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Personalized Coalesced Model based on Multidimensional Healthy Behavior Index for Lifestyle Adaptation

PhD. Public Defense Presentation

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Agenda

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  - Motivation
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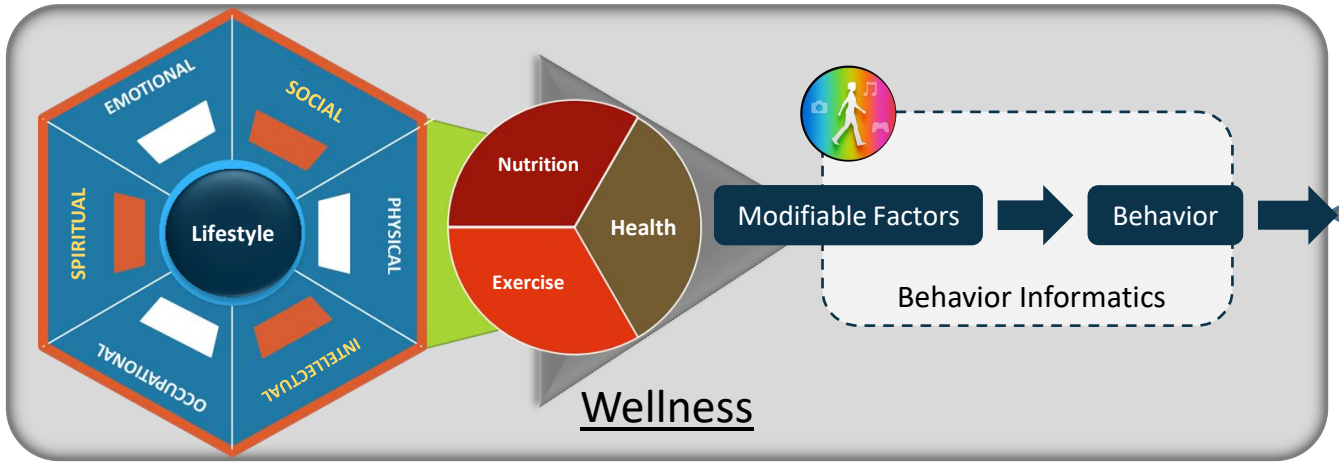
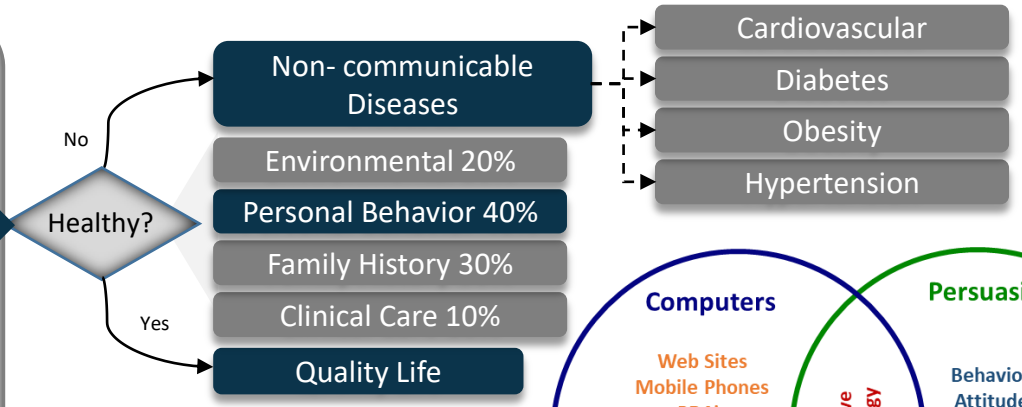
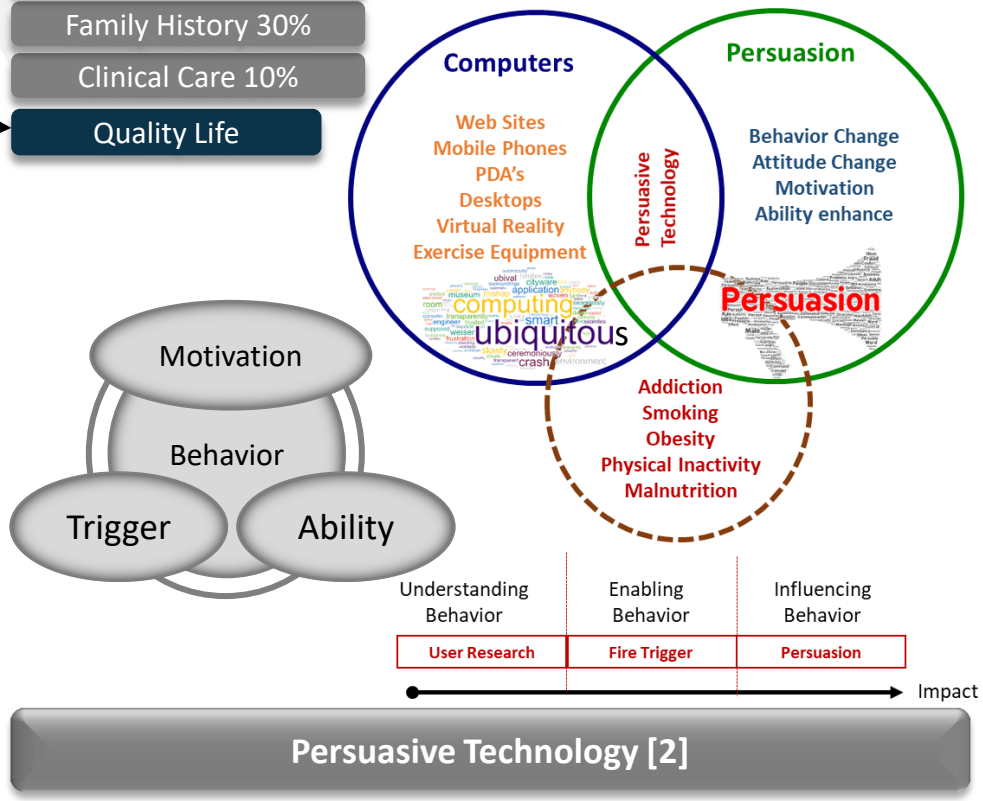
Introduction



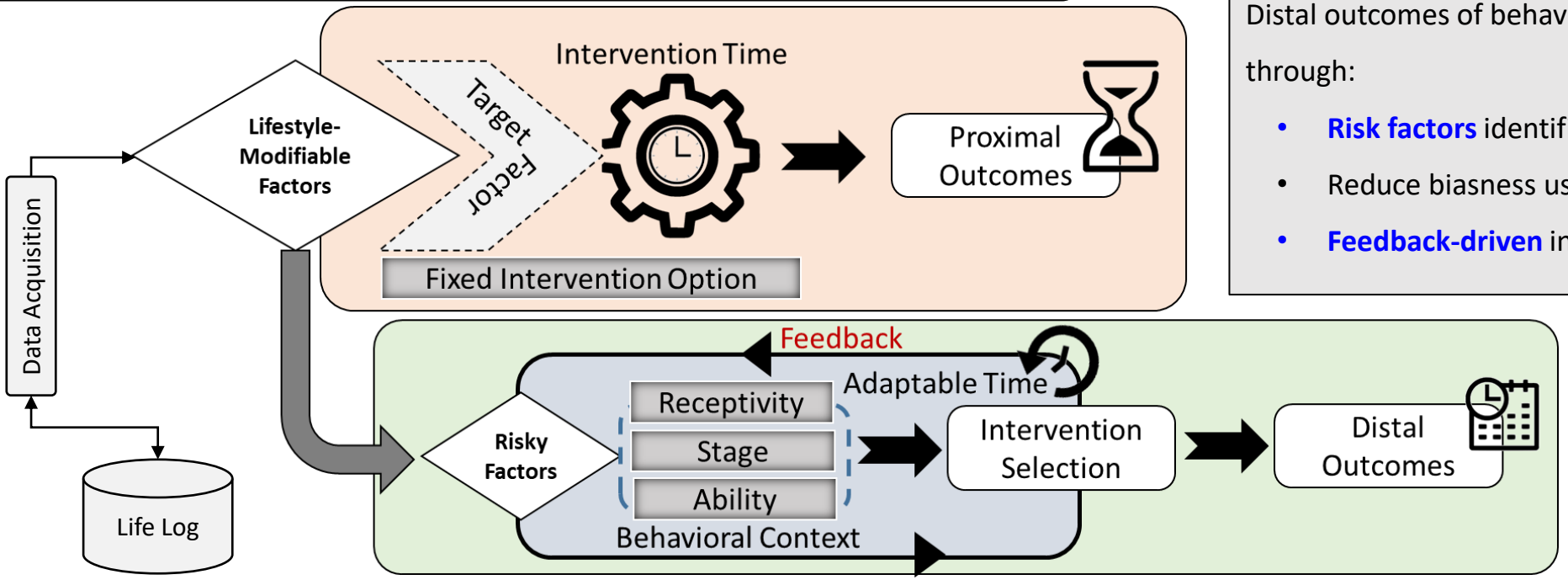


- *"Health is driven by multiple factors that are intricately— linked of which **personal behavior** is major component." [1]*
- *Lifestyle is a combination of multiple modifiable and non-adaptable factors. Non-adaptable factors include family history, gender, age, ethnicity and many other [3].*
- *Major causes of non-communicable diseases are the modifiable factors like unhealthy diet, smoking, inactivity, drinking and sleeping and leads to behavior [4].*
- *The behavior adaption requires that three elements must converge at the same moment for a behavior to change: Motivation, Ability, and a Prompt. [2]*



