ABSTRACT

Background: Awareness of health and sustainability is increasing and can be supported by suitable smartphone applications. Most applications are designed based on commercial or ad-hoc considerations, although models for improving behavioural patterns and motivation have been studied in psychology and the social sciences. These models have so far not been widely applied to application design.
Objective: Grocery shopping is one example where behaviour-supporting applications are being widely used. This paper aims at reviewing existing applications in this domain and determine how these support motivational aspects identified by current behavioural models.
Methods: Existing behavioural theories are merged into a single redundancy free and comprehensive model. The model is used to categorise application features to assess the type and strength of support with respect to motivating healthy and sustainable grocery shopping behaviour.
Results: The most popular Android applications in this area are evaluated, identifying potential strengths and weaknesses with respect to optimally supporting desired behaviour.
Conclusion: The most popular applications do not support desired behaviour best. By indicating which aspects of the behavioural model are supported by a mobile application it is possible to identify features not included that could be supplemented or improved in future application development.

Keywords: health; sustainability; behavioural theories; application design requirements; grocery shopping; recipe apps

1 INTRODUCTION

Grocery shopping is an essential part of living a healthy and sustainable lifestyle. The interplay between individual-level and environmental factors determines food choices and eating habits (Brug, 2008). For this reason, not only the (mal-)adaptive behaviour but also the context in which the behaviour occurs needs to be taken into account to develop evidence-based health behaviour change interventions (Davis, Campbell, Hildon, Hobbs, & Michie, 2015).

There is evidence that grocery shopping situations in particular can be very stressful and demanding for many, because of countless temptations and distractors (Aylott & Mitchell, 1999). Countering these temptations requires intensive planning to overcome unwanted behavioural habits. Supporting people in adopting behaviour with a healthier outcome, has proven to be challenging. While incentives make people act in a more desired way as long as the incentive is given (Abrahamse, Steg, Vlek, & Rothengatter, 2005), motivating people to change their behaviour also in the long term remains an unresolved issue across domains including dieting, energy efficiency, or reduction of waste to name a few.

Personalised approaches and tools like smartphone applications constitute an increasing contribution to health interventions (Metz, et al., 2000; Lowe, 2003). The WHO has coined the term mHealth since 2009 (Codyre, 2014) to address the growing health challenges in the world. Smart phones have gained a lot of attention recently through their almost endless possibilities and the fact that they have become so ubiquitous and pervasive (Spruijt-Metz & Nilsen, 2014). The uses of mobile devices have penetrated almost every aspect of our lives. There is, therefore, significant potential for both monitoring and influencing human behaviour utilising this technology. Nevertheless, neither health interventions (Davis, Campbell, Hildon, Hobbs, & Michie, 2015) nor smartphone applications (Riley, et al., 2011) are commonly designed with reference to theoretical concepts, or use only isolated components of a behaviour theory.

While behavioural change theories predominantly focus on interventions and their outcomes (e.g. (Davis, Campbell, Hildon, Hobbs, & Michie, 2015; Head, Noar, Iannarino, & Harrington, 2013)), practical considerations for designing smartphone applications have led to a field of user experience (UX) research, which aims at analysing and improving usability and effectiveness of products and systems (ISO9241, 2019). Both perspectives have been developed in parallel but thus far little synergies between the approaches have been exploited. UX evaluation methods can be broadly categorised into those that have to be integrated into the application development, for instance Visitor Behaviour Analysis (Wingify, 2021), and those that can be applied without having access to the application back-end. As an example of the latter Heuristic Evaluation (Wilson, 2014) has been proposed as a methodology for analysing application features with respect to achieving certain pre-defined desirable properties. It is based on defining suitable heuristics (Quiñones, Rusu, & Rusu, 2018) and evaluating application features with respect to support of these. Various heuristics have been proposed (Schön, Thomaschewski, & Bader, 2017), a popular choice being suggested by Nielsen (Nielsen, 1994; Nielsen Norman Group, 2021), although these are often adapted and augmented as required (e.g. (Reis, Páris, & Gomes, 2020; Suzianti, Minanga, & Fitriani, 2017)). A shortcoming of these approaches is that the definition of heuristics is ad-hoc and is lacking a theoretical underpinning, which behavioural theory has the potential to provide.

In this paper we aim to address this shortcoming by presenting a behavioural model derived from established psychological and social behavioural theories that provides guidelines for defining suitable heuristics to analyse application features accordingly. The presented approach is applied to the most popular recipe and grocery shopping applications available on the Google Play store and an evaluation with respect to heuristics support in a model-derived context is presented. Putting application features into a theoretical context allows for a better understanding of the ways how these features individually contribute to achieving the goal of behaviour change towards healthy and sustainable grocery shopping.

