Electrical and Human Feedback

How feedback solves some problems and creates new ones in circuits and design groups.

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IEEE CAS DLP Talk 2 (short version)
Mixed-Signal-ASICs Workshop, Windisch, 17.5.11

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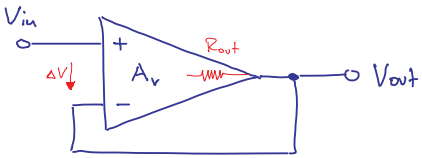
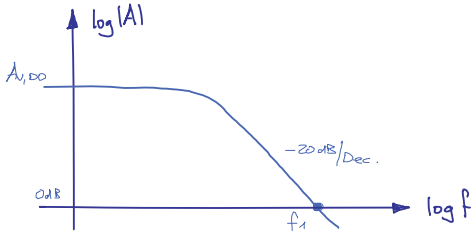
When things get more complex, they often become chaotic! If a team takes on more and more complex tasks, there comes the point where the old ways to work will suddenly not function anymore: some people will shout "why is what I do suddenly bad? It always worked!" They see chaos! Project managers fear it, and yet: we know that chaotic systems can do great things because of their self-organising properties.

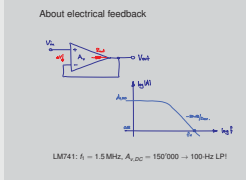
But let's start with electrical feedback. [1/1]

About electrical feedback





LM741: $f_1 = 1.5\,\text{MHz}$, $A_{v,DC} = 150'000 \rightarrow$ 100-Hz LP!



Op-amp with feedback.

– Gives a precise gain of one.

– Very low output impedance.

– low input swing

$\longrightarrow$ gives low distortion.

Problems?

$\longrightarrow$ Does all of this at the same time!

$\longrightarrow$ Can become unstable!

[2/3]

Feedback Complexity and Stability

no feedback, no interdependence

Stable.

Single loop, linear or weakly non-linear

Unstable: oscillating or sticking to one extremum.

Multiple loops, strong interdependence, non-linear

Chaotically unstable: Occasionally *very* extreme reactions.

Project team with strong interdependence:

How can we use extreme positive reactions to our advantage but at the same time be robust against extreme negative reactions?

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How can we use extreme positive reactions to our advantage but at the same time be robust against extreme negative reactions?

Different levels of complexity in feedback systems

– Chaotic means: extreme excitations in both directions.

⟶ Valid for both electrical and human feedback systems!

Complex project:

– many “nothing goes” waves, and then big advances;

– Project time is not the same as calendar time!

Experiment: Can you count?

. . . under time pressure . . .

30-second Basketball movie and brief discussion

André Gide: The direct path will only ever lead to the goal.

$\longrightarrow$ This may be fine for some projects, but not for R&D of complex systems. [5/10]

Overview

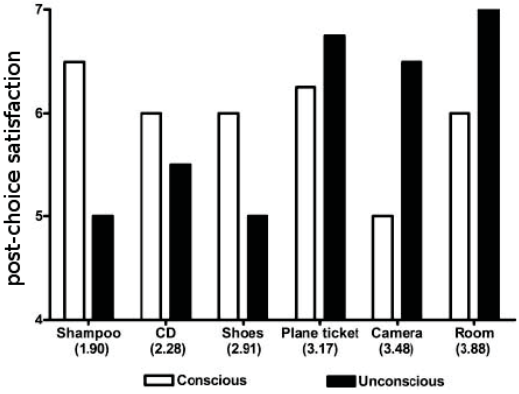
Overview

1 Introduction: About Electrical Feedback
2 Making the right choice
3 ADC Driver for Microelectrode Array
4 A 19-bit MEMS Accelerometer
5 Trust in (virtual) teams
6 Conclusion
7 Literature

This is a story about making the right choices in engineering projects. [1/11]

On making the right choice

[Dijksterhuis 06] tested the "deliberation-without-attention" hypothesis that simple choices indeed produce better results after conscious thought, but that choices in complex matters should be left to unconscious thought.



