CHI 2024
Surfing the World
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DeepStress

Supporting Stressful Context Sensemaking in Personal Informatics Systems Using a Quasi-experimental Approach

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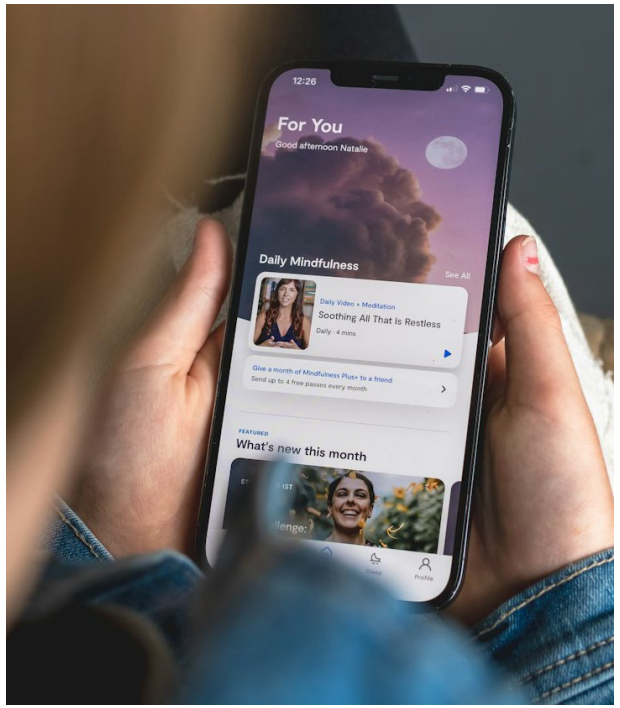
Personal Informatics: Gaining Insights from Own Data

Systems that assist users in gathering **personally relevant information**,
enabling them to **reflect on their self-tracking data** and **gain self-knowledge** (Li et al., 2010)



Li, Ian, et al. "A stage-based model of personal informatics systems." *Proceedings of the SIGCHI conference on human factors in computing systems*. 2010.

Personal Informatics: Gaining Insights from Own Data

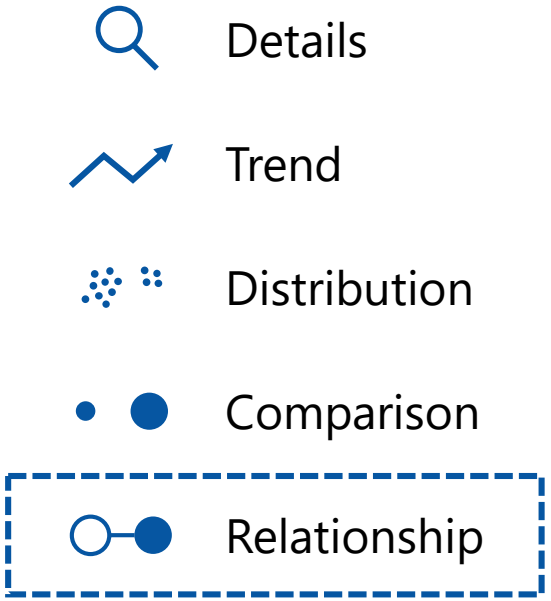
Existing HCI studies have proposed personal informatics systems targeting various **health and well-being domains** (Epstein et al., 2020)

Physical and mental health issues that require **long-term management** for optimal care

Epstein, Daniel A., et al. "Mapping and taking stock of the personal informatics literature." Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies 4.4 (2020): 1-38.

Data-Driven Insights: Relationship Analysis

Personal informatics systems support **correlational analysis**



Contextual factors ~ Well-being indicators
(Bentley et al., 2013)

Contextual factors ~ Sleep quality
(Liang et al., 2016)

Multifaceted personal data
(Jones and Kelly, 2018)

Bentley, Frank, et al. "Health Mashups: Presenting statistical patterns between wellbeing data and context in natural language to promote behavior change." *ACM Transactions on Computer-Human Interaction (TOCHI)* 20.5 (2013): 1-27.

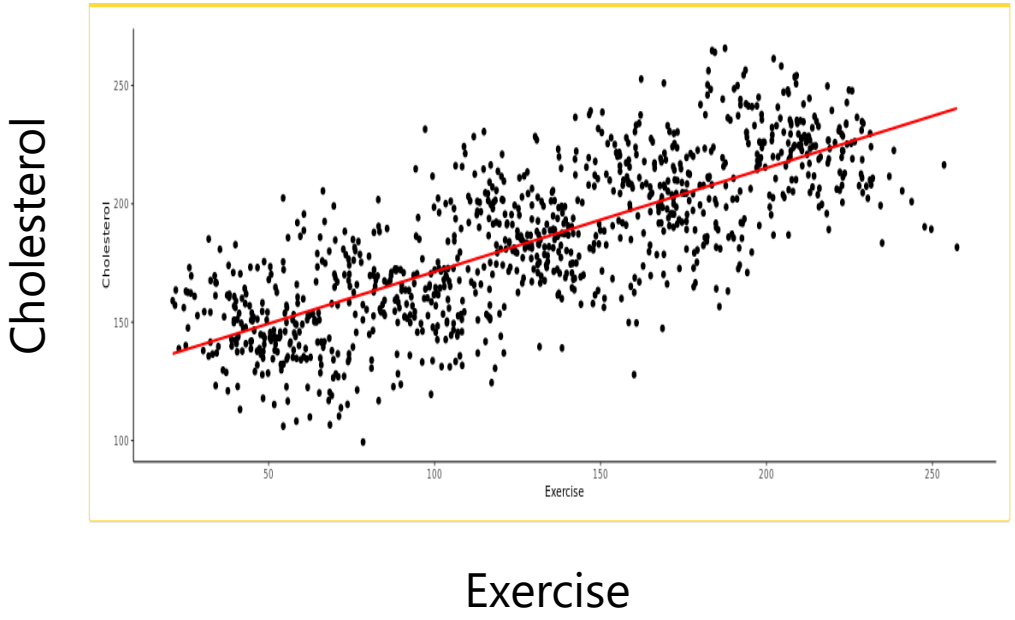
Liang, Zilu, et al. "SleepExplorer: a visualization tool to make sense of correlations between personal sleep data and contextual factors." *Personal and Ubiquitous Computing* 20 (2016): 985-1000.

Jones, Simon L., and Kelly, Ryan. "Dealing with information overload in multifaceted personal informatics systems." *Human–Computer Interaction* 33.1 (2018): 1-48.

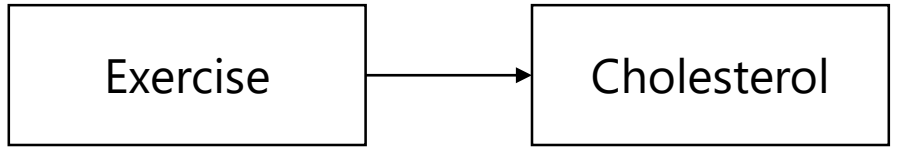
Exploring Causal Relationships from Self-Tracking Data

"**Correlation** does not imply **causation**"

Simpson's paradox (Pearl et al., 2016)



Does exercise cause higher cholesterol levels?



Pearl, Judea, et al. *Causal inference in statistics: A primer*. John Wiley & Sons, 2016.

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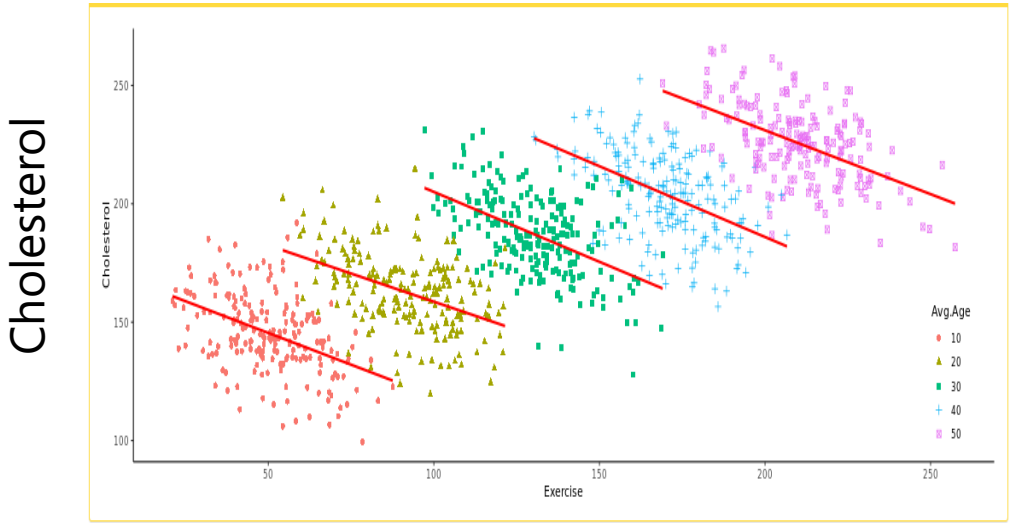
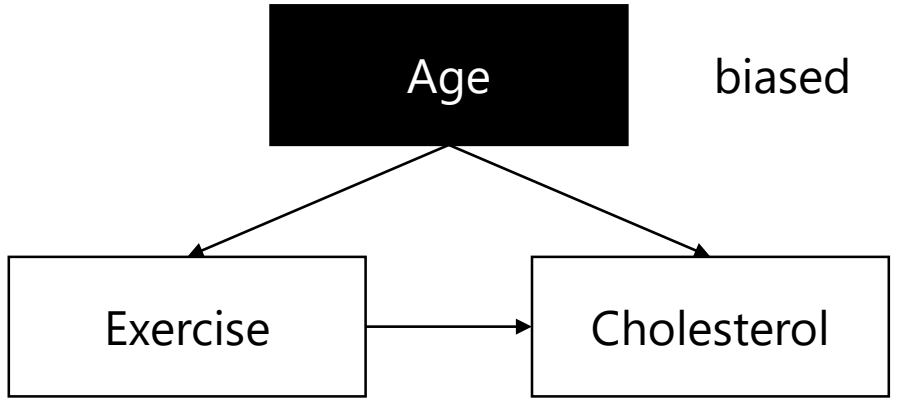


Exercise

There is a hidden "confounding" factor!



