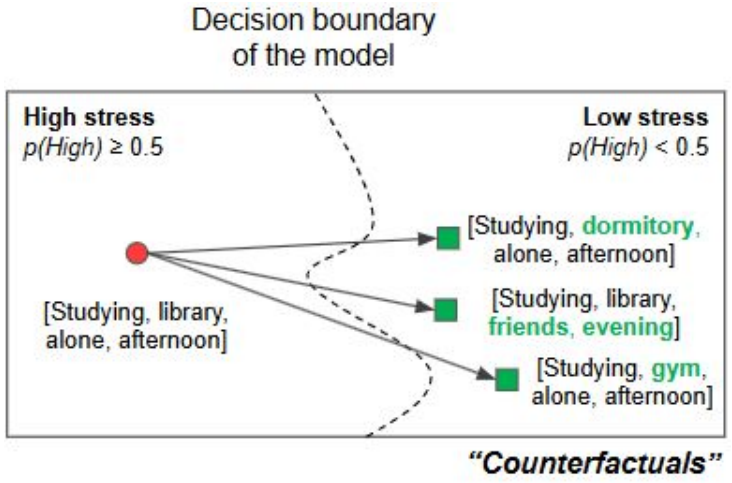
CHI 2025

CounterStress

Enhancing Stress Coping Planning through Counterfactual Explanations in Personal Informatics




Gyuwon Jung


Uichin Lee

KAIST

Interactive Computing Laboratory

Understanding Myself through Personal Informatics

The collection and reflection of personal data have become integral to daily life (Baumer et al., 2014)

Baumer, Eric P.S. et al. "Reviewing Reflection: On the Use of Reflection in Interactive System Design." DIS '14.
Li, Ian et al. "A Stage-Based Model of Personal Informatics Systems." CHI '10.

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Personal Informatics

(Li et al., 2010)

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Understanding Myself through Personal Informatics

Existing personal informatics research has targeted various health domains (Epstein et al., 2020)

Physical activity
(Kocielnik et al., 2018)

Nutrition
(Luo et al., 2019)

Sleep
(Liang et al., 2016)

Epstein, Daniel A et al. "Mapping and Taking Stock of the Personal Informatics Literature." IMWUT '20.
Kocielnik, Rafal et al. "Reflection Companion: A Conversational System for Engaging Users in Reflection on Physical Activity." IMWUT '18.
Luo, Yuhan et al. "Co-Designing Food Trackers with Dietitians: Identifying Design Opportunities for Food Tracker Customization." CHI '19.
Liang, Zilu et al. "SleepExplorer: a Visualization Tool to Make Sense of Correlations between Personal Sleep Data and Contextual Factors." Pers Ubiquit Comput 20 (2016).

Personal Informatics and Stress Coping Strategies

Personal informatics has also been studied in the stress management domain (Alhasani et al., 2020)

Visualization of contextual data and stress levels (Kocielnik et al., 2015, Sharmin et al., 2015)

Exploration of contextual factors **causally related** to stress (Jung et al., 2024)

Prediction of future stress and provision of interventions (Lee et al., 2020, Kim et al., 2022)

Alhasani, Mona et al. "A Systematic and Comparative Review of Behavior Change Strategies in Stress Management Apps: Opportunities for Improvement." Frontiers in Public Health (2022).
Kocielnik, Rafal et al. "Personalized Stress Management: Enabling Stress Monitoring With LifelogExplorer." KI-Künstliche Intelligenz 29 (2015).
Sharmin, Moushumi et al. "Visualization of Time-Series Sensor Data to Inform the Design of Just-in-Time Adaptive Stress Interventions." UbiComp '15.
Jung, Gyuwon et al. "DeepStress: Supporting Stressful Context Sensemaking in Personal Informatics Systems Using a Quasi-experimental Approach." CHI '24.
Lee, Kwangyoung et al. "Toward Future-Centric Personal Informatics: Expecting Stressful Events and Preparing Personalized Interventions in Stress Management." CHI '20.
Kim, Taewan et al. "Prediction for Retrospection: Integrating Algorithmic Stress Prediction Into Personal Informatics Systems for College Students' Mental Health." CHI '22.

Personal Informatics and Stress Coping Strategies

Existing personal informatics systems have limited support for actionable coping strategies

Stress self-awareness

Coping planning by users

Personal Informatics and Stress Coping Strategies

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Simply **avoiding the major stress factor** may not be a practical solution

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Overall stress levels are **shaped by multiple factors**, requiring a **comprehensive approach** to effective stress management

Personal Informatics and Stress Coping Strategies

An alternative approach is to offer coping strategies that are **feasible and tailored to the users' specific situations** for effectively achieving the desired outcome

Activity: study




Stress level: Very high

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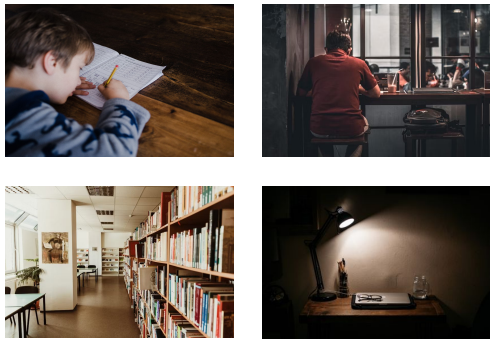

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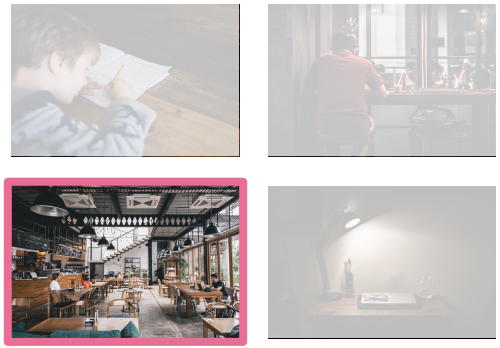

Stress level: Low
(location: library → **cafe**)

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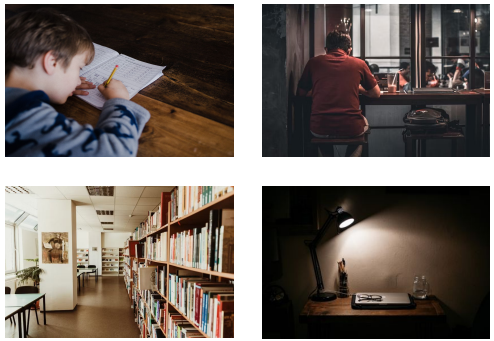

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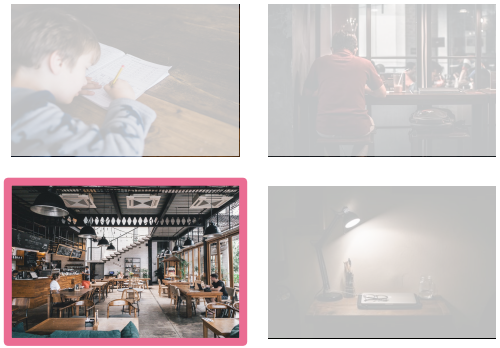

Stress level: Low
(location: library → **cafe**)

Stress level: Very low
(location: library → **cafe**)
social: alone → **friends**)

Objective

Design a personal informatics system that supports **personalized stress-coping planning** by suggesting **necessary changes** to reduce stress in a given situation

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Design a personal informatics system that supports **personalized stress-coping planning** by suggesting **necessary changes** to reduce stress in a given situation

Exploring **counterfactual scenarios** (“what-if” situations) to achieve a target stress level using self-tracking data

Counterfactual Explanations

An example-based explanation technique that offers insights into model predictions within the domain of machine learning and artificial intelligence (Molnar, 2021)

