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An analysis of physical activity coping plans: mapping barriers and coping strategies based on user ratings

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ABSTRACT

Introduction: Personalising recommendations for physical activity coping plans can help bridging the physical activity intention-behaviour gap. Data-driven 'black-box' approaches result in recommendations that prove difficult to explain, and may have undesired consequences. This study aimed to explicitly link barriers and coping strategies using end-user input.

Method: 152 participants (85 female) took part in an online task. Participants were asked to judge the relevance of coping strategies for barriers to physical activity, and under which circumstances coping strategies were relevant for a given barrier. Data was aggregated and heat maps were produced. Necessary conditions for the relevance of each combination were coded and their frequencies were reported.

Results: Relevance of 1570 combinations of barriers and coping strategies were assessed, with 2 combinations rated 'always relevant' by all participants, and 37 combinations rated as 'always relevant' by no participants. Barriers differ strongly in how many coping strategies are relevant for them, and coping strategies differ strongly in how many barriers they are relevant for. Resulting aggregates concerning the average rating as 'never relevant', 'always relevant' and 'relevant under certain conditions' are shared for each barrier coping strategy combination, as are the conditions associated with different barriers and coping strategies.

Discussion: This study introduces a novel method to create rules for recommendations using input from stakeholders. The datasets created throughout this research are available for re-use in future research, as well as for clinical practice and (digital) intervention development. This data can be used as a base for explainable personalised recommendations for physical activity coping plans.

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Introduction

Reducing physical inactivity is an effective way to improve population health by decreasing risks of non-communicable diseases and all-cause mortality (Warburton & Bredin, 2017). While many people have an intention to be more active, they often fail to translate this into behaviour; we call this the physical activity intention-behaviour gap (Rhodes & de Bruijn, 2013). Planning can help to bridge this gap (Sniehotta, Scholz, et al., 2005). We typically divide planning into two kinds: action planning (i.e. what someone is planning to do when, where and with whom) and coping planning (i.e. what barriers could occur, and how we could cope with these) (Schwarzer, 2008). However, planning is often experienced as effortful by users (Degroote et al., 2020; Osch et al., 2010), and user-created plans are often of poor quality (De Vet et al., 2011). In particular, the creation of coping plans is experienced as challenging (Degroote et al., 2020). Personalised recommendations can help decrease user burden and increase plan quality (Degroote et al., 2020), but are not straightforward to implement. While this kind of support could be provided in one-on-one consultations with healthcare providers, regularly attending such sessions is not feasible for most individuals due to time, resource and staff constraints, especially in the context of primary preventions.

Automatically creating relevant recommendations for use in digital interventions is a promising avenue for making support more accessible compared to traditional one-on-one consultations. However, to generate relevant recommendations for physical activity action and coping plans, we need to understand which coping plans are relevant under which circumstances. There are multiple approaches to automatically create recommendations. For example, recommender systems use data-driven machine learning approaches that provide personalised recommendations to users based on their past behaviours, or based on the behaviours of similar users (Lü et al., 2012). These approaches can utilise large amounts of data to achieve personalised recommendations. Typically, these algorithms are able to take into account the effects of many variables in interaction with each other, in a way that is often not possible or comprehensible for humans (Zhang et al., 2020), resulting in recommendations that are most likely to be carried out. One of the main problems with these systems is the 'black-box approach' (Loyola-Gonzalez, 2019; Vayena et al., 2018). While we know the input for the algorithm and its output, the underlying reasoning remains unknown. This can result in reinforcing problematic existing patterns, such as by recommending household chores primarily to women (Schroé et al., 2022).

There are calls for a 'white-box', explainable approaches (Loyola-Gonzalez, 2019). These approaches aims to combine rules based on domain knowledge with data-based methods typically used in machine learning. In the context of physical activity plans, these rules can result in a complex network of information. This becomes more complex when providing recommendations for both the action plan and the coping plan.

Little research exists to guide the creation of such 'white-box' personalised recommendations. Most of the research focuses on when individuals engage in physical activities (Jinhyuk et al., 2020; Liao et al., 2015). There are some studies about who plans and performs what kind of activities (Beenackers et al., 2012; Braun, Schroé, Van Dyck, et al., 2024; Cusatis & Garbarski, 2019), and in which circumstances people create what kind of plans (Braun, Schroé, Van Dyck, et al., 2024). However, to create relevant recommendations, we also need to know how the different aspects of each plan relate to each other. For example, some coping strategies (e.g. 'splitting up the activity into multiple smaller activities') are only relevant for a subset of action plans and barriers (e.g. only relevant if the barrier is time-related and the activity allows to be split up). Some of these relationships are of logical nature (e.g. care responsibilities are only a barrier to those that have care responsibilities). However, many others are context-dependent and sometimes unexpected. For example, 'it might rain' can be a barrier even for an activity planned indoors if relocation is required.

Beyond data-driven research on which coping strategies are relevant for which barriers, information provided by domain experts and end-users may prove valuable in a white-box approach (Ongenae et al., 2014). In our use case, healthcare providers or other experts on physical activity can offer insights into different coping strategies. Moreover, end-users can provide critical information on relevance, as they are more familiar with the implementation of physical activity plans, and what has and has not worked for them in the past.

Present study

The study aims to (1) create a basis for explainable rules for physical activity coping plans by linking barriers and coping strategies, and (2) describe conditions that are necessary for that connection to be relevant based on user input. To achieve this, we used lists of barriers and coping strategies from previous research (Braun, Schroé, De Paepe, et al., 2023; Braun, Schroé, Van Dyck, et al., 2024). In a first stage, expert input and literature research were used in order to create lists of relevant barriers and coping strategies, and identify preliminary relevant combinations of barriers and coping strategies. In a second stage, expert input was collected in two workshops. Finally, based on the identified combinations, end user input was collected via an online platform.

Materials and method

This study was pre-registered on osf (Braun et al., 2024).

Participants

Participants were recruited using prolific (app.prolific.com), a website that allows recruitment for online studies from a pool of participants. Participants needed to speak English and be older than 18 years, and had to be located in a Western European country, specifically Germany, Ireland, Andorra, France, Belgium, Netherlands, Monaco, Liechtenstein, Austria and Switzerland. We strived for an equal distribution of male and female participants. The study was estimated to take maximum 45 min, and participants were paid 7€ for valid participation. The study was approved by the ethics committee of the faculty of psychology and educational sciences at Ghent University (ID 2023-082). All participants provided informed consent.

