentional gluten consumption – typically the most common cause of non-adherence (Hall et al.,  
6 2013) – happens outside of conscious awareness and is not easily amenable to accurate self-report,  
7 as not all individuals with CD are symptomatic upon exposure. Even for those who are symptomatic,  
8 the realisation of accidental consumption is a post-hoc one, and although attributed to gluten, other  
9 factors (e.g., other intolerances/allergies, stomach bug) may be responsible for the observed  
10 reaction. Methodologically, it is therefore not surprising that rational factors, such as those  
11 encompassed by most behaviour change theories, are limited in predicting unintentional gluten  
12 consumption.

13           One of the major challenges of behaviour change is the continued maintenance of changes  
14 after initial improvements. In a systematic review of over 100 behaviour change theories (Kwasnicka,  
15 Dombrowski, White, & Sniehotta, 2016), five maintenance-specific themes were identified. As  
16 applied to GFD adherence, maintenance motivation (theme 1) refers to the development of personal  
17 reasons to *continue* following a GFD, as once the salience of pre-diagnosis symptoms is reduced,  
18 their power as a continued motivator is also likely reduced. GFD adherence is a complex behaviour  
19 requiring active self-regulation (theme 2; e.g., reading labels and planning if eating out) for success  
20 in both initiation and maintenance phases. With repeated performance over time, these behaviours  
21 should become habitual or automatic (theme 3) and require less conscious regulation. Psychological  
22 resources (theme 4) refer to internal resources that can be drawn on to prevent lapses in GFD  
23 adherence when self-control may be low or fluctuating due to factors such as tiredness, low mood,  
24 or stress, or from the effort involved in maintaining adherence itself. Difficulties in assessing such  
25 state-based experiences in a cross-sectional design meant that psychological resources were  
26 operationalised here as the frequency of cognitive (temptation) and behavioural (intentional and

1 unintentional gluten consumption) consequences of lowered psychological resources and self-  
2 control. Social and environmental influences (theme 5) include the supportiveness of the people and  
3 environments in which the GFD is being attempted. These constructs received support in a within-  
4 person study of adherence to a weight loss maintenance plan (Kwasnicka, Dombrowski, White, &  
5 Sniehotta, 2017), but have not been applied together in other behaviours. Finally, previous research  
6 has highlighted the importance of three additional constructs for behavioural maintenance: namely,  
7 priority level, and the balancing of unrelated goals that may either facilitate or conflict with goal  
8 achievement (Conner et al., 2016; Preece, Sniehotta, Francis, & Gebhardt, 2010) – for example,  
9 the goal of maintaining a strict GFD may sometimes conflict with the goal of being social, whereas  
10 the goal of healthy eating may facilitate the GFD. Confidence for this task (concurrent self-regulatory  
11 efficacy) is correlated with both GFD adherence and quality of life in patients with CD (Dowd & Jung,  
12 2017).

13           Given the lifelong necessity of the GFD for patients diagnosed with CD, viewing adherence  
14 through the lens of maintenance may advance current understanding beyond that determined using  
15 theories of motivation and initiation. Previous theory- and non-theory-based research in CD also  
16 supports the relevance of several maintenance constructs. For example, the perceived ability to  
17 maintain adherence despite changes in mood and stress (similar to psychological resources) was  
18 related to GFD adherence (Leffler et al., 2008); and social (e.g., avoiding social eating, not wanting to  
19 draw attention to oneself or inconvenience/burden others, perceived social support) and  
20 environmental factors (e.g., travelling and school/work) are often cited as difficulties associated with  
21 the GFD (e.g., Hall et al., 2013; Leffler et al., 2008; Sainsbury & Mullan, 2011; Zarkadas et al., 2013).  
22 As outlined, the roles of habit (Kothe et al., 2015) and planning (Dowd et al., 2016) have also been  
23 supported. Finally, relationships between participant characteristics (e.g., GFD duration),  
24 acceptability (e.g., of goal setting and planning tasks, length of intervention), and attrition following  
25 participation in a successful TPB-based intervention provide indirect support for their relevance  
26 (Sainsbury, Mullan, & Sharpe, 2015a).



1           The aims of this study were to firstly understand whether, and how, the ten aforementioned  
2 maintenance constructs could be used to advance understanding of GFD adherence; and secondly,  
3 to determine the contribution of these constructs to predicting GFD adherence, over and above the  
4 well-supported variables of intention and self-efficacy (Kothe et al., 2015; Sainsbury & Mullan, 2011;  
5 Sainsbury et al., 2013a). Depressive symptoms, which have a moderate association with GFD  
6 adherence (Sainsbury & Marques, 2018) and partially explained the failure to translate intentions  
7 into behaviour (Sainsbury et al., 2013a), were also included. It was hypothesised that each of the ten  
8 maintenance constructs would be associated with GFD adherence – that is, better adherence would  
9 be related to: (1) more frequent self-regulation, (2) stronger habits, (3) stronger maintenance  
10 motivation (particularly autonomous and future-oriented motivations), (4-6) less frequent  
11 temptation and intentional and unintentional gluten consumption in circumstances when  
12 psychological resources and self-control are low, (7) better social and environmental support, (8-10)  
13 higher goal priority and facilitation, and less goal conflict. Consistent with previous studies, it was  
14 anticipated that stronger intentions, higher PBC, and lower levels of psychological distress would be  
15 associated with better GFD adherence, although the maintenance constructs would add to the  
16 prediction of adherence beyond that accounted for by these variables. It was also expected that  
17 more frequent self-regulation and a longer time since diagnosis would be associated with stronger  
18 habits; higher levels of psychological distress and lower PBC would each be associated with more  
19 frequent temptation and un/intentional gluten consumption; and lower priority and higher goal  
20 conflict would be associated with both lower maintenance motivation and intention.