Motivation

- **Self Quantification** in digital wellness [5, 22]
- Healthy **habits formation** instead of fitness [26]
- **Pace-gap** between behavior theories and emerging technology [12]



Behavior Change Intervention Receptive Effect

Distal outcomes of behavior adaptation can be achieved through:

- **Risk factors** identification using life log [5, 15, 16]
- Reduce biasness using **implicit feedback** [21]
- **Feedback-driven** intervention reframing [23]

R Reasons
C Characteristics
A Advantages

R Homogeneous behavior stage based intervention

R Coarse-grained behavior target

C Identification of behavior context through life log

C Stratification on the basis of behavior stage

A Increase receptivity of intervention

A Personalization supports the stimulation and attraction

Problem Statement

Problem Statement

Digital wellness deficient to achieve healthcare goal due to underutilization of personalized behavior **adaptation model** for **habit formation** and user **engagement retention**[9,6,12,17,19].

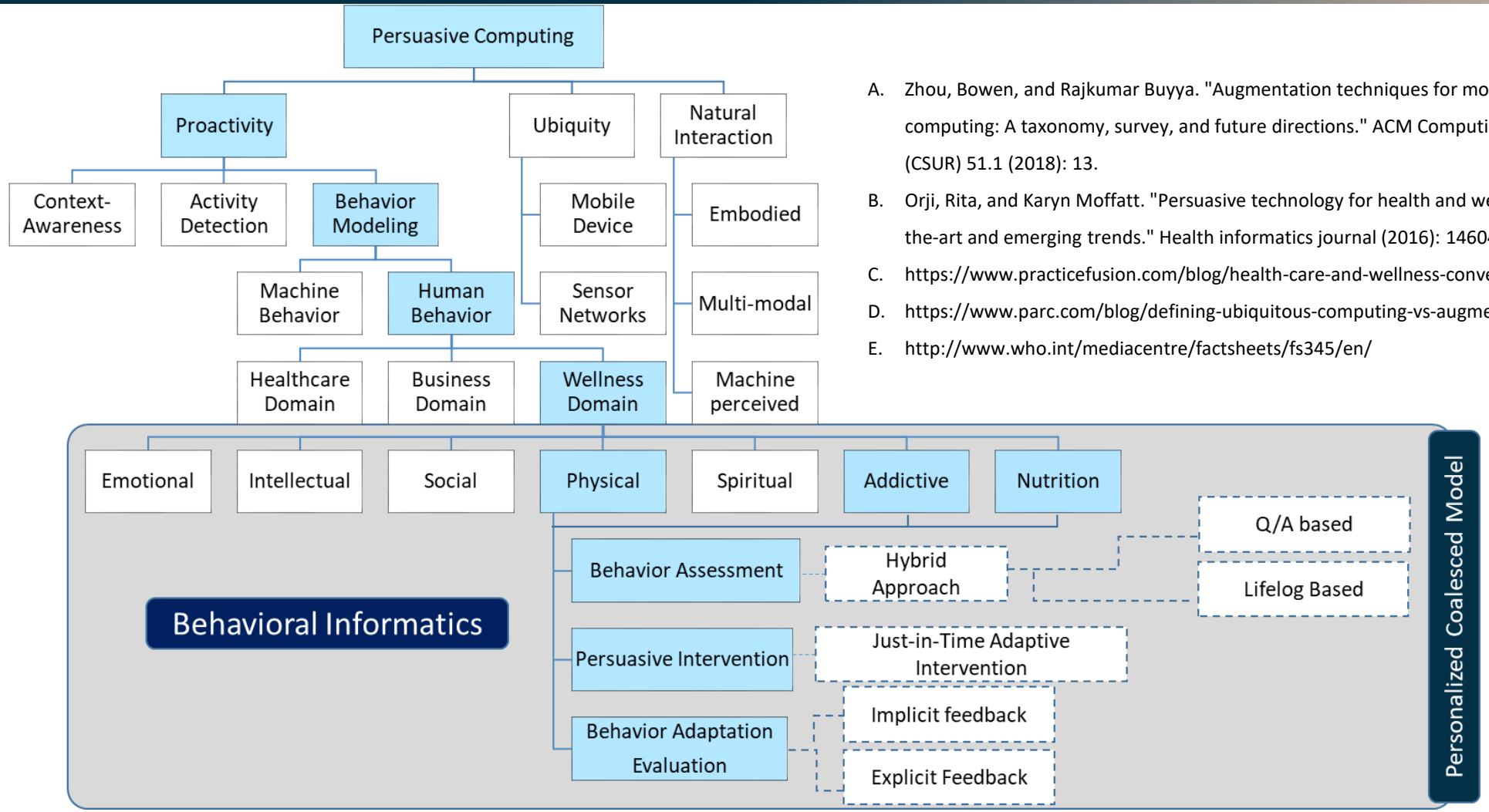
Goal

Develop a comprehensive methodology in order to **quantify multidimensional factors** of behavioral context based **assessment** and **intervention**.

Requirements

R1	Factors Identification	• How to select **relevant lifestyle risk factors**?[7,12]
R2	Behavioral Context Identification	• How to recognize **behavioral stage**?[14,16-18]
R3	Intervention Adaptation	• How to target **personalized adaptive intervention**? [12,6,21] • How to utilize feedback in **intervention reframing**? [15,23]

Research Taxonomy [A-E]



A. Zhou, Bowen, and Rajkumar Buyya. "Augmentation techniques for mobile cloud computing: A taxonomy, survey, and future directions." ACM Computing Surveys (CSUR) 51.1 (2018): 13.
B. Orji, Rita, and Karyn Moffatt. "Persuasive technology for health and wellness: State-of-the-art and emerging trends." Health informatics journal (2016): 1460458216650979.
C. https://www.practicefusion.com/blog/health-care-and-wellness-converging-concepts/
D. https://www.parc.com/blog/defining-ubiquitous-computing-vs-augmented-reality/
E. http://www.who.int/mediacentre/factsheets/fs345/en/

Related Work

R3	R2	R1	References	Methodology	Limitations
Goal Target based fixed time intervention	Non graded Behavior Indication	Single Lifestyle Factor	[14] Arrogi et al. Evaluation of stAPP: intervention to reduce prolonged sitting. (2019)	• Supports the **self monitoring** and **feedback** on behavior status. • Focused on the reduction of **sedentary behavior**. • Highlight the **consequences** of the behavior.	• **Goal setting** for the target behavior is missing. • Habit formation and **adaptation of behavior** is not concerned. • **Indexing** of the focused behavior is missing.
			[18] Dunn et al. Dietary self-monitoring through calorie. (2019)	• Focused on dietary self-monitoring through **calories-tracking** • Twice-weekly weight-loss **podcasts** to guide about the diet intake. • Feedback on the recorded and tracked **dietary behavior**.	• **Goal setting** for the target behavior is missing. • Indexing of the focused behavior is missing. • Habit formation and **adaptation of behavior** is not concerned.
			[16] Baskerville et al. Effect of intervention on quitting smoking (2018)	• It supports the user driven **behavior goal** setting to **quit smoking** • Behavior feedback in term of **financial** and health benefits. • Self monitoring of the behavior to enhance the motivation and **crush the craving**.	• Self-monitoring of behavior outcome is not focused. • **Review of behavioral goal** is missing • Habit formation is missing and no support for **graded task**.
			[17] Crane et al. A smartphone app to reduce excessive alcohol consumption (2018)	• Provides information about **health consequences and environment** • Informative intervention for reducing the **alcohol** consumption. • **Self monitoring** of the behavior through feedback.	• Missing goal setting and **action planning** for addictive habits • Grading of the behavior for **self-quantification** is not focused. • Habit formation and adaptation of behavior is not concerned.
		Multiple Lifestyle Factor	[21] Kliemann et al. Development of the top tips habit-based weight loss app. (2019)	• It supports the user driven behavior **goal setting** and **action planning**. • **Self monitoring** of the behavior through feedback and its outcomes. • **Informative intervention** to manage the diet for **obese** and **overweight**.	• Verification of **behavioral goal** is not concerned. • **Habit formation** is missing and no support to **grad behavior**. • **Consequences of the behavior** are not highlighted.
	Goal based Behavior Grading		[13] Gonzalez-Sanchez et al. Using a smartphone app in changing cardiovascular risk factors… (2019)	• It supports the user **driven behavior goal** setting • Informative intervention for **Mediterranean diet** and evaluation. • **Self monitoring** of the behavior through feedback.	• Monitoring of **behavior outcome** is not focused. • **Review** of behavioral goal is missing • **Habit formation** is missing although support **graded task**.
			[15] Brindal et al. Weight loss maintenance and well-being (MotiMate) (2019)	• Feedback on **behavior monitoring**, **behavior outcomes** and support **self monitoring**. • It focuses on **weight management** through tracking of food and exercise. • Weekly **graphical report** of diet and its impact on weight.	• Missing **daily** or **weekly goal setting** for diet and **exercise.** • Behavior adaptation and **framing** are not focused.