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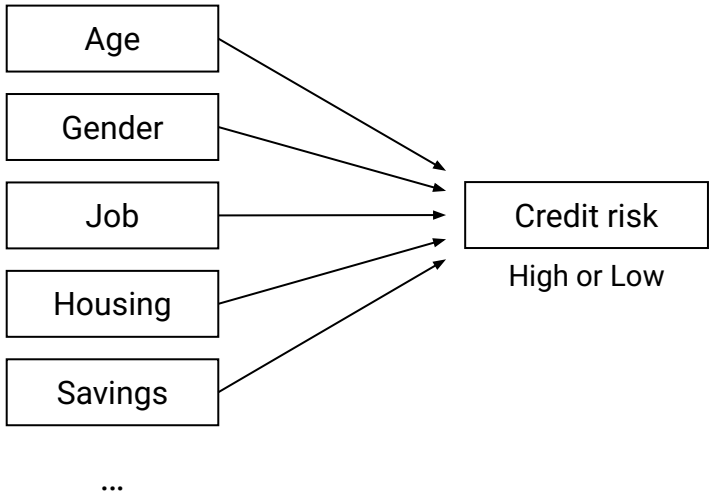

Predict the probability of having a low credit risk (using a machine learning model)

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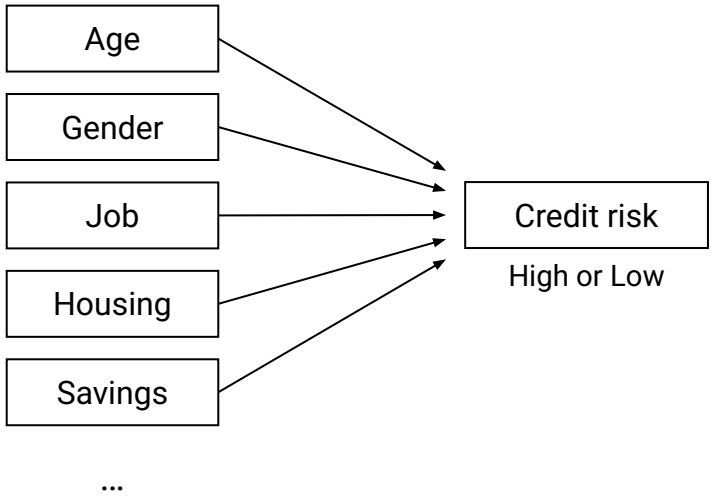

Predict the probability of having a low credit risk (using a machine learning model)

Customer	Age	Savings	Job	...	Prob. of "Low"
1	58	rich	unskilled	...	0.242
2	23	little	highly skilled	...	0.673
3	45	moderate	skilled	...	0.452
...	...	...	...	...	...

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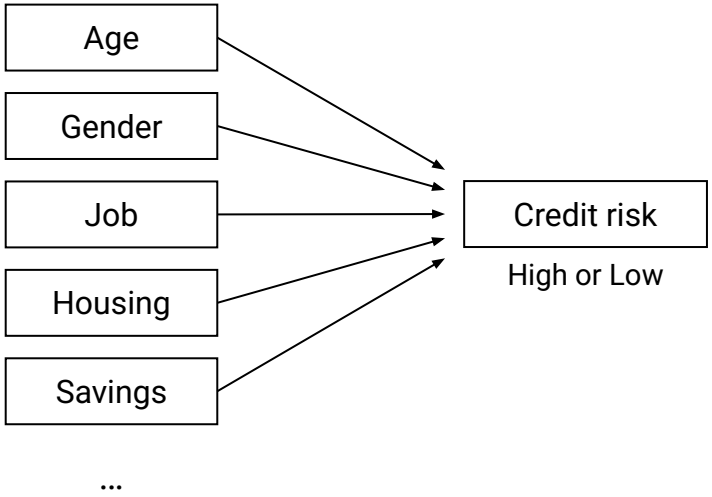

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How does the model generate these predictions?

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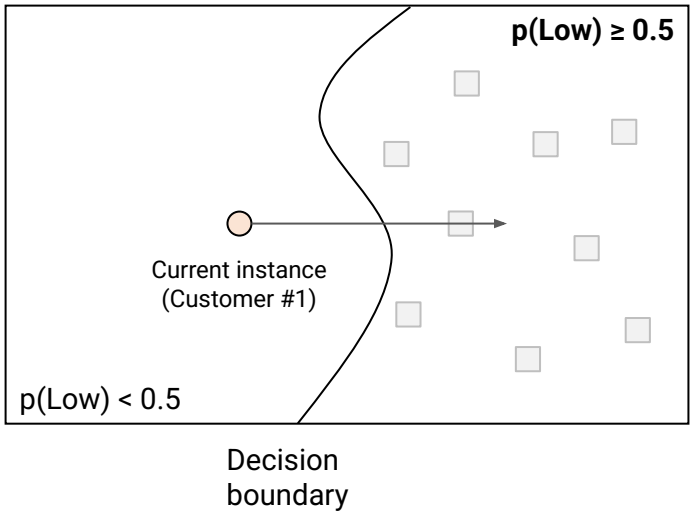

"For a given instance, what is **the minimal change** to feature values needed to **change the prediction** to a predefined outcome?"

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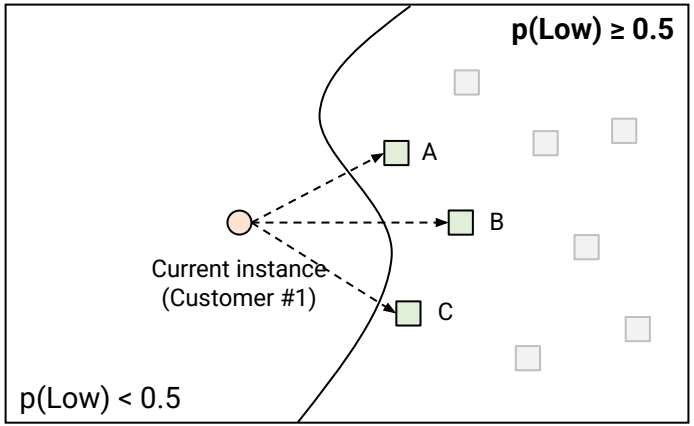

"For a given instance, what is **the minimal change** to feature values needed to **change the prediction** to a predefined outcome?"

Customer	Age	Savings	Job	...	Prob. of "Low"
1	58	rich	unskilled	...	0.242
A	58	rich	**skilled**	...	0.589
B	58	**very rich**	unskilled	...	0.624
C	**37**	rich	unskilled	...	0.713

Explains how the prediction was made through counterfactual (i.e., "what-if") scenarios

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Implementing Counterfactual Explanations

Explore which changes in contextual factors are necessary from the current situation to reduce stress to the desired level

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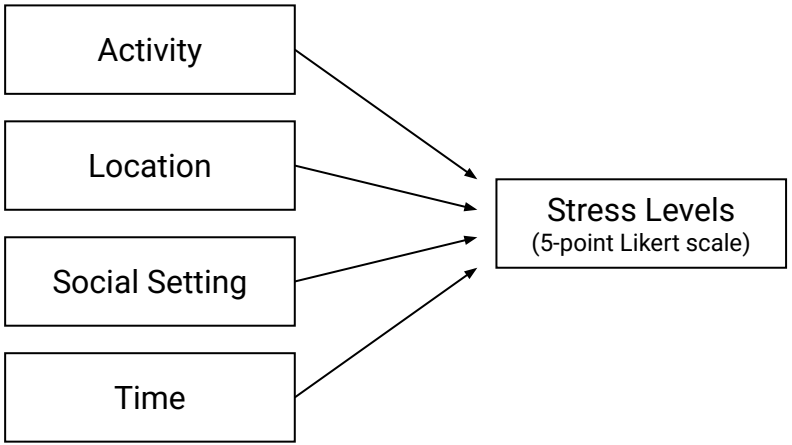
Contextual factors



Self-reported dataset

Activity	Location	Social	Time	Stress
Meeting	Library	Friends	Afternoon	4
Resting	Dormitory	Alone	Evening	1
Class	Classroom	Friends	Morning	5
Eating	Home	Family	Afternoon	2
...	...	...	...	...