2 MODEL-BASED EVALUATION OF BEHAVIOUR-SUPPORTING APPLICATIONS

Behavioural theories have been proposed in the past to assess and influence behaviour in various settings. However, these theories typically focus on very specific aspects and, therefore, do not lend themselves well to the categorisation of a broad spectrum of functionalities offered by smartphone applications for supporting a wider range of behaviours. A review of the state of the art of theories of behaviour and behavioural change in the context of health interventions has been presented by Davis at al. (Davis, Campbell, Hildon, Hobbs, & Michie, 2015), who identified a total of 82 approaches of which only 4 theories accounted for 63% of all work and another 4 account for 12% of articles. These 8 dominant behavioural models in descending order of popularity are the Transtheoretical Model of Change (TTM) (Prochaska, Redding, & Evers, 2015), the Theory of Planned Behaviour (TPB) (Ajzen, From Intentions to Actions: A Theory of Planned Behavior, 1985), the Social Cognitive Theory (SCT) (Bandura, 1999), the Information-Motivation-Behavioural-Skills model (IMB) (Fisher & Fisher, 2002), the Health-Belief-Model (HBM) (Strecher & Rosenstock, 1997), the Self-Determination-Theory (SDT) (Ryan & Deci, 2000), the Health-Action-Process approach (HAPA) (Schwarzer, 1992), and the Social-Learning-Theory (SLT) (Miller & Dollard, 1941), which is a pre-cursor model to the SCT.

Out of these we identified the SCT to be the most useful theory for the task of understanding the cognitive process of interaction between a person, the application, and the environment. The SCT has been applied to various domains and has broad empirical support (e.g. (Strong, Parks, Anderson, Winett, & Davy, 2008; Phipps, et al., 2013)). We did not consider the TTM, which has been criticised for lacking empirical support (West, 2005; Cahill, Lancaster, & Green, 2010), nor did we include the TPB and SDT in this work, which both focus on inventories for operationalising the assessment of intentions (Ajzen, 2006) and motivation (Ryan & Deci, 2021), respectively and, therefore, are not directly applicable to the evaluation of application features. The HBM and the HAPA are specific to health and the perception of health risks, and, therefore, may not generalise to other types of behaviour supporting applications.

While the IMB provides a model of how behaviour is driven by self-efficacy and motivation, we instead propose to use the High-Performance-Cycle (HPC) (Locke & Latham, 1990) and the Action-Regulation-Theory (ART) (Hacker, 1986), which are similar but provide a more elaborate cognitive process model of behaviour and its influencing variables, and have empirical support (Selden & Brewer, 2000; Borgogni & Dello Russo, 2012; Hörisch, Wulfsberg, & Schaltegger, 2020).

Most behavioural models are developed with a specific application in mind and focus on specific individual parameters. At the same time the concepts are overlapping, and the models exhibit a great level of redundancy (Davis, Campbell, Hildon, Hobbs, & Michie, 2015; Steel & König, 2006). The integration of well-established theories into a single more comprehensive behavioural model can overcome this limitation and contribute to a broader understanding of the psychological factors involved (e.g. (Blanke, 2008; Blanke, Beder, &

Klepal, 2016; Blanke, Beder, & Klepal, 2017)). Such a model then allows to derive criteria for the Heuristics Evaluation of applications, indicating how well the cognitive parameters of a behaviour are supported. While the heuristics chosen for the Heuristics Evaluation approach are usually formulated as issues commonly encountered by UX designers and, therefore, require panels of such UX experts to be evaluated, the concepts derived from the behavioural theories provide very detailed and specific definitions relating to the cognitive processes guiding a behaviour instead. Therefore, we argue that they can be applied to the evaluation task without the need of dedicated UX expertise calling for consensus amongst experts as required by Heuristics Evaluation. Instead, empirical support for the evaluation criteria is derived from the body of research carried out in the field to validate the underlying concepts as indicated above, thus not only providing confidence in the choice of the criteria, but also alleviating the need for repeated statistical analysis based on expert panels or focus groups as is common practice in UX design. Figure 1 shows an integration of behavioural models, which incorporates the concepts of the three selected theories: the High Performance Cycle (HPC) (Locke & Latham, 1990), the Action-Regulation Theory (ART) (Hacker, 1986), and the Social Cognitive Theory (SCT) (Bandura, 1999).