Challenges, Solutions & Methodology

	Challenges		Solutions	Methodology
R1	• **Ad-hoc** selection of lifestyle risk factors[7,12].	S1	• Identification of prominent **lifestyle-related risk factors**	• **Healthy Behavior Index** based on salient risk factors
R2	• **Coarse-grained** behavior targeting[14,16-18]	S2a	• **Stratification** on the basis of behavior stage	• **Transtheoretical** Model based stage identification
R3	• Lacking in **behavioral context** for intervention [12,6,21].	S2b	• **Stimulate** the intervention based **receptivity**.	• **Personalized adaptive** intervention
R3	• Feedback driven intervention **reframing** [15,23]	S2b	• **Feedback loop** for User satisfaction	• Decision modeling based on **explicit** and **implicit** feedback.

Proposed Idea

Limitations

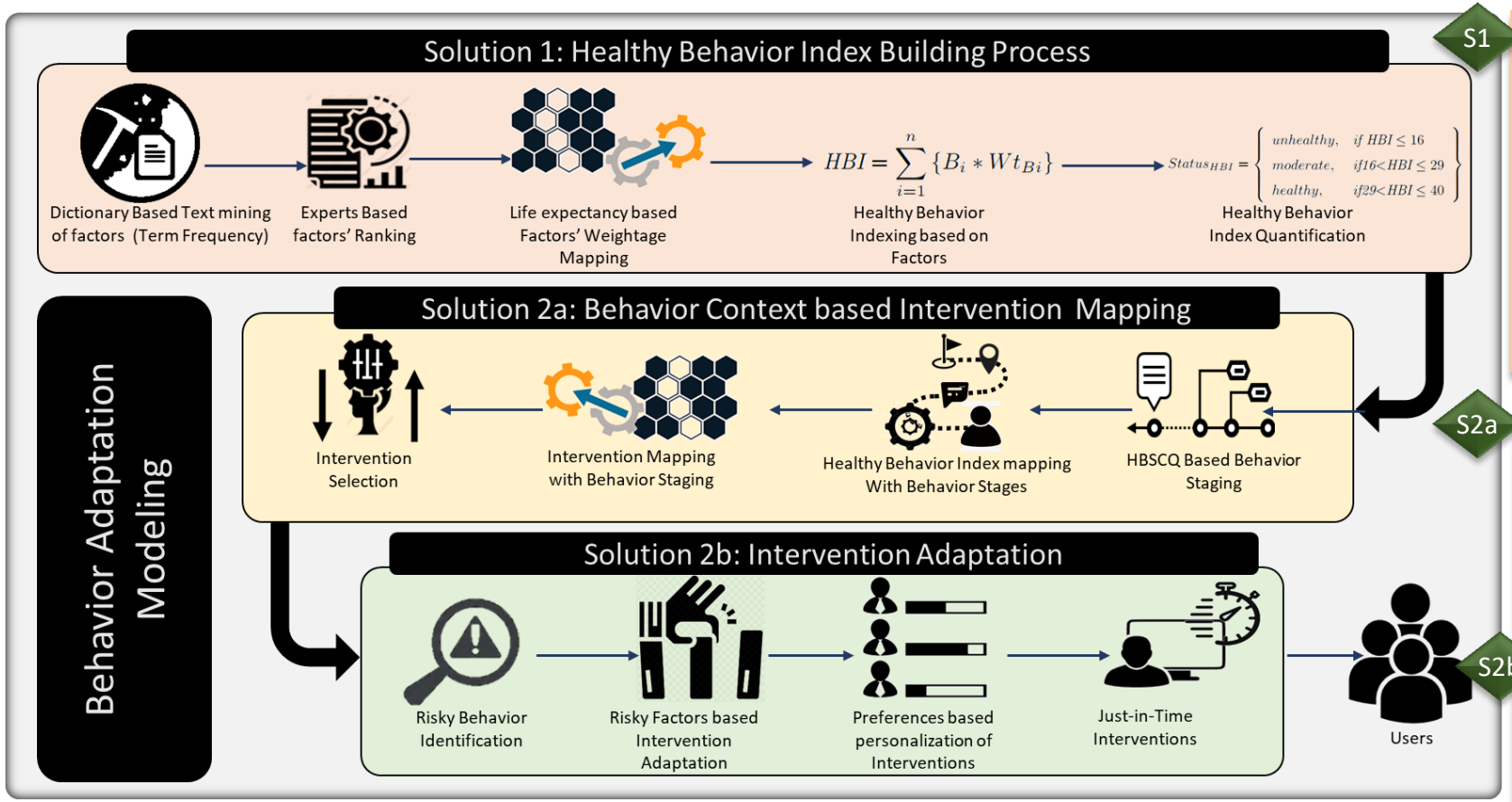
Existing Methodologies Focus on:

R1
- Specific Factor
- Log Visualization
- User derived goal
- Ignoring Vital Factors

Existing approaches follows:

R2
- One-size fits all
- Homogeneous behavior state

R3
- Time based Intervention
- Factor Status Feedback



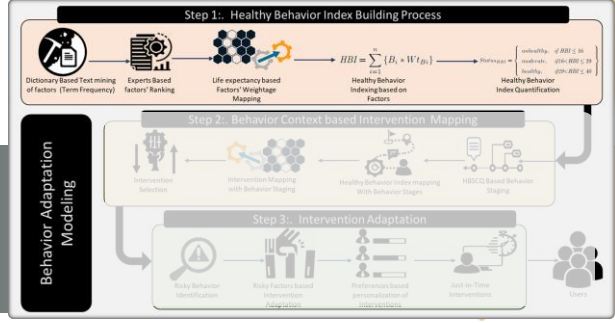
Solutions

S1
Identification of ***prominen***t lifestyle related ***risk factors*** having inter rate agreement with high ***Cohen's Kappa***, and construction of comprehensive ***Healthy Behavior Index*** based on life expectancy based derived ***weightage*** [24].

S2a
Stratification by ***Transtheoretical*** model depends on ***behavioral context through ensemble learner technique*** [25]

S2b
Personalized adaptive intervention to ***stimulate*** the ***receptivity*** and employ ***feedback*** through ***risk factors' indexing*** [5,22,24, 25].

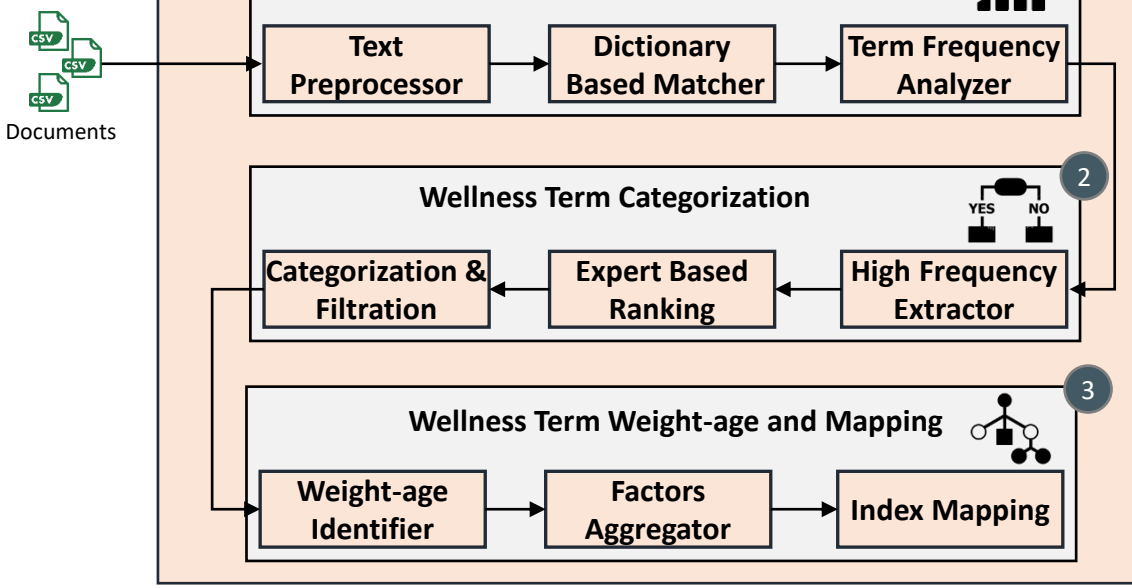
[24] Bilal et al. (2020). On computing critical factors based healthy behavior index for behavior assessment. *International journal of medical informatics*, *141*, 104181.
[25] Bilal et al. (2020). Towards user-centric intervention adaptiveness: influencing behavior-context based healthy lifestyle interventions. *IEEE Access*, *8*, 177156-177179.