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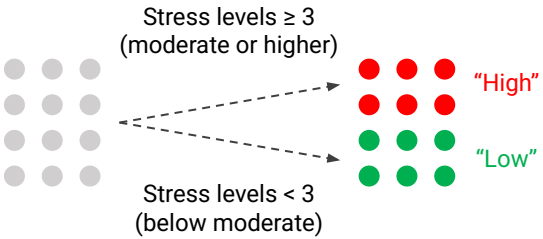

(1) Label the samples' stress state based on a specific threshold (e.g., moderate level)

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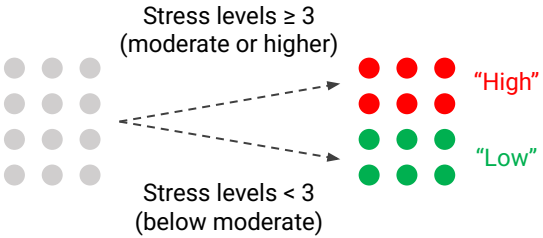

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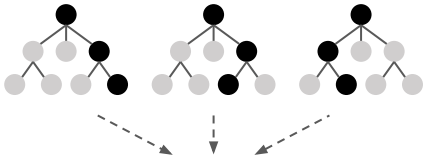

Estimate the probability of stress being classified as "High" (i.e., p(High))

(2) Build a machine learning model (e.g., Random Forest)

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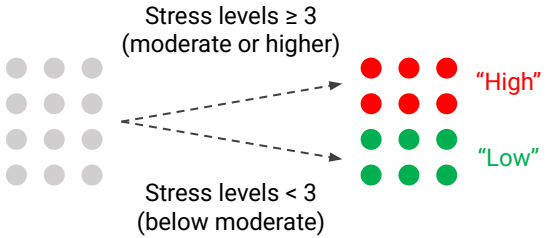

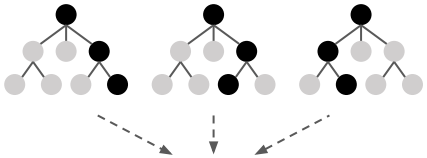

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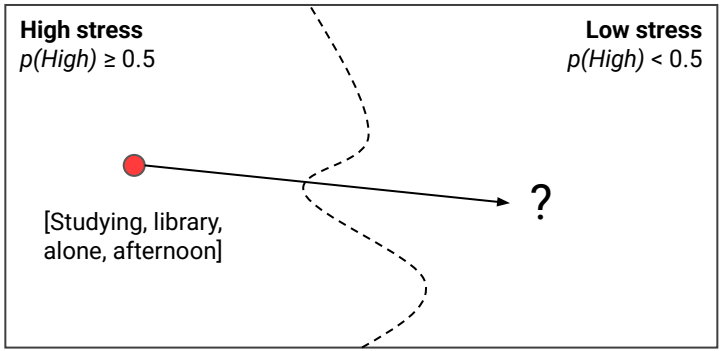
Decision boundary of the model



(3) Generate counterfactuals (the green squares) for the selected situation (the red circle)

Implementing Counterfactual Explanations

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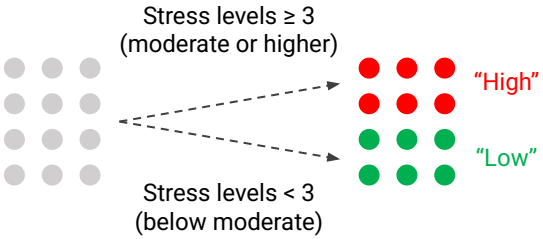

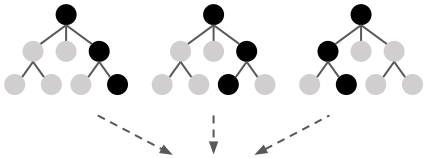

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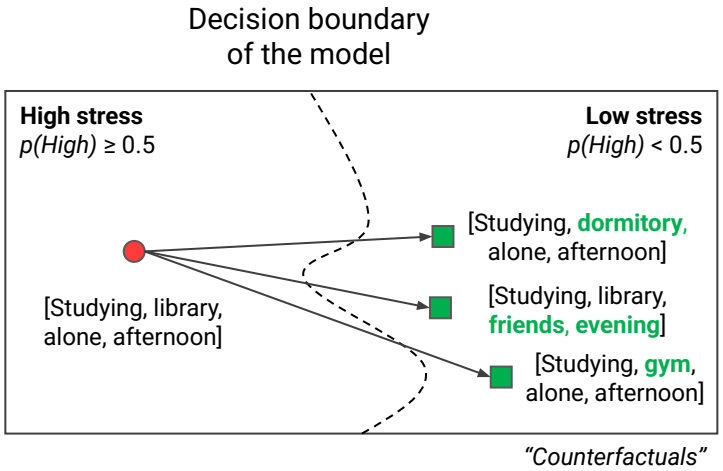

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Not Every Instance Can Act As a Counterfactual

Desirable properties of the generated counterfactuals (Guidotti, 2022)

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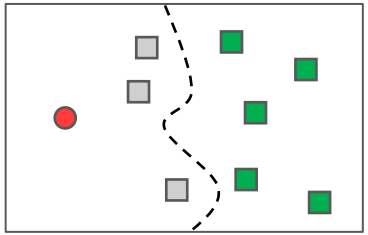

Validity
(crossing a decision boundary)

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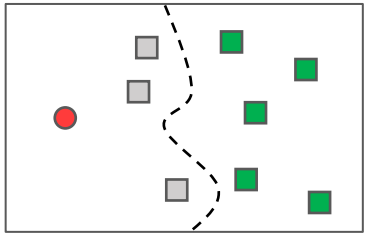

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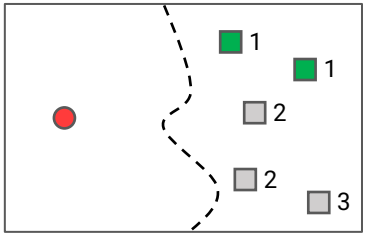

Minimality
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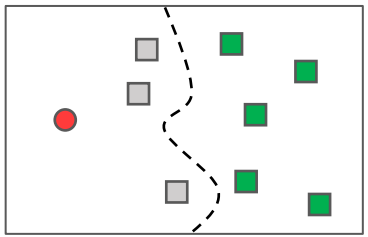

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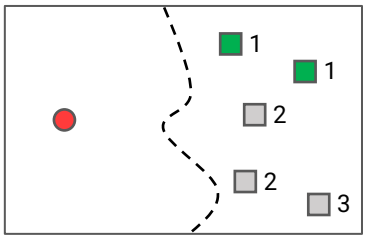

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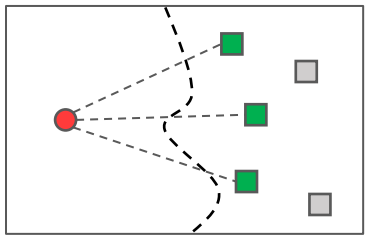

Similarity
(close to the original)

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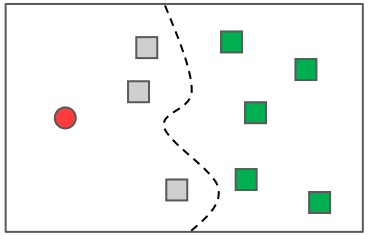