Experimental approach – random assignment

Pearl, Judea, et al. *Causal inference in statistics: A primer*. John Wiley & Sons, 2016.

Exploring Causal Relationships from Self-Tracking Data

Self-experimentation, which involves experimenters conducting experiments on themselves

Personal food triggers of irritable bowel syndrome
(Karkar et al., 2017)

Most data in personal informatics systems is collected in the form of **"observational data"**

The experimental approach is feasible only when **manipulating conditions is readily achievable**

Users are required to **adhere to the randomly assigned conditions** for causal investigation

Karkar, Ravi, et al. "Tummytrials: a feasibility study of using self-experimentation to detect individualized food triggers." *Proceedings of the 2017 CHI conference on human factors in computing systems*. 2017.

Objective

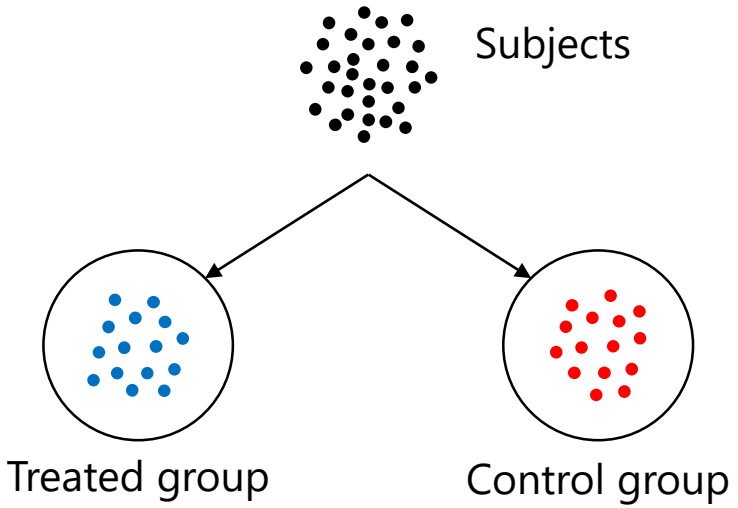
Design a personal informatics system that supports users in **exploring causal relationships** through **a quasi-experimental approach**

Investigating contextual factors **causally linked** to perceived stress levels using self-tracking data

Quasi-Experimental Approach

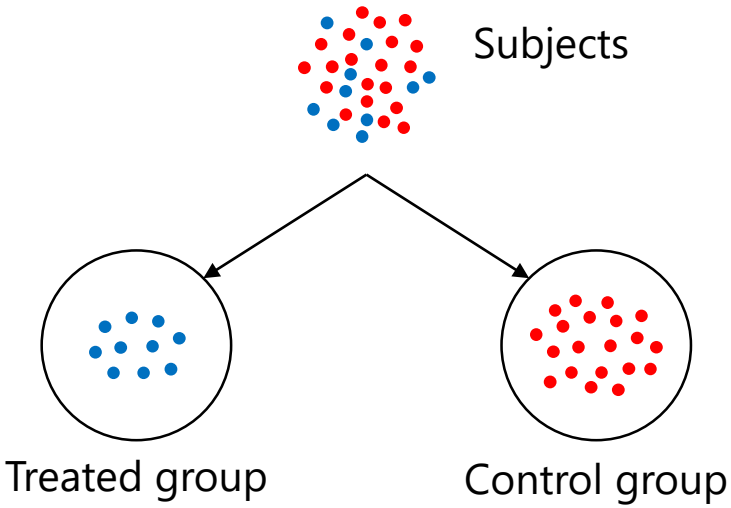
Random allocation of subjects

Experimental



Any change in outcome is likely attributed to the treatment (unbiased)

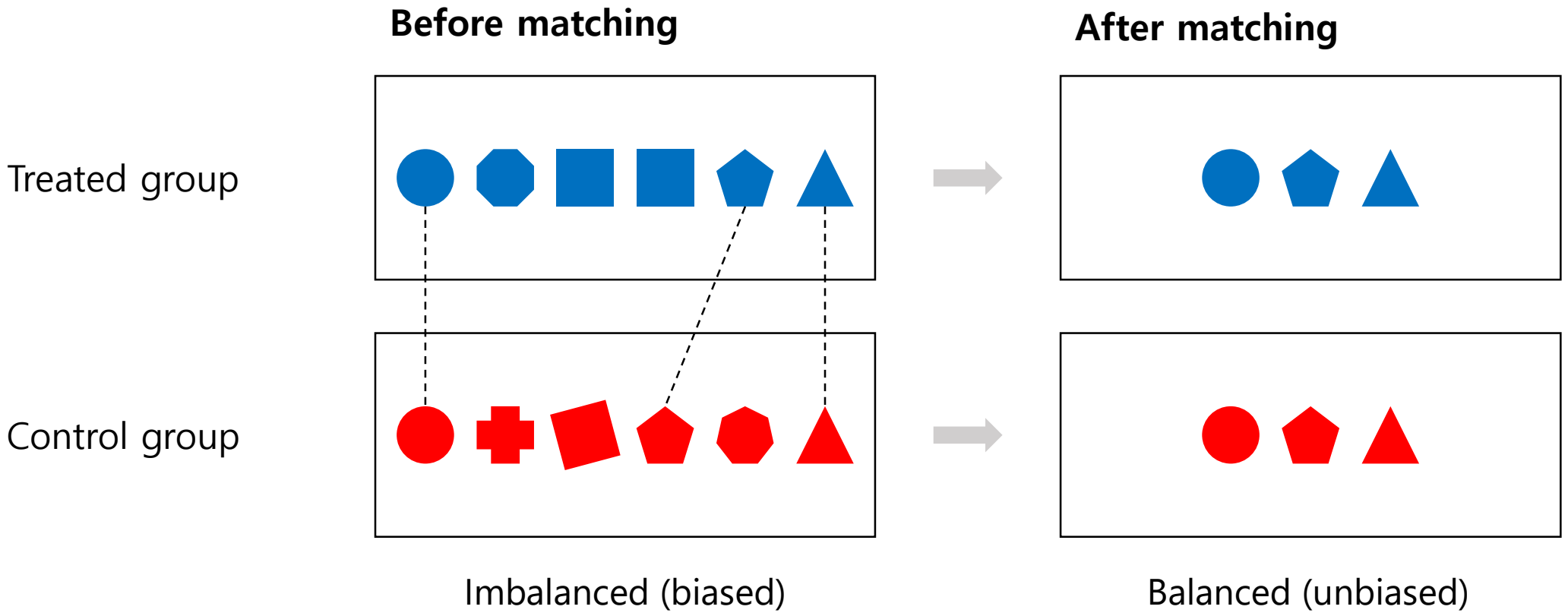
Quasi-Experimental



Any change in outcome can be influenced by external factors other than the treatment (biased)

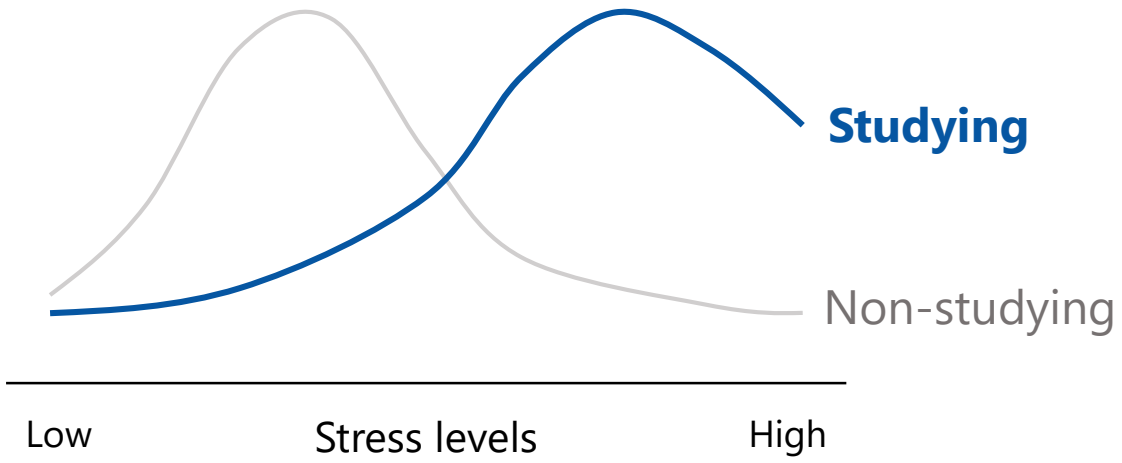
Quasi-Experimental Approach

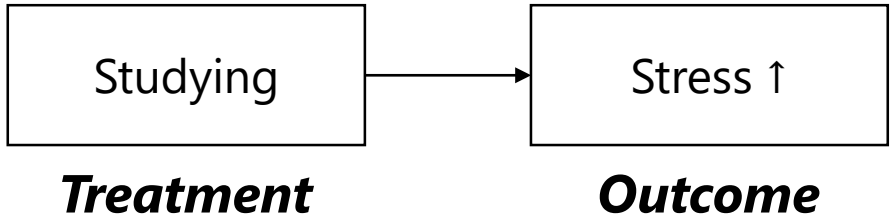
"Matching" – pairing subjects having identical combinations of confounding factors



Implementing a Quasi-experimental Approach

"Could studying be the cause of my increased stress?"