168 participants finished the task, of which 152 (85 female, 2 non-binary) passed all attention checks (section 'Attention checks') and were included in analysis. This number was chosen so that each question would be answered by a minimum of 25

Table 1. Overview of participant characteristics.

Country of residence	Freq	Freq (%)	Age group	Freq	Freq (%)
United Kingdom	63	39	18–24	13	8
Netherlands	36	22	25–34	39	23
Germany	19	12	35–44	28	47
France	17	10	45–54	12	7
Ireland	10	6	55–64	10	6
Austria	6	4	65–75	2	1
Belgium	5	3			
Switzerland	4	2			
Mauritius	1	1	Education level	Freq	Freq (%)
Portugal	1	1	Doctoral degree or equivalent	8	5
Romania	1	1	Master's degree or equivalent	48	29
			Bachelor's degree or equivalent	53	32
			Post-secondary non-tertiary education	15	9
			Short-cycle tertiary education	7	4
			Upper secondary education	29	17
			Lower secondary education	6	4

participants, which we considered sufficient for the explorative purposes of this study based on previously suggested minimum numbers per combination (Simmons et al., 2011). Participants' age group, country of residence and education levels are described in Table 1.

Procedure

Before the study, participants received information on the study's aim, what participation involves, and received information concerning privacy and personal data. They were then asked for their informed consent.

Sociodemographic information regarding gender, age group, and highest level of education was collected in order to be able to describe the sample. This was followed by a questionnaire concerning relevant coping strategies for different barriers concerning physical activity plans. First, due to the complexity of the questionnaire, a training item was implemented. Here, participants were asked to rank two coping strategies, one of which was deemed to be clearly relevant, and the other one clearly irrelevant. If participants replied as expected, they could proceed to the questionnaire. If not, participants were asked if they were sure, and the expected answers were clarified. The instructions for the task were repeated, and participants could then proceed to the questionnaire, as described in the materials section.

Material

Preparational work

In order to create a list of potential barriers, we consulted (1) existing theory and classification systems, (2) researchers in the fields of behavioural sciences and physical activity promotion, (3) existing data on physical activity plans, and physical activity data, and (4) end users. For both barriers and coping strategies, we departed from coping plans that were created by university students in an 8-day diary study (Braun, Schroé, Van Dyck, et al., 2024). Open-text data was coded by the researchers. For the barriers, the code book was created from scratch based on the text data. For the coping strategies, we departed from the self-enactable techniques (Knittle et al., 2020), which has been shown to be a valuable starting point for such classification in previous research (Braun, Schroé, De Paepe, et al., 2023).

The resulting barriers were mapped to the Mechanisms of Action subontology (Schenk et al., 2022) and coping strategies mapped to the Behaviour Change Techniques subontology (Corker et al., 2022) of the Behaviour Change Intervention Ontology (BCIO, Michie et al., 2017), in dialogue with researchers from the BCIO. Definitions were added for each barrier and coping strategy that was not yet defined in the BCIO. The final list used in the current study contains 50 barriers and 64 coping strategies. Instances relevant to physical activity plans were created for each barrier and coping strategy.

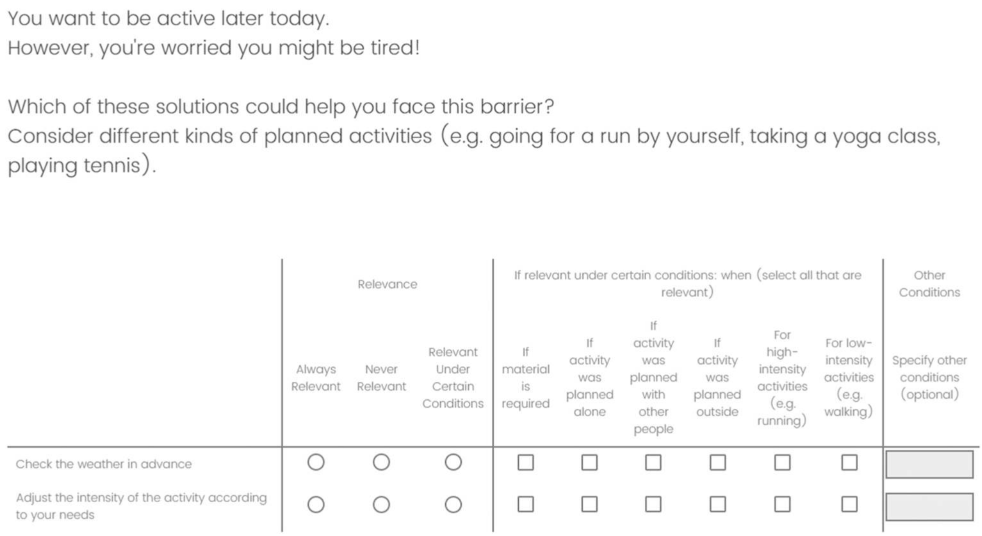
Due to the amount of barriers and coping strategies, it was not feasible to test each combination. When there was an obvious disconnect between a barrier and coping strategy (e.g. 'material might be broken' as barrier and 'check the weather in advance' as coping strategy), these combinations were deemed irrelevant for further investigations. In order to determine this, expert workshops were conducted; six researchers working in physical activity research, representing both a health psychological and medical science perspective, took part in a 2-h workshop linking coping strategies to barriers of physical activity. Then, data from previous studies (Braun, Schroé, Van Dyck, et al., 2024) and the theories and techniques tool (Human Behaviour Change Project, 2018) was consulted. Last, four members of the research team (GC, ADP, FDB, MB) independently judged the relevance of coping strategies in a template based on the information extracted from the different sources of information described above. Exclusion was done conservatively, as to not exclude potentially relevant combinations. In the end, a total of 1093 combinations were deemed relevant to test.

Task implementation

The online task was implemented using Qualtrics (https://www.qualtrics.com/uk/), and participants were asked to submit their answers from a desktop computer only – not from mobile phones or tablets. This was done to ensure that questions were shown as intended on the participant's screen.