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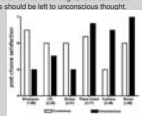
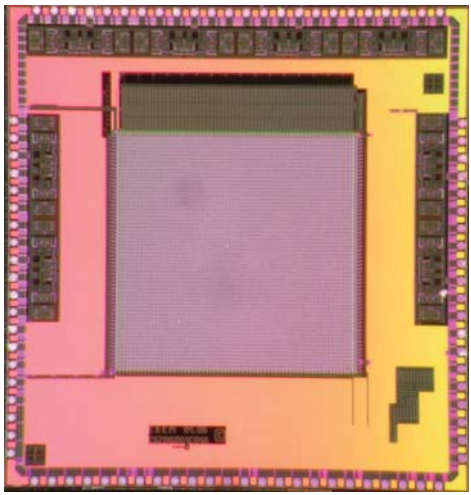


Reason: **Conscious thought** is rule-based and very precise, but it suffers from the low capacity of consciousness, making it less suitable for very complex issues.
Unconscious thought can only conform to rules in that it detects recurring patterns, but it does not suffer from low capacity. Indeed, it has been shown that during unconscious thought, large amounts of information can be integrated into an evaluative summary judgment.
In practice, "deliberation-without-attention" can mean: carefully collect information about something, then do other things and sleep over it, then decide intuitively.

– Note: the decision is not rated according to any objective measures (who would set them anyway), but according to SATISFACTION!

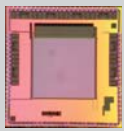
– First example: make a task simpler by removing feedback and making it a "conscious-thought problem".

ADC Driver for Microelectrode Array



(with Simon Neukom and Yue-Li Schrag, CSEM Zürich)

ADC Driver for Microelectrode Array



(with Simon Neukom and Yue-Li Schrag, CSEM Zürich)

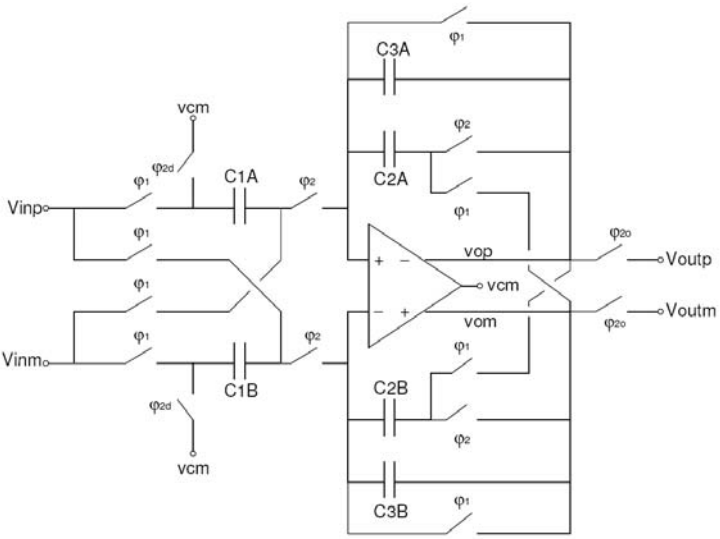
Chip to measure nerve cell signals.

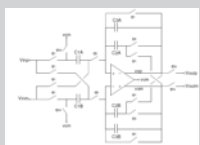
– 16 Off-chip ADCs each need a balanced 4-MSample driver.

– Very little time available

$\longrightarrow$ No complex project time! No chaos! [1/15]

Switched-capacitor driver amplifier





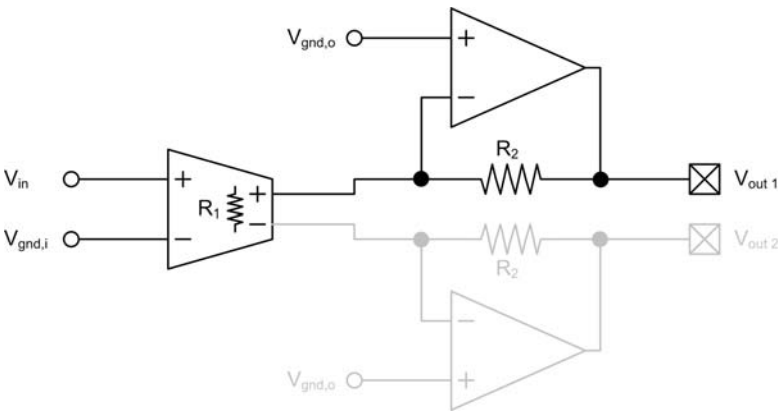
Problem was: the SC amplifier that was used before would have had to be modified to have more gain and also a level shift

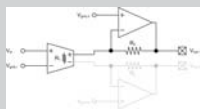
$\longrightarrow$ would have meant a totally different structure!