Implementing a Quasi-experimental Approach

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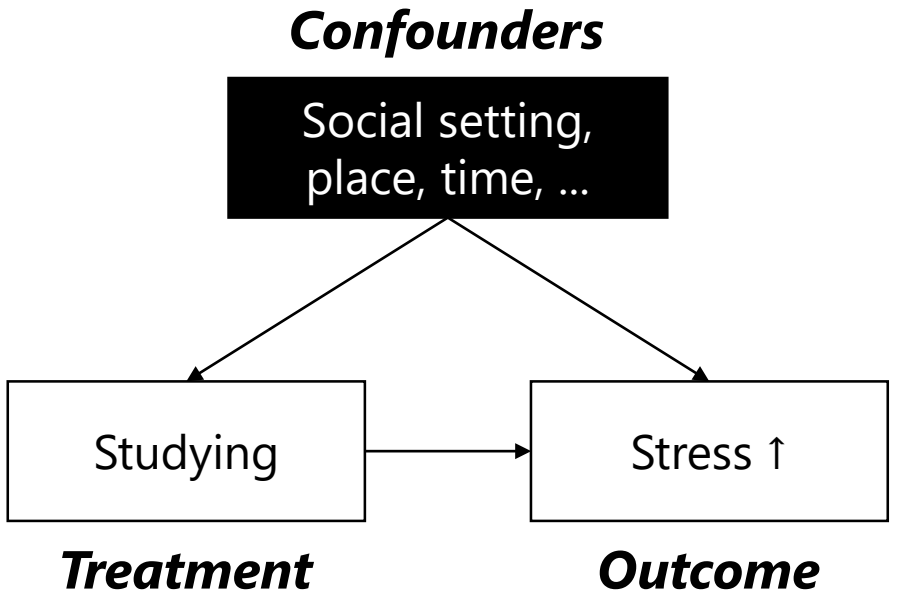
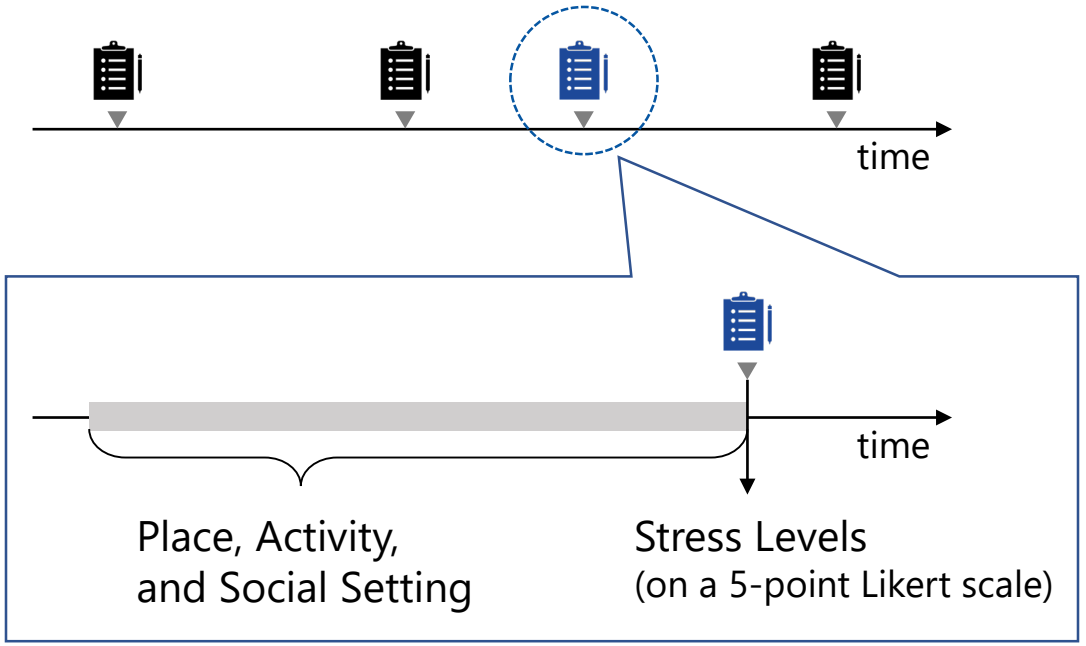


Implementing a Quasi-experimental Approach

Collect data using Experience Sampling Method (ESM)
to capture users' context and stress levels



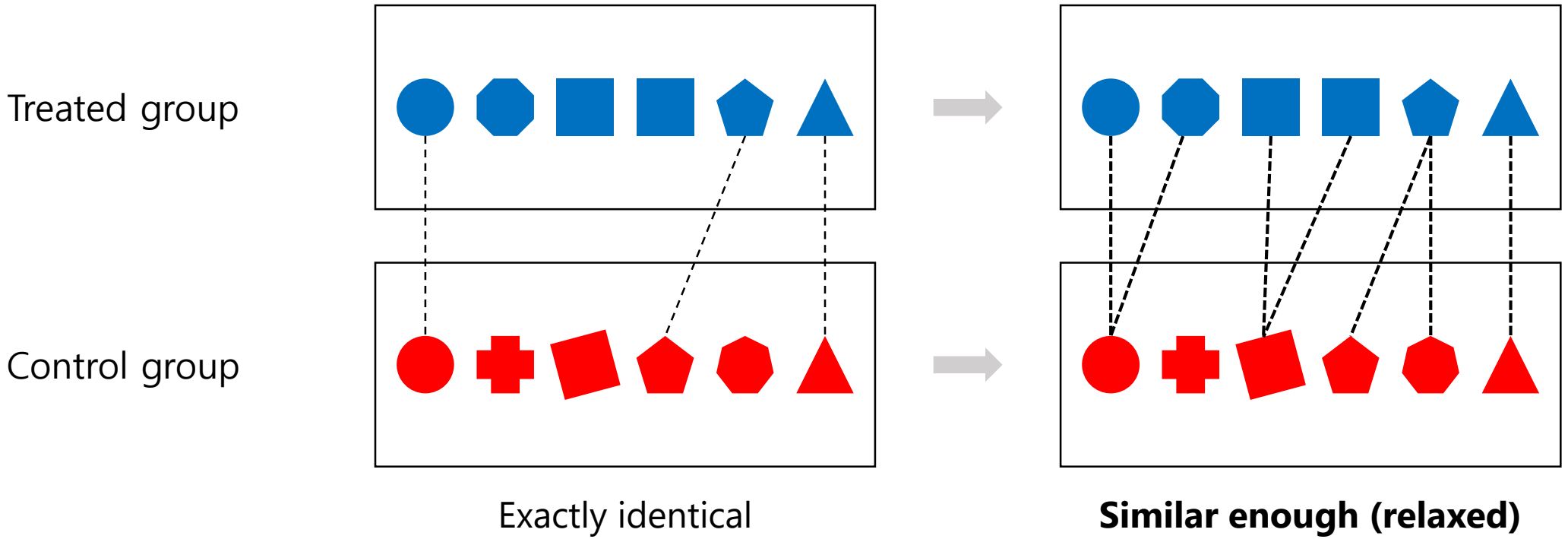
Context Type	Contexts Provided By the ESM Survey
Place	Home, Classroom, Dormitory, Library, Restaurant, Cafe, Pub, Club room, Laboratory, Place for exercise, Place for leisure, Outdoor, Place for part-time job, Public transportation
Activity	Class, Studying, Research, Resting, Meeting, Eating, Drinking, Part-time work, Club activity, Socializing, Leisure activity, Exercise, Moving
Social Setting	Alone, Family, Boyfriend/Girlfriend, Roommate, Friend, Colleague, Professor

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

Implementing a Quasi-experimental Approach

Allow users to create groups of contextual factors based on similarity

Coarsened Exact Matching (Iacus et al., 2012)



Iacus, Stefano M., et al. "Causal inference without balance checking: Coarsened exact matching." *Political analysis* 20.1 (2012): 1-24.

Implementing a Quasi-experimental Approach

Allow users to create groups of contextual factors based on similarity

Coarsened Exact Matching (Iacus et al., 2012)