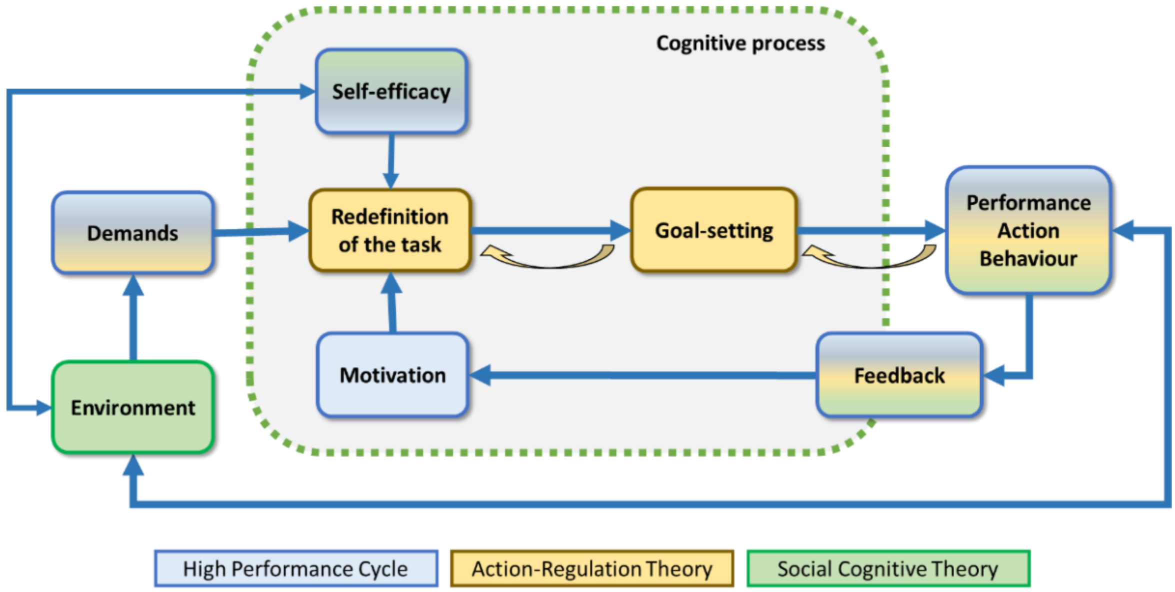

Figure 1 Nested double cycle of behaviour

We will briefly outline in the following the process of development of this comprehensive behavioural model. The model represents a nested double cycle of behaviour, integrating leading aspects from each of these theories, broadening the scope and overcoming individual limitations. It is based on the framework provided by the HPC, on which the other theories are superimposed. While the HPC does not account for the cognitive processes involved, this shortcoming is overcome by integrating the ART. The ART offers a description how demands and tasks are taken over and translated into precise and visualisable action plans. The HPC and ART address mainly work processes, therefore by including the SCT this focus is expanded, and a clear notion of the interface between the individual and his/her environment is introduced. These three theories provide a qualitative layout that enables the analysis of smartphone applications in a systematic way. The next section describes the main elements and provides a synthesis of this integrated model.

Demands are challenges, which are externally imposed on the individual, e.g. by policy on public health and sustainability, that initiate a cognitive process. The **redefinition of the task** follows these demands, describing the process of personalisation, e.g. the translation of the demand to follow a healthy and sustainable diet into meaningful personal goals, e.g. the planned recipes meeting the demanded requirements. The next step of the process concerns **goal-setting**, where the refinement of goals into sub-goals and the development of precise personalised action plans takes place, e.g. shopping lists to follow when implementing the preparation of recipes. **Self-efficacy** needs to be taken into account when redefining goals. Self-efficacy refers to personal abilities in the given context, for instance with regards to the difficulty level of cooking. After setting superordinate goals and specifying them in sub-goals and precise action-plans under consideration of context and personal skills the actual **behaviour** happens. Behaviour is the outcome of the cognitive process and does not have a matching feature within a supporting smartphone application, because all features are designed to support the behaviour itself. Every behaviour triggers **feedback**, which gives information on the progress that the behaviour provides with regards to achieving the overall goals. Feedback can lead to adjustment of behaviour or to re-organisation of sub-goals and superordinate goals. Furthermore, the right feedback at the right time in the right context can affect the motivation to show the future behaviour in question. **Motivation** is understood as a general tendency to show a certain behaviour, which can be supported by motivational cues such as simple, straightforward information like a colour coded system for nutritional values or information on the carbon footprint. The nested double cycle of behaviour reflects the cognitive process in the context of the **environment**, assuming a reciprocal causal relationship between the behaviour and the circumstances, for example when encountering obstacles during a grocery shopping situation.