$\longrightarrow$ all parameters linked

$\longrightarrow$ complex situation; chaos threatens . . . [1/16]

Open-loop continuous-time driver amp



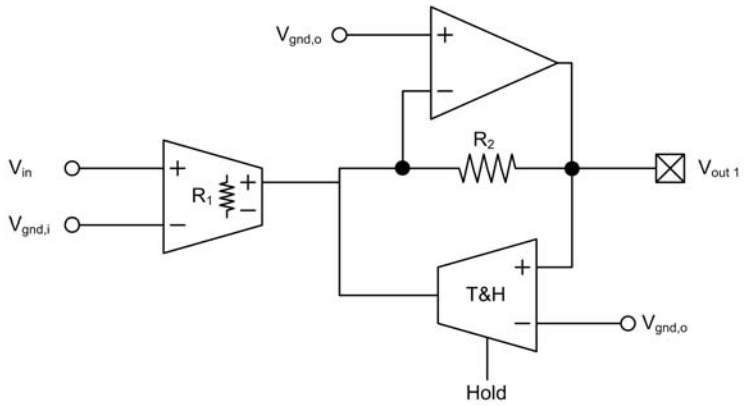


Transconductor with poly resistor converts V_{in} to a current; and a transresistance amplifier converts it back to a voltage.

$\longrightarrow$ Loop open, level shift simple: different reference voltages.

$\longrightarrow$ Gray: second (balanced) output. [1/17]

Track-and-hold offset compensation



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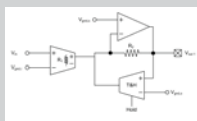
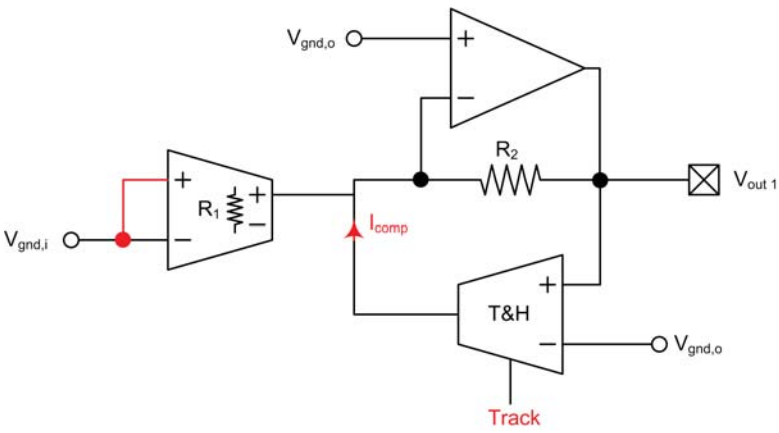


This makes it possible to inject an offset-compensating current using one current-output track-and-hold circuit per output.

Tracking phase of offset compensation



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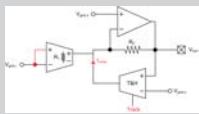
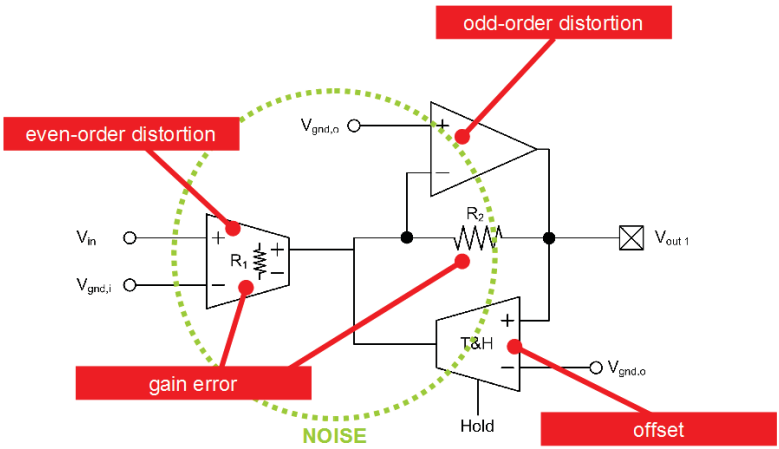


There is one offset compensation phase after each read-out frame of the microelectrode array

$\longrightarrow$ compensates *all* offsets except the offset of the T&H amplifier

All building blocks are simple, standard circuits; I'll not discuss them here today.