Questions were structured as follows: first, participants were provided with a scenario. For most barriers, the plan was 'You want to be active later today'. However, if barriers were only relevant to specific plans (e.g. 'rain' is only a relevant barrier for plans outdoors, 'my activity partner might cancel' is only a relevant barrier for plans together with another person), this was included in the plan (e.g. 'You want to be active with a friend later today'). Participants were then asked to indicate which coping strategies might help them face the barrier. They were prompted to consider different kinds of activities, and were provided with some examples that differed in intensity, social context (alone vs not alone), location (indoors vs outdoors) and required materials (nothing required vs something required).

Within each question, participants were provided with 10 coping strategies. They were then asked to rate the relevance of the coping strategy for the barrier (Always Relevant, Never Relevant, Relevant Under Certain Conditions). They could further choose which conditions need to be met for the coping strategy to be relevant ('If material is required', 'If activity was planned alone', 'If activity was planned with other people', 'If activity was


You want to be active later today.
However, you're worried you might be tired!

Which of these solutions could help you face this barrier?
Consider different kinds of planned activities (e.g. going for a run by yourself, taking a yoga class, playing tennis).

	Relevance			If relevant under certain conditions: when (select all that are relevant)						Other Conditions
	Always Relevant	Never Relevant	Relevant Under Certain Conditions	If material is required	If activity was planned alone	If activity was planned with other people	If activity was planned outside	For high-intensity activities (e.g. running)	For low-intensity activities (e.g. walking)	Specify other conditions (optional)
Check the weather in advance	○	○	○	☐	☐	☐	☐	☐	☐	
Adjust the intensity of the activity according to your needs	○	○	○	☐	☐	☐	☐	☐	☐	

Figure 1. Example question from the questionnaire.

planned outside', 'For high-intensity activities', 'For low-intensity activities'). They could also enter different conditions in an open text field. An example of a question is shown in Figure 1.

If a barrier had more than nine coping strategies deemed relevant by the expert panel, it was separated into multiple questions. For example, if a barrier had 24 relevant coping strategies, it was separated into 3 questions with an equal amount of relevant coping strategies. Coping strategies deemed irrelevant by the expert panel were then added to each question until it contained 10 items. Any set of coping strategies contained at least one strategy that was assumed to be irrelevant. Thus, if a barrier had 19 relevant coping strategies, it was separated into three questions rather than two. This was done to help participants differentiate between relevant and irrelevant items.

This resulted in a total set of 157 questions, each containing one barrier and ten coping strategies. These questions contained a total amount of 1570 barrier – coping strategy combinations, of which 1093 were deemed relevant by researchers. Each participant was presented with a random set of 25 questions in order to keep the task feasible. Multiple questions concerning one barrier but different coping strategies could be presented to one participant.

Attention checks. Attention checks were added to ensure high quality of the results. First, a question in the same format as the remaining questions was asked, with the instructions to fill in 'Always relevant' for each coping strategy. Second, participants were directly asked how much attention they gave the study (ranging from 'very little attention' to 'my full attention') and whether they consider their answers to be relevant for the study (yes/no). For the latter two questions, participants were informed that their reimbursement did not depend on the answer to the question.

User testing. The task was tested by multiple friendly users in order to improve clarity and finalise the length of the task. No further piloting with the target group was carried out.

Data processing and analysis

Data processing

Data of participants was removed if participants indicated that their data would not be useful for analysis (n = 3), participants indicated that they had not paid sufficient attention to the task (n = 8), participants did not pass attention tests throughout the tasks (n = 5) or participants provided answers to less than 80% of the questions (this was never the case). Out of 168 participants, data of 152 participants was included in analysis. Open text entered under 'Other conditions' was coded by one of the researchers (MB). Codes were created iteratively.

Data analysis

Analysis is primarily descriptive. Relevance is depicted as relative occurrence of the categories 'Always relevant', 'Relevant under certain conditions' and 'Never relevant' for each barrier – coping strategy combination. Average relative frequencies as well as standard deviations were calculated for each barrier and each coping strategy. Heatmaps with barriers on the y-axis and coping strategies on the x-axis were created, depicting the relative frequency of 'Always relevant' ratings. Both barriers and coping strategies were further divided into subgroups in order to provide an easier overview of the heatmap. Barriers were divided into (1) barriers concerning behavioural opportunity, e.g. having access to facilities, usable materials or space, (2) barriers concerning bodily and affective feelings, e.g. pain, feeling tired or hunger, (3) barriers concerning capability, e.g. physical skill, time management capability, and (4) barriers concerning motivation, beliefs and goal conflict, e.g. unexpected goal conflict for time or evaluative belief about sweating due to physical activity. This categorisation is based on classes in the mechanisms of action ontology (Schenk et al., 2022), though some categories were merged. Coping strategies were divided into (1) strategies reviewing the behavioural plan, e.g. adapting the intensity or moving the activity indoors, (2) strategies concerning social support, information and awareness, e.g. advice to seek emotional support or inform about health benefits, (3) goal directed strategies, e.g. advise goal integration or monitoring, and (4) strategies that help prepare for an activity, e.g. appropriate sleep or prepare the required material. This categorisation is based on parent classes in the behaviour change techniques ontology (Corker et al., 2022), though some categories were further divided or merged to create roughly evenly divided groups.

User ratings of coping strategies that were deemed relevant and irrelevant by researchers before data collection were compared in Welch t-tests by comparing relative frequencies of 'Always relevant' and 'Never relevant' ratings, respectively.

For each coping strategy, frequency tables were created with counts of specified conditions. Co-occurring conditions were counted separately (e.g. if someone noted that a certain strategy was relevant 'If material is required' and 'If activity was planned alone', each of those categories got an additional count). Frequency tables were also created for each combination.

Results

Relevance of barrier – coping strategy combinations

Two combinations of coping strategies and barriers were deemed always relevant by all participants rating them ('remind myself of the positive effects doing this will have on my physical health' for 'feeling tired', and 'keep goal in mind' for 'I will not be able to focus during the activity'). Those combinations were also judged to be relevant by researchers. In contrast, 37 combinations were never rated as always relevant, eight of which were considered never relevant by 95% of participants. While four of these were considered irrelevant by researchers (e.g. 'I can't relocate due to other responsibilities' – 'Take medication to help with the symptoms'), four were considered possibly relevant by experts (e.g. 'it is too dark' – 'find social support in a pet'). No combination was rated as 'Relevant under certain conditions' by all participants. The combination 'Pain' and 'Shorten activity' has most such ratings with 74% of participants. 81 combinations were never rated as 'Relevant under certain conditions'. Some combinations have highly divided ratings, e.g. 'Keeping track of my activity using a device, such as a fitness tracker' was rated as always relevant for the barrier 'feeling embarrassed' by 55% of participants, and as never relevant by the remaining 45% of participants.