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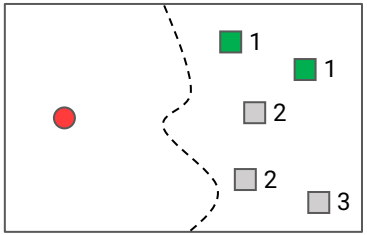

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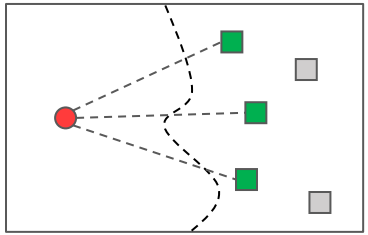

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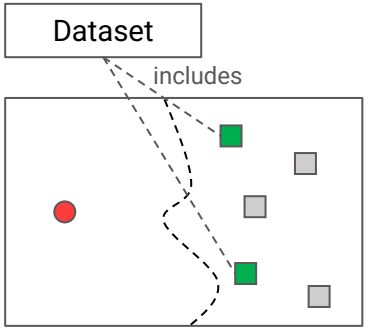

Plausibility
(happened in the past)

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CounterStress

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Review Screen

Summary and detailed view of the user's **stress history**

CounterStress

Review Screen	Summary and detailed view of the user's **stress history**
Analysis Screen	**Correlational and causal relationships** between stress levels and contexts

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CounterStress

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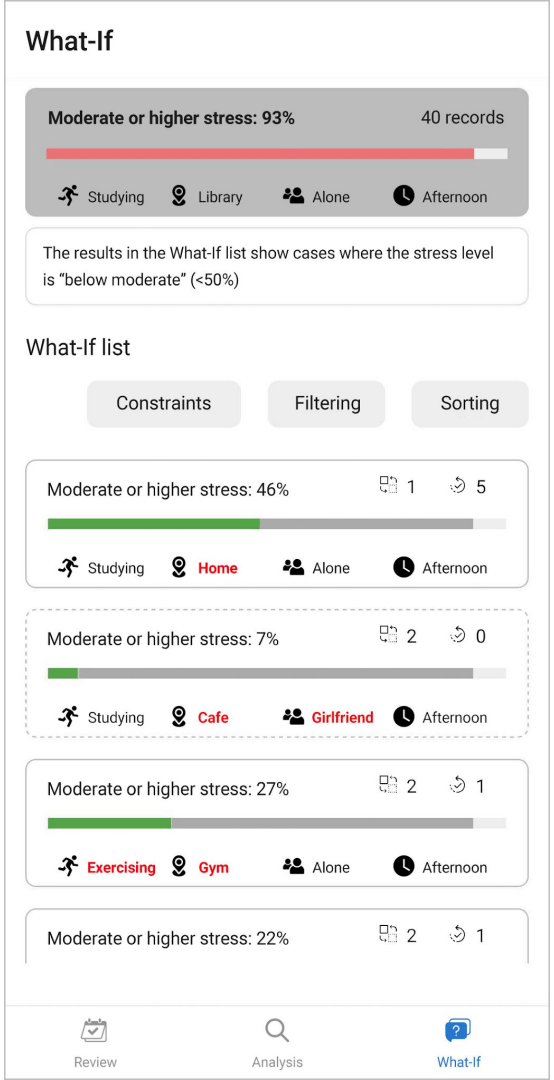
Analysis Screen

What-If Screen



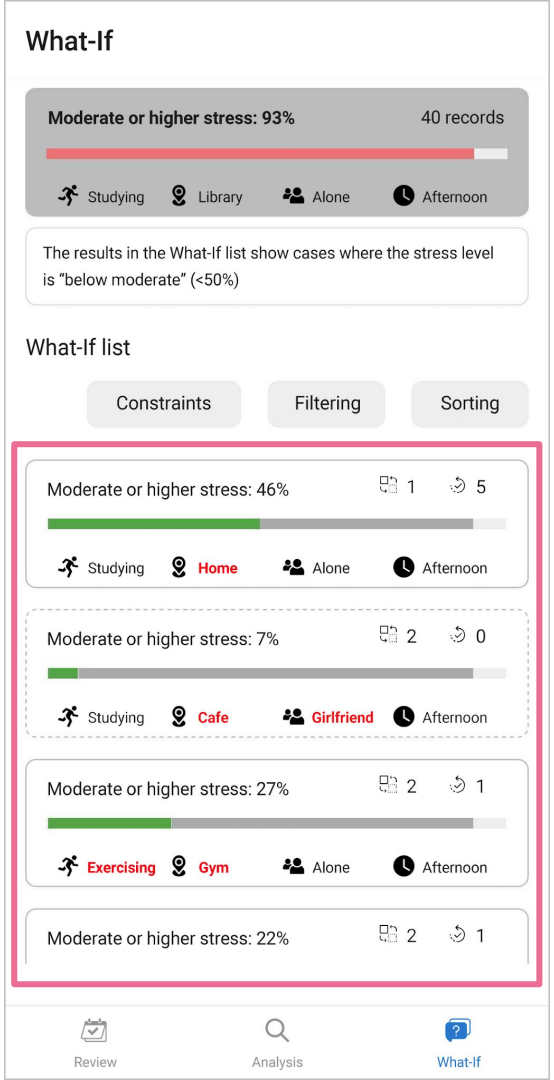
Counterfactual-based coping strategies for the selected situation (i.e., a combination of contextual factors)

CounterStress

Review Screen

Analysis Screen

What-If Screen



Counterfactual-based coping strategies for the selected situation (i.e., a combination of contextual factors)

Counterfactual scenarios that could reduce stress to **below a moderate level**

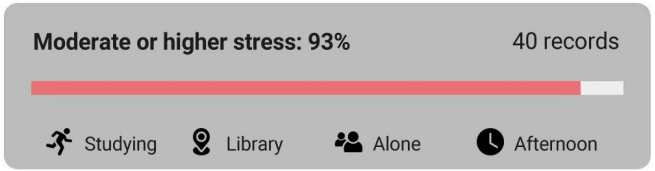
CounterStress

Review Screen

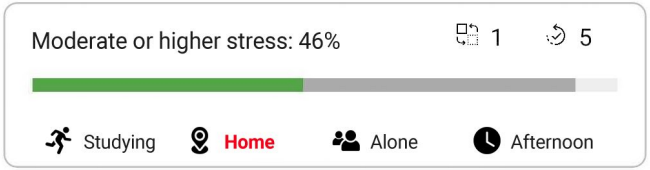
Analysis Screen

What-If Screen

“Target” instance



“Counterfactual” instance



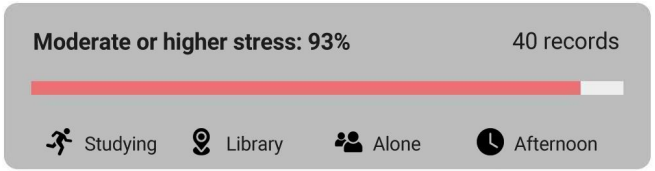
CounterStress

Review Screen

Analysis Screen

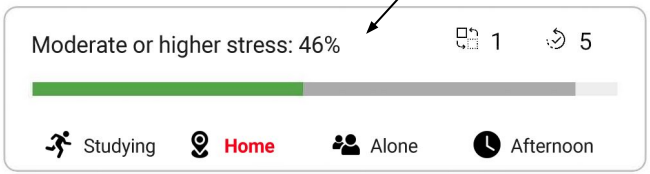
What-If Screen

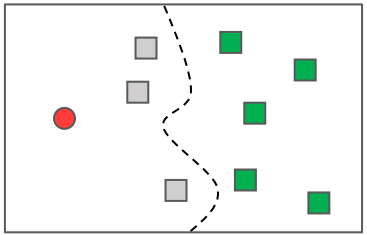
“Target” instance



Probability of being classified as “high stress” (p)
(High stress: ≥ 3 (moderate) out of 5)

