Behave: Pushing End-Users' Behavioral Change in Software Energy

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Behave Project

ANR JCJC Project

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Behave Project

Coordinated by Dr Adel Noureddine, Associate Professor at the University of Pau and Pays de l'Adour

Funded by ANR – JCJC 2022

Goal: reducing the energy footprint of software through users' behavioral changes

Ambitious fundamental and applied research project

noureddine.org/research/behave

Research Goals

- Advancing the understanding of human behaviors regarding reducing the energy impact of software systems

- Providing tools and technical approaches to support end users in achieving energy reductions in their software usage

Research Questions

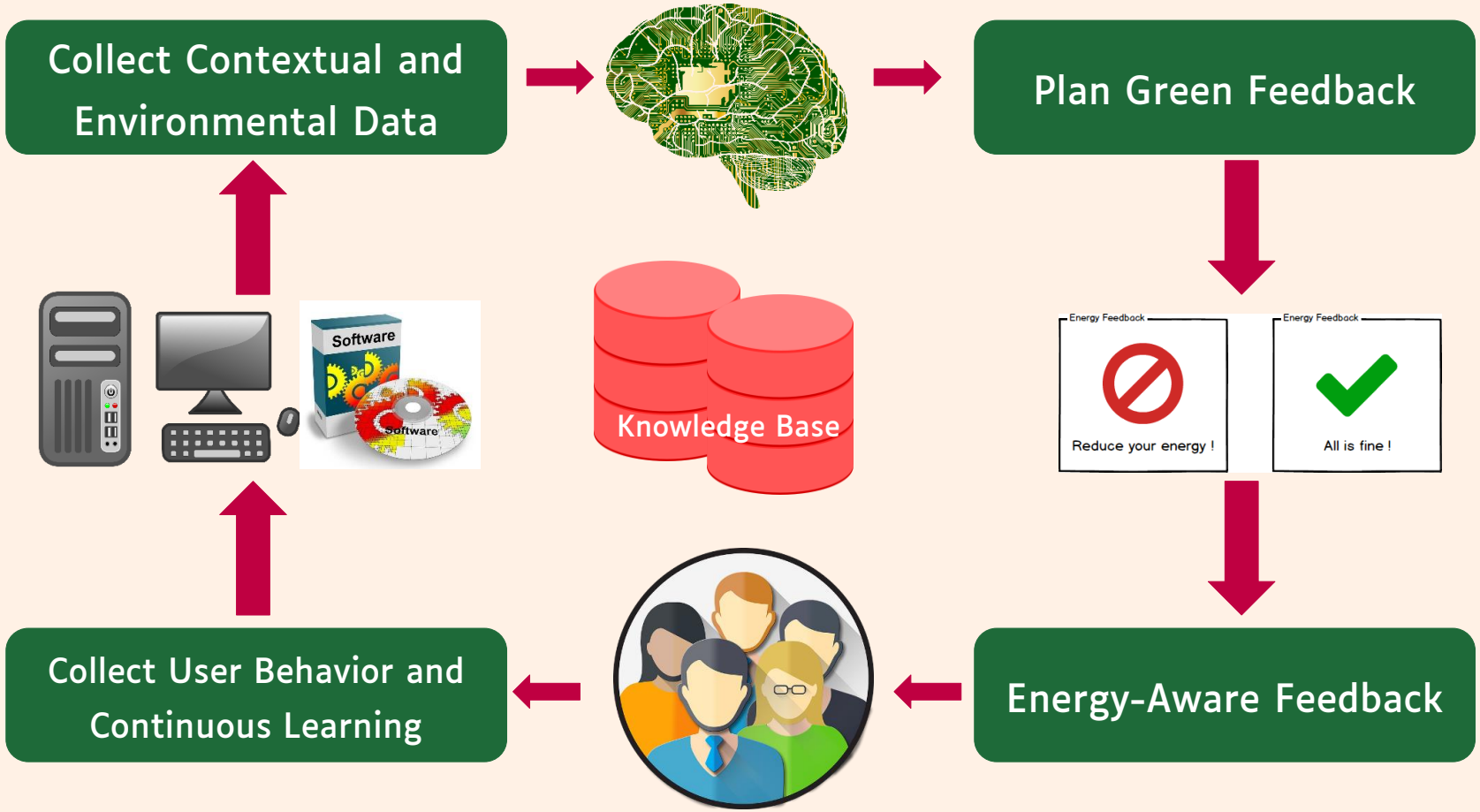
- Can raising user awareness of the environmental impact of software, through green feedback, drive behavioral changes in software energy consumption?