## 21 **METHOD**

### 22 *Participants and recruitment*

23           This was part of a wider study designed to investigate the patient-relevant factors (e.g.,  
24 demographic, disease, knowledge, psychological) associated with adherence to a GFD (Halmos et al.,  
25 2017). The inclusion criteria were that participants needed to be aged  $\geq 13$  years and have a biopsy-  
26 confirmed diagnosis of CD (self-reported for the purposes of inclusion). Here, only those  $\geq 16$  years

1 were included, as several measures had not been validated in non-adult samples. Recruitment took  
2 place in February and March 2017, and involved: email advertisements disseminated by Coeliac  
3 Australia and Coeliac New Zealand to their members and at state-based gluten free expos; adverts  
4 posted and shared on social media (Facebook pages of state CD organisations and general CD  
5 support groups); and word of mouth. Ethical approval was granted by the Melbourne Health Human  
6 Research Ethics Committee (LNR/16/MH/169).

### 7 *Materials and procedure*

8 Interested participants clicked a web-link in the email/advertisement and were directed to  
9 SurveyMonkey (SurveyMonkey Inc., 2016) to read a participant information statement and complete  
10 the screening questions before accessing the online survey. Eligible participants provided informed  
11 consent and were told that they could stop answering the survey at any time. Questions elicited  
12 information about a range of demographic (i.e., age, gender, education, ethnicity), diagnostic (e.g.,  
13 year of diagnosis, reason for diagnosis), and illness variables (e.g., symptoms; see Halmos et al., 2017  
14 for conference abstract; full text in preparation), and the target variables of interest for the  
15 theoretical analysis of maintenance. A copy of the questionnaire can be found in the online  
16 supplementary material.

17 *GFD adherence:* the Coeliac Dietary Adherence Test (CDAT) is a 7-item self-report  
18 questionnaire that has good psychometric properties and correlates highly with the 'gold standard'  
19 adherence measure, a dietitian-rated assessment (Leffler et al., 2009). Each item is rated on a 5-  
20 point Likert scale; responses are summed to provide a total score (range = 7-35); and higher scores  
21 indicate poorer adherence (7-12 = excellent or very good adherence; 13-17 = moderate; 18-35 = fair-  
22 to-poor).

23 *Intention and PBC:* two subscales from the Theory of Planned Behaviour in Coeliac Disease  
24 questionnaire, which have acceptable internal consistency (intention:  $\alpha = .68$ ; PBC:  $\alpha = .81$ )  
25 (Sainsbury & Mullan, 2011), were used. One additional item measured confidence to maintain a  
26 strict GFD in the presence of unexpected barriers and was added to the original scale for scoring

1 purposes. Each item is rated on a 7-point Likert scale; the total score for each construct represents  
2 the average of relevant items (range = 1-7); higher scores indicate stronger intentions and higher  
3 confidence, respectively.

4 *Psychological distress:* the Kessler Psychological Distress Scale (K-10) was used to measure  
5 depression and anxiety, over the past 4 weeks (Kessler et al., 2002). The scale includes 10 items,  
6 each measured on a 5-point Likert scale assessing the frequency of symptoms; the total score  
7 represents the sum of all items (range = 10-50); and higher scores indicate greater distress (10-19 =  
8 well; 20-24 = mild mental disorder; 25-29 = moderate mental disorder; 30-50 = severe mental  
9 disorder). Items in the K-10 were derived from those included in 18 previous measures of  
10 depression, anxiety, and general distress, and narrowed down following expert consensus and pilot  
11 testing. The resultant 10-item scale has undergone rigorous psychometric testing, including further  
12 pilot testing via telephone administrations and face-to-face interviews, validation against the  
13 Structured Clinical Interview for DSM-IV (SCID), and inclusion in large government health surveys in  
14 the USA and Australia. Results showed that the scale has excellent precision and discriminates  
15 reliably between cases and non-cases, across a range of sociodemographic characteristics (Kessler et  
16 al., 2002).

17 *Maintenance constructs:* novel scales were used to measure each of the maintenance-  
18 relevant constructs (except habit). A draft version of the maintenance questionnaire was reviewed  
19 by members of the health psychology group at the Institute of Health and Society, Newcastle  
20 University, for coverage of the relevant constructs. Prior to recruitment, the newly-developed  
21 questionnaire (maintenance constructs plus the CD history and dietetic questions) was also piloted  
22 in a face-to-face group setting with eight adult members of Coeliac Victoria, and separately with two  
23 members of Coeliac NSW. After completing the questionnaire individually, the volunteers discussed  
24 any items (content and/or wording) that concerned them and notes were passed onto the research  
25 team. In addition, the questionnaire was reviewed by the multi-disciplinary study team  
26 (gastroenterologist, dietitian, and three psychologists), two additional practicing dietitians, and

1 research staff members at the Walter and Eliza Hall Institute who were not involved in the study  
2 (two research nurses, post-doc, research assistant). Changes to the wording and content of  
3 questions were then made, as appropriate. A copy of the full questionnaire can be found in the  
4 online supplementary material.

5 *Habit*: a single item ('X is something I do automatically') from the Self-Report Habit Index  
6 (SRHI; Gardner, Abraham, Lally, & de Bruijn, 2012; Verplanken & Orbell, 2003) was used to measure  
7 the level of automaticity of each component behaviour involved in achieving GFD adherence, rather  
8 than the complex behaviour of adherence as a whole (as suggested by Kothe et al., 2015): (1)  
9 reading ingredients lists and nutritional labels and 'may contain' statements to identify gluten  
10 containing ingredients; (2) taking measures to avoid cross-contamination when preparing food at  
11 home; (3) asking questions about food preparation and the risk of cross-contamination when eating  
12 away from home; (4) telling the person who is cooking/preparing food about your CD and need for a  
13 strict GFD; (5) planning ahead when eating away from home; and (6) having gluten free foods on  
14 hand in case of a lack of availability when away from home. Responses were given on a 7-point  
15 Likert scale with higher scores reflecting more habitual behaviour. Component behaviours were  
16 informed by those included in the Biagi GFD score (Biagi et al., 2009) and examples elicited in an  
17 interview study (Sainsbury & Mullan, 2011). Choice of this item from the 12-item SRHI was informed  
18 by data showing that it best captured the construct of automaticity and was well-understood by  
19 participants (B. Gardner, personal communication, November 17, 2016).

20 *Self-regulation*: six items referred to the above component behaviours, reflecting the  
21 frequency with which each was performed to ensure strict adherence to the GFD (rated on a 5-point  
22 Likert scale: never-always; recoded to 7-points so the mean was comparable to habit). One  
23 additional item, adapted from the Action and Coping Planning Scales (Sniehotta, Schwarzer, Scholz,  
24 & Schuz, 2005), measured coping planning (i.e., having a plan for how to maintain strict GFD  
25 adherence in the presence of unexpected barriers; rated on a 7-point Likert scale) and was  
26 combined with the component behaviour items for the purposes of scoring.

