# Memory Load A Factor That Links the Usability of Individual Interaction Components Together

## Abstract

An underlying assumption of **component-based software engineering** for interactive systems is that the overall usability of a new assembled system mainly depends on the usability of its individual components. This paper challenges this assumption by presenting findings of a lab experiment. Here users were asked to use two calculators, one with a small display and one with a large display. Results show a significant change in the way users solved equations with the two calculators when faced with high memory demands.

Although the effects of memory load is not new, these findings show empirically how it can also affect the interaction with components not directly responsible for it. Therefore when constructing a new system out of ready-made components, developers should still evaluate the new system as a whole since usable components tested in isolation might still have a negative effect on the way users interact with other components.

## Research Question

Can memory load cause components to affect each other's usability negatively? This would make an overall usability prediction of a system based on the usability of the individual components less valid.

## Experimental Setup

### Calculators

- Two interaction components: **Editor** and **Processor**.
- Two versions of the Editor: **Large** display and **Small display**.

### Tasks

- Calculate the cost of several building projects based on a textual description.
- Two types of equations: easy (no brackets needed), and difficult (nesting depth of 2 brackets).
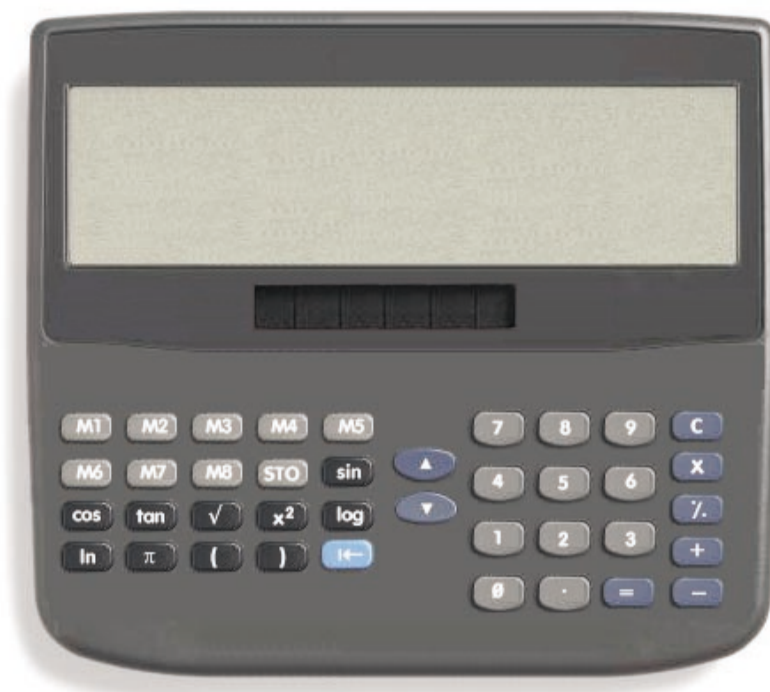