Place

Classroom

Public transportation

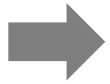
Dormitory

Home

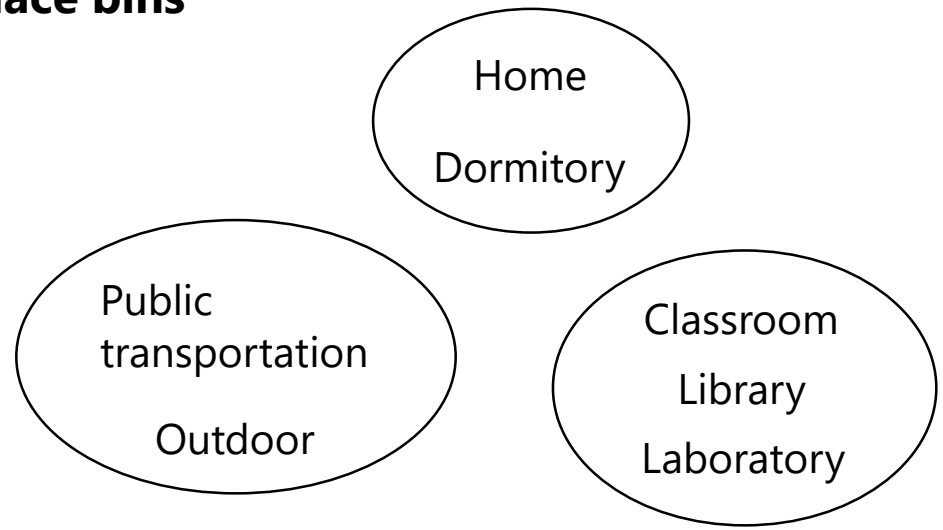
Laboratory

Library

Outdoor



Place bins



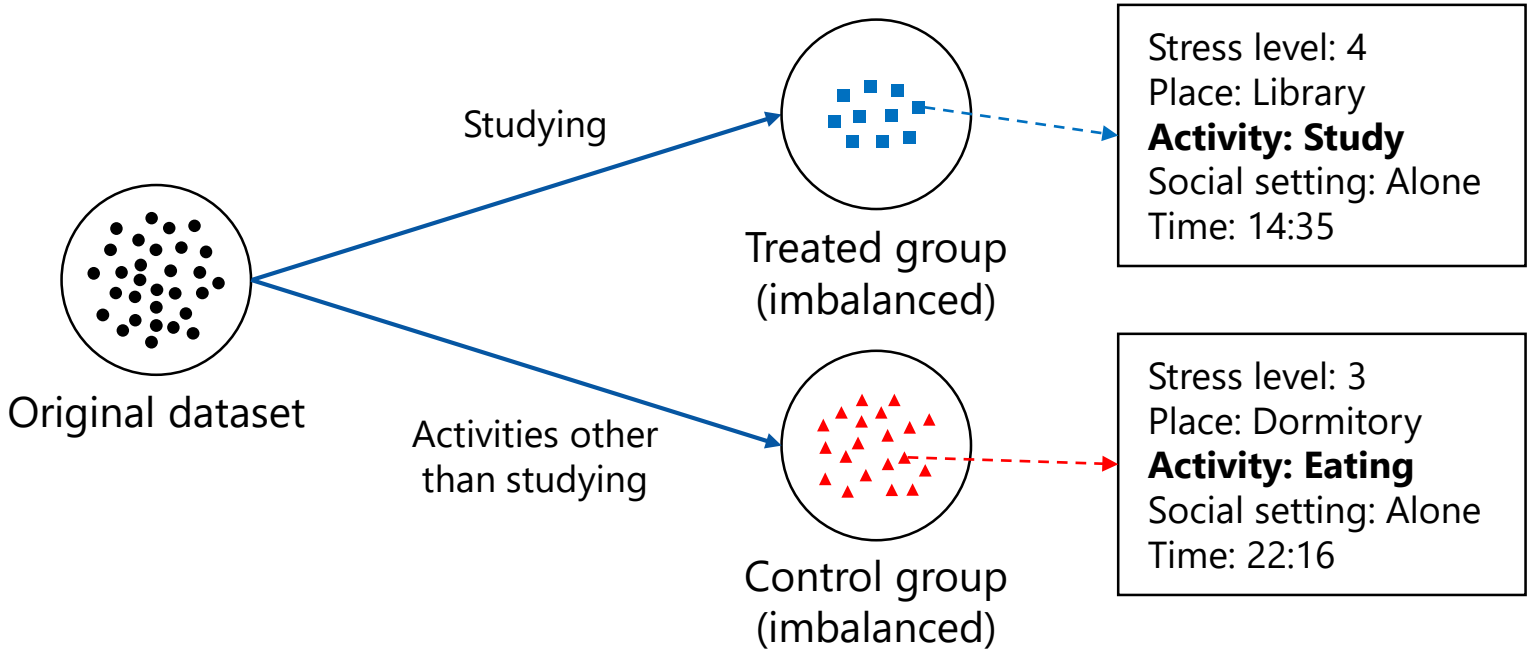
Contexts are considered **"similar enough"**
as long as they belong to the same coarsened bin

Iacus, Stefano M., et al. "Causal inference without balance checking: Coarsened exact matching." *Political analysis* 20.1 (2012): 1-24.

Implementing a Quasi-experimental Approach

Assign samples to treated or control group

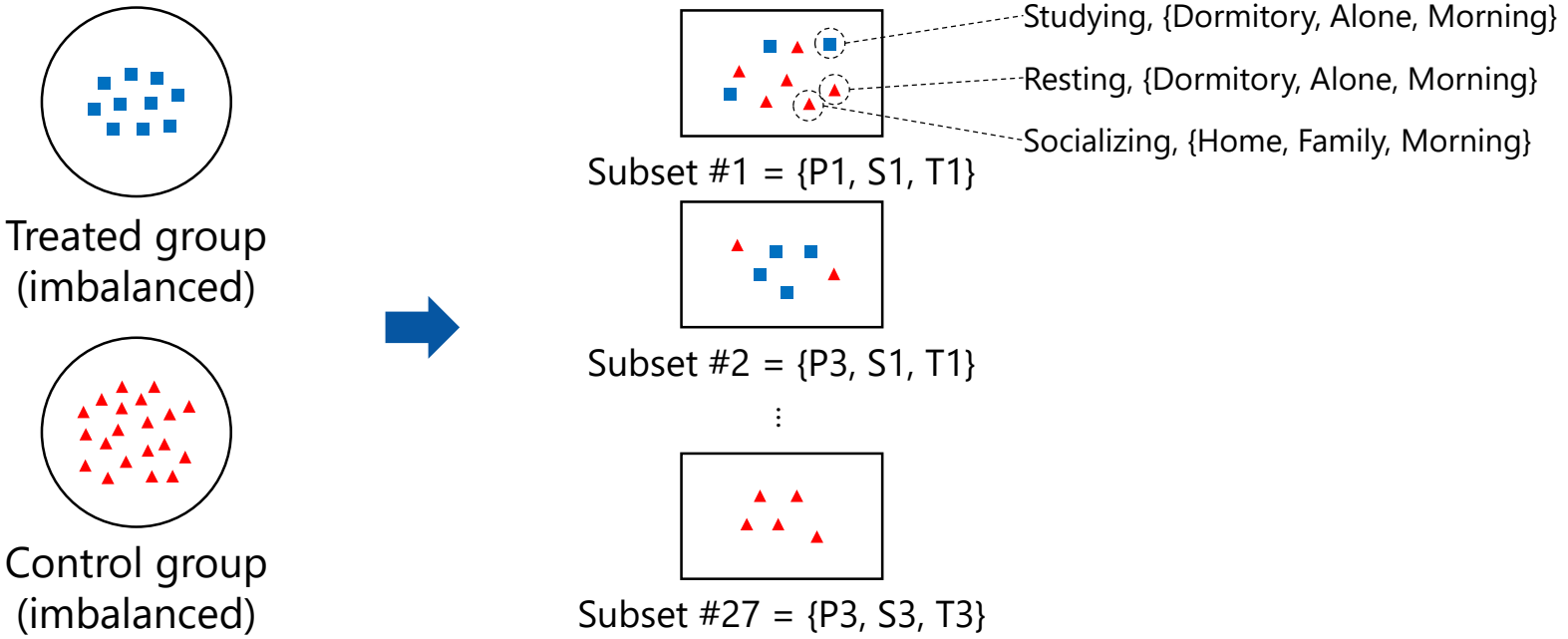
Treatment = **Studying** (activity)



Implementing a Quasi-experimental Approach

Allocate samples to subsets based on combinations of user-defined coarsened bins

Balancing contextual factors other than the "activity" type



User-defined coarsened bins

P

Place bins
P1: Home, Dormitory
P2: Public transportation, Outdoor
P3: Classroom, Library, Laboratory

S

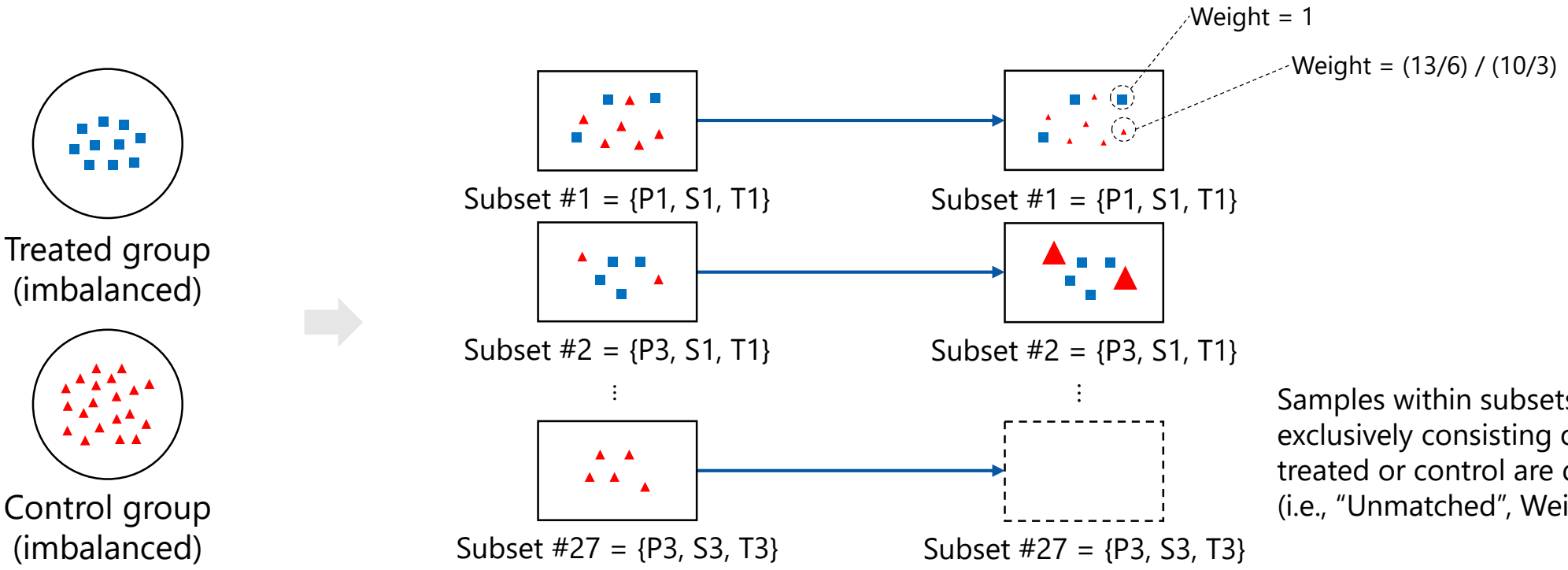
Social setting bins
S1: Alone, Family
S2: Professor, Colleague
S3: Boyfriend/Girlfriend, Friend