Solution 1: Healthy Behavior Index Generation

S1

Workflow for Healthy Behavior Index Generation



1 $$tf = \frac{\sum_{i=0}^{n} t}{N}$$

2 $$k = \frac{\bar{P} - \bar{P}_e}{1 - \bar{P}_e} \quad (1)$$

$$\bar{P} = 0.9615 \quad (2)$$

$$\bar{P}_e = 0.5722 \quad (3)$$

$$k = 0.9100 \quad (4)$$

3 $$f^i = \frac{1}{(N-1)M+1}\left(w_k x_i^k + \sum_{j \neq k}\sum_{i} w_j x_j^i\right).$$

$$HBI = \sum_{i=1}^{n} \{B_i * Wt_{Bi}\}$$

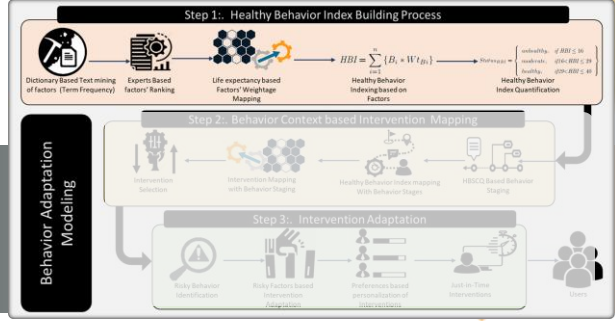
Highlights of the idea

- Identifies the **Wellness Factors**, and **Categorization of factors** based on term frequency [24].
- Expert based **ranking of factors** for identification and authentication of wellness domain using Cohen's Kappa based on **inter-rater agreement** .[24,25]
- Wellness **factors' weight-age** identification based on **life expectancy impact** [8].

Different to existing approaches

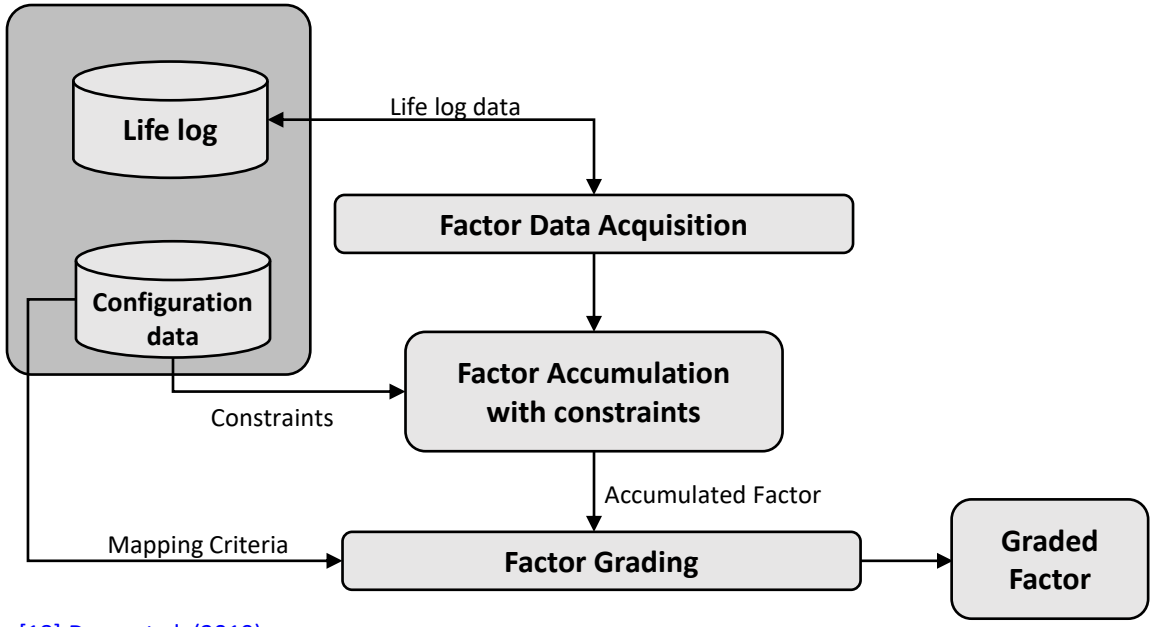
- Studies usually consider **single factor** or combination of 2 factors to analyze the behavior change[14,16-18].
- Correlation of multiple factors for the impact on behavior change are not considered for understanding the **holistic impact**.
- **Linear aggregation** of the factors miss lead about the impact of factors on wellness [19].

[24] Bilal et al. (2020). On computing critical factors based healthy behavior index for behavior assessment. *International journal of medical informatics*, *141*, 104181.



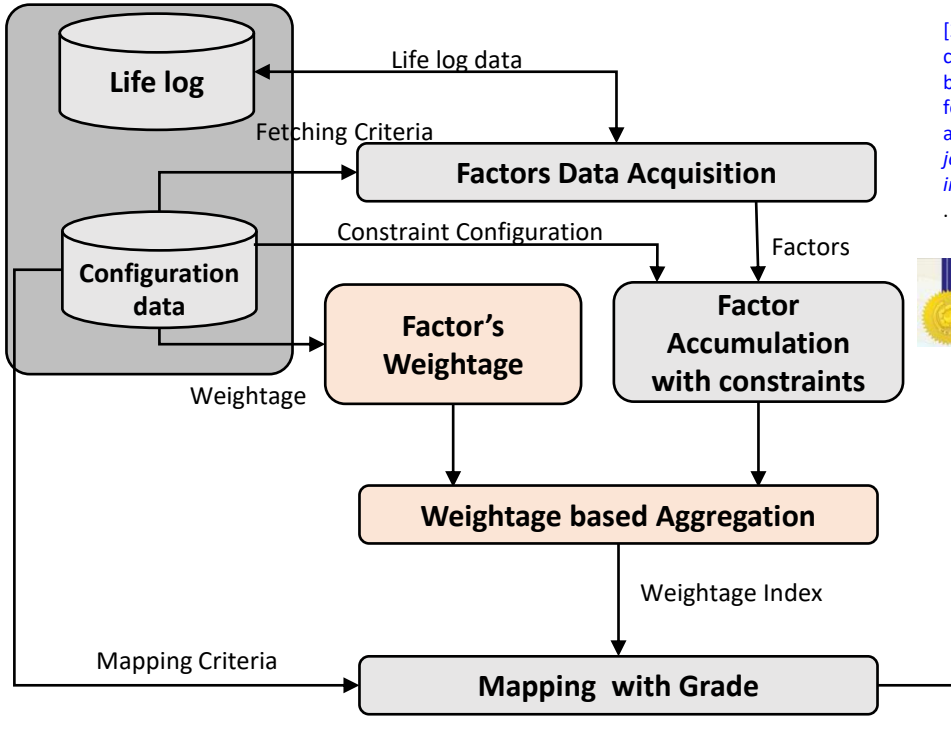
Solution 1: Index Generation Comparison

Existing approach for Factor Grading



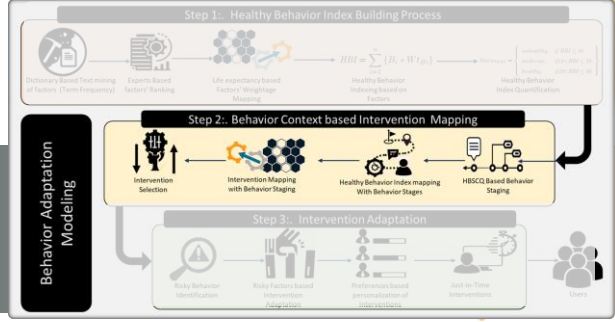
[18] Dunn et al. (2019)

Proposed approach of Index Generation



[24] Bilal et al. (2020). On computing critical factors based healthy behavior index for behavior assessment. *International journal of medical informatics*, *141*, 104181.