- Can an automated and artificially intelligent green feedback loop drive long-term behavioral change for users?

Scientific Challenges

- Concept of software and energy consumption to non-computing users
- Analyzing the diverse users' behaviors and motives
- Sustaining long-term behavioral changes

Approach and Objectives



Impact of green feedback on users' software behaviors

The Impact of Green Feedback on Users' Software Usage

Adel Noureddine, Martín Diéguez Lodeiro, Noelle Bru, and Richard Chbeir

In IEEE Transactions on Sustainable Computing journal (T-SUSC), 2023

Context

- Software energy consumption is a major concern for all relevant parties (developers, architects, administrators, users)
- Users are often forgotten in the energy optimization equation
- The next major shift in energy reductions needs to involve end users

Research Question

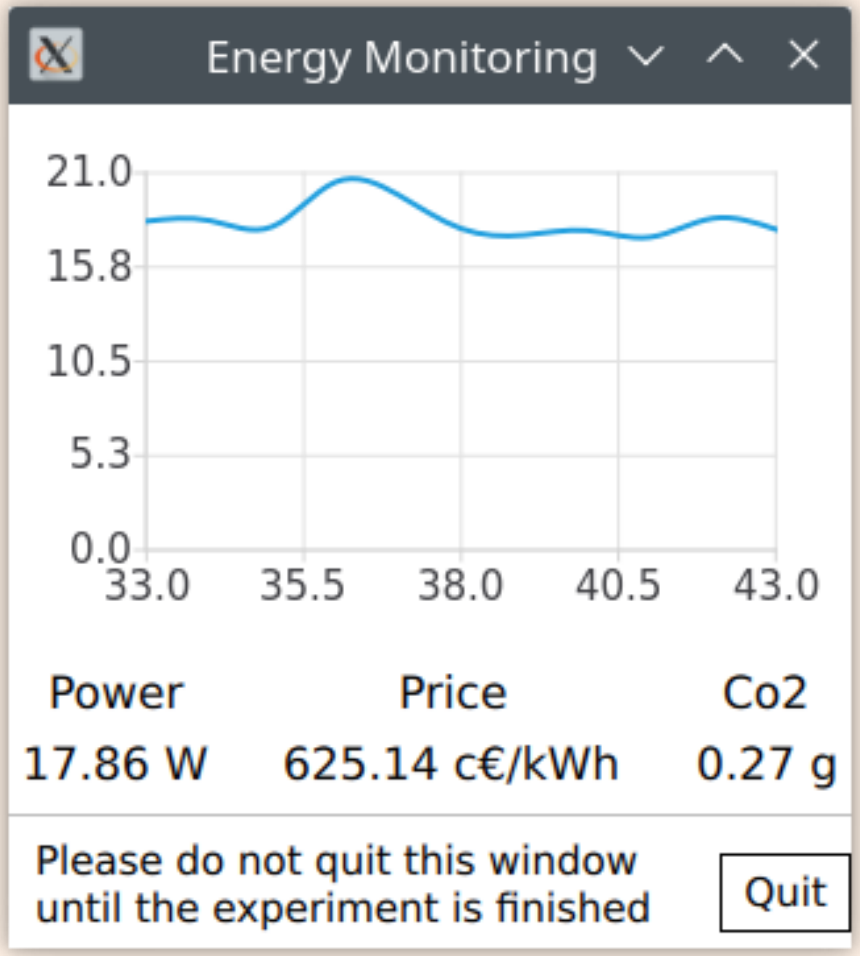
Can raising user energy awareness, through live green feedback, drive behavioral change in software energy consumption?