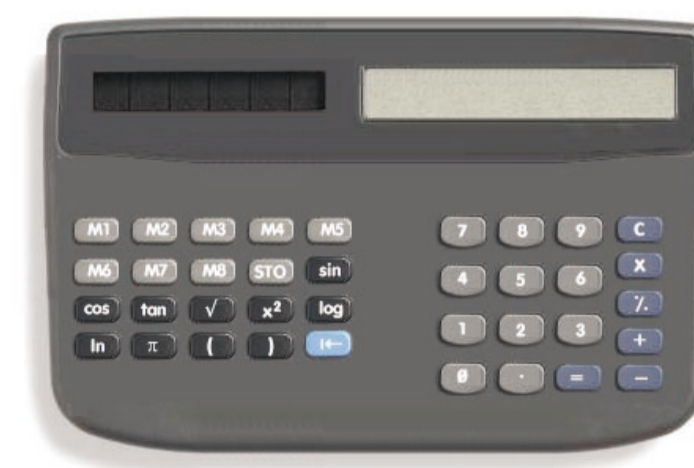Figure 1: Calculator with large display.
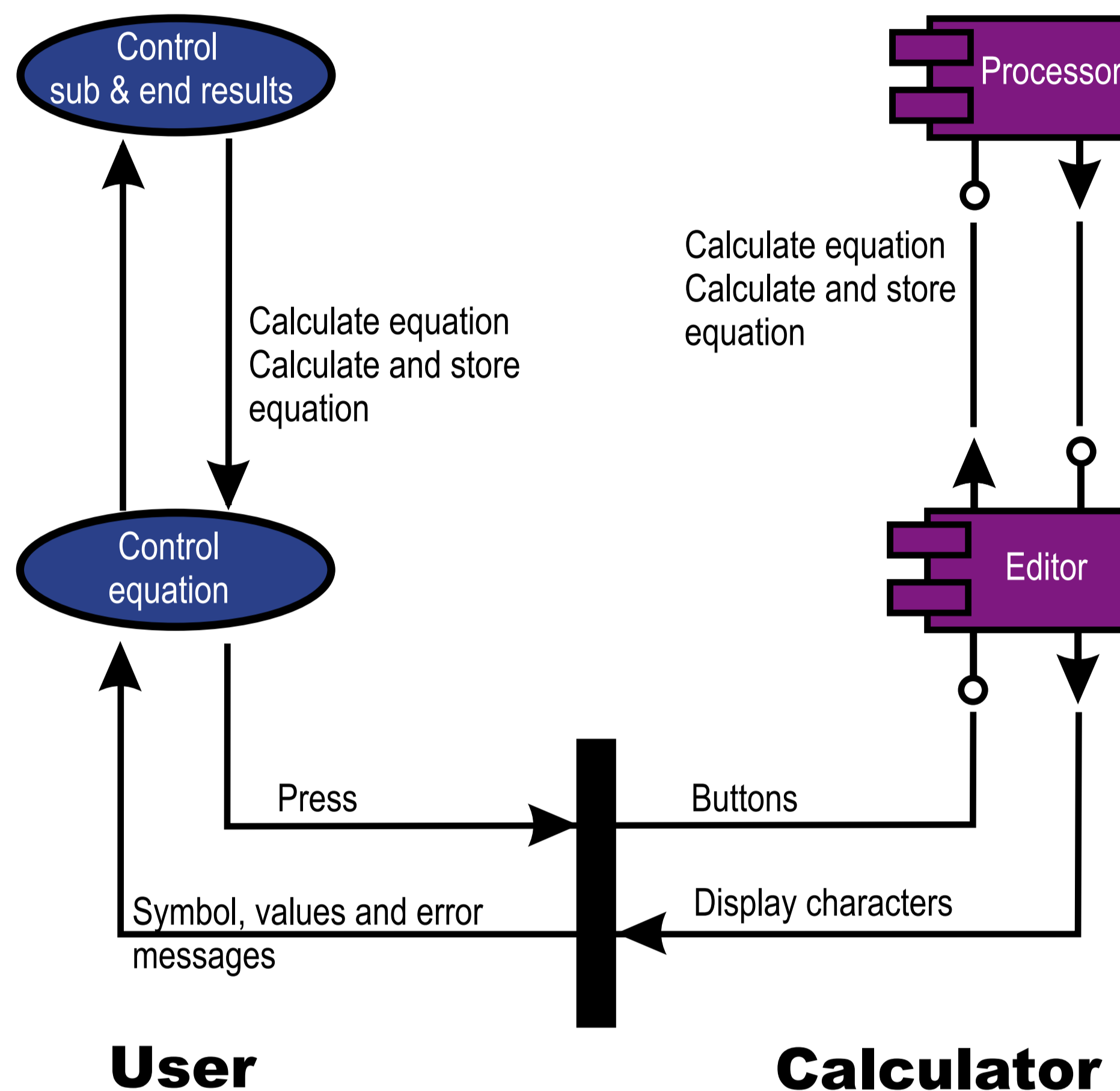


Figure 2: Calculator with small display.



Figure 3: Layered interaction structure between a user and a calculator. The user and calculator's components communicate by sending messages. The message exchange with the Processor is **mediated** by the **Editor** component.