1 Psychological resources: operationalised as the cognitive and behavioural consequences of  
2 lowered or fluctuating self-control, participants indicated the frequency of (1) temptation to break  
3 their GFD, and (2) intentional and (3) unintentional gluten consumption, under 11 conditions when  
4 the availability of psychological resources is likely to be reduced: tired, busy/limited time, break in  
5 usual routine, bored, stressed, upset/down, emotionally exhausted, low energy, unmotivated,  
6 physically unwell, and unable to see any positive effect of the GFD. Due to the difficulty of measuring  
7 unintentional gluten consumption directly (as, by definition, it happens outside of present-moment  
8 awareness), this was inferred from the frequency of “being less careful or paying less attention to  
9 your diet, being less likely to plan in advance, or taking more risks with label reading or other  
10 measures you would typically use to avoid gluten.” The specific conditions were informed by a  
11 measure of the frequency of depletion experiences, used in a weight loss maintenance trial (Evans et  
12 al., 2015). Each item was measured on a 5-point Likert scale (never-always), with higher scores  
13 indicating more frequent temptation and consumption. Although intentional and unintentional  
14 gluten consumption reflect patient behaviours and therefore overlap to some extent with the  
15 measure of GFD adherence, an important difference is that the CDAT score reflects the *outcome* of a  
16 series of complex behaviours, rather than behaviour per se. Further, by linking un/intentional gluten  
17 consumption specifically to the experience of conditions in which psychological resources and self-  
18 control are likely to be lowered, this construct can be differentiated from self-regulation, which  
19 simply reflects frequency of performance of the component behaviours.

20 Social and environmental support: participants indicated the practical and emotional  
21 support received in relation to maintaining a strict GFD and, if there was somebody close to them  
22 (e.g., family member) with CD, they also indicated practical and emotional support from those  
23 people. Three items measured the supportiveness of the home, work/study, and weekend  
24 environments. Choice of these domains was based on the division into practical and emotional  
25 support in existing social support scales (e.g., Mitchell et al., 2003), and evidence for the relevance  
26 of different environments (e.g., home, work, and socialising/eating out which are likely to happen

1 more on weekends) in previous GFD research (e.g., Leffler et al., 2008; Sainsbury & Mullan, 2011).  
2 Each item was measured on a 0-100-point sliding scale (not at all-completely).

3 Maintenance motivation: 15 items measured reasons for continuing to follow a GFD on a  
4 day-to-day basis (which may be different to what motivated the initiation of a GFD in the first place).  
5 The specific reasons were drawn from the attitude items of the Theory of Planned Behaviour-Coeliac  
6 Disease questionnaire (e.g., to avoid symptoms and long-term health complications, to feel  
7 physically and emotionally well; Sainsbury & Mullan, 2011); and autonomous (e.g., following a GFD  
8 has become part of who I am/is consistent with other things that matter to me) and controlled  
9 motivation items (e.g., I would feel guilty if I did not follow a GFD; other people expect me to) from  
10 self-determination theory, as previously applied in a weight loss context (Pelletier, Dion, Slovinec-  
11 D'Angelo, & Reid, 2004). The latter also overlap with the subjective norm items from the TPB  
12 (Sainsbury & Mullan, 2011). All items were answered using a 0-100-point sliding scale (not at all-  
13 completely).

14 Goal priority, goal conflict, goal facilitation: single-items, rated on a 7-point Likert scale  
15 (strongly disagree-strongly agree), were used for each construct. For goal priority (reverse-scored)  
16 and facilitation, higher scores indicated greater priority and facilitation, whereas a higher conflict  
17 score indicated that more got in the way of the GFD. Items were adapted from a series of studies on  
18 the impact of goal priority and conflict on the intention-behaviour gap, for which some single items  
19 were used (Conner et al., 2016). Question framing was different here as the behaviour of GFD  
20 adherence is not time-bound (i.e., needs to be performed for life). Conflict and facilitation were  
21 asked about separately based on evidence that they are not merely two ends of the same  
22 continuum (Presseau et al., 2010).

### 23 *Data analysis*

24 Time since diagnosis was computed by subtracting the year of diagnosis from 2017; age at  
25 diagnosis was computed by subtracting this value from current age. Raw data from validated  
26 questionnaires were combined to produce one score per construct (i.e., GFD adherence,

1 psychological distress, intention, PBC). Due to positive skews on both time since diagnosis (towards  
2 more recent; skewness = 1.97, kurtosis = 6.00) and GFD adherence (towards better adherence;  
3 skewness = 0.89, kurtosis = 1.04), natural log transformations were applied to create distributions  
4 that approached normality (time: -0.39, -0.64; adherence: 0.18, -0.33). Untransformed values were  
5 used for descriptive purposes and transformed for inferential statistics. Differences in GFD  
6 adherence and psychological distress, by gender, were assessed using independent samples *t*-tests.

7         Descriptive statistics (% or mean and standard deviation; SD) were computed for each  
8 maintenance item. For each of self-regulation, habit, psychological resources (temptation and  
9 un/intentional gluten lapses), social and environmental support, and maintenance motivation, a  
10 factor analysis using the principal components extraction method and promax rotation was  
11 conducted to determine the number of components emerging from the data (based on eigenvalues  
12  $\geq 1$ ). An oblique rather than orthogonal rotation was chosen as it was expected that items within  
13 each construct (and therefore any extracted components) would be correlated with each other.  
14 Subscale scores represented the average of relevant items; Cronbach's alphas indicated internal  
15 consistency.

16         Spearman's correlations were conducted to determine the bivariate relationships between  
17 GFD adherence, time since diagnosis, and the ten maintenance constructs (individual items and  
18 subscale scores). A hierarchical multiple regression analysis was used to determine the variance  
19 accounted for by the maintenance constructs and their unique role in predicting GFD adherence. At  
20 step 1, intention and PBC were entered to confirm the predictive capacity of the TPB for GFD  
21 adherence. At step 2, the 10 maintenance-relevant constructs were entered, followed by  
22 psychological distress at step 3 to examine the ways in which the theoretical relationships changed  
23 when depression was accounted for.