Sungyoung Lee, Bilal Hafiz Syed Muhammad, "사용자 건강 상태 제공 방법 및 장치", 출원인: 경희대학교 산학협력단, Registration No. 1021666700000, 2020년 10월 12일



Solution 2a: Behavior Intervention Mapping

S2a

Workflow for Behavior Intervention Mapping

Profile and Life log Data

- HBSCQ
- Life log
- Profile

Offline BSP-Model Construction Process

Factors Quantification
- Categories Identification
- Mapping Scale
- Grading Criteria

Ensemble Modeling
- Naïve Bayes
- Decision Tree
- Support Vector Machine
- Model Construction

Online Intervention selection Process

Life log Quantification
- Life log Factor Reader
- Factor Quantifier
- HBI Generator

Beh-Stg Identification
- Model Loader
- Behavior Stage inference

Intervention Selection
- Load Intervention Categories
- Beh-Stg Mapping

1

$$C^*(x) = argmax_y \sum_{i=1}^{T} \delta(C_i(x) = y)$$

2

$$M = \sum_{i=1}^{n} \{M_{\text{ISCORE}}\}/\text{time},$$

3

$$\text{HBI} = \sum_{i=1}^{n} \{B_i{*}\text{Wt}_{\text{Bi}}\}.$$

$$HBI = \begin{cases} UH, & HBI \le \mu - \delta \\ M, & \mu - \delta < HBI < \mu + \delta \\ H, & HBI \ge \mu + \delta \end{cases}$$

Intervention Categories

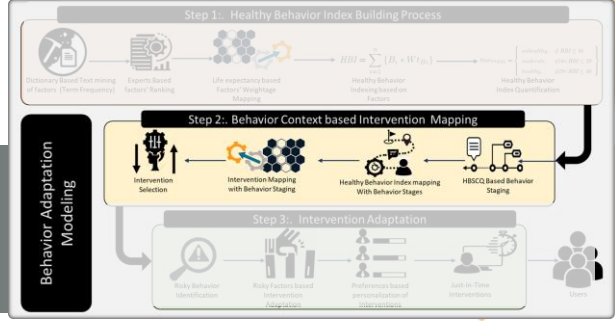
[25] Bilal et al. (2020). Towards user-centric intervention adaptiveness: influencing behavior-context based healthy lifestyle interventions. *IEEE Access*, *8*, 177156-177179.

Highlights of the idea

- Quantification of the life log to build **healthy behavior index** for **comprehensive grading [24,25]**.
- Offline process of **Behavior stage Prediction** model based on **Ensemble learner** for the identification of probable behavior stage [25].
- Online process of **intervention mapping** with the predicted behavior stage to intervene the user based on **behavioural context [25]**.

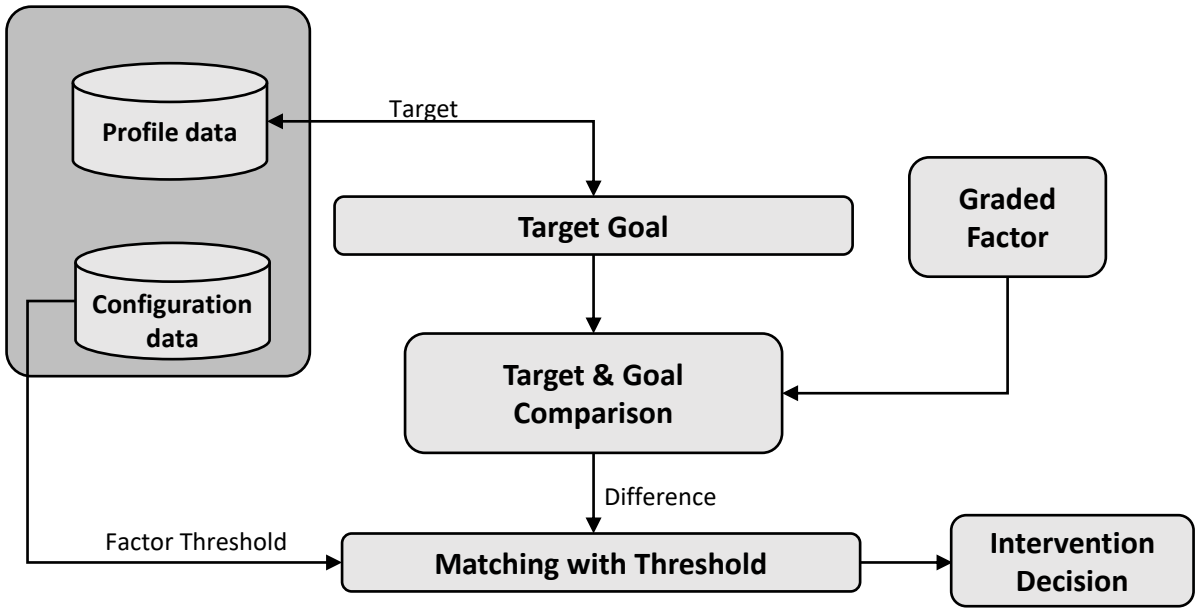
Different to existing approaches

- Understanding of the **behavioural stage** ignored while intervene the user [13,15,21].
- Generalized intervention strategy to focus on **proximal outcome**



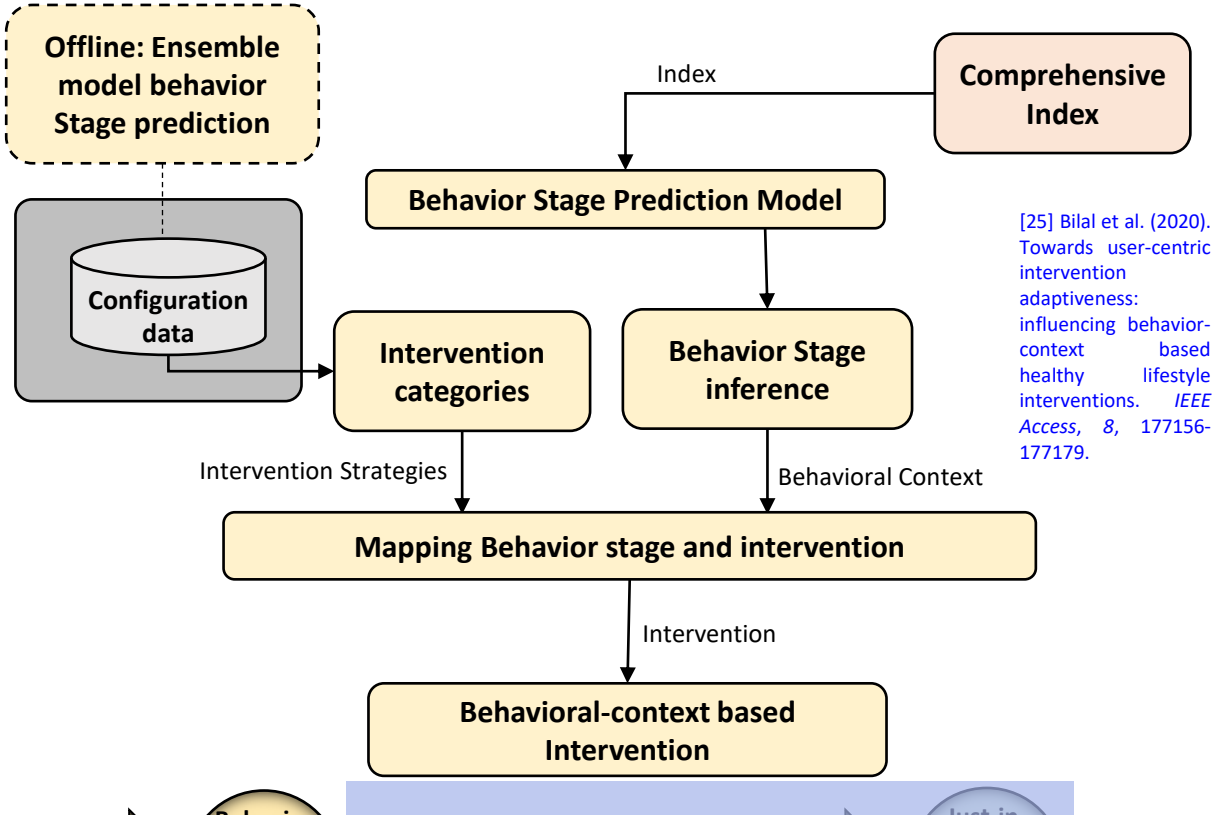
Solution 2a: Behavior Intervention Mapping Comparison

Existing Approach of Intervention Decision

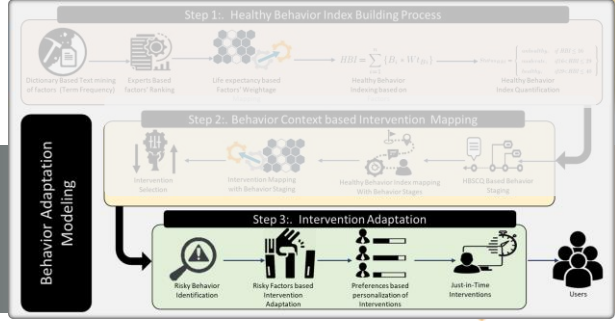


[13] Gonzalez-Sanchez et al. (2019)