Sources of some non-idealities



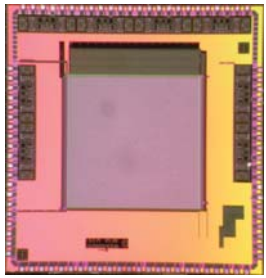
Sources of some non-idealities

The different non-idealities come from different building blocks! So each performance parameter except noise can be designed almost independently.

$\longrightarrow$ very different from SC where you change something *here* and things change *there*, *there* and *there*.

History of this amplifier

- Sixteen channels.
- Very low crosstalk.
- All electrical design to specs, characterization, and layout done in only two weeks (weekend off . . .).
- Worked first time right.
- Used a quarter of the power of the previous SC buffer.
- Unaltered use for three chips.
- Simple re-design for different technology.
- Publication? — Reject. Too simple.



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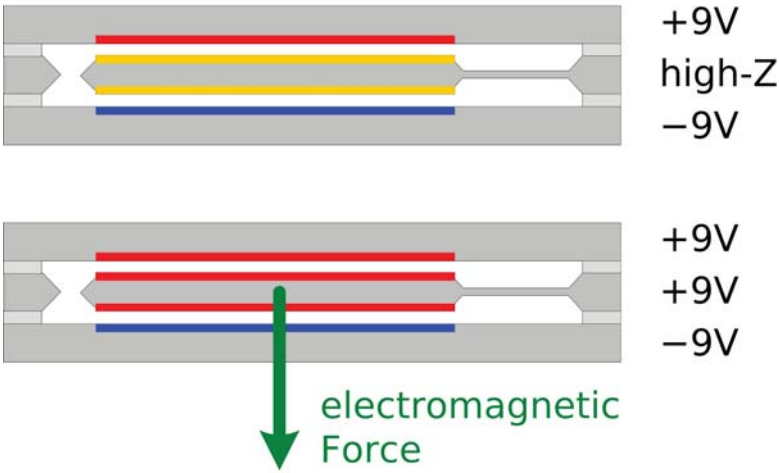
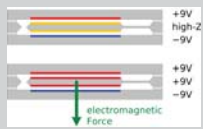
Ten days is a *very, very* short time for achieving this!

Now let's go to a complex project!