Behaviour is the outcome of a complex process comprising various aspects, all of which are covered by the underlying behavioural theories with varying degrees of focus. The interaction between these factors as elaborated in the integrated model depicted in Figure 1 suggests that maximum impact is expected to be achievable if they are covered by corresponding features of the reviewed applications. Thus, to analyse recipe and food shopping smartphone applications we propose to use these building blocks of the nested double cycle of behaviour and to map them onto specific features in a systematic way. Such a review can help to better understand the cognitive processes underlying grocery shopping, and how they are optimally supported by the application in question.

The proposed comprehensive and integrated model also ensures that features missing from the applications can be identified, which indicates potential aspects that are not covered by a particular app. We categorise applications, therefore, in terms of their capacity to support healthy and sustainable grocery shopping according to these concepts. Note, that the evaluation criteria derived from behavioural models are indicative of the support of a specific behaviour, they do not relate to other quality factors that are evaluated in UX design such as usability, low-barrier access, cost efficiency or trust. All these must be considered as well to be successful; the presented approach is, therefore, not intended to replace existing UX practices but to augment and underpin the aspects relating to changing or influencing behavioural patterns, such as in achieving a healthy and sustainable diet.

3 METHOD

To achieve healthier and more sustainable food choices the associated behaviour can be supported by recipe and food shopping smartphone applications. Such recipe and food shopping applications can be analysed using the integrated model described in Figure 1, which lays out relevant behavioural aspects as part of the behavioural process having an impact on healthy and sustainable behaviour. The individual features of the recipe and food shopping applications can be compared with concepts of the described model and therefore categorised and analysed regarding the impact they might have on healthy and sustainable behaviour.

In this review we identified the most popular food planning, recipe and shopping list applications. The selection of the Applications was based on the following criteria:

- Listed in the “Food & Drink” category of the Google Play Store on the 21st Aug 2020 and available in an English language version in Ireland
- More than 1M installs and at least 100 ratings on the Google Play Store on the 21st Aug 2020
- Providing recipe planning support and grocery shopping list features
- Not specific to a shop (e.g. 7-Eleven), delivery service (e.g. Domino’s Pizza) or product (e.g. Thermomix)

All applications matching these criteria ordered by their popularity on the Google Play store according to AndroidRank.org (AndroidRank.org, 2020) are listed in Table 1. This resulted in retaining the 27 most popular food planning, recipe and shopping list applications.

Table 1 Most popular food shopping and recipe applications

Rank	Title	Installs	Total ratings	Average rating
23	Cookpad - Create your own Recipes	10.0 M	237129	4.71
50	Tasty	5.0 M	121797	4.7
56	Yummly Recipes & Shopping List	5.0 M	109866	4.53
62	Allrecipes Dinner Spinner	5.0 M	77738	4.57
71	Cookbook Recipes	5.0 M	49397	4.39
119	myTaste Recipes	1.0 M	47548	4.19
132	My CookBook Recipe Manager	1.0 M	33396	4.71
134	BigOven Recipes, Meal Planner, Grocery List & More	1.0 M	32730	4.53
139	Kitchen Stories - Recipes & Cooking	1.0 M	29595	4.7
177	Mealime - Meal Planner, Recipes & Grocery List	1.0 M	16698	4.61
188	Easy Recipes	1.0 M	14543	4.67

208	Salad Recipes FREE	1.0 M	12402	4.3
209	Recipe book: Recipes & Shopping List	1.0 M	12352	4.28
218	Food Planner	1.0 M	10931	3.74
228	All Recipes Free - Food Recipes App	1.0 M	9861	4.38
253	Quick and Easy Recipes	1.0 M	7080	3.84
255	Magic Fridge: Easy recipe idea and anti-waste	1.0 M	6782	4.12
256	All free Recipes: World Cuisines	1.0 M	6536	4.38
261	Cake Recipes FREE	1.0 M	6027	4.17
262	Recipes Home - Free Recipes and Shopping List	1.0 M	5929	3.77
263	Chicken Recipes	1.0 M	5846	4.37
268	Diet Recipes	1.0 M	5121	4.74
274	Healthy Recipes	1.0 M	4478	4.4
278	Rice Recipes: Fried rice, pilaf	1.0 M	3940	4.26
281	FitMenCook - Healthy Recipes	1.0 M	3768	4.56
289	Lunch Recipes	1.0 M	3001	4.37
298	Salad Recipes: Healthy Foods with Nutrition & Tips	1.0 M	1558	4.16

The integrated model outlined in the previous section (see Figure 1) provides a framework, underpinned by empirical support for the underlying models, which allows to understand what features need to be included in an application to optimally support the cognitive processes involved in healthy and sustainable food shopping behaviour. We reviewed the applications listed in Table 1 and identified features that support positive dietary choices. These features were then mapped onto the corresponding concepts of the behavioural model using the definitions of the underlying theories (see Table 2). Some features can be mapped to more than one concept; therefore, features are identified by unique numbers in brackets. This mapping allows to identify for each application if a feature is present or not.