### Easy Equation

**Calculate the price for rebuilding the garage**

The following amounts should be charged for materials: 679.56 for a door to the garage, 217.98 for the electrical mechanism to open and close the door, 579.15 for cements and bricks, 856.38 the floor, 157.36 for lighting, 362.49 for a frame and a dividing door between the garage and the house, 185.50 for remaining materials. A surcharge of 1543.50 has to be paid for tools. An amount of 374.56 should be charged for transport and disposal of the debris from the demolition work and 635.00 for contingencies. Also an environmental surcharge of 215,83 has to be paid. All these cost already include VAT.

The renovation will take place in week 11 (S=11*pi/52=0.66), in which a reduction of 323.59 is applied on the labour cost of the draughtsman and 356.35 on the labour cost of the painters. Next, the customer can claim a 223.78 reduction on electricity and paintwork, since he is regular costumer. However, a surcharge of 72.17 for the electrician and 86.23 for the carpenter has to be paid, these workers are on training and replacement workers have to be hired from other companies.

| | Hourly rate | | | | Hours |
|---|---|---|---|---|---|
| Electrician | 6° | Sin (2*S)+72 | → | M3 | 26 |
| Mason | 7° | Sin (3*S)+61 | → | M1 | 48 |
| Foreman | 5° | Sin (2*S)+85 | → | M2 | 13 |
| Painter | 14° | Sin (S)+74 | → | M6 | 15 |
| Draughtsman | 18° | Cos (S)+74 | → | M4 | 23 |
| Carpenter | 12° | Cos (S)+62 | → | M5 | 12 |
| All prices include VAT | | | | | |

**Optimal Solution**

```
M3*26 +
M4*23 +
M1*48 +
M6*15 +
M5*12 +
M2*13 -
323.59 - 356.35 - 223.78 -185.23 +
72.17 + 86.23 + 679.56 + 217.98 +
579.15 + 856.38 + 157.36 + 362.49 +
185.5 + 1543.5 + 374.56 + 635 +
215.83 =
```

### Difficult Equation

**Calculate the price for underfloor heating and house insulation**

An amount of 3468 should be charged for materials and as a write-off of 1273 for the tools. A surcharge of 14.42% has to be paid for contingencies on labour, material and tools. This surcharge and an environmental surcharge of 106 are exempt from value-added tax (VAT). On all other costs (including labour cost) a 17.5% VAT is applied.

The renovation will take place in week number 47 (S = 47*pi/52 = 2.84), in which a reduction of 8.47% is applied on the hourly rate of the carpenter, and the electrician. Furthermore, the customer can claim a 12.37% reduction on the hourly rate of the fitter and the carpenter because of an advertising campaign of the Electricity Company. Extra workers have to be hired from other companies because of increased activity in the winter. Therefore, a surcharge of 3.78% has to be paid for the hourly rate of the painter and the fitter.

| | Correction for season | | | Hourly rate | Hours |
|---|---|---|---|---|---|
| Painter | 14°Sin (S) | → | M5 | 74,- | 15 |
| Bricklayer | 6°Sin (2*S) | → | M2 | 72,- | 12 |
| Electrician | 6°Sin (3*S) | → | M1 | 61,- | 13 |
| Foreman | 5°Sin (2*S) | → | M6 | 85,- | 11 |
| Fitter | 18°Cos (S) | → | M4 | 74,- | 48 |
| Carpenter | 12°Cos (S) | → | M3 | 62,- | 21 |
| All prices are without VAT | | | | | |

**Optimal Solution**

```
((M1 + 61) × 13 × (1 - 0.0847) +
(M4 + 74) × 48 × (1.0378 - 0.1237) +
(M2 + 72) × 12 +
(M6 + 85) × 11 +
(M5 + 74) × 15 × 1.0378 +
(M3 + 62) × 21 × (1 - 0.0847 - 0.1237)
+ 3468 + 1273
) × (1.1442 + 0.175) + 106 =
```

## Experimental Hypothesis

Mental effect creates a link between the Editor versions and the interaction strategy with the Processor.