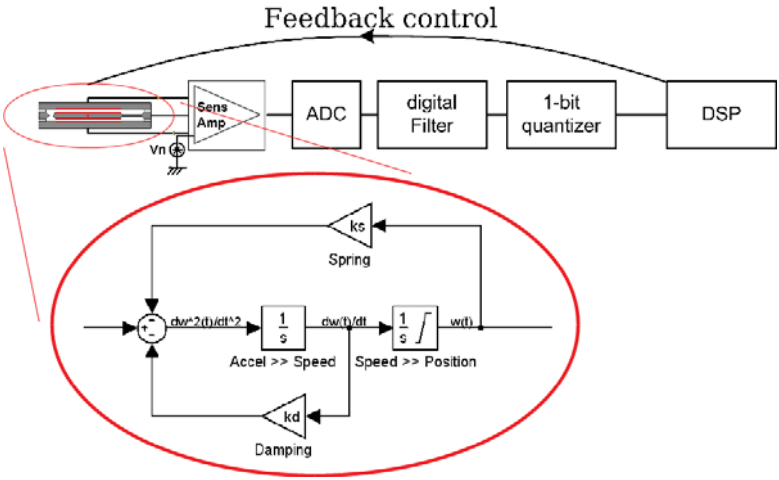
MEMS acceleration sensor

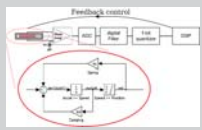




How the sensor works

Closed-Loop ΣΔ System



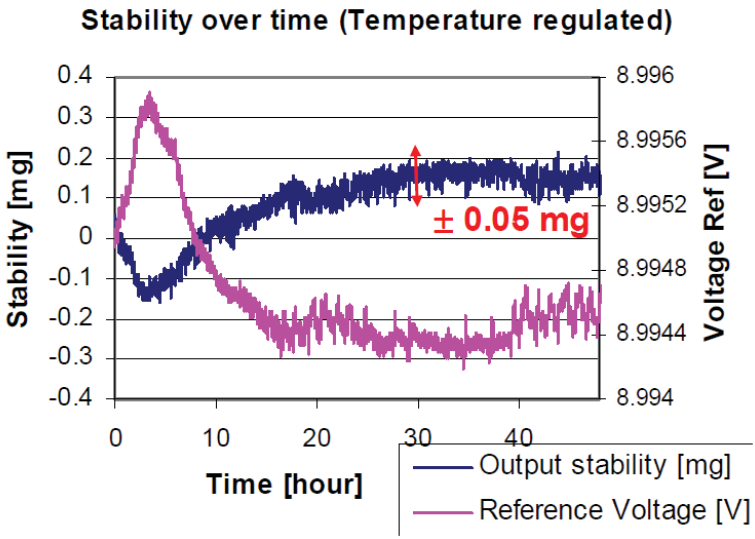


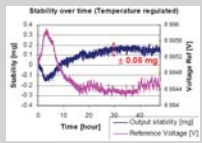
Sensor converts acceleration to position

⟶ integrates twice.

– System with feedback: like the feedback amplifier at the start: stabilizes gain, reduces distortion. [1/25]

19-bit resolution and long-time stability



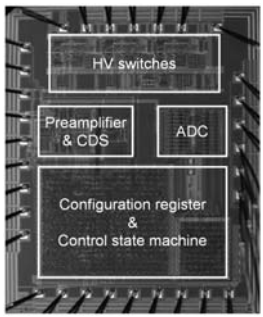


Very difficult and time consuming to measure, [Zwahlen 10] [1/26]

Specialists and performance parameters

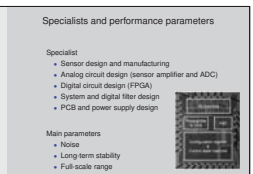
Specialist

- Sensor design and manufacturing
- Analog circuit design (sensor amplifier and ADC)
- Digital circuit design (FPGA)
- System and digital filter design
- PCB and power supply design



Main parameters

- Noise
- Long-term stability
- Full-scale range



Who has an influence on what?

$\longrightarrow$ Everyone on almost everything!

$\longrightarrow$ Attempt was made to divide the project into work packages and differentiate precisely.

And this failed badly.

Project team with lots of interdependence

no feedback, no interdependence

Stable.

Single loop, linear or weakly non-linear

Unstable: oscillating or sticking to one extremum.

Multiple loops, strong interdependence, non-linear

Chaotically unstable: Occasionally *very* extreme reactions.

Project team with strong interdependence:

How can we use extreme positive reactions to our advantage but at the same time be robust against extreme negative reactions?

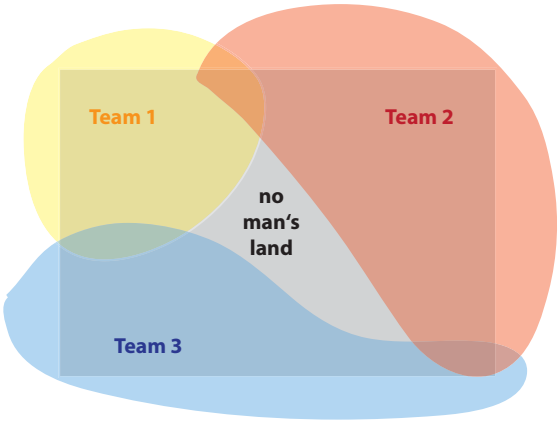
Project team with lots of interdependence
Project team with strong interdependence:
How can we use extreme positive reactions to our advantage but at the same time be robust against extreme negative reactions?

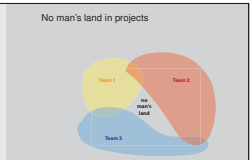
One example for non-robustness: Especially in complex projects, “Divide et Impera” (Macchiavelli) generates a big no man’s land!