A detailed table of each combination and the respective counts of 'Always relevant', 'Relevant under certain conditions' and 'Never Relevant', as well as a total count and relative frequencies, can be found on osf.[1] Heatmaps of the relative frequency that combinations of barriers and coping strategies were rated 'Always relevant' can be found in Figure 2 for Coping strategies that are goal directed, Figure 3 for Coping strategies where one prepares for the activity, Figure 4 for Coping strategies where the activity is adapted and Figure 5 for Coping strategies concerning social support and information and awareness.

Overall, we found that some strategies are rated as always relevant more often than others. For example, 'advise to keep behavioural goal in mind', 'increase the salience of emotional consequences' or 'advice to pace activity' are on average rated as always relevant 75%, 75% and 67% of times, respectively. In contrast, 'make a goal public', 'plan inclusion of audiovisual media' and 'advice to seek emotional support' are on average considered relevant only 13%, 14% and 17%, respectively.

Comparison of researcher and end-user judgement

Coping strategies that were determined to be relevant by researchers were more often rated as 'Always relevant' than those that were not determined as relevant by researchers, as can be seen in Figure 6. Relatedly, those who were deemed irrelevant were rated as 'Always relevant' 33.46% (SD = 20.35%) on average while those that were relevant were rated as 'Always relevant' 50.45% (SD = 24.11%) of times. This difference was significant with a $t(68) = -13.29$, $p < .01$. Coping strategies that were deemed irrelevant by the researcher group were more often rated as 'Never relevant' with an average of 47.53% (SD = 19.91%) compared to coping strategies that were considered relevant with an average of 30.14% (SD = 22.46%) as can be seen in Figure 6. This difference is significant with $t(653) = 14.09$, $p < .01$. However, there was overlap between the groups, as can be seen in Figure 6.

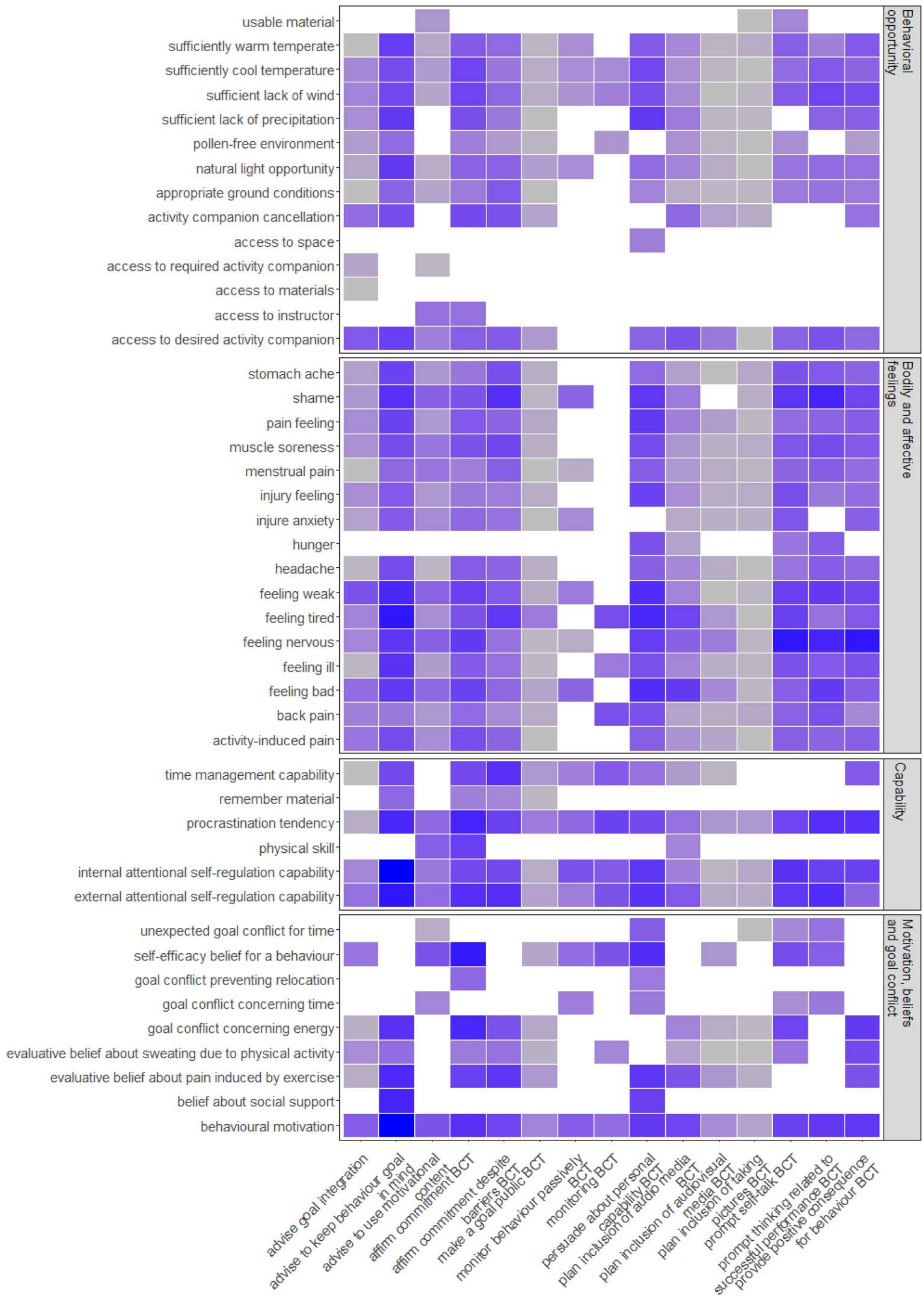


Figure 2. Heat map of relative frequency of 'Always relevant' ratings for goal-directed coping strategies (x-axis) for different barriers (y-axis). Note: Gradient from grey to blue indicates relative frequency of 'Always relevant' answers, with blue indicating maximum frequency. White fields are combinations that have not been tested.