Table 2 Operationalisation of concepts from the model into potential application features

Concept in model	Summary of concept	Supporting feature
Demands	Challenges imposed on the individual, e.g. by policy on public health and sustainability, that initiate the cognitive process	Recipe database specifically to support a healthy diet (1)
		Recipe database specifically to support a sustainable diet (2)
Redefinition of the task	Personalisation of demands, e.g. to follow a healthy and sustainable diet, into meaningful personal goals, e.g. the planned recipes meeting the demanded requirements	Recipe suggestions including information on nutritional values (3)
		Recipe suggestions including information on carbon footprint (4)
		Browse recipes by category to ease defining a goal according to the demands (5)

		Browse recipes by ingredient to ease defining a goal according to the demands (6)
		Search recipes and ingredients using a search field to simplify the finding preferred options (7)
		Create a personalised list of recipes to prepare (weekly plan) to enable longer-term goal planning (8)
		Create a personalised list of recipes remembered for later (favourites) to ease finding preferred options (9)
Goal-setting	Refinement of goals into sub-goals and development of precise personalised action plans, e.g. shopping lists to follow when implementing the preparation of recipes	Create shopping list from selected recipes refining higher level goals into actionable plans (10)
		Merge ingredients consistently on shopping list even when aggregating different units to generate action plans which minimise cognitive strain (11)
		Include additional products into the shopping list to enable personalisation of action plans (12)
		Delete entire recipes from the shopping list to accommodate feedback loops during the process (13)
		Delete single ingredients from the shopping list to facilitate personalisation of the action plan (14)
		Adapt amounts for ingredients to accommodate different serving sizes to personalise the action plan (15)
Self-efficacy	Consideration of personal abilities in the given context, for instance with regards to the difficulty level of cooking	Indication of difficulty level for each recipe to accommodate personal abilities (16)
		Detailed cooking instructions to support the decision for or against a recipe (17)
Feedback	Information on the progress that the behaviour provides with regards to achieving the overall goals in order to motivate better behaviour	Recipe suggestions including information on nutritional values (3)
		Recipe suggestions including information on carbon footprint (4)
		Nutritional information for the ingredients to increase knowledge of health benefits (18)
		Carbon footprint information for the ingredients to increase knowledge of sustainability impacts (19)

Motivation	General tendency to show a certain behaviour, which can be supported by motivational cues such as simple, straightforward information like a colour coded system for nutritional values or information on carbon footprint	Recipe suggestions including information on nutritional values (3)
		Recipe suggestions including information on carbon footprint (4)
Environment	Reciprocal causal relationship between the behaviour and the encountered circumstances, for instance when encountering obstacles	Include additional products into the shopping list to enable accommodating individual circumstances (12)
		Delete entire recipes from the shopping list to accommodate feedback loops during the process (13)
		Delete single ingredients from the shopping list to allow for adjustments based on the circumstances (14)
		Marking ingredients as unavailable to enable the application to dynamically react to unforeseen circumstances (20)
		Adapt shopping list and create list of items to put back to dynamically react to changes in the environment (21)
		Suggestions to select an alternative recipe in case an obstacle was encountered, taking into consideration unavailable ingredients (22)
		Dynamic adaption of shopping list to accommodate new recipes while shopping (23)

The next step is then to evaluate the applications listed in Table 1 with respect to the features and the corresponding theoretical concepts indicated in Table 2. For each application/feature pair we determined if the feature is supported by the application or not. In cases where implemented features did not exactly match but tried to achieve similar outcomes to the features selected for this evaluation, partial support was considered and counted as ½. As a result, we created a matrix of applications and features, indicating how many features each application implements to support a specific aspect of the model. The matrix can be aggregated by "model concept", indicating the respective level of support across the spectrum of reviewed applications, as well as by "individual application", indicating the specific level of support provided by that application.

In summary the proposed evaluation methodology comprises four steps

- Select relevant applications (Table 1)

- Identify features in the selected applications and map them to the concepts of the behavioural model (Table 2)
- Determine the level of support for each application/feature pair resulting in a concept support matrix (Table 3)
- Aggregate the level of support by concept (Table 4)
- Evaluate individual applications with respect to concept support (Figure 2)

4 RESULTS

As a result of the applied method a matrix of applications and matching features was obtained (Table 3), with the colour coding in the table corresponding to the colour coding of the behavioural model (Figure 1).