Proposed Approach of Behavior Intervention Mapping



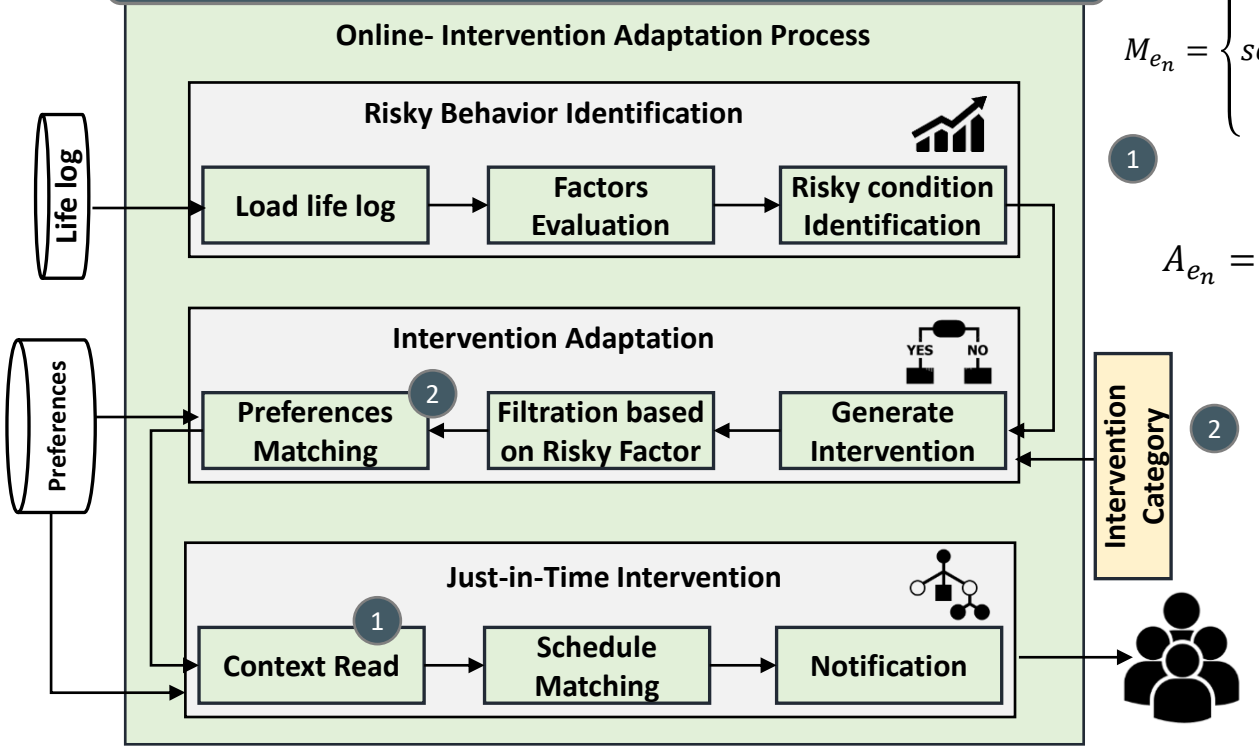
[25] Bilal et al. (2020). Towards user-centric intervention adaptiveness: influencing behavior-context based healthy lifestyle interventions. *IEEE Access*, *8*, 177156-177179.



Solution 2b: Intervention Adaptation

S2b

Workflow for Intervention Adaptation



$$M_{e_n} = \left\{ sortedlist \sum_{L_{T=1}}^{L_{T=n}} \sum_{S_{T=1}}^{S_{T=m}} \{e_n \geq T_e\} \right\}$$

1

$$A_{e_n} = \{\{\sum_{T_1}^{T_n} t.e_n\} > T_{Threshold}\}$$

2

$$Rec_{fi} = I_{Rec} \cap P_{fi}$$

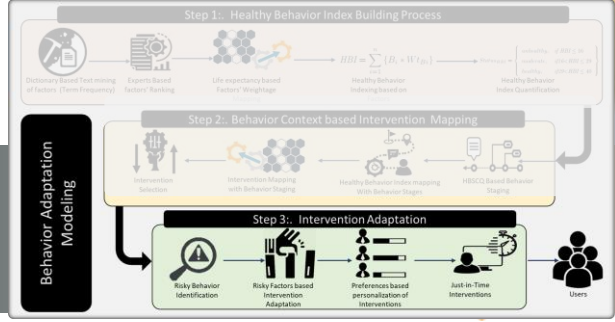
Highlights of the idea

- Analysis of **factors** and **sub factors** to identify the **risky condition** to emphasis in the intervention[24].
- **Adaptation** of the intervention based on the **risky factors** as well as **user preferences** under the constraint of recommendations [25].
- Trigger the notification process based on **the intervention category** and **behavioural-context** of the user [5,22,25].

Different to existing approaches

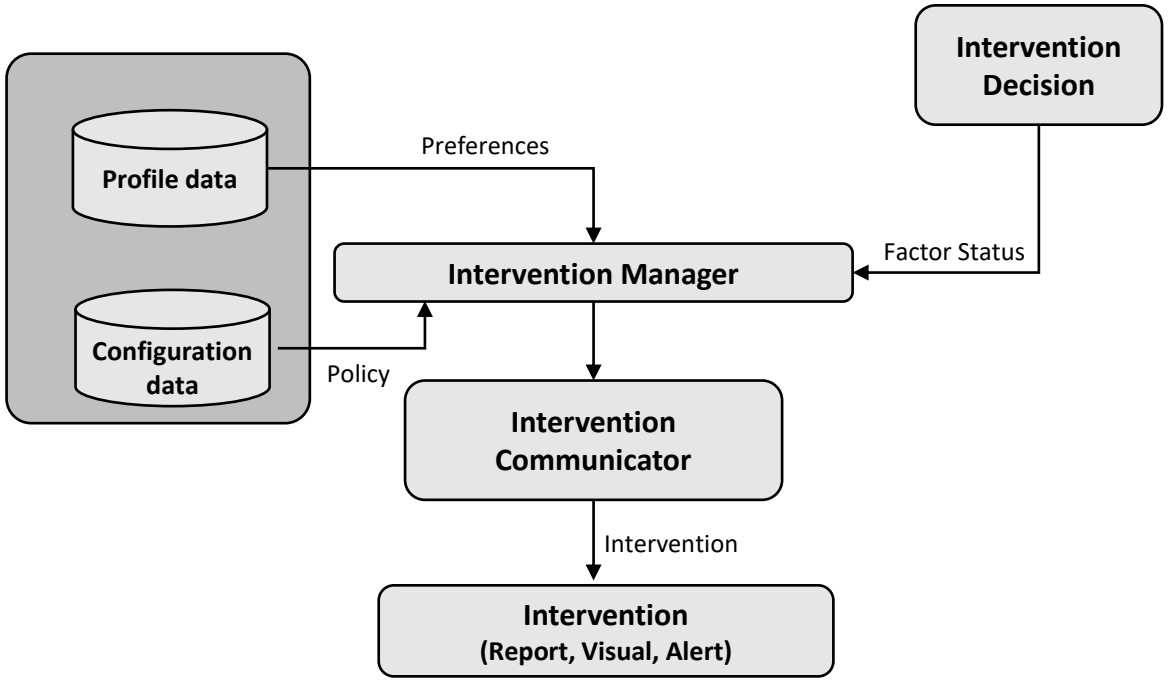
- Existing methodology intervene on once in **daily,** or **weekly** [15].
- Behavioral **stage and context** is not considered while intervene the user[13].
- Under utilization of **feedback** for the **refinement** and assessment of **receptivity** for the further intervention generation [18].

[25] Bilal et al. (2020). Towards user-centric intervention adaptiveness: influencing behavior-context based healthy lifestyle interventions. *IEEE Access*, *8*, 177156-177179.