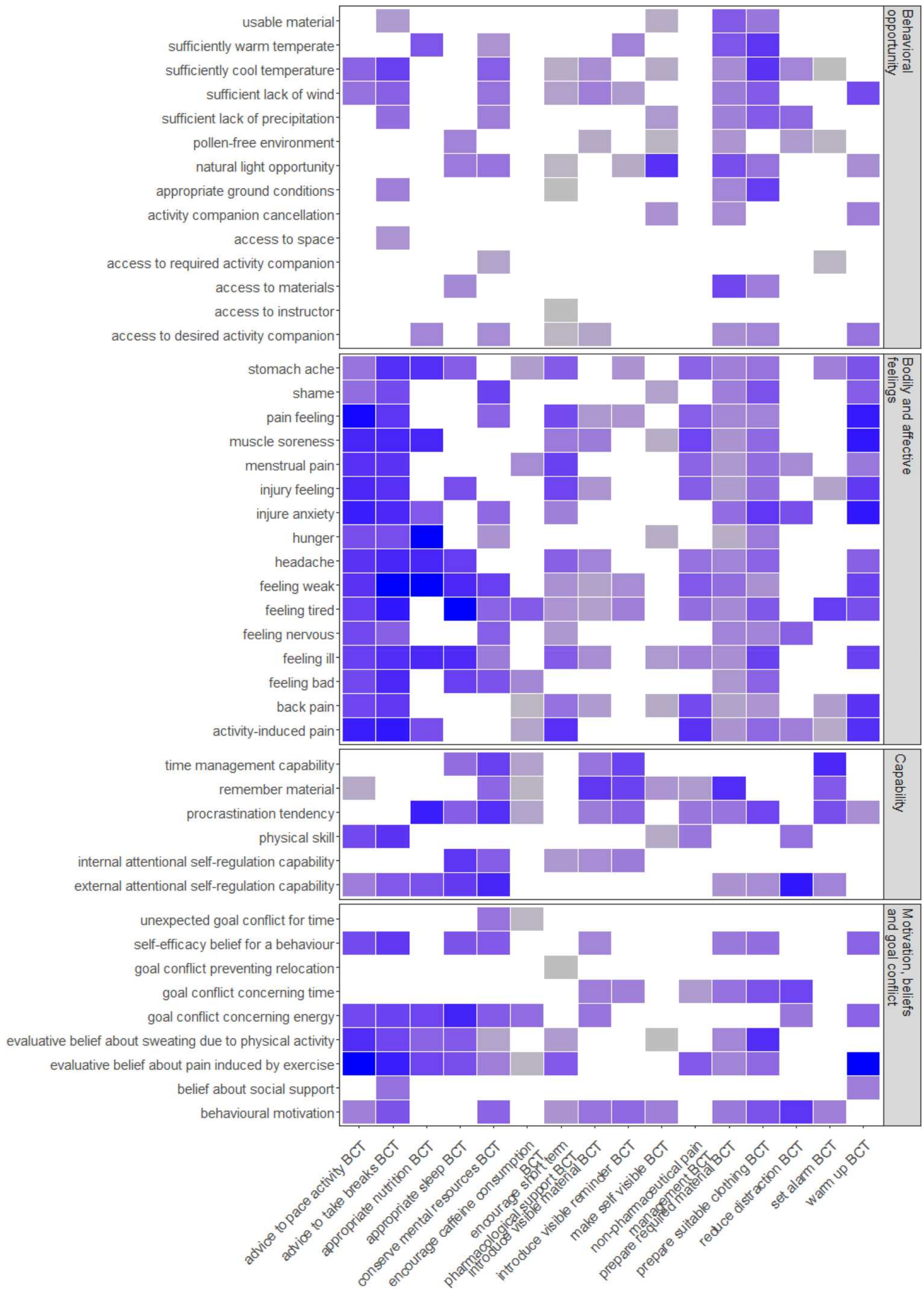


Figure 3. Heat map of relative frequency of 'Always relevant' ratings for coping strategies used to prepare for an activity. (x-axis) for different barriers (y-axis). Note: Gradient from grey to blue indicates relative frequency of 'Always relevant' answers, with blue indicating maximum frequency. White fields are combinations that have not been tested.