24         Given the large sample, effect sizes and 95% confidence intervals rather than *p* values were  
25 used to indicate significance. For correlations, the coefficient represented the effect size; for *t*-tests,  
26 means and SD were used to compute the effect size (Cohen's *d*), which were interpreted according

1 to Cohen's guidelines ( $r$  of 0.1/0.3/0.5 indicate small/medium/large effects, respectively;  $d$  of  
2 0.2/0.5/0.8 indicate small/medium/large effects respectively; Cohen, 1988).

### 3 **RESULTS**

#### 4 *Response rate*

5 A total of 7393 people accessed the online survey and 7227 consented to participate. Of  
6 these, 7044 had CD (95.3%) and provided some information. A small group were unsure about their  
7 diagnosis ( $n = 114$ ) or answered 'no' to this question ( $n = 69$ ), with all such participants being  
8 excluded from analysis. To be included, respondents needed to have a diagnosis of CD, be  $\geq 16$  years  
9 of age, completed the primary outcome measure (GFD adherence), and provided data for at least  
10 one of the theoretical constructs ( $n = 5773$ ; 78% of those who accessed the survey). Most  
11 participants heard about the survey via Coeliac Australia or Coeliac New Zealand (65.9%), followed  
12 by social media (27.6%), word of mouth (2.2%), their gastroenterology clinic or healthcare  
13 professional (1.8%), a newspaper article (1.8%), a state-based Gluten Free Expo (0.1%), or other  
14 (0.5%).

#### 15 *Sample characteristics*

16 The final sample ( $n = 5773$ ) was predominantly female (83.2%), married or partnered  
17 (78.7%), and had a mean age of 50.2 years ( $SD = 15.9$ , range = 16-94). Most were currently living in  
18 Australia (84.9%; New Zealand: 14.3%; other: 0.8%) and identified as Caucasian (96.1%; the  
19 remainder identified as Asian, Aboriginal, Pacific Islander, Maori, or other). The sample was well-  
20 educated, with half having completed undergraduate (28.7%) or post-graduate qualifications  
21 (21.1%) and a further 21.6% having completed a TAFE certificate (secondary schooling: 16.9%; less  
22 than secondary education: 11.6%; missing: 1.1%).

23 Respondents had been diagnosed with CD between 0 and 71 years ago ( $M = 10.3$ ,  $SD = 9.4$ ;  $n$   
24 = 120 confirmed their diagnosis but did not provide a date), at the age of between 0 and 84 years ( $M$   
25 = 39.7,  $SD = 15.6$ ). The mean GFD adherence score ( $M = 12.1$ ,  $SD = 3.3$ , range = 7-29) fell in the  
26 excellent or very good range, as did the scores of 60.5% of the sample; 33% were classified as having



1 moderate adherence, and 6.5% had fair-to-poor adherence. The difference in adherence between  
 2 men ( $M = 11.3, SD = 3.1$ ) and women ( $M = 12.3, SD = 3.3$ ) equated to a small effect size ( $d = .31$ ).  
 3 Scores for intention ( $M = 6.4, SD = 1.4$ ) and PBC ( $M = 6.5, SD = 0.7$ ) were both high. Based on their  
 4 psychological distress scores ( $M = 17.2, SD = 6.7, \text{range} = 10-50$ ), 71.7% of the sample were classified  
 5 as being well, 14.4% fell into the mild mental disorder category, 7.2% moderate, and 6.6% severe.  
 6 The mean distress score for men ( $M = 15.4, SD = 5.9$ ) and women ( $M = 17.5, SD = 6.8$ ) placed them in  
 7 the well category, and the difference between them was small ( $d = .33$ ).

### 8 *Scale properties*

9 Factor analyses on each of the multi-item maintenance scales indicated that items loaded on  
 10 one factor per construct, except for maintenance motivation, which formed four subscales  
 11 (described separately). Total scores were therefore computed from the average of relevant items,  
 12 and all had acceptable internal consistency (except one of the motivation subscales). Descriptive  
 13 statistics and scale properties including reliability, eigenvalues, and the amount of variance  
 14 accounted for by the first component for each of the maintenance scales are shown in Table 1 (note:  
 15 goal priority, conflict, and facilitation were assessed using single items and so were not subject to  
 16 factor analysis).

17

18 **Table 1.** Summary of scale properties

	Mean (SD)	Range	Cronbach's alpha	Eigenvalue	% of variance
Self-regulation	6.0 (0.9)	1-7	.78	3.1	45
Habit	6.0 (1.0)	1-7	.85	3.5	58
Temptation	1.4 (0.7)	1-5	.96	7.8	71
Intentional	1.1 (0.4)	1-5	.96	8.1	74
Unintentional	1.3 (0.6)	1-5	.95	7.7	70
Support	81.5 (19.1)	0-100	.85	3.3	66
Motivation: wellbeing	74.7 (19.9)	0-100	.81	5.0	33
Motivation: symptoms	81.1 (20.3)	0-100	.77	1.7	12
Motivation: controlled	59.5 (25.7)	0-100	.55	1.2	8
Motivation: long-term health*	93.3 (13.7)	0-100	NA	1.0	7
Goal priority*	6.1 (1.4)	1-7	NA	NA	NA
Goal conflict*	1.9 (1.4)	1-7	NA	NA	NA

Goal facilitation*	4.3 (2.0)	1-7	NA	NA	NA
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1 Temptation, intentional, and unintentional all refer to the frequency of cognitive or behavioural  
2 lapses when psychological resources and self-control may be low (e.g., when tired, stressed);  
3 support refers to both social (practical and emotional) and environmental support (home,  
4 work/study, weekend); eigenvalues and % variance based on factor analysis with principal  
5 components extraction method and promax rotation; \* single-item component/scale  
6

7

8 *Maintenance motivation*

9           Avoidance of long-term health problems was the strongest motivator for following a strict  
10 GFD on a day-to-day basis (see Supplementary Table 1). This was followed by wanting to feel  
11 physically well, GFD is ‘part of who I am’, and symptom avoidance (both since following a GFD and  
12 prior to diagnosis). ‘Because other people expect me to’ was the least motivating factor. Promax  
13 rotation identified 4 components with eigenvalues over 1, which together accounted for 59.3% of  
14 the variance. The first component, labelled ‘wellbeing’, consisted of items reflecting autonomous  
15 motivations (i.e., satisfaction, enjoyment, consistency with identity and values) and wellbeing (e.g.,  
16 energy, emotional wellbeing, healthy diet). The second component contained motivations related  
17 predominantly to symptoms (e.g., avoiding symptoms experienced pre- and post-diagnosis, feeling  
18 physically well). There was some overlap, with increased energy, emotional wellbeing, and being  
19 able to achieve more loading on both components 1 and 2. Component 3 contained the three  
20 controlled motivations, and component 4 contained the single item relating to avoidance of long-  
21 term health problems. For the purposes of computing subscale scores, items with cross-loadings  
22 only contributed to the component for which they had the highest loading.