## Design & Participants

- 2x2 within-subject design: editor (small or large), equation difficulty (difficult, or easy).
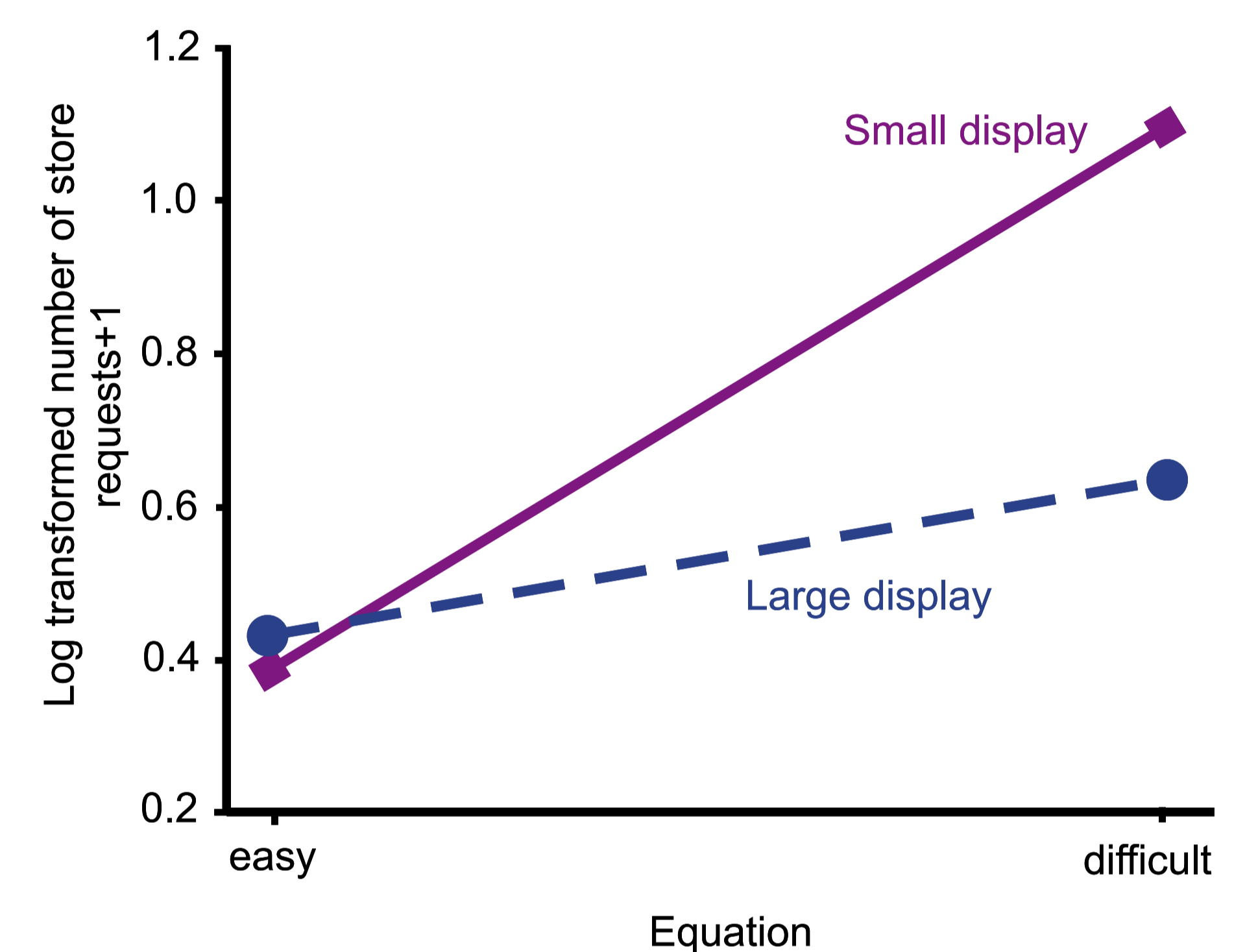- 24 students of Technische Universiteit Eindhoven.