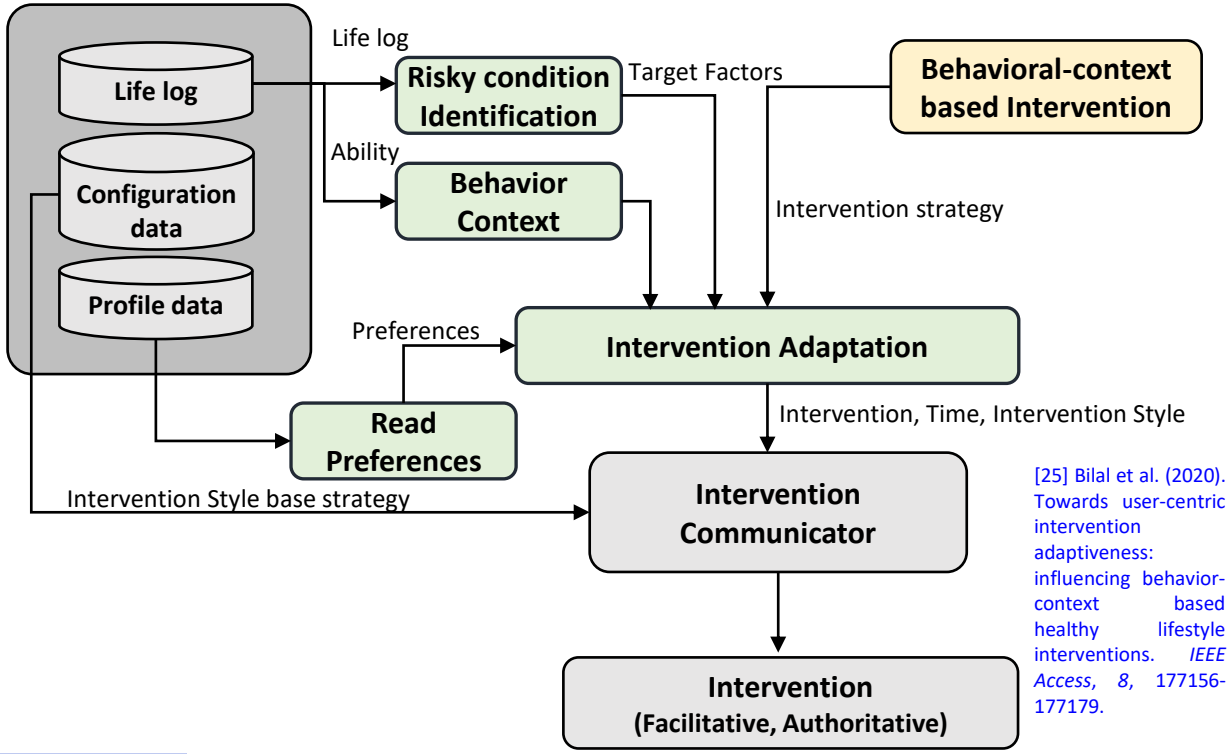
Solution 2b: Intervention Adaptation Comparison

Existing Approach for Intervention Generation

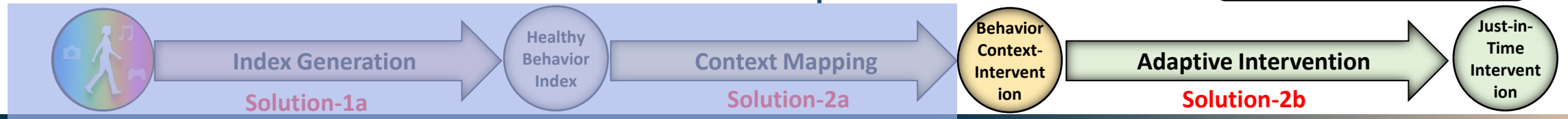


[15] Brindal et al. (2019)

Proposed Approach of Intervention Adaptation



[25] Bilal et al. (2020). Towards user-centric intervention adaptiveness: influencing behavior-context based healthy lifestyle interventions. *IEEE Access*, *8*, 177156-177179.



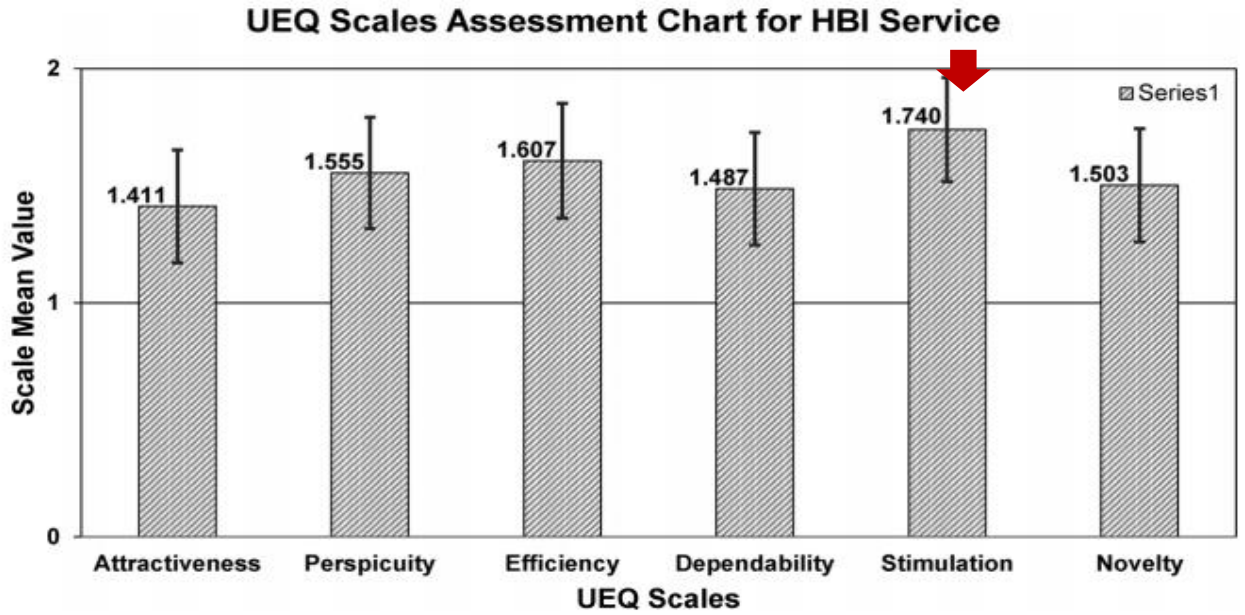
Comparative Analysis

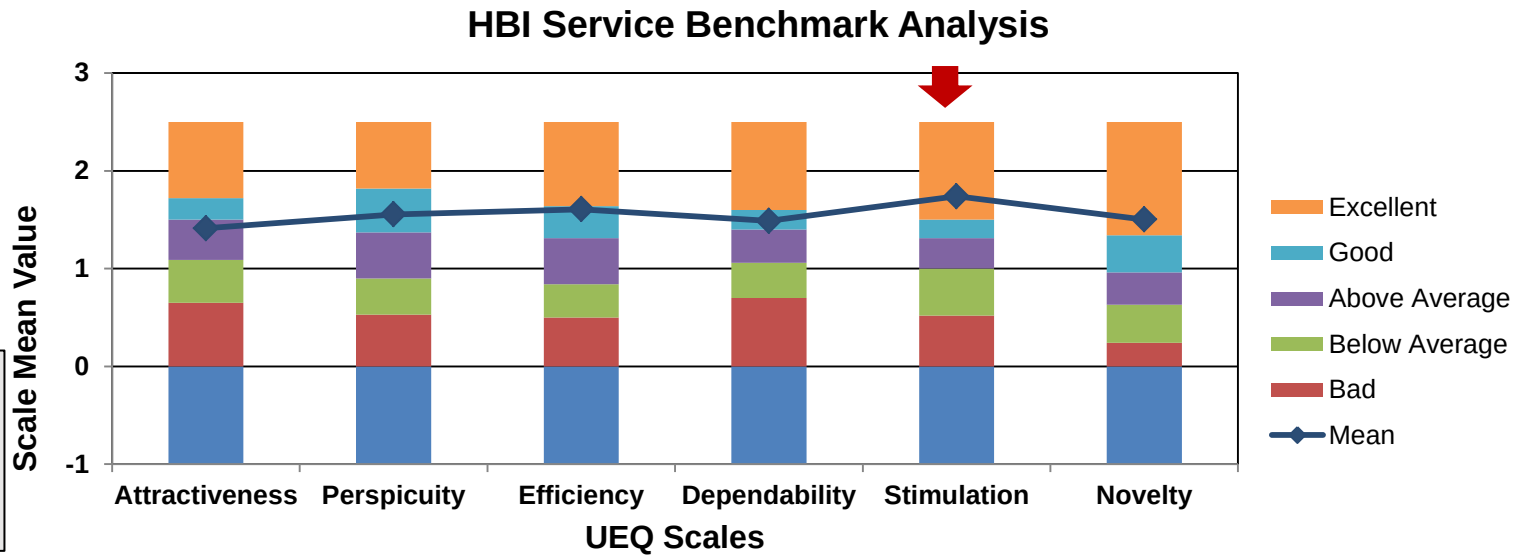
	Goal Oriented	Self Monitoring	Behavior Adaptation	Behavior Education	Behavior Formation & Analysis	Alert	Focus Factors	Behavioral Feedback	Recommendation & Remarks
[13] Gonzalez-Sanchez et al.(2019)	User Based	✓	×	×	×	×	Dietary habits, Physical activity	✓	End of day Report along with full day recommendation
[14] Arrogi et al. (2019)	×	✓	×	✓	×	✓	Sedentary Behavior	✓	No recommendation, visualization of prolonged sitting
[15] Brindal et al. (2019)	×	✓	×	✓	×	✓	Diet and Physical Activity	✓	Feedback driven recommendation on entry data.
[18] Dunn et al. (2019)	×	✓	×	✓	×	×	Dietary Habits	×	Generic podcasts for recommendation twice weekly
[16] Baskerville et al. (2018)	User Based	✓	×	✓	×	×	Smoking cessation	✓	Graphical and tabular report to highlight the status of smoking
[17] Crane et al. (2018)	×	✓	×	✓	×	✓	Alcohol Consumption	✓	Daily progress and mission indicator
[21] Kliemann et al. (2019)	User Based	✓	×	✓	×	✓	Dietary Habits	✓	Promote self-regulatory eating skills through goal diary
Proposed	**Expert Based**	✓	✓	✓	✓	✓	**Diet, Physical activity, Smoking, Alcohol**	✓	**Personalized context based just-in-time recommendation**