T

Time bins
T1: Morning
T2: Afternoon
T3: Evening

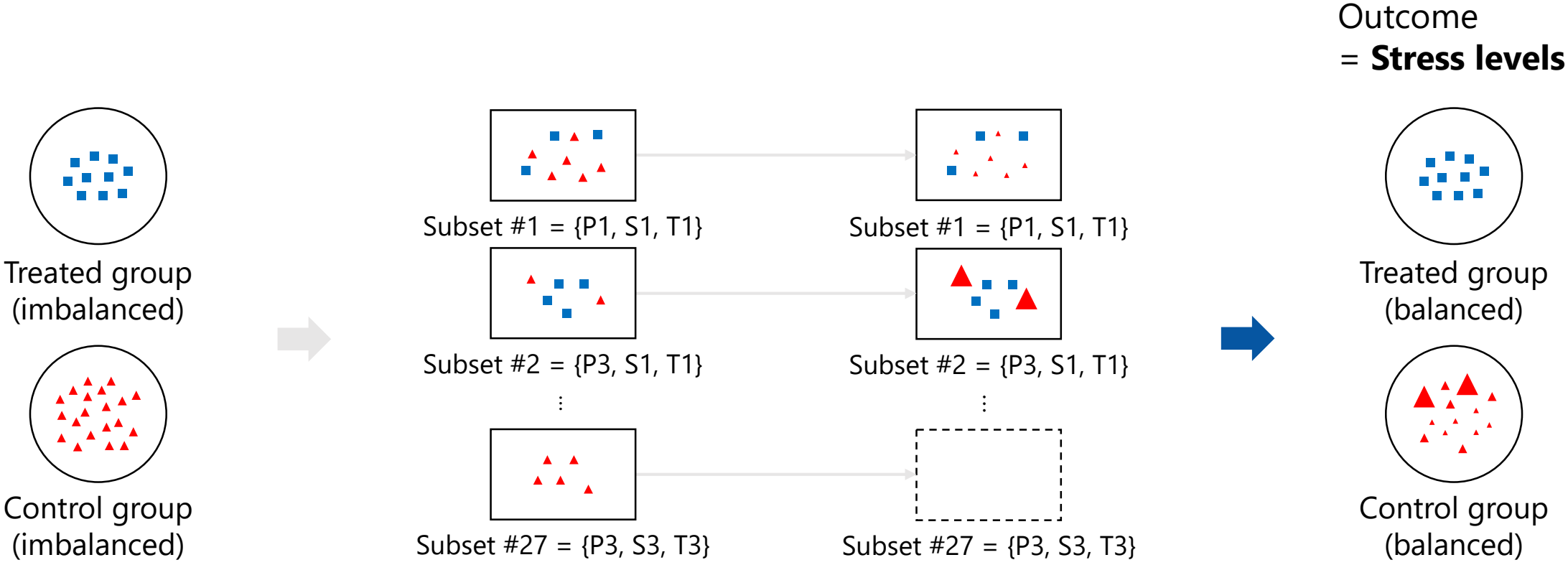
Implementing a Quasi-experimental Approach

Weight samples by relative proportions for each subset



Implementing a Quasi-experimental Approach

Compare outcomes (i.e., stress levels) of balanced groups



User Study Design

Participants Recruitment

24 participants (9 women, 15 men; age: M=21.3 (SD: 2.1))

Undergraduate students from diverse academic majors (e.g., natural science, engineering, …)

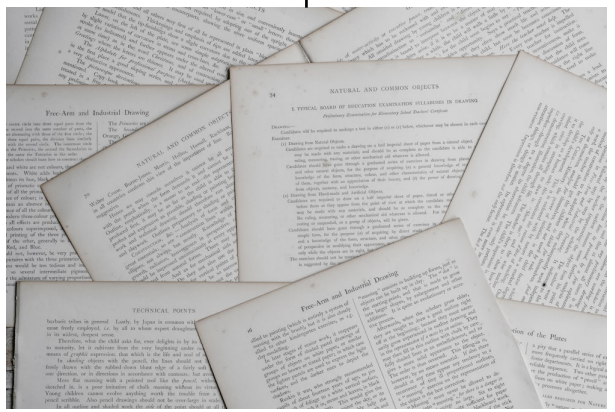
Data Collection

On average, 566.9 ESM surveys were collected over 6 weeks (SD: 156.8, max: 867, min: 258)

System Design

DeepStress

Preliminary Interview



Literature Review

DeepStress

Summary View

Calendar View

Context View

Correlational perspective; analysis without balancing confounding factors

Analysis View

Causal perspective; analysis with balancing confounding factors

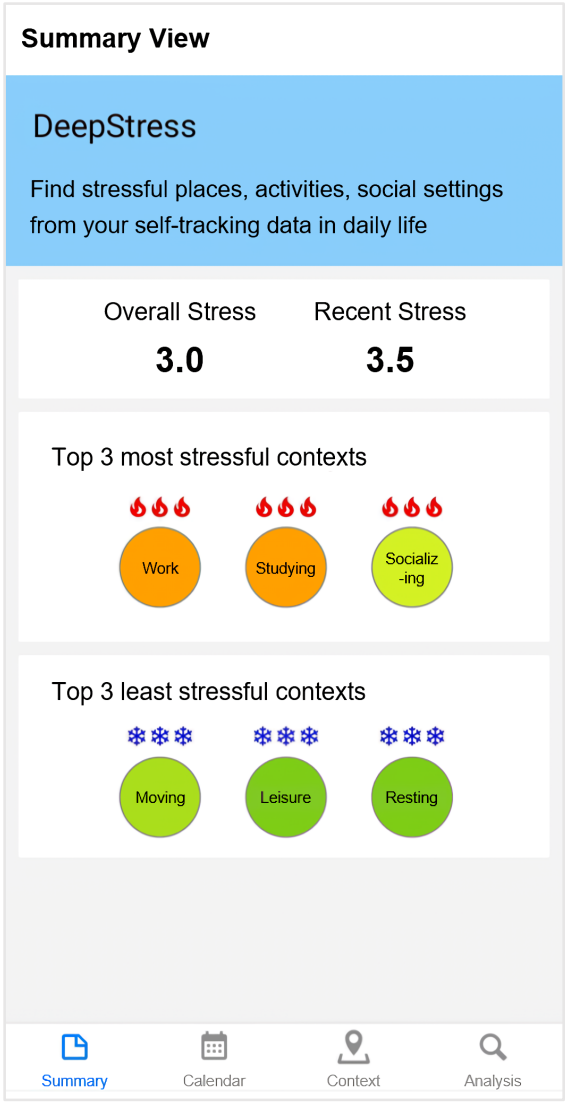
DeepStress

Summary View

Calendar View

Context View

Analysis View



A brief overview of the users' stress levels and stressful contexts as a landing page

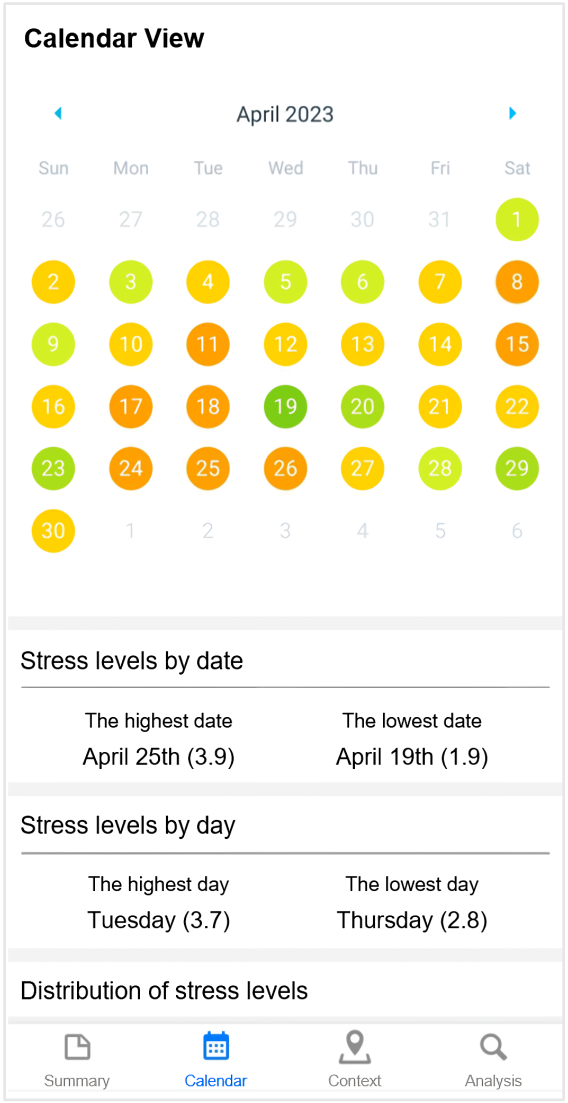
DeepStress

Summary View

Calendar View

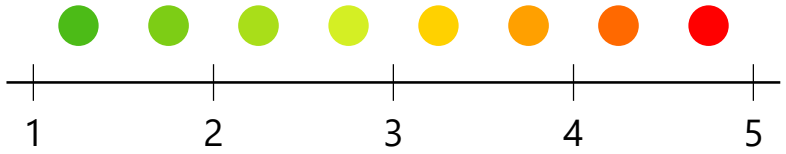
Context View

Analysis View



Summary and detailed records together, enabling users to reflect on their stress history

Color-coded according to the daily average stress level



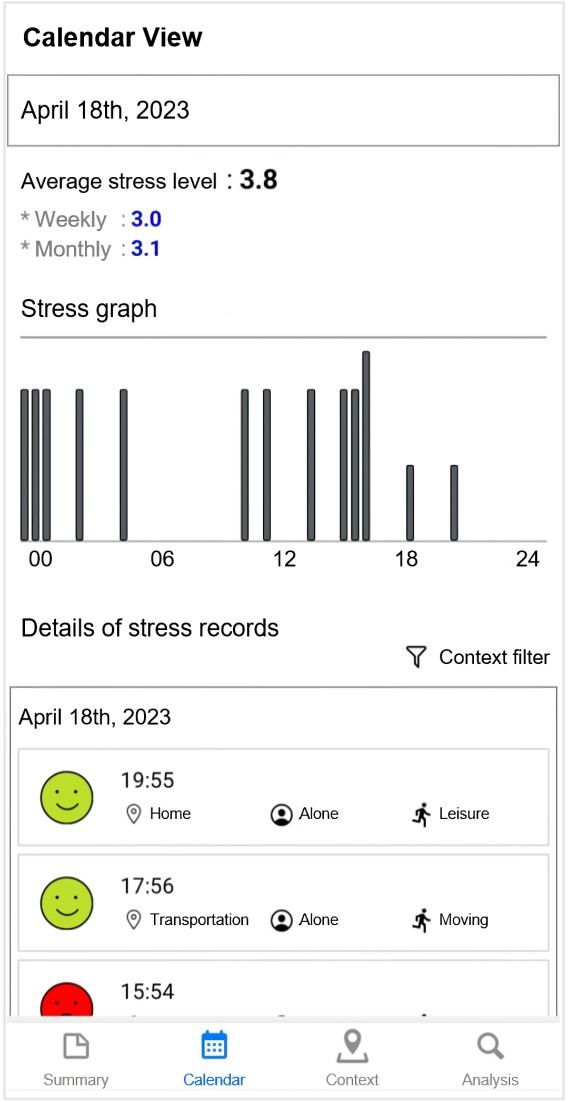
DeepStress

Summary View

Calendar View

Context View

Analysis View



Summary and detailed records together, enabling users to reflect on their stress history