23 *Self-regulation and habit*

24           Reading ingredient lists and ‘may contain’ statements was the most frequently used self-  
25 regulatory behaviour, followed by communicating with people involved in food preparation about  
26 CD and the need for a GFD, both of which were used ‘always’ or ‘often’ by more than 92% of the  
27 sample (see supplementary Table 2). For label reading, the level of automaticity was also high;  
28 whereas, although frequently used, communication was not automatic for as many people. Asking

1 questions about food preparation and cross-contamination was the least frequently used and  
2 automatic behaviour. Coping planning was used less frequently than other self-regulatory  
3 behaviours, with 71.6% of the sample either agreeing or strongly agreeing that they had a plan for  
4 how to maintain a GFD even when unexpected things got in the way.

#### 5 *Psychological resources*

6           Between 68 and 81% of the sample reported that they ‘never’ felt tempted to break their  
7 GFD under each of the 11 circumstances in which psychological resources and self-control may be  
8 low; less than 2% said they ‘always’ felt tempted (see Supplementary Table 3). Intentional gluten  
9 consumption was rare under any circumstances (88-94% never), with a maximum of 1.5% endorsing  
10 ‘always’ or ‘often’. Being less careful with the GFD was more common than intentional gluten  
11 consumption across all circumstances (70-89% never). Being physically unwell, not being able to see  
12 any positive effect of the GFD, and feeling bored were the circumstances *least* likely to elicit  
13 temptation and consumption. Being busy/having limited time and a break in the usual routine were  
14 the circumstances in which people were *most* likely to report temptation and consumption.

#### 15 *Social and environmental support*

16           The mean scores for practical and emotional support were reasonably high (see  
17 Supplementary Table 4); the difference between practical and emotional support equated to a small  
18 effect size ( $d = 0.22$ ). Roughly half the sample (47.5%) knew somebody with CD. The mean score for  
19 practical support from others with CD was slightly lower than the general practical support received  
20 ( $d = .21$ ). The emotional support received from other people with CD was comparable to general  
21 emotional support ( $d = 0.14$ ). The mean score for a supportive home environment was high and  
22 more supportive than the work/study ( $d = 0.73$ ) or weekend environment ( $d = 0.40$ ). The weekend  
23 environment was more supportive than the work/study environment ( $d = 0.50$ ).

#### 24 *Goal priority, and conflict vs. facilitation*

25           Most respondents (79.6%) strongly disagreed or disagreed that other activities and goals  
26 were a higher priority than maintaining a strict GFD. Only 3.8% strongly agreed or agreed to its lower

1 priority. Most (80.3%) also reported that other priorities, activities, and goals did not get in the way  
2 of them maintaining a strict GFD. Scores for goal facilitation were more varied: 25.3% neither agreed  
3 nor disagreed that other priorities, activities, and goals helped them to maintain a strict GFD, 36.2%  
4 agreed or strongly agreed, and 24.4% disagreed or strongly disagreed.

#### 5 *Relationships between the maintenance-relevant constructs*

6 All 13 of the resulting maintenance scales (the original ten constructs, including motivation  
7 which was split into four subscales) were correlated with GFD adherence in the expected directions  
8 (medium effect sizes, except goal facilitation: small, and controlled motivation: trivial; see  
9 Supplementary Table 5). All bivariate correlations between these variables were as expected, such  
10 that better self-regulation and stronger habits, more support, higher priority and motivation  
11 (wellbeing, symptoms, long-term health), fewer barriers, and more facilitators were all related to  
12 experiencing less frequent temptation and being less likely to intentionally or unintentionally  
13 consume gluten when psychological resources and self-control were low (medium-to-large effects,  
14 except goal facilitation: trivial or small). Controlled motivation was only associated with the  
15 wellbeing- and symptom-based motivation subscales.

16 Higher psychological distress scores were significantly correlated with poorer GFD  
17 adherence (large effect size), and with *lower* intentions, PBC, habit, support, wellbeing-based  
18 motivation, goal priority, and facilitation; and *more* temptation, intentional and unintentional  
19 consumption, and goal conflict. The largest associations were with support and temptation (medium  
20 effects), PBC, unintentional consumption, and goal conflict (small-to-medium). The correlations with  
21 time since diagnosis were trivial-to-small, although generally in the direction of a more favourable  
22 profile being associated with longer time since diagnosis.

#### 23 *Predicting GFD adherence*

24 At step 1, intention, and PBC accounted for 17.7% of the variance in GFD adherence. PBC  
25 had a medium-to-large effect on adherence, while the effect of intention was trivial (see Table 2). At  
26 step 2, the 13 maintenance-relevant variables accounted for an extra 12.3% of the variance (total

1 30%). The unique effect of most was only small, with social support, temptation, and PBC having the  
2 strongest effects. At step 3, psychological distress added a further 13.2% to the model and was the  
3 strongest predictor of adherence (medium-to-large effect). Here, the influences of several variables  
4 were considerably weakened (e.g., temptation and social support). In contrast, the influences of self-  
5 regulation and intentional gluten consumption were strengthened. The strongest predictors after  
6 distress were self-regulation, intentional gluten consumption, and PBC, all of which had equivalent,  
7 small magnitude effects. The total variance accounted for in the final model was 43.2%.