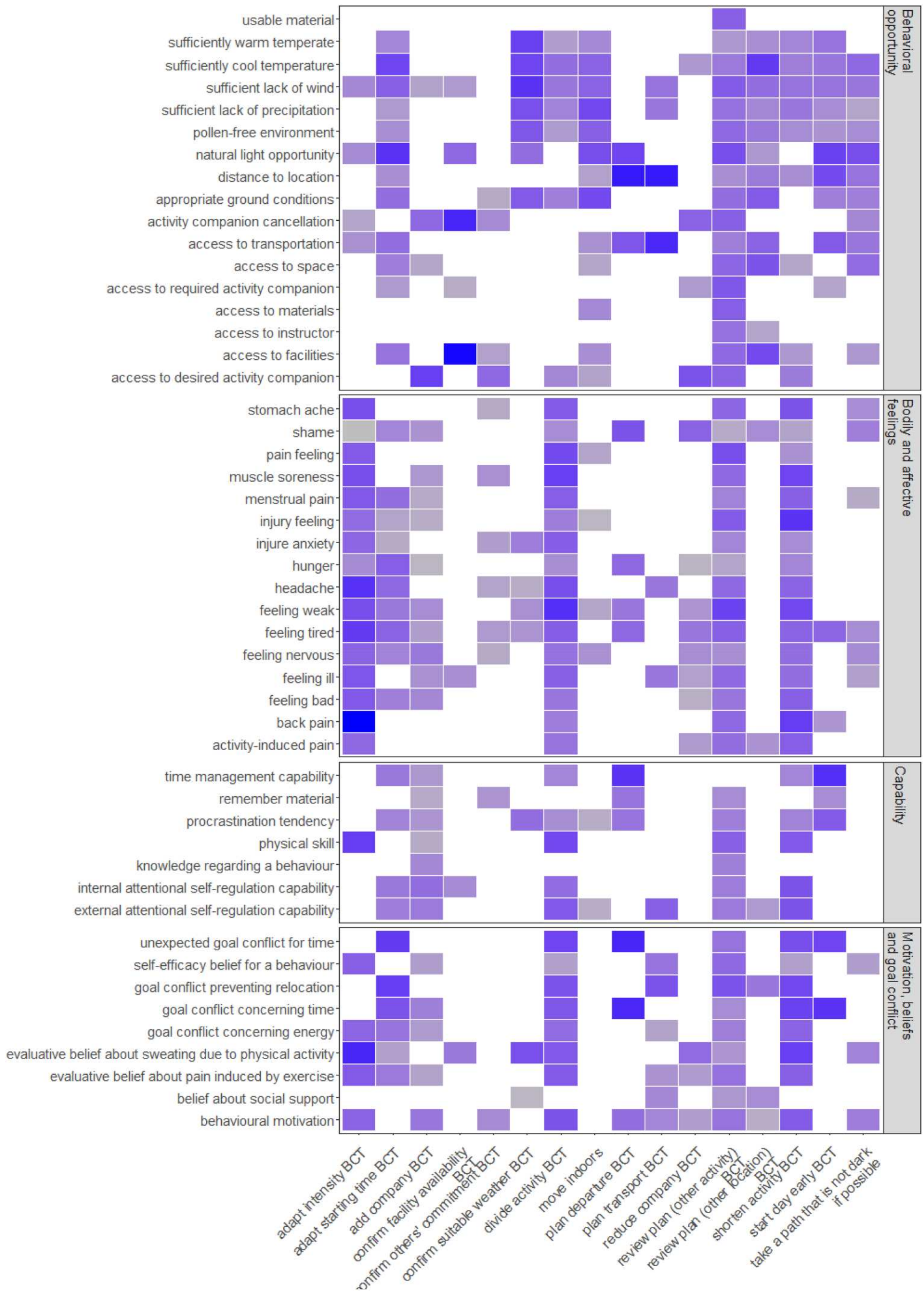


Figure 4. Heat map of relative frequency of 'Always relevant' ratings for coping strategies that adapt the activity (x-axis) for different barriers (y-axis). Note: Gradient from grey to blue indicates relative frequency of 'Always relevant' answers, with blue indicating maximum frequency. White fields are combinations that have not been tested.

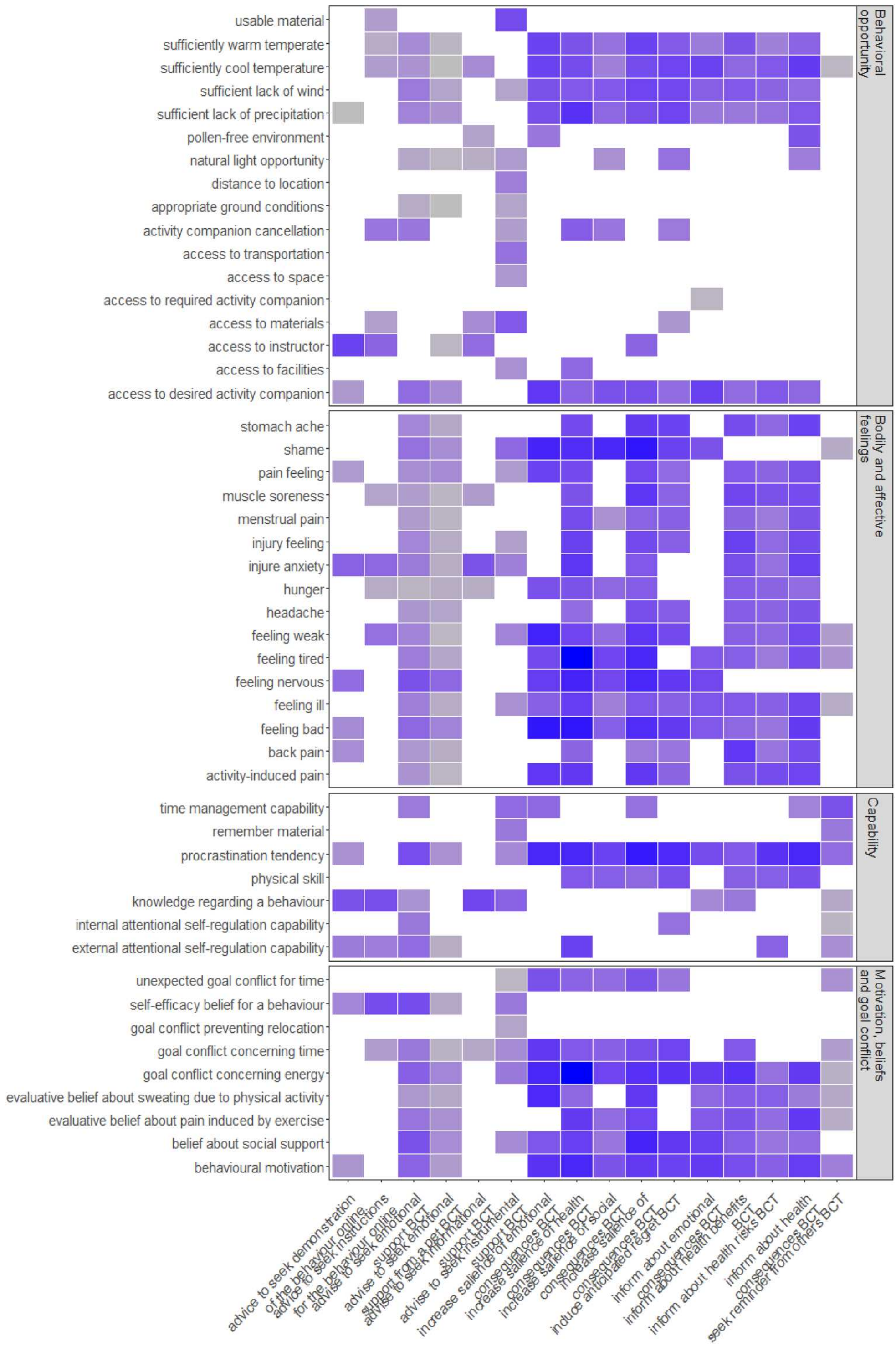


Figure 5. Heat map of relative frequency of ‘Always relevant’ ratings for coping strategies related to social support, information and awareness (x-axis) for different barriers (y-axis). Note: Gradient from grey to blue indicates relative frequency of ‘Always relevant’ answers, with blue indicating maximum frequency. White fields are combinations that have not been tested.