- What do users know about energy consumption of software?
- What perceptions do users have on software and energy?
- Will green feedback of software usage lead to behavioral change and energy reductions?

Experimental field study

- First of its kind field study in software engineering with a control group
- Study the short-term behavioral change of users after providing them with green feedback
- Study the perception and user awareness in regard to energy consumption of software

Green visual feedback tool



Participants Profile

- 95 computer science students
- Control group (A1): 2 classes, 47 students
- Treatment group (A2): 3 classes, 48 students
- Majority males, a third females, average age 22 year

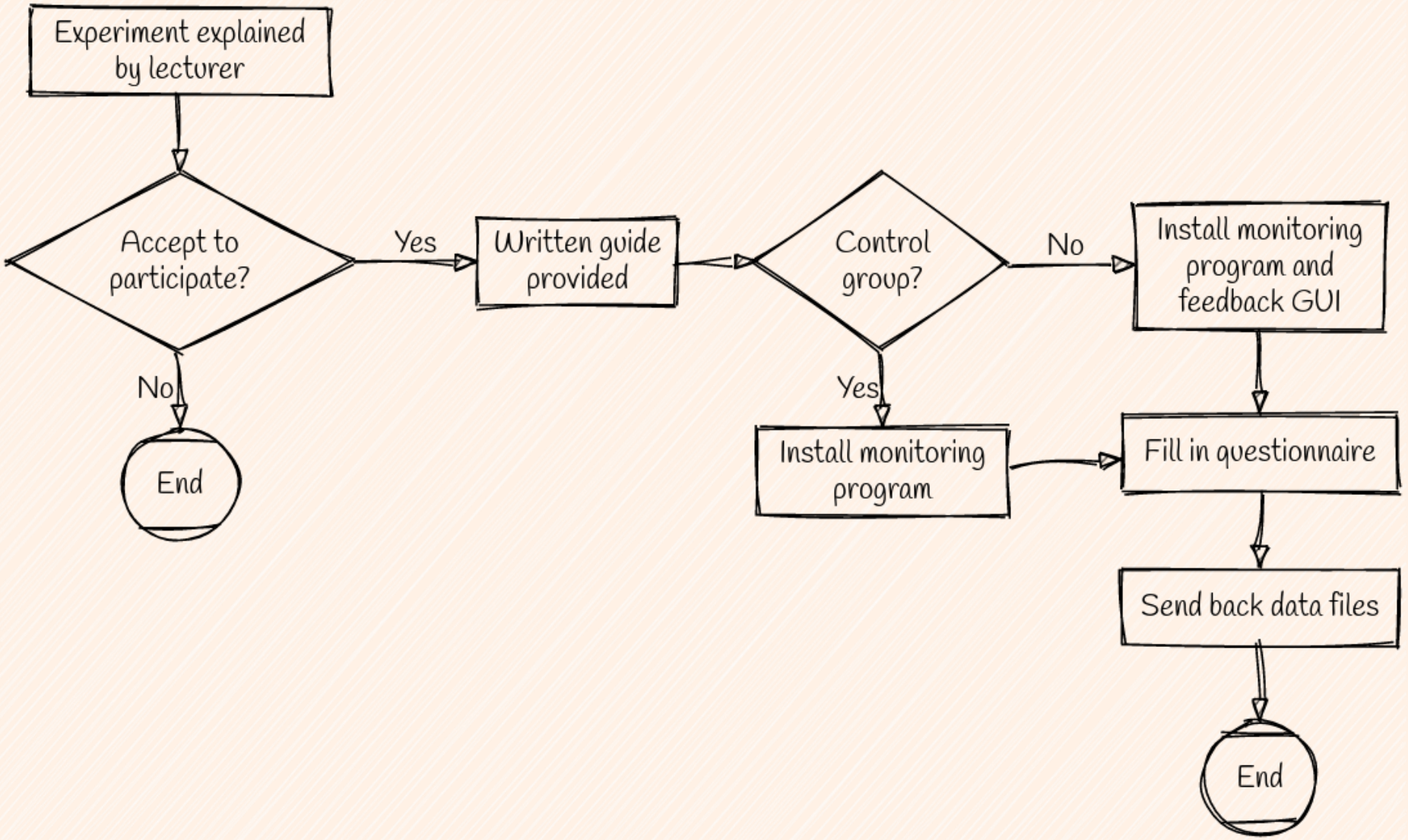
Participants Profile

- 2 hours class session with same workload (write a research document with online resources)
- Windows or macOS laptop with Intel processor or MacOS
- 52 valid power data files (26 for each group)
- Metrics collected: power consumption, CO2 emissions, cost of electricity, software used, and active window