Table 3 Model/feature support by the most popular food shopping and recipe applications

	Demands		Redefinition of the task							Goal-setting						Self-effic.		Feedback				Motivation		Environment						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	3	4	18	19	3	4	12	13	14	20	21	22	23
Cookpad - Create your own Recipes							(✓)[1]		✓								✓													
Tasty	✓	(✓)[2]	✓[3]		✓		(✓)[1]		✓								✓	✓[3]				✓[3]								
Yummly Recipes & Shopping List		(✓)[2]	✓[3]		✓		(✓)[1]	✓	✓	✓		✓	✓	✓	✓		(✓)[4]	✓[3]				✓[3]		✓	✓	✓				
Allrecipes Dinner Spinner	✓	(✓)[2]	✓[3]		✓	(✓)[5]	✓	✓	✓	✓	(✓)[6]	✓		✓	✓	(✓)[7]	✓	✓[3]				✓[3]		✓		✓			(✓)[8]	
Cookbook Recipes	✓	(✓)[2]			✓		(✓)[1]	✓	✓	✓			✓	✓	✓	✓	✓								✓	✓				
myTaste Recipes							(✓)[1]		✓								(✓)[4]													
My CookBook Recipe Manager			✓[3]				✓	(✓)[9]	✓	(✓)[10]			(✓)[10]	✓	✓	(✓)[7]	✓	✓[3]				✓[3]			(✓)[10]	✓				
BigOven Recipes, Meal Planner, Grocery List & More	✓	(✓)[2]	(✓)[3,9]		✓	✓	✓	(✓)[9]	✓	✓	(✓)[6]			✓	✓	(✓)[7]	✓	(✓)[3,9]				(✓)[3,9]				✓				
Kitchen Stories - Recipes & Cooking	✓	(✓)[2]	✓[3]		✓		✓		✓	✓			✓	✓	✓	✓	✓	✓[3]				✓[3]			✓	✓				
Mealime - Meal Planner, Recipes & Grocery List	✓	(✓)[2]	(✓)[3,9]		✓		✓	✓	✓	✓	✓			✓	(✓)[11]	(✓)[12]	✓	(✓)[3,9]				(✓)[3,9]				✓				
Easy Recipes					✓		✓	✓	✓	✓			✓	✓			✓			✓					✓	✓				
Salad Recipes FREE	✓[13]	(✓)[13]			✓		(✓)[1]	✓	✓	✓			✓	✓	✓	✓	✓								✓	✓				
Recipe book: Recipes & Shopping List		(✓)[2]			✓	✓	✓		✓	(✓)[10]		✓	(✓)[10]	✓		(✓)[7]	✓							✓	(✓)[10]	✓				
Food Planner							(✓)[14]	✓		✓				✓	✓		(✓)[4]									✓				
All Recipes Free - Food Recipes App					✓				✓	(✓)[10]		✓		✓			✓							✓		✓				
Quick and Easy Recipes					✓											(✓)[7]	✓													
Magic Fridge: Easy recipe idea and anti-waste		✓[15]	✓			✓	(✓)[16]		✓						✓	(✓)[12]	✓	✓				✓					✓		✓[17]	
All free Recipes : World Cuisines			✓		✓	✓	(✓)[1]		✓	(✓)[10]		✓	(✓)[10]	✓				✓				✓		✓	(✓)[10]	✓				
Cake Recipes FREE					✓		(✓)[1]	✓	✓	✓			✓	✓	✓	✓	✓								✓	✓				
Recipes Home - Free Recipes and Shopping List			✓		✓		✓		✓	✓		✓		✓			✓	✓				✓		✓		✓				
Chicken Recipes							(✓)[1]		✓	(✓)[18]				✓			✓									✓				
Diet Recipes					✓		✓	✓	✓	✓			✓	✓			✓			✓					✓	✓				
Healthy Recipes	✓	(✓)[2]	✓		✓	✓	(✓)[1]		✓	(✓)[10]		✓	(✓)[10]	✓				✓				✓		✓	(✓)[10]	✓				
Rice Recipes : Fried rice, pilaf			✓		✓	✓	(✓)[1]		✓	(✓)[10]		✓	(✓)[10]	✓				✓				✓		✓	(✓)[10]	✓				
FitMenCook - Healthy Recipes	✓	(✓)[2]	✓		✓		✓		✓	✓[9]		✓[9]		✓	✓		✓	✓				✓		✓[9]		✓				
Lunch Recipes			✓		✓	✓	(✓)[1]		✓	(✓)[10]		✓	(✓)[10]	✓				✓				✓		✓	(✓)[10]	✓				
Salad Recipes: Healthy Foods with Nutrition & Tips	✓		✓		✓	✓	✓	✓		✓	✓		✓	✓			✓	✓				✓			✓	✓	✓		(✓)[8]	