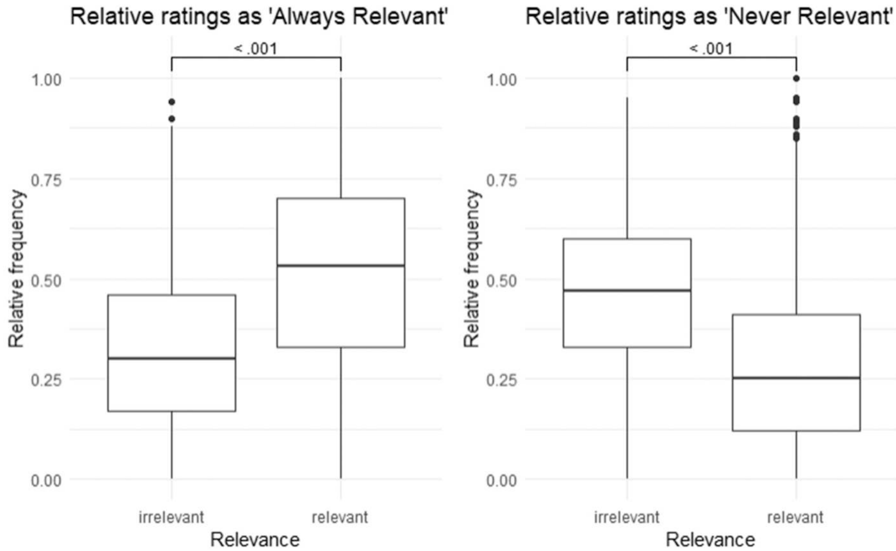


Figure 6. Relative frequencies of 'Always relevant' and 'Never relevant' ratings by end-users (y-axis) depending on pre-determined relevance by researchers (x-axis).

Conditions for each coping strategy

For each coping strategy, possible conditions under which the combination is relevant were examined. A full table of conditions and counts per combination is available on osf (see Note 1), as well as a table of conditions for specific barrier – coping strategy combinations. Free text input was coded by MB as *other profile-related conditions* (e.g. 'Depending on the injury', 'If I have a pet'), *other activity-related conditions* (e.g. 'If the activity is long enough', 'If the workout is not going well'), *other conditions related to the implementation of the coping strategy* (e.g. 'Only long-term', 'If doing so serves as a distraction'), *other context-related conditions* (e.g. 'If it is not so hot that it gets dangerous', 'If there is a space available'). An overview of all codes that were used and their total frequencies, is provided in Table 2. Multiple choice options were used more than free-text options, with 'If activity was planned outside' being chosen most frequently. Conditions pertaining to one's own physical health, as well as the physical context were most frequently reported in the free text.

Table 2. Frequencies of conditions for relevance.

Condition	Freq	Rel. freq (in%)
Multiple choice conditions		
If activity was planned outside	6820	35.45%
If activity was planned alone	3179	16.53%
For high-intensity activities (e.g. running)	2437	12.67%
If activity was planned with other people	2406	12.51%
If material is required	2067	10.74%
For low-intensity activities (e.g. walking)	1778	9.24%
Free text answers		
Other profile	182	.95%
Other context	156	.81%
Other Activity	67	.35%
Implementation	49	.25%

Discussion

In this study, we created a set of relevant combinations of barriers and coping strategies in the context of coping plans for physical activity based on literature, data and expert-input. We then collected input from end-users on the relevance of these combinations. Participants provided their input based on abstract scenarios in an online task. Next to the relevance of particular coping plans to overcome barriers, we also requested participants to rate to what extent particular conditions were deemed necessary for coping strategies to work.

The primary outcome of this work is a rich dataset for reuse in (digital) interventions, containing detailed information on the relevance and conditions for each barrier – coping strategy combination. This dataset is openly available on OSF. When further exploring this dataset, we have come to four main conclusions. **First**, some combinations of barriers and coping strategies are consistently rated the same by most participants, with 95% of participants rating 14 combinations as 'always relevant' and 8 combinations as 'never relevant'. For other combinations, the relevance ratings varied between individuals. This indicates that some coping strategies are somewhat universal, while the relevance of others depends strongly on the individual. While we do not know what caused these differences, individual factors, such as age, activity level or personal preference, social factors, such as living situation or availability of people to be active with, and environmental factors, such as walkability of the neighbourhood, are likely candidates. Personalisation will be more strongly relevant for coping strategies that are only relevant for some individuals. Personalisation will be more strongly relevant for coping strategies that are only relevant for some individuals. *Second*, barriers differed strongly in the amount of relevant coping strategies, with some not having a single coping strategy that individuals consistently found relevant, and others having up to 13 highly relevant coping strategies. In the same vein, coping strategies differed in how many barriers they were considered relevant for, with some being rated as highly relevant for no barriers and others for up to 16 barriers. *Third*, to our surprise, some combinations that were considered irrelevant by the research team, and were implemented solely as a quality control measure were nevertheless rated as relevant by large amounts of end-users. *Fourth*, we identified conditions under which certain combinations would be relevant, which were related to the profile, activity, context, or the implementation of the coping strategy.

Our study is part of a broad strategy to develop a white-box approach to deliver personalised recommendations, allowing us to avoid reinforcing systemic patterns that reside in data. White-box approaches are explainable, in contrast to back-box approaches (Loyola-Gonzalez, 2019). Our results should be viewed as one piece of the jigsaw puzzle towards relevant recommendations. White-box approaches typically make use of different sources of information, integrating data, user-input and expert-input (Loyola-Gonzalez, 2019). As such, our results need to be complemented by additional input from researchers and medical professionals. Researchers could consult healthcare providers to gain insights into which coping strategies they consider the most appropriate, from a physical health perspective (e.g. personal trainers, physiotherapists), a mental health perspective (e.g. clinical psychologists, health psychologists), and a motivational perspective (e.g. behavioural scientists).

A challenge in our research was to keep the task feasible. Using the full set of combinations would result in 3200 questions. We finally dropped combinations that the research team evaluated as irrelevant, resulting in 1093 remaining combinations that were deemed relevant. These were then split into 157 questions, of which participants were randomly assigned 25 each. A different possibility would have been to select only the most frequently occurring barriers (e.g. lack of time, lack of motivation). However, this approach also limits knowledge and recommendations to the most frequent barriers, potentially restricting personalisation. Still another possibility is to make use of triangulation, including literature synthesis and expert consensus, in order to connect mechanisms of action and behaviour change techniques (BCT, Johnston et al., 2018). While the present study did incorporate existing datasets and expert input within preliminary work, future studies could take this one step further by input from actual users to arrive at a meaningful base for further recommendations.