## Results



Figure 4: The mean of the logarithmically transformed number of store-request (plus 1) send to the **Processor**.
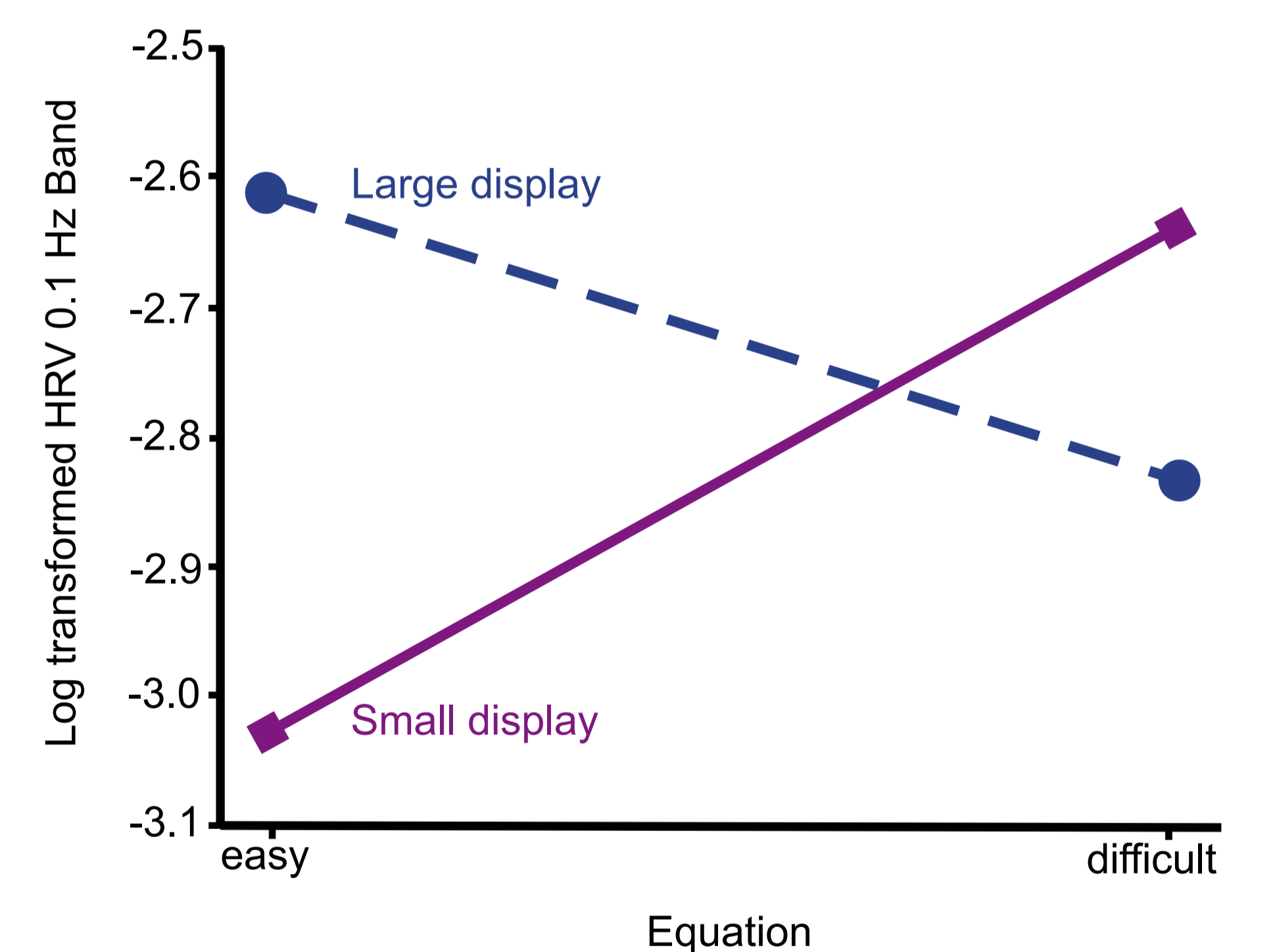


Figure 5: The mean of the logarithmically transformed **Heart Rate Variability** (HRV) of the 0.1 Hz Band. A decrease in HRV is interpreted as an increase in mental effort.

## Implications

- Mediating components can cause a **bottleneck** in the interaction with higher-level components.
- Although components can be designed and tested in isolation, a final overall usability tests remains necessary.

**Brunel** UNIVERSITY WEST LONDON

**Willem-Paul Brinkman**, Brunel University
**Reinder Haakma**, Philips Research Laboratories Eindhoven
**Don G. Bouwhuis,** Technisch Universiteit Eindhoven