Experiment 1- Solution1: Healthy Behavior Index as Service

Demographics

	No. of users	% of users
Age (year)		
35–40	25	24.27%
41–50	52	50.48%
50 and above	26	25.24%
Gender		
Male	65	63.10%
Female	38	36.89%
Health issues		
Obesity	33	37.86%
Hyperlipidemia	25	24.27%
Hypertension	21	20.39%
Diabetes	24	20.30%
Course completion		
Complete	99	96.12%
left	4	3.89%
Smart devices expertise		
Expert	20	19.42%
Intermediate	76	73.79%
Novice	7	6.80%





Analysis

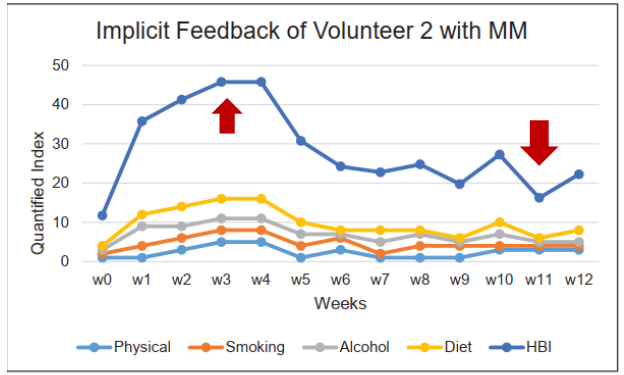
User Experience Questionnaire (UEQ)

- Benchmark **163** studies and 4818 participants dataset
- Stimulation with Confidence interval : **0.222(1.740 to 1.962)**
- Grade: **Excellent (average >1.5)**

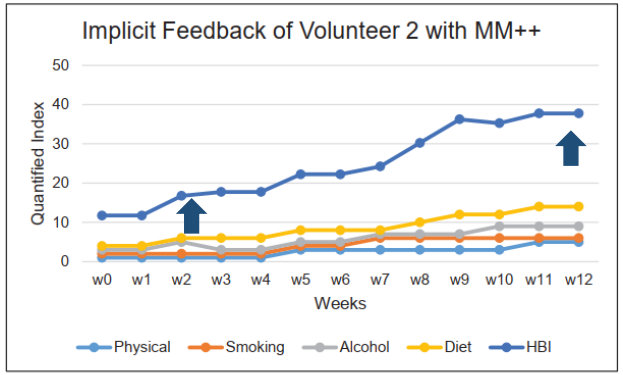
[24] Bilal et al. (2020). On computing critical factors based healthy behavior index for behavior assessment. *International journal of medical informatics*, *141*, 104181.

Experiment-2: Solution2 Impact of adaptive Intervention

Scenario #	Physical Activity	Smoking	Alcohol	Diet
S1	Unhealthy	Unhealthy	Unhealthy	Unhealthy
S2	Normal	Normal	Normal	Unhealthy
S3	Unhealthy	Normal	Unhealthy	Normal
S4	Normal	Healthy	Healthy	Normal

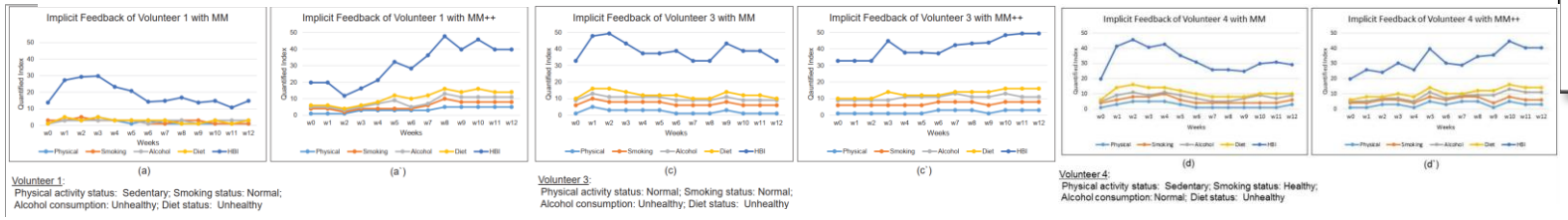


(b)



(b`)

Volunteer 2:
Physical activity status: Sedentary; Smoking status: Unhealthy;
Alcohol consumption: Unhealthy; Diet status: Unhealthy



Analysis

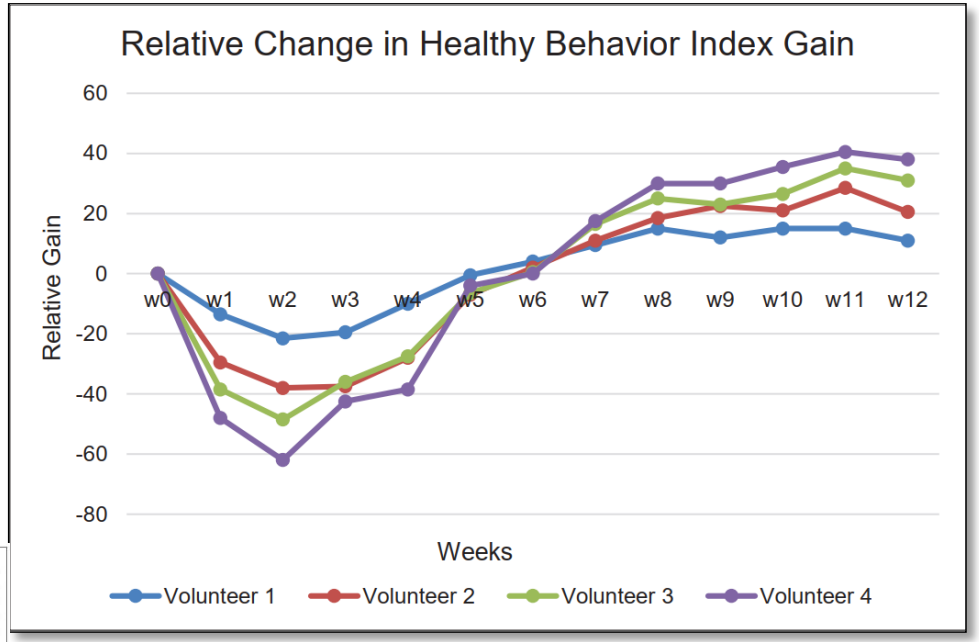
Existing Approaches:

- HBI exponentially increase for first 4 weeks and then decline towards initial stage

Proposed Approach:

- HBI improves continuously with slow phase

Change in Gain



[25] Bilal et al. (2020). Towards user-centric intervention adaptiveness: influencing behavior-context based healthy lifestyle interventions. *IEEE Access*, *8*, 177156-177179.

Conclusion

Thesis Contributions

- Comprehensive multidimensional **Healthy Behavior Index**
  - Critical lifestyle adaptable factors identification
    - Factors identification using text mining
    - **Rank factors** using Cohen's Kappa Inter-rater agreement
  - Healthy Behavior Index (HBI) generation
    - **Weightage identification** through life expectancy
    - Combinatorial **HBI average for Behavior categorization**.
  - **UEQ benchmark** ranked **Stimulation** as **Excellent**
- Personalized coalesced model for **adaptive intervention**
  - Ensemble model for mapping **Transtheoretical stages**
  - **Risk factors and profile preferences based interventions**
  - eSURVEY portfolio marked as **Desired**

Uniqueness

- **Lifestyle** critical factors **ranking** for **weightage index**
- **Behavioral-context** mapping for **intervention selection**
- Personalized adaptive intervention for **distal outcomes**

Publications

Published papers

- **SCIE Journals (12)**
  - First Author: 2 Published
  - Co-author: 10 Published
- **Local Journals (4)**
  - Co-Author: 4 Published
- **Conferences (23)**
  - First Author: International: 10
  - Co-Author: International: 8
  - First Author Local Conferences: 5
- **Domestic Patents (06)**
  - Applied Local: 4
  - Applied International :1
  - Registered Local: 1

Papers in progress

- SCIE Journal (01)
  - Bilal et. al...
- Patent to be applied (01)

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Thank you for your attention!

Q & A?