Although our method has advantages, and provided a rich and meaningful set of relevant combinations and conditions, there are some issues to further consider. Most importantly, some barrier-coping strategy combinations that were considered irrelevant by the research team, were sometimes rated as highly relevant by participants. There are multiple possible explanations for this discrepancy.

First, due to the abstract nature of the task, explicit reasoning and decision making is required on the part of end-users. Providing additional support and instructions for the task, for example by providing a video where the context of the task is elaborated upon further, could help improve results of this task. Furthermore, conducting cognitive interviews (Beatty & Willis, 2007), potentially with end-users prior to data collection could help to make the task more easy and user-friendly. Alternatively, different approaches to exploring the relevance of barrier – coping strategy combinations can be considered. Knowledge about one's personal risk situations and the best way to deal with these are grounded in experience. The coping strategies are defined by interactions between individuals and their environment (Sniehotta, Schwarzer, et al., 2005). It may therefore be difficult to think about barrier – coping strategy combinations that participants potentially do not often experience. One option is to make use of diary studies where participants are to recollect the barriers they have faced and which coping strategies they used. Another option is to use intervention studies with action- and coping planning where participants choose a barrier and receive different suggestions for coping strategies. Relevance of coping strategies can then be investigated based on (1) user rating of relevance within the respective situation, (2) user selection in the moment of plan creation or (3) user evaluation of the coping strategy in the evening. While such methods have their own challenges, they can be a valuable addition to the current dataset.

Second, in some cases, participants seemed to interpret what is considered relevant differently than researchers. In one such example, the coping strategy 'making sure to eat well before and after, and time your meals appropriately' was considered as 'always relevant' by 88% of participants for the barrier 'I will procrastinate it'. Here, participants might have interpreted the barrier as a lack of motivation, and the coping strategy of appropriate nutrition to represent an additional commitment to the activity. However, when determining relevance, the research team mostly considered whether the solution (e.g. 'eating at appropriate times') would address the barrier (e.g. 'procrastination'), which we considered not to be the case. These findings could be due to the researchers' deeper understanding of the specific context for determining relevance (e.g. 'creating day-level coping plans for physical activity'), while participants might have had a broader perspective. A possible avenue to avoid this discrepancy is to align research and participant perspectives more strongly by providing additional context and support for the task. While we have provided instructions and examples in written form, this might have been insufficient. A different perspective is that the pre-selection by the researchers might not have been representative of how participants experience relevance for coping strategies. Future research could explore this by testing the full range of combinations, or making a more comprehensive selection of combinations. This could, for example, be done by involving a small group of participants in the initial selection process, and being even more conservative in excluding combinations from the study.

We aim to work towards a white-box solution of recommendations of coping plans for physical activities. One of the advantages of this approach is that it does not automatically reproduce the inherent biases that lie within the data in the resulting recommendations.. However, there may also be biases in our approach. As such, it is crucial to reflect upon the biases in our research process, so that we can counteract them where possible. Most importantly, the initial list of barriers and coping strategies used was also based on data collected in a primarily white, female, highly educated, healthy and young sample. We attempted to counter biases by having the researchers evaluate the appropriateness of coping plans for barriers using theory-based and experience-based arguments instead of evidence-based arguments. Also, an evaluation of the appropriateness was carried out by the research team. Our approach may be more explainable and may have reduced biases, but it does not guarantee that no biases are present. While we attempted to counteract these biases by involving multiple sources of information beyond data, ongoing critical reflection and revision remain warranted.

Implications for interventions

The results of the current study can inform interventions that use coping planning to promote physical activity. This can be implemented in various ways. Where researchers or healthcare providers create plans together with clients, or clients are asked to create plans from scratch, identified barriers can be matched with the list in order to find relevant coping strategies. The list can be expanded and adapted in clinical practice depending on the target population. For example, some barriers might be specific to particular clinical groups, e.g. 'low blood sugar' in individuals with diabetes, and have not been covered in the current study.

In digital interventions aiming to provide personalised recommendations for physical activity coping plans, this data can also be used to inform recommendations in a way that is human-understandable and informed by expert insights by integrating them in white-box models for coping plan recommendations (Loyola-Gonzalez, 2019). A digital intervention that uses coping planning can then use this knowledge to provide a set of recommendations for coping strategies to users once they have chosen an anticipated barrier. In this, coping strategies that were considered highly relevant for the barrier by the majority of participants should be given priority at first, and should be supplemented by those strategies that are more *divisive*, i.e. that have been rated as highly relevant by some users and as irrelevant by others. Using reinforcement learning, the intervention could then learn which strategies are relevant for a given user, and provide increasingly personalised recommendations for coping strategies. Similarly, the insights we have gained concerning conditions for the relevance of certain combinations can be used by taking aspects of the user profile, the action plan and the context into account when recommending coping strategies. In order to leave agency with the user, the user should then be able to either choose a coping strategy from the set of suggestions, or to create their own plan independently of the suggestions.

Limitations

This study has some limitations. First, the current study focused on input from individuals from the general adult Western European population. Due to our primary recruitment channel being Prolific, it is not certain that participants accurately represent the target population. This limits the generalizability of our findings. Second, some aspects of diversity, such as ethnicity, religion, or disabilities, have not been taken into account during recruitment. This is particularly important as we work with group aggregates for a majority of the conclusions in this study. Future research could expand upon this study by exploring how individuals from different sociodemographic groups, or other groups that might be relevant to physical activity barriers and coping strategies, such as those with different activity levels, rate the relevance of coping strategies for barriers differently. Third, the differences between relevant and irrelevant barriers and coping strategies were less pronounced than we had expected based on researcher input. Many combinations deemed irrelevant were not tested in this study, and we have thus no information on these combinations. Fourth, data collection procedure was only tested with friendly users, but not with members of the target group. Fifth, ratings were about relevance, which is not the same as effectiveness. We do not yet now which combinations are empirically effective. Designs to investigate effectiveness will require careful deliberation, as barriers cannot be assigned to individuals at random, and feasibility will need to be taken into account due to the large amount of combinations. Adaptations of micro-randomized trials (Klasnja et al., 2019) could be a valuable starting point to investigate this further.

Note

1. https://osf.io/qbpsu/.

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Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki and was approved by an Institutional Review Board/Ethics committee. See details under Methods. Data related to this manuscript is available on the Open Science Framework: https://osf.io/qbpsu/.

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