8  
9  
10

1 **Table 2.** Summary of hierarchical regression analyses predicting GFD adherence

	<i>B</i>	95% <i>CI</i> ( <i>B</i> )	$\beta$	<i>R</i> <sup>2</sup> ( $\Delta$ )	<i>F</i>
Step 1					
Intention	.000	-.004, .005	.002		
PBC	-.151	-.160, -.142	-.421	.177	594.47
Step 2					
Intention	.004	.000, .008	.022		
PBC	-.046	-.057, -.035	-.128		
Self-regulation	-.013	-.023, -.003	-.046		
Habit	-.008	-.017, .002	-.029		
Motivation: wellbeing	-.001	-.001, .000	-.060		
Motivation: symptoms	.001	.000, .001	.045		
Motivation: controlled	.000	.000, .000	-.011		
Motivation: LT health	-.001	-.002, -.001	-.064		
Temptation	.050	.039, .061	.141		
Intentional	.049	.029, .070	.076		
Unintentional	.016	.001, .032	.035		
Support	-.003	-.003, -.002	-.184		
Goal priority	-.003	-.007, .002	-.014		
Goal conflict	.013	.008, .018	.069		
Goal facilitation	-.003	-.006, .000	-.026	.300 (.123)	157.87
Step 3					
Intention	.002	-.002, .006	.009		
PBC	-.037	-.047, -.028	-.104		
Self-regulation	-.030	-.039, -.021	-.109		
Habit	-.003	-.012, .005	-.013		
Motivation: wellbeing	.000	-.001, .000	-.028		
Motivation: symptoms	.000	.000, .000	.009		
Motivation: controlled	.000	.000, .000	-.025		
Motivation: LT health	-.001	-.002, -.001	-.058		
Temptation	.014	.004, .024	.039		
Intentional	.068	.049, .086	.104		
Unintentional	-.009	-.023, .005	-.019		
Support	-.001	-.001, -.001	-.081		
Goal priority	-.003	-.007, .002	-.014		
Goal conflict	.011	.006, .016	.060		
Goal facilitation	-.001	-.004, .002	-.007		
Psych. distress	.017	.016, .017	.418	.432 (.132)	262.24

2 Note: PBC = perceived behavioural control; based on n = 5542 who had a complete dataset;  
 3 outcome (CDAT with natural log transformation): higher scores indicate poorer adherence.

4

5

6

## 1 **DISCUSSION**

2           The GFD is the only way to manage CD, and must be strictly maintained for life after  
3 diagnosis (Green & Cellier, 2007). Despite the optimistic disease trajectory if this is achieved, many  
4 patients struggle with their adherence (Hall et al., 2009). Current clinical care of patients with CD  
5 tends to focus on patient knowledge and practice of the GFD, and there is scant regard for the roles  
6 of patient behaviour and the attitudes that shape adherence to the GFD (e.g., Ciacci et al., 2015). By  
7 understanding these psychological aspects, it may be possible to develop clinically-relevant  
8 approaches that can be applied to support patients to maintain long-term adherence. The primary  
9 aim of this study was to determine the fit of a collection of maintenance-specific theoretical  
10 constructs (Conner et al., 2016; Kwasnicka et al., 2016; Pesseau et al., 2010) to the understanding  
11 and prediction of GFD adherence, over and above the known influences of intention and PBC (Kothe  
12 et al., 2015; Sainsbury & Mullan, 2011; Sainsbury et al., 2013a), and in combination with depressive  
13 symptoms, which are also associated with poorer adherence (Sainsbury & Marques, 2018). The  
14 recruitment of more than 5500 individuals with CD allowed for precise estimates of the constructs  
15 and the relationships between them, and all hypotheses were supported.

16           Strength of motivation/intention has been associated with GFD adherence in several studies  
17 (Dowd et al., 2016; Hall et al., 2013; Sainsbury & Mullan, 2011; Sainsbury et al., 2013a), although its  
18 influence is typically diminished when other variables are accounted for, reflecting the premise that  
19 motivation is a necessary but not sufficient condition for behaviour. In a conference abstract  
20 (otherwise unpublished), greater autonomous motivation was associated with better GFD  
21 adherence (Weiss et al., 2013), but little more is known about the specific types of motivation  
22 related to adherence in this population. Although the primary reason for following a GFD in people  
23 with CD will be their diagnosis (Dowd et al., 2016), over time, the development of intrinsic reasons  
24 for adherence are likely to be associated with better adherence and wellbeing (Ng et al., 2012; Ryan  
25 & Deci, 2000). Consistent with this, autonomous (i.e., satisfaction/enjoyment of behaviour and  
26 consistency with values) and wellbeing-based motivations (i.e., satisfaction with outcomes, including

1 reduced symptoms) were most strongly associated with GFD adherence. In line with previous work  
2 showing that subjective norms were not relevant in CD (Sainsbury & Mullan, 2011), 'because other  
3 people expect me to' had the lowest mean score and controlled motivations were unrelated to  
4 adherence.

5           Most people engaged in label reading and told the person who was preparing their food  
6 about their CD and need for a GFD, the former being more automatic than the latter. The  
7 discrepancy in automaticity between the two behaviours may reflect the fact that, if the same,  
8 limited number of people (e.g., family members and close friends) are responsible for food  
9 preparation in most situations, this behaviour would not be required on every eating occasion. In  
10 contrast, it is recommended by Coeliac Australia that even frequently-consumed foods and  
11 ingredients are checked every time, as manufacturers may have altered their ingredients or  
12 production methods, rendering a previously safe product no longer suitable. Forward-planning,  
13 coping planning, and having gluten free food on hand in case of lack of availability were used by  
14 roughly three-quarters of the sample. While probably making living with CD easier, failure to  
15 perform these behaviours on some occasions would not necessarily result in lapses in adherence like  
16 not reading labels would. Of some concern, only two-thirds of the sample asked questions about  
17 food preparation and cross-contamination risks when eating away from home, and this was the least  
18 automatic of the behaviours that comprise adherence. When combined with the observed  
19 relationships between more frequent self-regulation and better adherence, this suggests that some  
20 people with CD are placing themselves at risk by not engaging in behaviours that are needed to  
21 protect their health.