“Counterfactual” instance





Validity
(crossing a decision boundary)

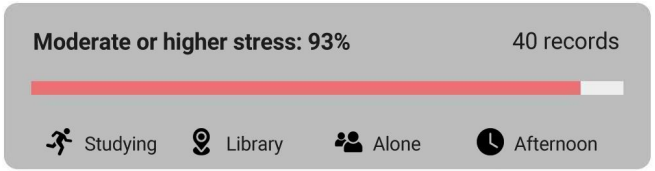
CounterStress

Review Screen

Analysis Screen

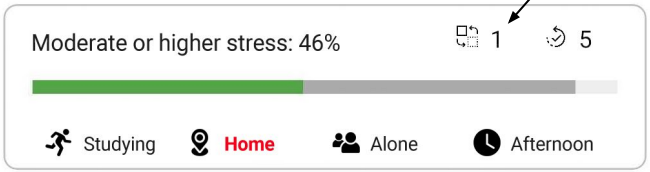
What-If Screen

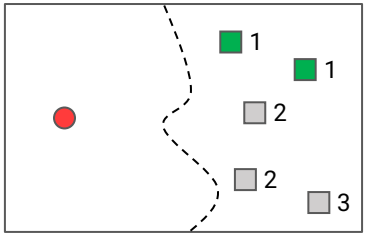
“Target” instance



Number of changed factors (n)

“Counterfactual” instance





Minimality
(smallest possible change)

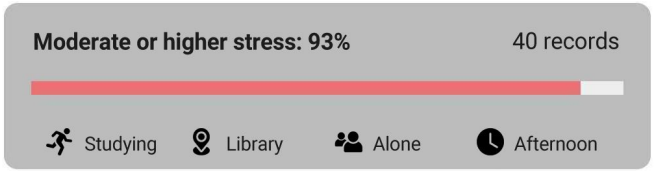
CounterStress

Review Screen

Analysis Screen

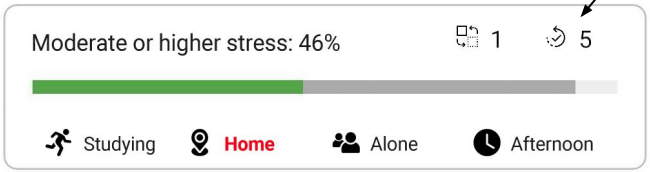
What-If Screen

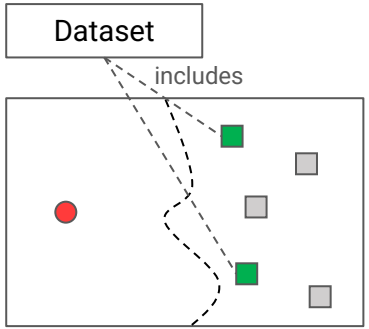
“Target” instance



Historical frequency (f)

“Counterfactual” instance





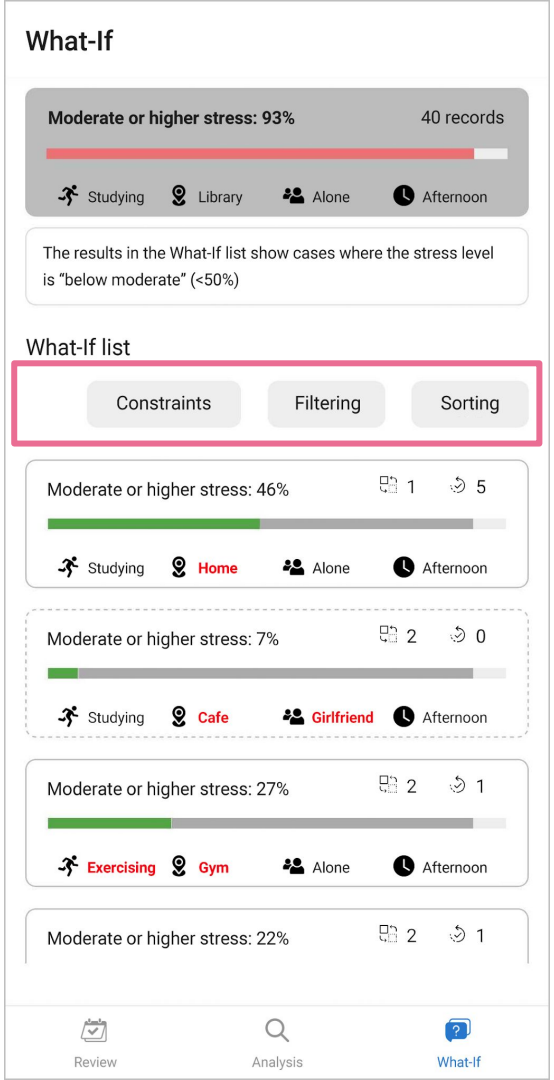
Plausibility
(happened in the past)

CounterStress

Review Screen

Analysis Screen

What-If Screen



Counterfactual-based coping strategies for the selected situation (i.e., a combination of contextual factors)

Conditions for determining which counterfactuals to display

Constraints: keep specific factors unchanged

Filtering: set the range for each criterion (i.e., probability of high stress, number of factors changed, and historical frequency)

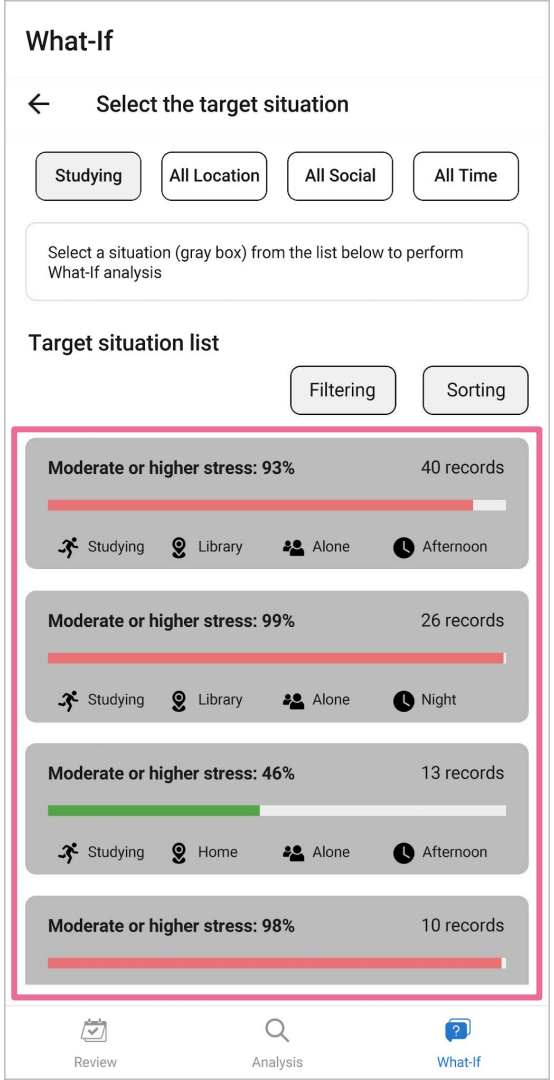
Sorting: apply ascending / descending sorting