Variations in stress levels throughout a specific day

Timeline of detailed records (collected through ESMs)

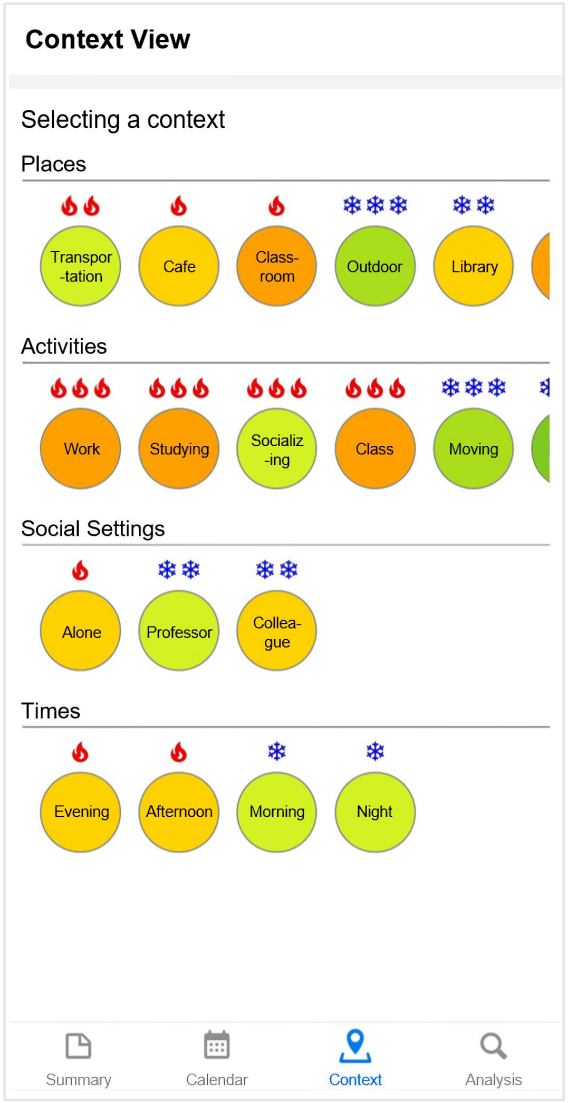
DeepStress

Summary View

Calendar View

Context View

Analysis View



Stress levels within a given context
and the relationships with other contexts

Average stress levels (~Correlation)

Negatively correlated

Positive correlated

Causal relationship (after balancing confounding factors)

❄ Cause of decreased stress

🔥 Cause of increased stress

❄ p < .05

❄❄ p < .01

❄❄❄ p < .001

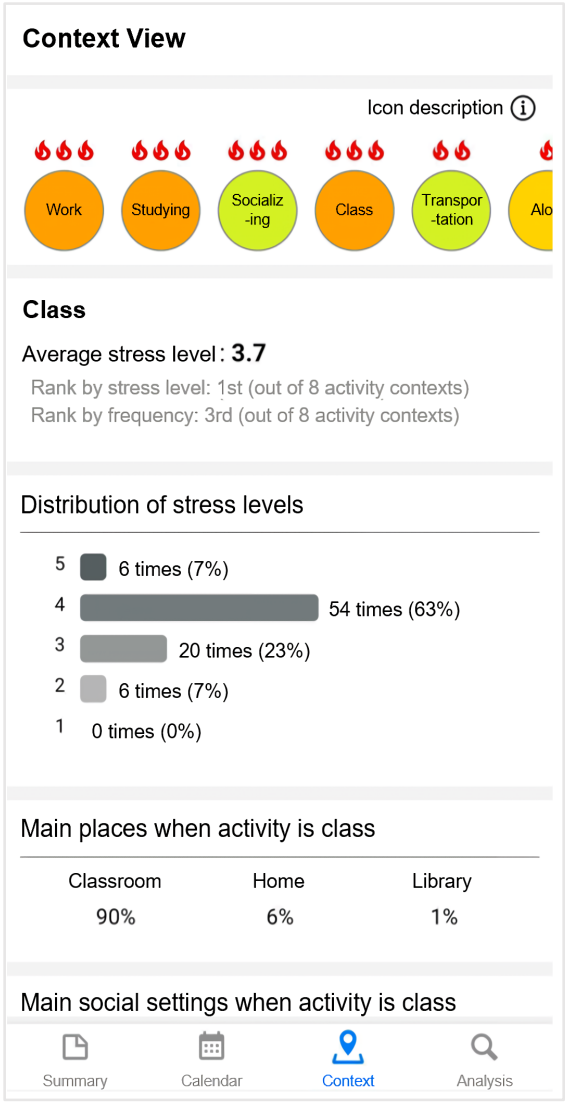
DeepStress

Summary View

Calendar View

Context View

Analysis View



Stress levels within a given context
and the relationships with other contexts

Ranking of the context based on
(1) average stress level and (2) frequency

Distribution of stress levels (their respective ratios)
within the context

Relationships with other contexts
(Frequency of co-occurrence)

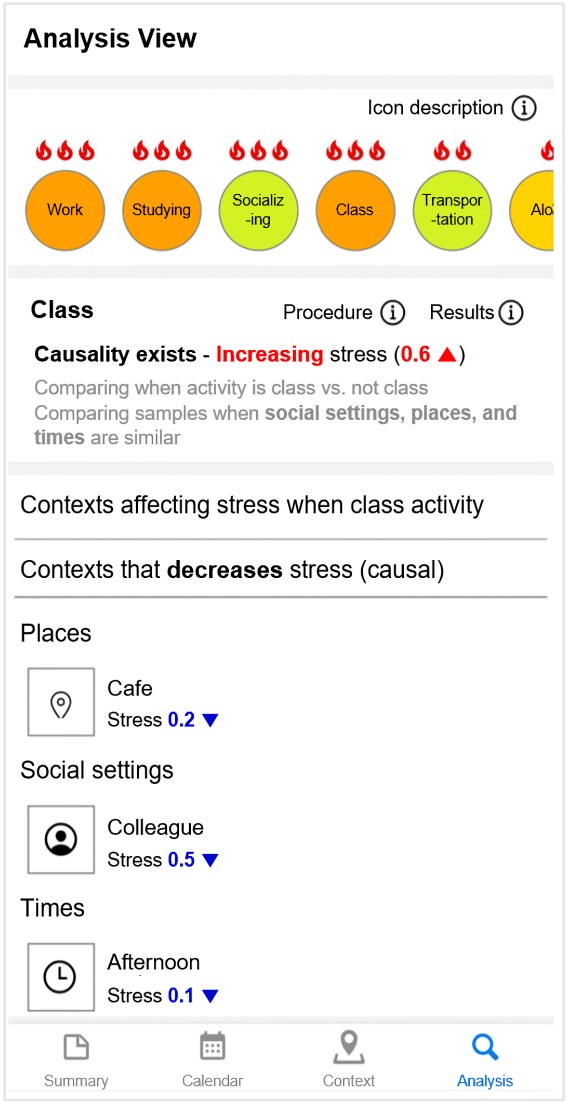
DeepStress

Summary View

Calendar View

Context View

Analysis View



Causal relationship between a given context and stress levels

Other contexts affecting stress levels

Evaluation

Lab-based user study
(Lab settings)

1 week follow-up
Field diary study
(Real world scenarios)

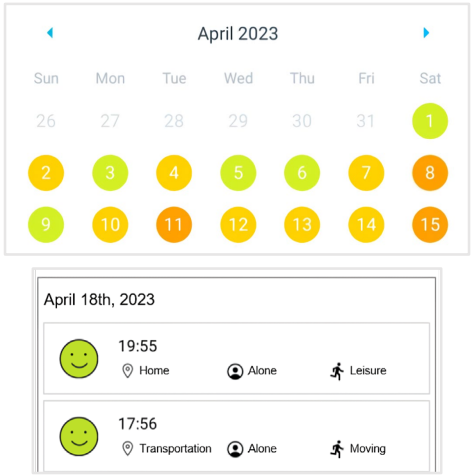
Evaluation

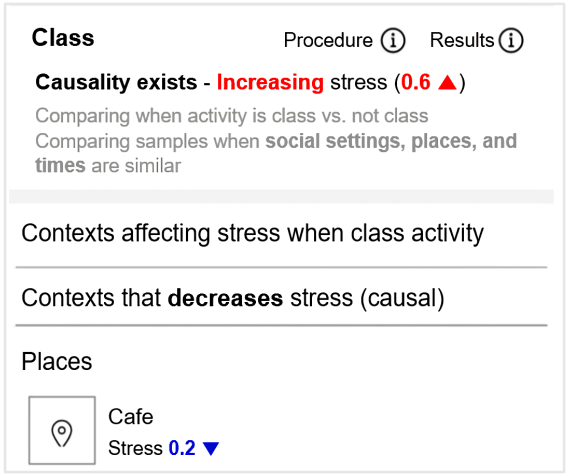
How does DeepStress support users in exploring their stressful contexts?