22           The magnitude of the habit-adherence correlation and the non-unique influence of habit  
23 when controlling for other variables was comparable with the previous study (Kothe et al., 2015).  
24 Differences in the level of automaticity of each component behaviour, however, supports the  
25 decision to assess these separately, and suggests that while some aspects of the GFD are prone to  
26 becoming habitual, others may continue to require conscious regulation, even with repeated



1 performance over time. The former tended to reflect individually-controlled behaviours compared  
2 to more complex behaviours with a social or communication element, which have previously been  
3 identified as factors that can impede adherence (e.g., Sainsbury & Mullan, 2011). A similar pattern  
4 was observed within the social and environmental data, with the home environment being more  
5 supportive than either the work/study or weekend environments, where presumably the influence  
6 of other people on the ability to maintain strict adherence is greater. The cues in the home  
7 environment are also probably more stable than those away from home, which is an important  
8 aspect of habit formation. This is consistent with previous research showing that being in control of  
9 the household food and kitchen, and comfort following the GFD at work, were associated with  
10 better adherence (Leffler et al., 2008; Sainsbury & Mullan, 2011). All social and environmental  
11 support items were related to GFD adherence, and the total support score represented the  
12 strongest relationship across the univariate and multivariate analyses. Thus, while patient behaviour  
13 remains key in adherence, context also needs to be considered.

14           While motivation/intention were high and self-regulation frequent, there were  
15 circumstances related to the depletion of psychological resources in which participants felt tempted  
16 to break their diets. Conceptually, these fell into three main categories, although all items loaded on  
17 one component. The circumstances in which temptation, and indeed both intentional and  
18 unintentional gluten consumption, were *most* likely were practical in nature – that is, being busy or  
19 having limited time and having a break from their usual routine. As inferred above, this may reflect  
20 the importance of the interaction between environmental factors, such as the ease of finding gluten  
21 free foods when eating away from home, and the capacity for self-control depending on the  
22 availability of psychological resources. Factors of a physical or internal drive-related nature (i.e., no  
23 positive effect of the GFD, physically unwell, tired, lacking energy, bored, unmotivated) were *least*  
24 likely to be associated with temptation and consumption. Emotional factors (i.e., stress, upset or  
25 down, emotionally exhausted) fell in the middle of practical and physical factors regarding the  
26 frequency of eliciting temptation.

1 Intentional consumption of gluten was uncommon under any circumstances, which is  
2 consistent with previous evidence (Dowd et al., 2016; Hall et al., 2013). Direct self-report of  
3 unintentional gluten consumption is problematic and previous research has failed to identify  
4 predictors comparable to intentional consumption (Dowd et al., 2016; Hall et al., 2013). Here, the  
5 frequency of behavioural lapses when psychological resources and self-control were likely to be low  
6 was used as a proxy for unintentional gluten consumption. All items and the subscale score were  
7 moderately correlated with poorer GFD adherence and strongly associated with PBC. Again, while  
8 lapses in self-regulation will not guarantee the ingestion of gluten, if occurring with any regularity,  
9 they will certainly place the individual at risk over the longer-term, and therefore represent  
10 important targets for intervention. Finally, as predicted, placing a higher priority on the GFD  
11 compared to other goals and activities, and experiencing less goal conflict and more facilitation,  
12 were related to better adherence.

13 The predictive capacity of intention and PBC in the multivariate analysis was comparable to  
14 previous research, with PBC again exerting a stronger impact than intention (Kothe et al., 2015;  
15 Sainsbury & Mullan, 2011; Sainsbury et al., 2013a). As expected, the maintenance constructs added  
16 variance and the total was considerably higher than previous predictive models (Kothe et al., 2015;  
17 Sainsbury & Mullan, 2011; Sainsbury et al., 2013a). Constructs for which the confidence interval did  
18 not include zero were support, PBC, all three components of psychological resources (temptation,  
19 and un/intentional gluten consumption), goal conflict, and self-regulation, although the unique  
20 influence of the latter four were trivial.

21 Depressive symptoms show a moderate association with GFD adherence (Sainsbury &  
22 Marques, 2018), but the nature of this relationship has not been confirmed. More interesting,  
23 therefore, was the change in pattern of predictors when psychological distress (the strongest  
24 predictor) was added in the final step. Here, the previously trivial influence of self-regulation was  
25 strengthened, suggesting that in the presence of distress, more active self-regulation is needed to  
26 ensure good adherence. Additionally, the influence of temptation was reduced, while intentional

1 gluten consumption in the context of reduced psychological resources became an important  
2 predictor of worse adherence. Combined, this suggests that most temptation and consequent lapses  
3 in self-regulation when depleted (i.e., unintentional consumption) are accounted for by feeling  
4 distressed – that is, depression appears to undermine otherwise good self-regulation and reliance on  
5 gluten-avoidance habits, resulting in some people being less vigilant with their diets.

6           In contrast, intentional gluten consumption in these same circumstances exerted a strong  
7 influence on adherence even when distress was accounted for, suggesting that lowered  
8 psychological resources also impact adherence via temporary dips in the intention and ability to  
9 adhere, regardless of the level of psychological distress. Emotional eating (as prompted by  
10 depression, boredom, and anger/anxiety, but not specifically in relation to the consumption of  
11 gluten) was previously assessed and was not related to GFD adherence, while the increased use of  
12 adaptive, and decreased use of maladaptive, emotion regulation strategies was related to both  
13 poorer GFD adherence and increased depression (Kerswell & Strodl, 2015). Thus, it appears that the  
14 combination of lowered resources and the ability to effectively regulate behaviour *and* emotions in  
15 these circumstances is key in determining their impact on adherence. The still significant influences  
16 of PBC and support (albeit reduced) suggest that these factors may be protective in the presence of  
17 distress. These findings extend previous work (Sainsbury & Marques, 2018) by suggesting specific  
18 means via which depression may impact the intention-behaviour gap.