Questionnaire survey

- Collect the perception of the energy cost of the experiment
- Rate energy cost of multiple software
- Perception of the visual feedback tool (except for the control group)

Experimental field study



Lessons Learned

- Users underestimate the energy consumption of their devices and software
- Users perceive the operating system as the most consuming software
- Programming and communication programs are perceived as high-consuming software
- Technical-savvy users understand the energy weight of the cloud infrastructure

Lessons Learned

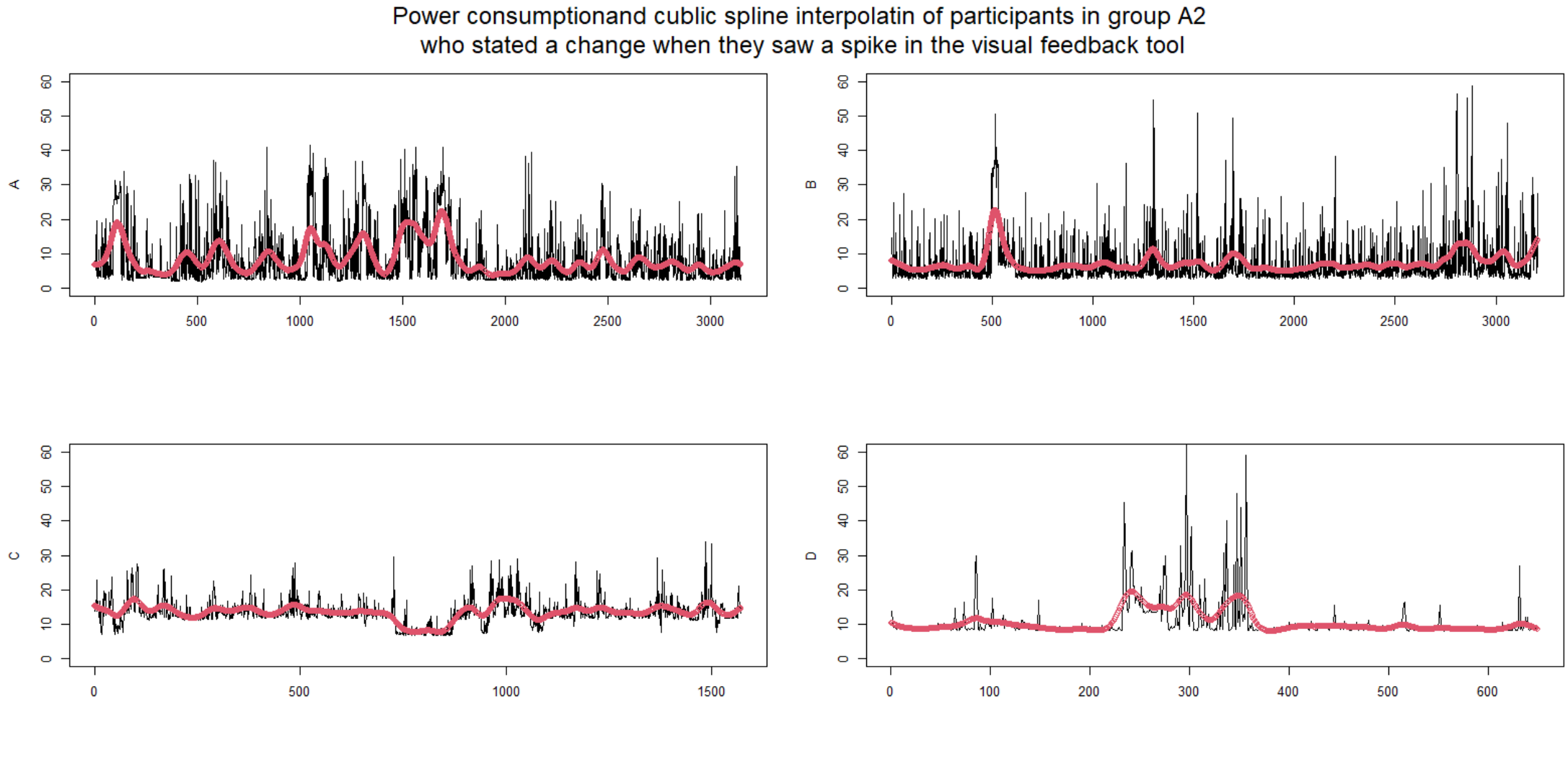
- Live green feedback helps in raising awareness of energy consumption
- Green feedback tools must be minimal and seamlessly integrated to avoid being distracted
- Metaphors and evolving charts are more useful than green metrics