CounterStress

Review Screen

Analysis Screen

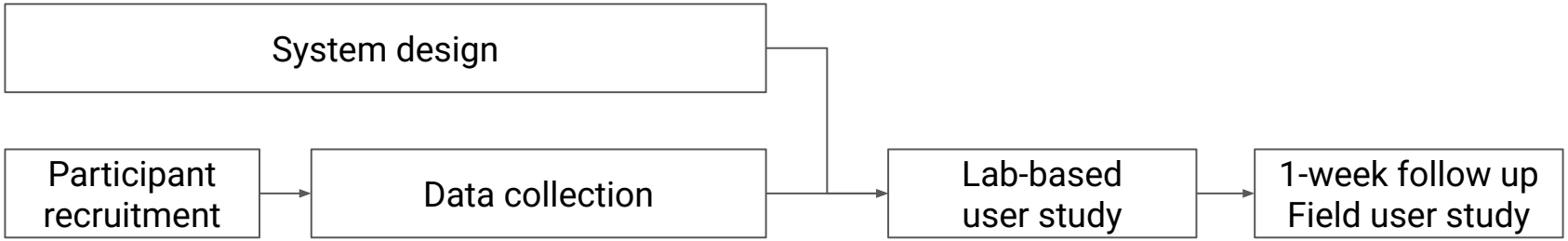
What-If Screen



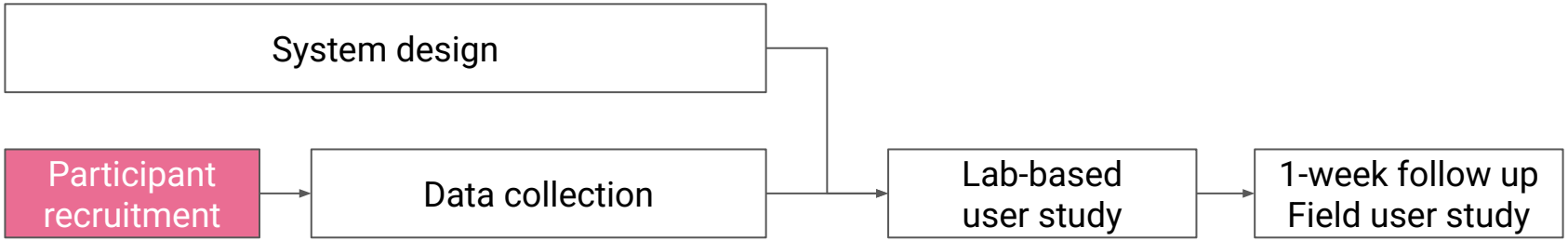
Counterfactual-based coping strategies for the selected situation (i.e., a combination of contextual factors)

List of **situations experienced** by the user (i.e., situations found in the collected data along with the probability of experiencing high stress)

User Study

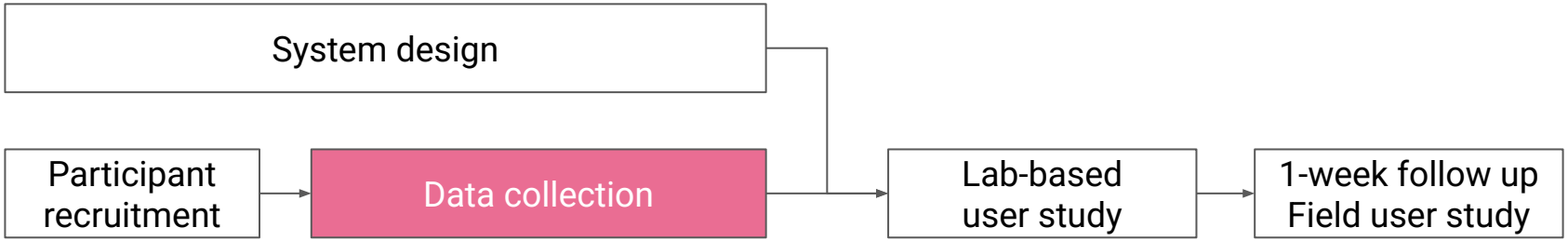

System design
Participant recruitment
Data collection
Lab-based user study
1-week follow up Field user study

User Study



12 participants (3 women, 9 men; age: M=23.1 (SD: 2.1))
Undergraduate students from a large university

User Study

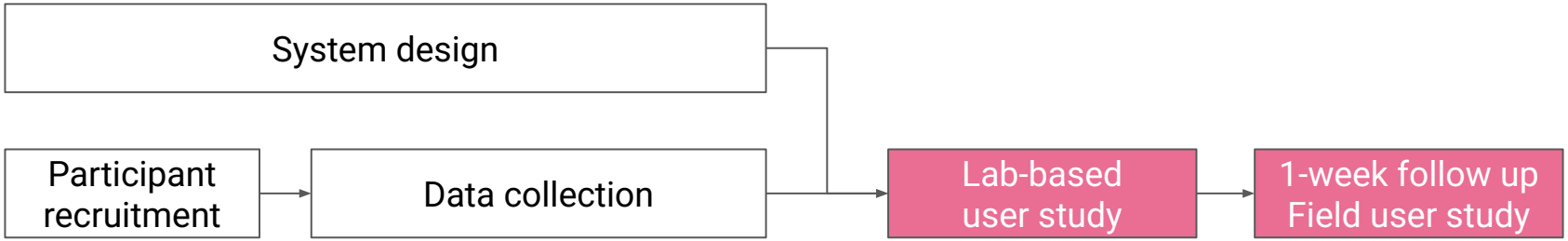


On average, 558.4 samples per person (SD: 144.2) were collected over six weeks using the Experience Sampling Method (ESM)

Context Type	Context Items
Activity	Studying, Class, Resting, Working, Research, Meeting, Exercising, Eating, Social Activities, Drinking, Leisure Activities, Club Activities, Moving, Waiting, Preparing, Others
Location	Dormitory, Home, Classroom, Library, Laboratory, Workplace, Restaurant, Cafe, Pub, Store, Gym, Club Room, Vehicle, Outdoors, Leisure Facility, Others
Social Setting	Alone, Family, Friend, Girlfriend/Boyfriend, Roommate, Colleague, Professor, Others

+ **Time** – response time, recorded automatically

User Study



Lab-based user study: Examine how participants used CounterStress **in a lab setting** and evaluated the system's data-driven insights (interview)

Field user study: Investigate how participants used CounterStress and applied the provided information **in their daily lives** (diary)

Evaluation

RQ1: How do users **perceive** suggested counterfactual-based coping strategies?

RQ2: How do users **explore and select** counterfactual-based coping strategies?

RQ3: How do users **apply** counterfactual-based coping strategies in real-world settings?

Evaluation

RQ1: How do users **perceive** suggested counterfactual-based coping strategies?

Enabling the simulation of the impact of contextual changes on stress levels

*"I like that CounterStress can **predict** whether a strategy I've never tried before **will work for me or not.** Otherwise, I'd have to try everything out blindly."* (P10)

*"Evaluating things by changing conditions one by one like this would help me create **concrete strategies to lower stress effectively** (in specific situations)."* (P06)

Evaluation

RQ1: How do users **perceive** suggested counterfactual-based coping strategies?

Providing multiple coping strategies and allowing users to compare them

> *"It shows multiple strategies, allowing me to **choose the ones that seem the most suitable** for the given situation. I like that it offers **various options to apply** based on the situation."* (P09)

> *"Even in similar situations, like studying with friends in the club room, I noticed how much my stress changes depending on the time. I realized **small context changes can have a bigger impact** than I expected."* (P12)

Evaluation

RQ2: How do users **explore and select** counterfactual-based coping strategies?

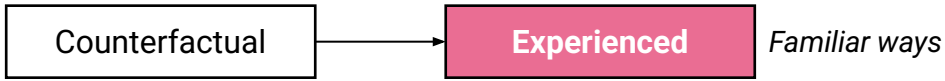
Evaluate coping strategies based on the three criteria in the counterfactual generation process

Evaluation

RQ2: How do users **explore and select** counterfactual-based coping strategies?