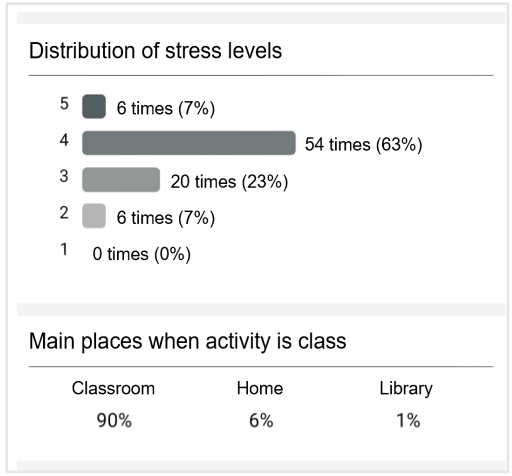
Enabling participants to recall past context and stress states readily

Allowing participants to identify stressful contexts while considering confounders

Letting participants consider relationships between multiple contexts

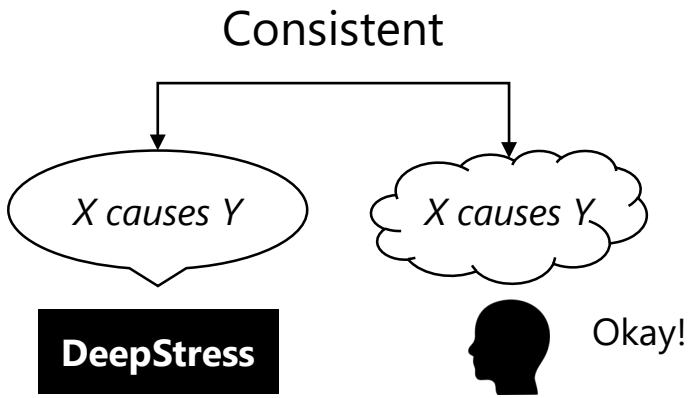






Evaluation

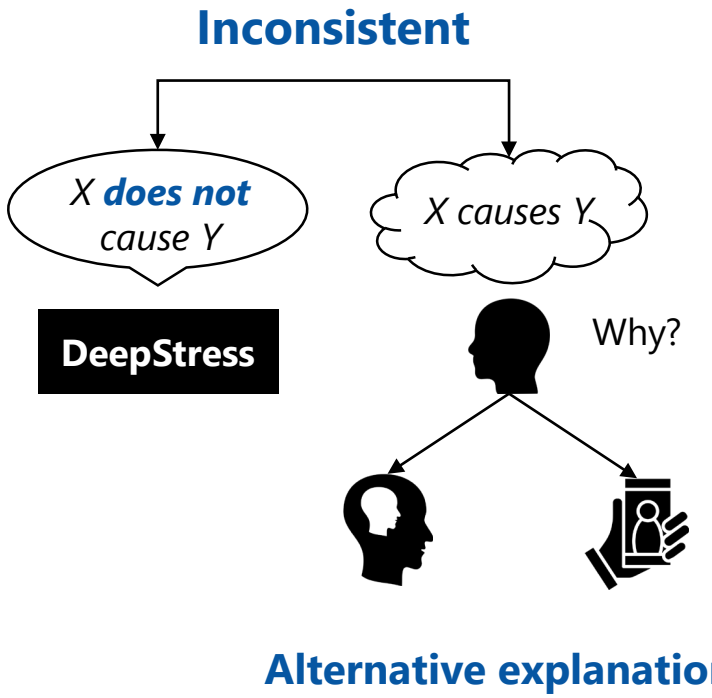
How do users interpret and conceptualize the causality results provided by DeepStress?



Reconfirming stressful contexts that are consistent with prior self-knowledge

Evaluation

How do users interpret and conceptualize the causality results provided by DeepStress?



Hypothesizing about the reason for unexpected causal analysis results

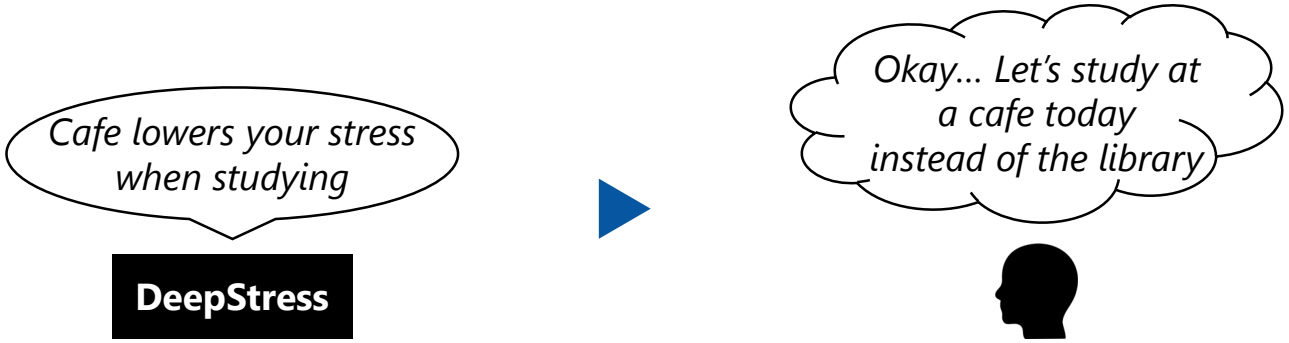
Evaluating alternative explanations using self-knowledge and self-tracking data

Evaluation

How do users utilize the information about stressful contexts in everyday life?

Understanding their own stress by revisiting the DeepStress data

Planning their every day towards lowering their stress levels

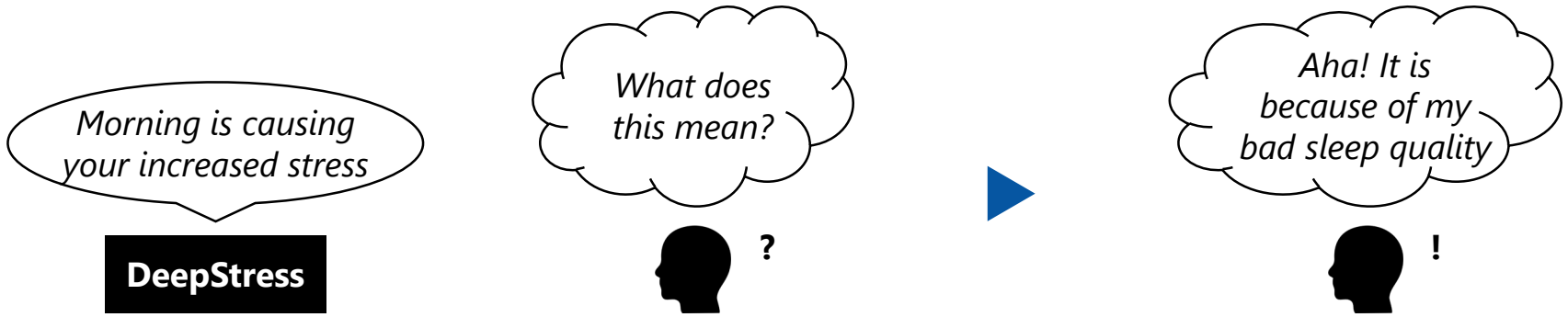


Evaluation

How do users utilize the information about stressful contexts in everyday life?

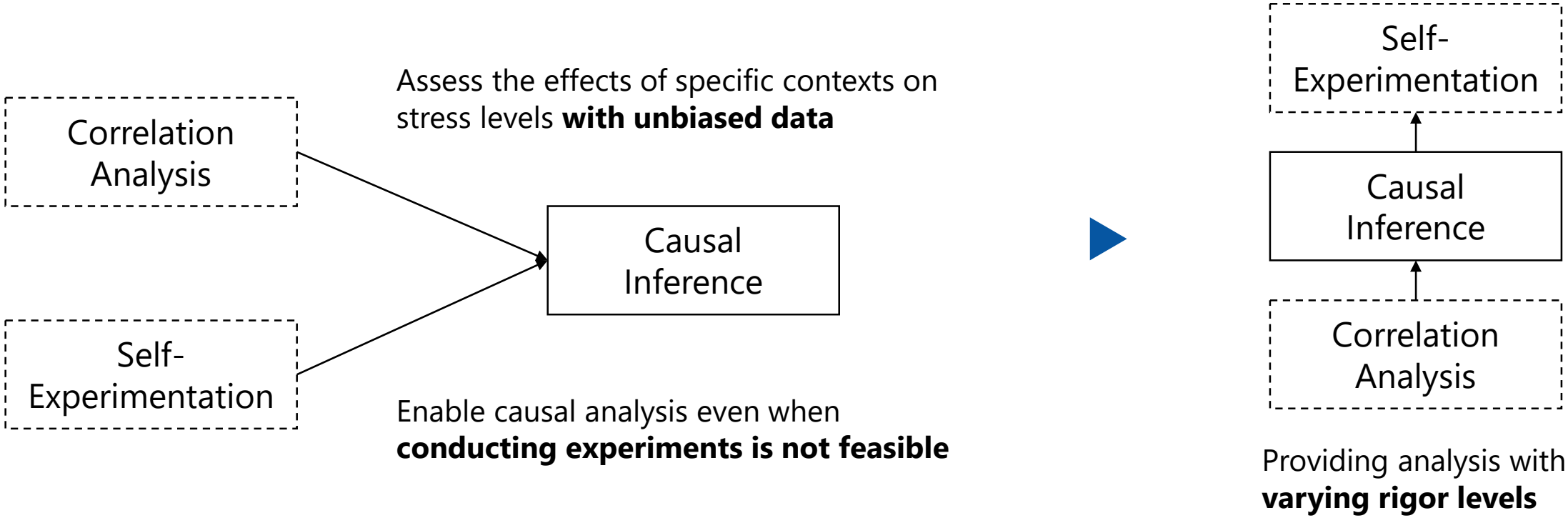
Conducting re-evaluation and detailed analysis of stressful contexts

Performing causality-driven coping actions when stress management is required



Causal Inference in Personal Informatics

Exploring contextual factors **causally related** to stress levels from self-tracking data