1. Only searches keyword in recipe title
2. Vegetarian and/or vegan option available
3. Estimated based on serving size
4. Forwarding to instructions on external web page
5. Browse by ingredient category
6. No unified ingredient naming
7. Preparation time
8. Exclude ingredients from search
9. Only in premium version
10. One shopping list per recipe only
11. Adapt amount only for all recipes simultaneously
12. Database only contains easy recipes
13. Salads only
14. Manually import recipes from internet
15. Dynamic adaption of recipes to minimize food waste
16. Search only for ingredients
17. Recipes are adapted to accommodate missing ingredients
18. One recipe only

In summary, aggregating the data from Table 3 the following level of support for each of the concepts of the model can be observed across all the surveyed applications (see Table 4).

Table 4 Feature support for each concept

Concept in model	#	%
Demands	14.5	27%
Redefinition of the task	91.5	48%
Goal-setting	73.5	45%
Self-efficacy	29	54%
Feedback	11	10%
Motivation	9	17%
Environment	45	24%

Finally, we evaluated individual applications by determining how many features mapped to a particular concept are supported by each. The results derived from Table 3 are presented for the most popular applications (>5M installations) in Figure 2 as spider graphs. Such an approach can help to reflect how well different applications support healthy and sustainable food shopping. The graphs (Figure 2) reveal that there is no general observable trend and that popularity of an application (e.g. Cookpad, which is the one with the most installs) does not imply broad support of relevant features with respect to healthy and sustainable behaviours.

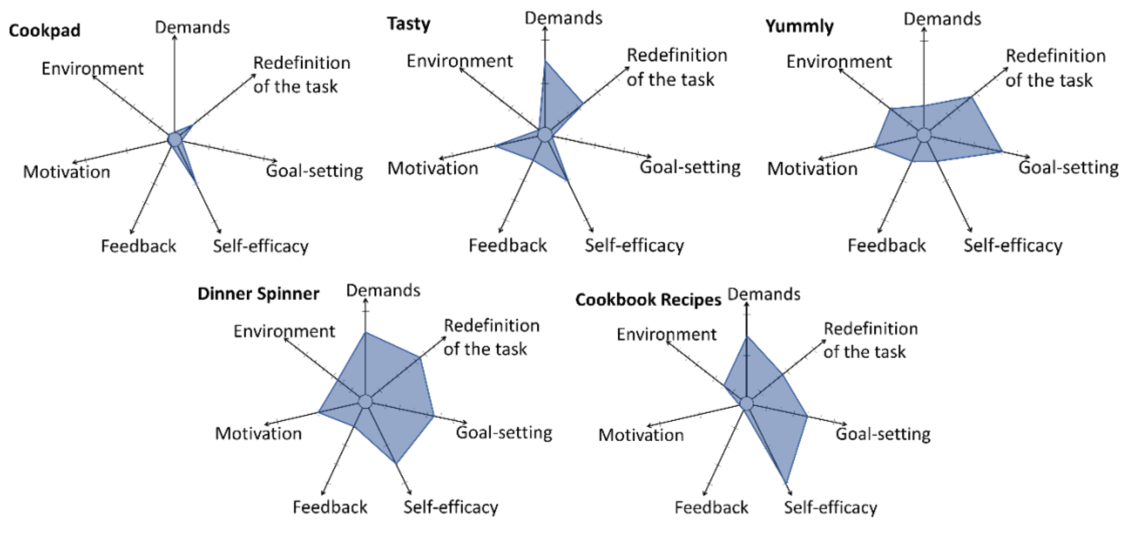

Figure 2 Spider graphs of features supporting a healthy and sustainable diet for the 5 most popular applications on the Google Play store.

5 Discussion

While all concepts of the model are supported by some of the reviewed applications, the level of support is not evenly spread. Features relating to feedback as defined by the behavioural theories is supported least (10%), which is most likely explained by the fact that the provision of individualised feedback on health and sustainability applications would necessitate the implementation of dedicated and consolidated product databases containing nutrition and carbon footprint information, which are not cost-effective to include into a commercially viable product. Open databases (Gray, 2014) could provide a cost-effective means for app developers to improve this aspect, and they exist for nutrition (U.S. Department of Agriculture, 2021); however, we are not aware of a similar extensive and openly available platform for sustainability information. In contrast, self-efficacy is well-supported (54%), which again is potentially explained by the more readily available information, that can be reliably and cost-efficiently crowd-sourced, such as recipes, comments, and likes. We observed that most of the mobile applications reviewed commonly depend on such user generated data (Krumm, Davies, & Narayanaswami, 2008), which, however, often is not usable for precise feedback due to lack of accuracy (Lukyanenko, Parsons, & Wiersma, 2014), and which is challenging to translate into reliable knowledge representations (Hitzler, 2021).