Lessons Learned

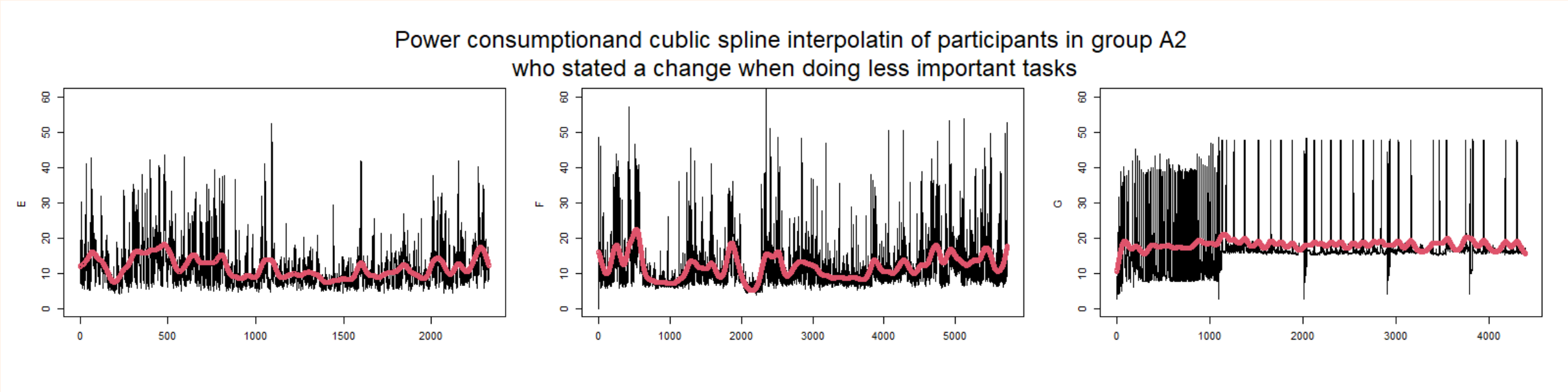
- Users resist behavioral change when the workload is important, or the energy consumption is perceived as low

- Users lack the knowledge and tools to apply software behavioral changes

Lessons Learned



Lessons Learned



Conclusion

- Green feedback helps in raising awareness
- But users lack the knowledge and tools to apply software behavioral changes
- Short-term behavioral changes require previous awareness and guidance so users can change behavior seamlessly
- Users resist software behavioral change unless the task was less important, or its perceived energy is low

Future Work

- Study additional metrics, feedback forms (visual, audio, etc.), and metaphors
- Produce software guides, labels and classifications, and study their impact
- Automatically recommend software or actions to reduce software energy consumption

→ Behave Project (ANR JCJC, started 11/2022)

Green Software and Human Actors: design, code, and behavior

- Community Workshop
- Co-located with ICT4S 2023, Rennes, France,
- Workshop: 5 June 2023
- Deadline for voluntary presentations: 7 April

- Bringing 3 communities together: green software, UX/UI design, behavioral studies
- https://gsha2023.sciencesconf.org/

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