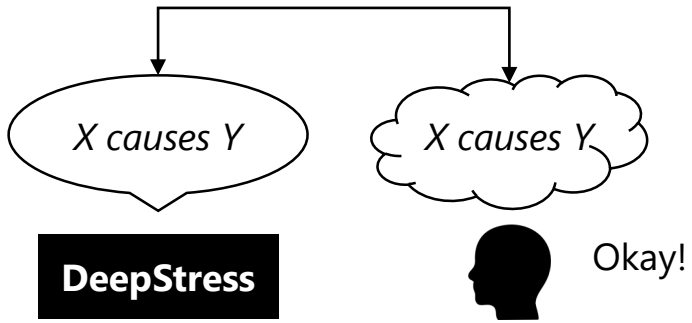


Sensemaking of the Causal Relationships

The overall process interpreted through the **sensemaking framework** (Mamykina et al., 2015)

HABITUAL MODE

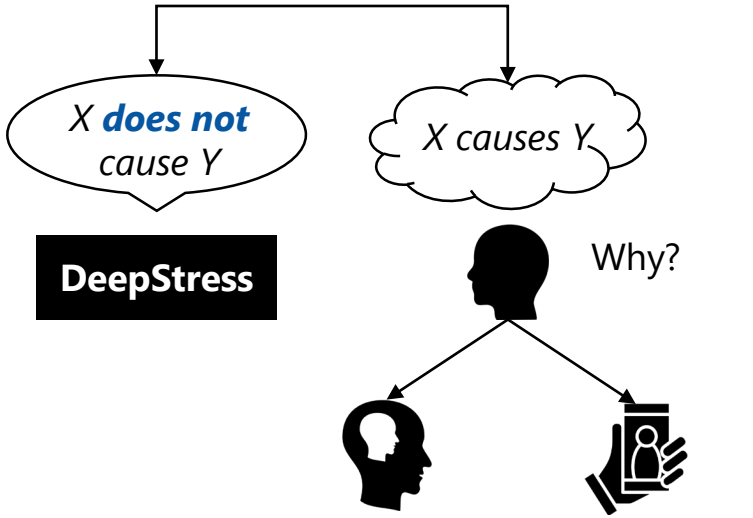
Consistent



Is there a **gap** between the new information and existing knowledge?

SENSEMAKING MODE

Inconsistent



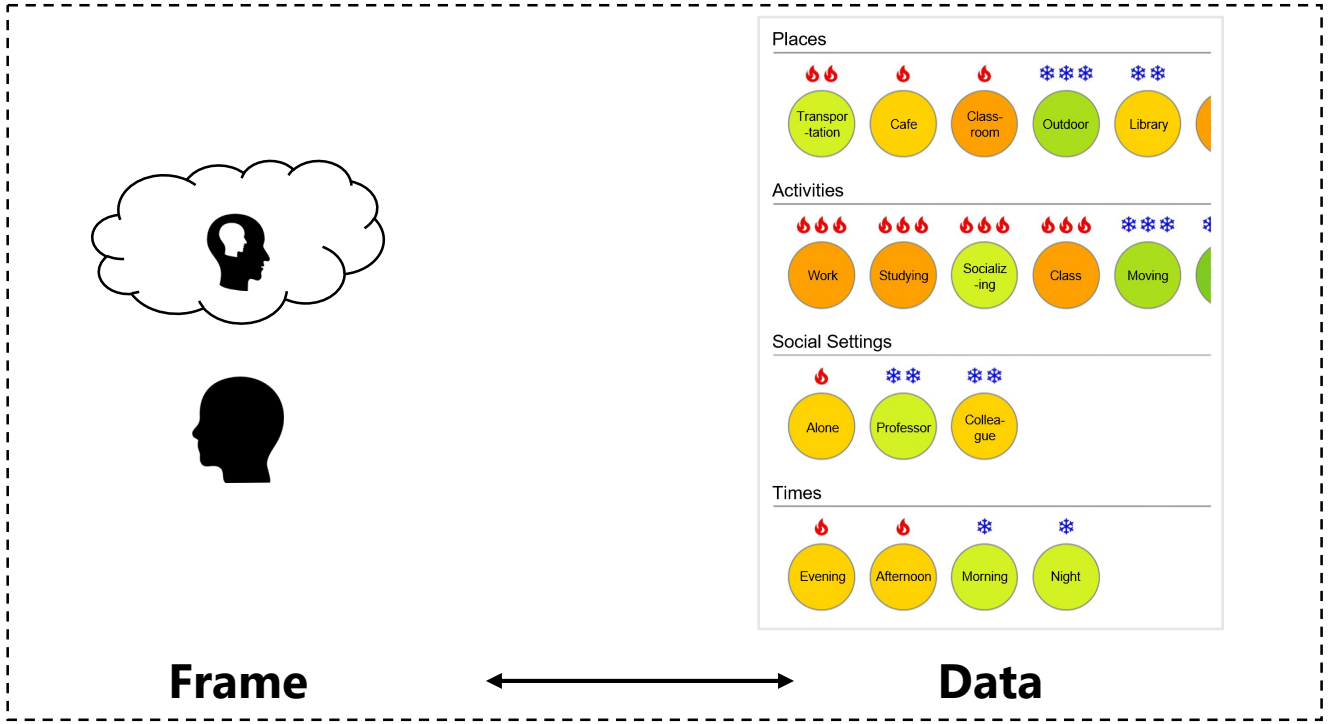
Alternative explanations

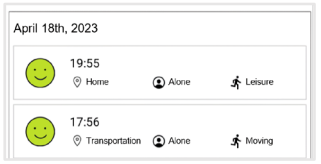
Mamykina, Lena, et al. "Adopting the sensemaking perspective for chronic disease self-management." *Journal of biomedical informatics* 56 (2015): 406-417.

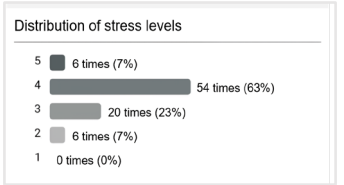
Sensemaking of the Causal Relationships

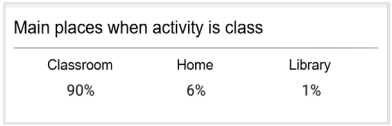
The overall process interpreted through the **data-frame theory of sensemaking** (Klein et al., 2007)

Gap does not exist





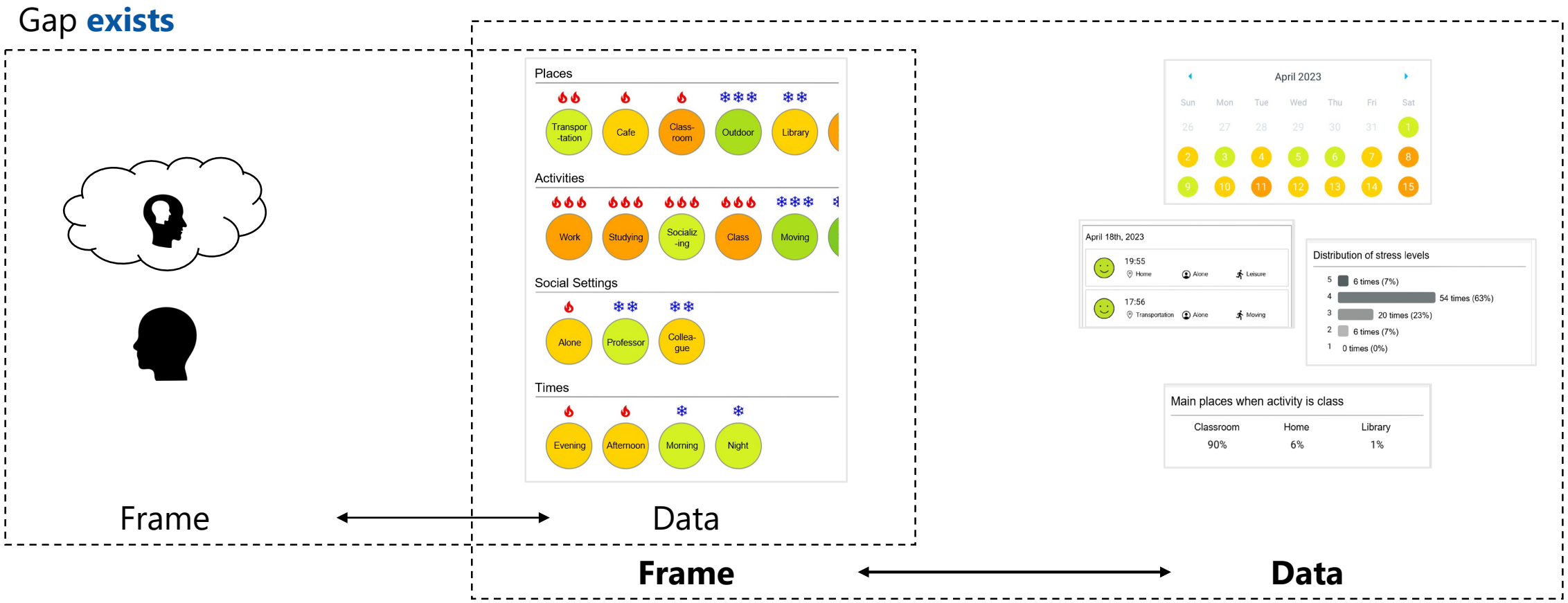




Klein, Gary, et al. "A data-frame theory of sensemaking." *Expertise out of context: Proceedings of the sixth international conference on naturalistic decision making*. Vol. 113. 2007.

Sensemaking of the Causal Relationships

The overall process interpreted through the **data-frame theory of sensemaking** (Klein et al., 2007)



Klein, Gary, et al. "A data-frame theory of sensemaking." *Expertise out of context: Proceedings of the sixth international conference on naturalistic decision making*. Vol. 113. 2007.

Takeaway

Personal informatics systems can be enhanced by providing **causal insights** through **quasi-experimental approaches**, enabling users to employ their data in health management

HCI research should continue to investigate methods for users to **easily understand and utilize data-driven insights**

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DeepStress

Supporting Stressful Context Sensemaking in Personal Informatics Systems Using a Quasi-experimental Approach

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