Evaluate coping strategies based on the three criteria in the counterfactual generation process

Historical frequency (plausibility): Prioritize situations that had been experienced in the past



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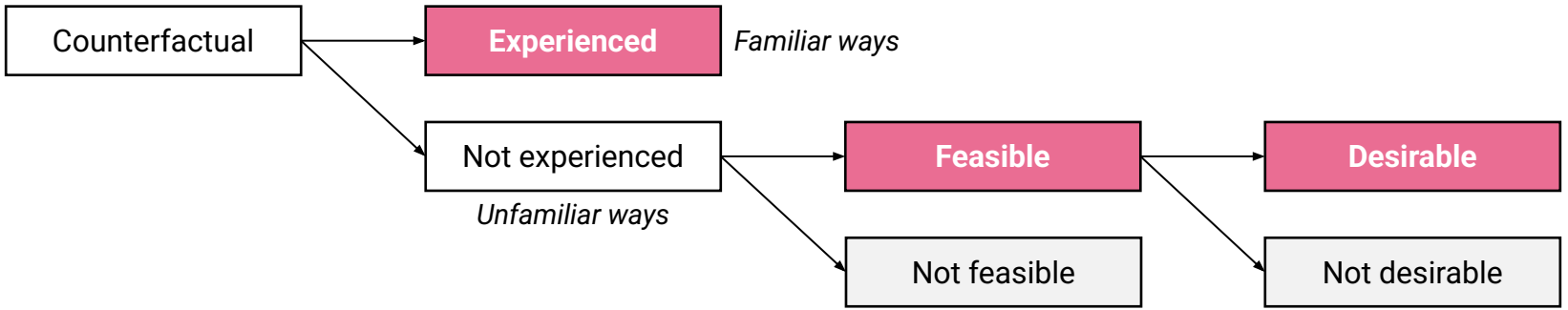


Evaluation

RQ2: How do users **explore and select** counterfactual-based coping strategies?

Evaluate coping strategies based on the three criteria in the counterfactual generation process

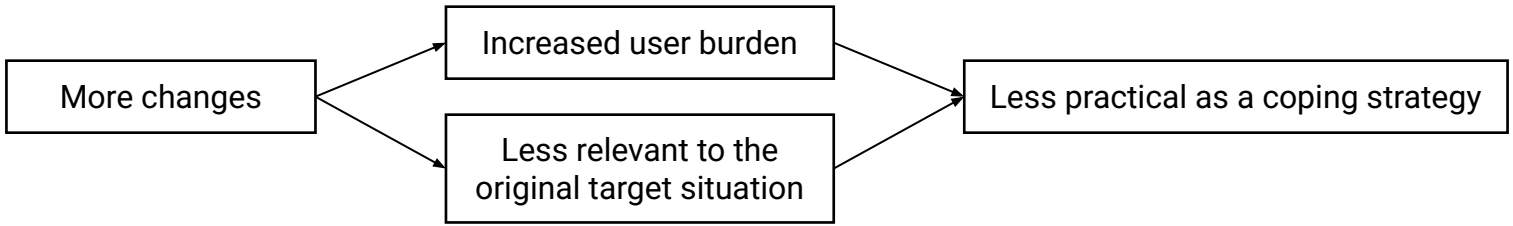
Number of factor changes (minimality): Prefer situations that require fewer context changes

Evaluation

RQ2: How do users **explore and select** counterfactual-based coping strategies?

Evaluate coping strategies based on the three criteria in the counterfactual generation process

Number of factor changes (minimality): Prefer situations that require fewer context changes



Evaluation

RQ2: How do users **explore and select** counterfactual-based coping strategies?

Evaluate coping strategies based on the three criteria in the counterfactual generation process

High-stress probability (validity): Pay less attention to how much the probability decreases

Evaluation

RQ2: How do users **explore and select** counterfactual-based coping strategies?

Set **constraints** to fix certain contextual factors while exploring changes in the remaining factors

Studying
Attending classes
Working

} Essential tasks in daily lives

Keep these contextual factors **fixed** and **adjust other types of factors!**

Evaluation

RQ3: How do users **apply** counterfactual-based coping strategies in real-world settings?

Utilize CounterStress across different situations

(1) Prepare strategies to minimize stress **before engaging in specific activities**

(2) Explore ways to relieve stress **when feeling stressed**

(3) Reflect on stress levels **at the end of the day**

Evaluation

RQ3: How do users **apply** counterfactual-based coping strategies in real-world settings?

Follow CounterStress's suggestions and experience their benefits

Spending more time in stress-relieving places (P06), completing important tasks early in the day (P10), and having meals at a restaurant rather than at the dormitory or convenience store (P08)

*"I tried writing my paper at a cafe instead of at home, and with a friend instead of alone. This really helped me **keep my stress low** while also **boosting my productivity**."* (P09)

Counterfactual Explanations in Personal Informatics

CounterStress supports users in planning stress-coping strategies, guiding them on **what changes to make** in specific situations

Counterfactual Explanations in Personal Informatics

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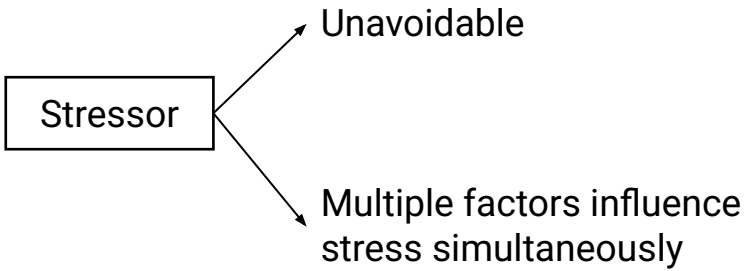

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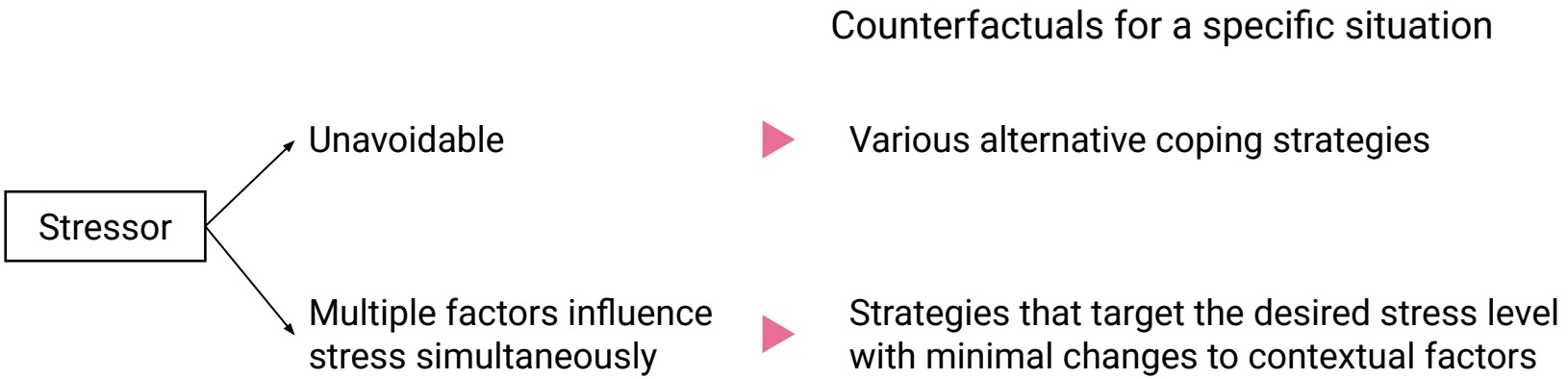

Counterfactual Explanations in Personal Informatics

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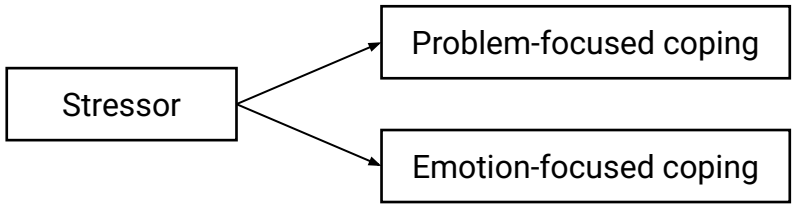
Lazarus and Folkman's transactional model of stress and coping (Lazarus, 1984)