Furthermore we noted, that the features specific to a healthy diet (1,3,18) are supported by 33%, 33%, and 7% of the reviewed applications, whereas the features specific to a sustainable diet (2,4,19) are only supported by 20%, 0%, and 0%, indicating that health currently appears more relevant than sustainability to application developers and users. This is consistent with the findings of Biasini et al. (Biasini, et al., 2021), who point out that health is a much more prevalent subject than sustainability concerning dietary behaviour.

Popularity of an application does not necessarily mean broad support of health and sustainable grocery shopping behaviours, which can be explained by the fact that different applications focus on different features and, therefore, support different aspects of the behavioural model. None of the reviewed applications was designed explicitly to include relevant concepts from the behavioural model depicted in Figure 1; for example the most popular application ("Cookpad") shows very little similarities in this regard (cf. Figure 2, top-left). This is due to the fact that its main focus is on sharing recipes with others and not on supporting the individual's grocery shopping behaviour. The "Dinner Spinner" application on the other hand shows a much greater overlap (cf. Figure 2, bottom-left), indicating a better focus on supporting the behaviour in question with regards to health and sustainability.

The presented methodology for assessing the support of model concepts by the applications is related to the Heuristic Evaluation approach (Wilson, 2014), which analyses applications by identifying usability problems with respect to a pre-determined set of heuristics. The development of usability heuristics is often ad-hoc and domain specific, although there have been attempts to standardise this process (Quiñones, Rusu, & Rusu, 2018). We advocate the use of well-established and empirically validated behavioural models (Strong, Parks, Anderson, Winett, & Davy, 2008; Phipps, et al., 2013; Selden & Brewer, 2000; Borgogni & Dello Russo, 2012; Hörisch, Wulfsberg, & Schaltegger, 2020) to formalise the choice of evaluation criteria with respect to behaviour relevant support aspects to supplement the usability criteria used in UX design processes (Nielsen, 1994; Nielsen Norman Group, 2021).

6 LIMITATIONS

Commercial considerations are the main driver for application development. Optimal support for (desired) behavioural outcomes (e.g. healthy and/or sustainable behaviour) is, therefore, not at the forefront of the design process, and feature development is guided by the availability of data and ease of implementation. The criteria used for selecting the applications in the current review are based on popularity. Assuming that the selection of applications installed and maintained constitutes a voting mechanism on the perceived usefulness of these applications by the users, it does not necessarily show how successful the applications are with respect to positively influencing behaviour. For example, the most popular application (cf. Figure 2, top-left) shows very little support for the behavioural concepts considered in this work, as it is focusing on social networking aspects and not on positively influencing the behaviour towards a healthy and sustainable diet.

The mapping of application features to the behavioural concepts of the model allows for a certain level of ambiguity. Furthermore, it is domain specific and will have to be adapted accordingly each time the proposed methodology is applied to a new area. For instance, as very few applications are targeting sustainable behaviour, there is very limited support observed in this domain; vegetarian/vegan options within the application were included in the survey, even if the motivation for choosing such a diet can be unrelated to sustainability.

Additional quality criteria, such as usability, low-barrier access, cost efficiency or trust were beyond the scope of the presented work despite their crucial importance to ensure the success of any application. By limiting the analysis to applications with >1M installs it can be assumed, however, that minimum quality standards are met. Nevertheless, the potential influence on popularity has not been part of this analysis.

7 CONCLUSION

We propose a model-based approach that gives the opportunity to analyse the available features offered by recipe and food shopping smartphone applications in the context of behavioural and motivational theories. In this review we can show how features of the most popular recipe and grocery shopping applications can be mapped to aspects of a rigorous behavioural model, and how this can be used to quantify which aspects of the model are supported by each application. Strengths and weaknesses of applications can be identified with regards to positively supporting the cognitive and motivational processes underpinning the behaviour.

Furthermore, it is possible to see which features are missing, but are relevant to support certain behaviour in the context of healthy and sustainable grocery shopping. This can help to understand which aspects need to be substituted or supported by other means or what features should be implemented in existing applications.

This methodology facilitates the use of behavioural models and theories for the design and development of applications, that aim at improving and eliciting desired behaviours.

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