19           The main limitation of this study was the cross-sectional design, which means that causation  
20 between the various theoretical constructs, and with adherence, cannot be established. Future  
21 research using prospective or longitudinal designs would help to elucidate how these factors  
22 influence each other and vary over time. Nonetheless, the very large sample size is a strength, which  
23 resulted in greater precision of measurement than has been possible in most previous studies,  
24 where sample sizes were typically in the range of 200-500. The large sample also somewhat  
25 outweighs the potential biases associated with recruitment via CD support groups, active members  
26 of whom may not be representative of the wider CD population. The imbalance towards more

1 recent diagnosis may suggest that established patients are less likely to be in contact with such  
2 support, although arguably, it is the newer group of patients who may be more in need of support  
3 with their adherence. Recruitment through official (Coeliac Australia/New Zealand and state  
4 organisations) and unofficial (Facebook groups) disease-specific support networks was undertaken  
5 to increase reach within the target population to include non-members of the Coeliac Society. The  
6 observation that these were the main sources of access to the survey, however, means that people  
7 from outside any organised networks were under-represented in the sample, posing a potential  
8 threat to generalisability.

9         There was a strong gender bias (83% female) over and above the established biological  
10 imbalance that exists in CD and other autoimmune conditions (Green et al., 2001), and the majority  
11 of the sample were Caucasian (96%). In a serogenetic screening study conducted in representative  
12 community cohorts of men and women in Australia, estimates of CD were considerably higher in  
13 women (1.9%) than men (1.2%) (Anderson et al., 2013). The sample on which these estimates are  
14 based mirrors the national Australian population by socioeconomic status, education, country of  
15 birth (only 2.3% were born in countries that are not predominantly Caucasian), and age breakdown  
16 (Anderson et al., 2013; Pasco, Nicholson, & Kotowicz, 2011). Thus, compared to recent estimates,  
17 the current sample is reasonably representative of the population of people diagnosed with CD in  
18 Australia, as well as the gender breakdown of Coeliac Australia membership (80% women; personal  
19 communication, January 12, 2018) and requests for CD serology testing per annum (two-thirds  
20 women; Anderson et al., 2013). The high levels of education reported in the sample (71.4% with  
21 undergraduate, post-graduate, or TAFE qualifications compared to 50.7% of the representative  
22 cohort with post-school qualifications) may, however, point to an additional bias and may have  
23 affected findings, as health literacy is likely to be linked to adherence (Berkman, Sheridan, Donahue,  
24 Halpern, & Crotty, 2011). Future research would therefore benefit from purposeful recruitment of  
25 groups currently under-represented in research (e.g., men, lower education, non-Caucasian

1 backgrounds, and patients who have chosen not to seek support from the Coeliac Society or other  
2 informal support group), as the relationships described here may differ.

3 A common limitation of GFD adherence research is the absence of a truly reliable and valid  
4 adherence measure that is feasible for use in large-scale research, and, in this way, this study is no  
5 different to previous work. It is well-established that while serological measures are reliable markers  
6 of intestinal damage at diagnosis, their use at follow-up is limited as they do not correlate well with  
7 the 'gold standard' dietitian-rated assessment or mucosal disease state, and produce frequent false  
8 negatives in known partially-adherent patients (Leffler et al., 2007; Vahedi et al., 2003). In contrast,  
9 the CDAT does correlate well with the 'gold standard' and was shown to be superior to serological  
10 tests (Leffler et al., 2009). While the addition of dietitian reports would clearly strengthen the  
11 current findings, in a study of >5500 people this would be financially and practically unfeasible. The  
12 findings can, however, be viewed with more confidence than studies that have utilised simple self-  
13 report measures of the frequency of gluten consumption, whether intentional or otherwise.

14 In the absence of existing measures to assess the maintenance constructs (except habit),  
15 novel questionnaires were used. Although the items and subscales performed well – that is, they  
16 were internally consistent, loaded on single components for each construct (except motivation), and  
17 correlated in the expected directions with adherence, PBC, and psychological distress – it was not  
18 possible to determine psychometric attributes such as construct or criterion validity, which  
19 represents a limitation and warrants further study. Nonetheless, they are a starting point and could  
20 also be adapted for use in other long-term behaviours. Further, the measure used to estimate the  
21 frequency of risk-taking when psychological resources and self-control are low may be of use in  
22 future GFD research as a proxy for unintentional gluten consumption.

23 This large study has demonstrated that the maintenance-relevant constructs of self-  
24 regulation, habit, maintenance motivation, psychological resources, social and environmental  
25 influences (Kwasnicka et al., 2016), and goal priority, conflict, and facilitation (Conner et al., 2016;  
26 Pesseau et al., 2010) are useful for understanding how adherence to a GFD in CD happens. The

1 combination of rational, automatic, and emotional processes used here advances previous research.  
2 While not all previously unstudied in this field, their application within a coherent theoretical  
3 framework is an advantage and provides a lens through which decisions about appropriate  
4 mechanisms for behaviour change interventions can be made.

5           For example, in addition to prompting self-regulation and habit formation, the present  
6 results suggest that interventions may benefit from encouraging participants to gain insight into how  
7 lowered self-control in various psychological states may directly or indirectly impact their  
8 adherence. Strategy-wise, considering ways to minimise the frequency of these experiences and/or  
9 develop ways to cope when they do occur, might then mean that lapses in adherence are less likely.  
10 Regarding specific types of motivation, the findings also suggest that encouraging people with CD to  
11 focus on the longer-term benefits of following a GFD, and the satisfaction and enjoyment that comes  
12 from being well, may yield greater improvements in maintenance of the GFD over time than  
13 perceiving no choice and being motivated by merely wanting to avoid symptoms, feelings of guilt, or  
14 because somebody told you to. Finally, teaching skills to elicit and mobilise available social support  
15 from friends and family, and achieving balance within the less supportive weekend and work/study  
16 environments may be of benefit.

17           The care of patients with CD typically involves a medical specialist (gastroenterologist),  
18 general practitioner, and dietitian. Even with optimal medical care, a sizeable proportion of patients  
19 fail to achieve full symptom relief or mucosal disease remission (Rubio-Tapia et al., 2010). Together  
20 with findings relating to the importance of patient demographic and diseases characteristics in  
21 determining adherence (Halmos et al., 2017), psychological factors clearly play an important role  
22 and need to be recognised and more effectively addressed. This and other psychological studies  
23 therefore highlight an important place for a health and/or clinical psychologist as a member of the  
24 multi-disciplinary team and provide guidance on how change may be achieved – it is time to shift  
25 focus away from prediction and towards intervention design, implementation, and evaluation, so

- 1 that existing theoretical knowledge can be translated into effective and evidence-based healthcare
- 2 practice.

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