Changing the stressor (**direct** approach)

Regulating one's emotion (**indirect** approach)

Lazarus, Richard S. "Stress, Appraisal, and Coping." *Springer,* 464 (1984)

Counterfactual Explanations in Personal Informatics

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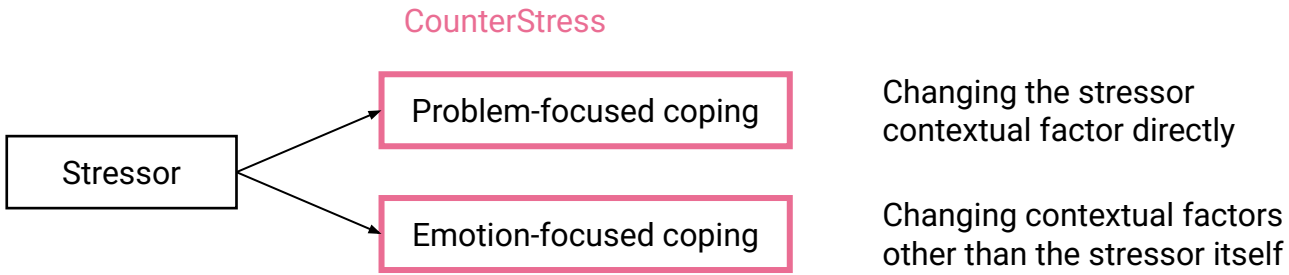


Lazarus, Richard S. "Stress, Appraisal, and Coping." *Springer,* 464 (1984)

Generating and Delivering Effective Counterfactuals

It is essential to carefully consider the **feasibility** of counterfactual-based coping strategies for users to apply in their daily lives

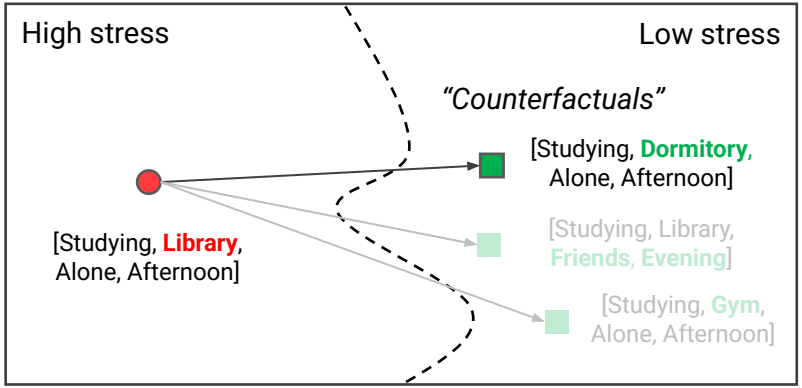
Use **statistical methods** (e.g., conditional probability)

Integrate **users' priorities and feedback**

Counterfactual Explanations X Causal Inference

Integrating counterfactual explanations with **causal inference** allows users to validate strategy effectiveness, ensuring **analytical rigor** while maintaining exploratory flexibility

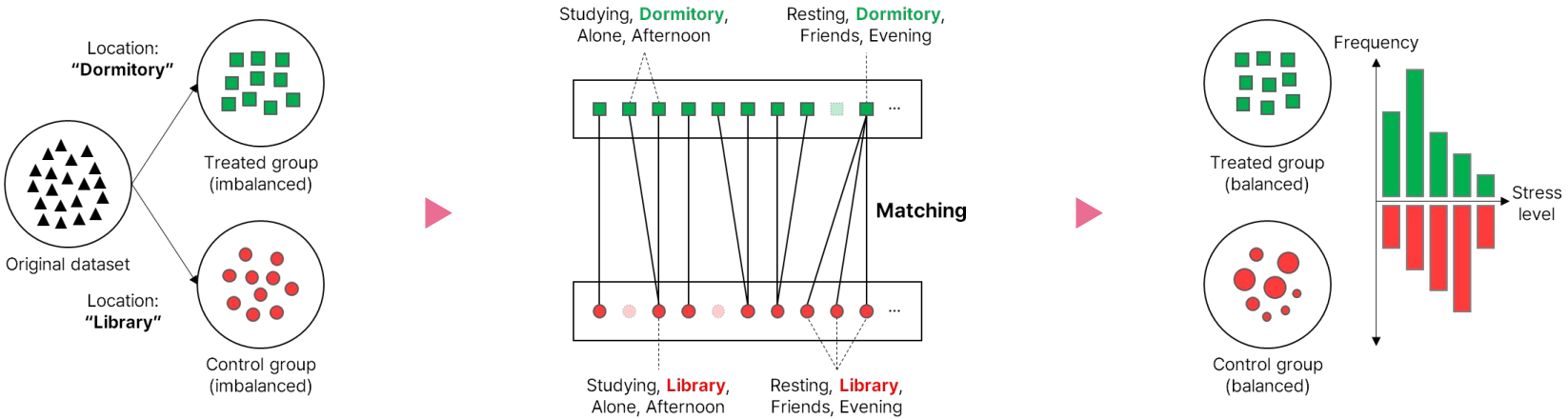
Counterfactual Explanations



Counterfactual Explanations X Causal Inference

Integrating counterfactual explanations with **causal inference** allows users to validate strategy effectiveness, ensuring **analytical rigor** while maintaining exploratory flexibility

Causal Inference (Quasi-Experimental Approach) (Jung et al., 2024)



Jung, Gyuwon et al., "DeepStress: Supporting Stressful Context Sensemaking in Personal Informatics Systems Using a Quasi-experimental Approach." CHI '24.

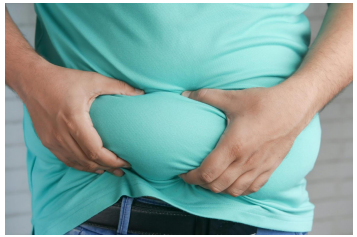
Application in Other Health and Well-being Scenarios

Scenarios where multiple factors influence a target health outcome, such as weight, sleep, productivity, chronic condition, and more (Kabir et al, 2023)






Does this approach really lower my body fat percentage?



What should I do now to bring my body fat percentage below 25%?

Kabir, Kazi Sinthia et al. "A Meta-Synthesis of the Barriers and Facilitators for Personal Informatics Systems." ACM IMWUT 7.3 (2023)

CHI2025

CounterStress

Enhancing Stress Coping Planning through Counterfactual Explanations in Personal Informatics

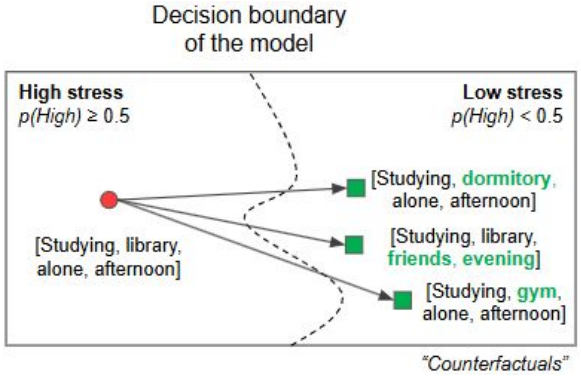
Gyuwon Jung and Uichin Lee

*More about **Gyuwon**!*

Key takeaways

Applying **counterfactual explanations** to **personal informatics** enables users to effectively derive the **necessary changes** from their everyday data to achieve their **desired health state**

HCI research should support not only self-reflection but also **practical guidance for meaningful actions**, even in the presence of **complex relationships** among multiple factors in everyday life data



KAIST Interactive Computing Laboratory