$\longrightarrow$ a divide and conquer approach applied to a complex project will conquer the team, not the problem!

– Now I will tell you what a “no man’s land is” and why only trust within a team can give robustness against its extreme effects.

No man's land in projects





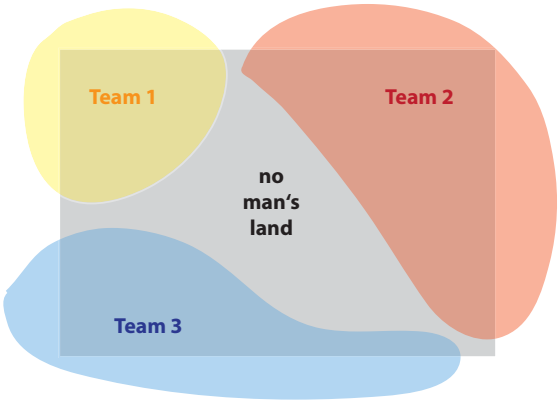
Each team (or person) believes the "no man's land" is the others' responsibility

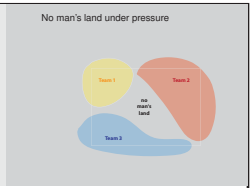
⟶ Vital tasks are not done,

⟶ especially the ones promising chaos

⟶ stress.

No man's land under pressure



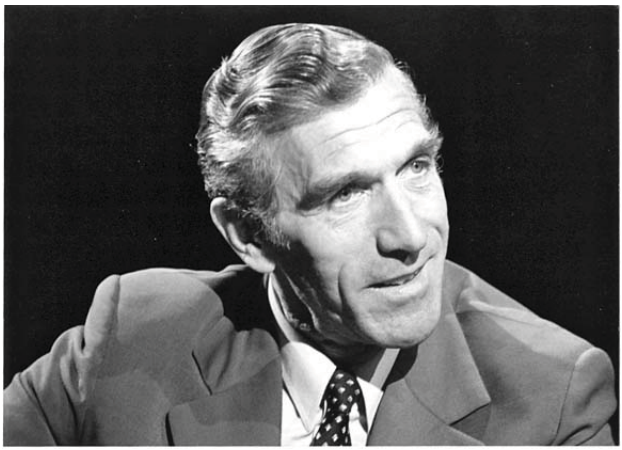


Under stress, people concentrate on their core business

$\longrightarrow$ no man's land grows!

$\longrightarrow$ If there is no trust atmosphere in the team by then, we run into Watzlawick's hammer.

Watzlawick's Hammer



Paul Watzlawick (1921–2007)

Watzlawick's Hammer

Paul Watzlawick (1921–2007)

A man wants to hang a picture on the wall. He's got a nail, but no hammer. His neighbour has one, so our guy decides to go over and borrow the hammer. But then he has doubts.
What if the neighbour does not want to give me his hammer? Yesterday I only got a hasty greeting from him. Maybe he was in a hurry? Or did he just pretend to be in a hurry because he doesn't like me? And why wouldn't he like me? I never did anything to him, he must imagine something there. You know, if anyone wanted to borrow my hammer, I'd immediately give it to him. Why won't he? How can he just refuse such a small favour? People like that guy poison one's life! And then this guy thinks I depend on him just because he's got a hammer and I haven't! Well, enough is enough!
And so he runs across the street, rings the bell, the neighbour opens, but before he can say "hello" our guy shouts "Keep your fucking hammer!!!!"
[translated from German by H. Schmid]

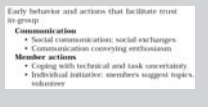
Early behavior and actions that facilitate trust in-group

Communication

- Social communication; social exchanges
- Communication conveying enthusiasm

Member actions

- Coping with technical and task uncertainty
- Individual initiative; members suggest topics, volunteer



What if our team is not in one location?

– (this already happens when people from a customer paricipate in a project)

⟶ What is a virtual team? A team “without common coffee breaks”.

In the above project: after a conflict intervention, we made a two-day retreat in the mountains . . .

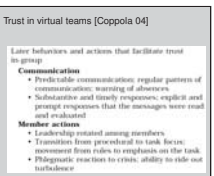
Later behaviors and actions that facilitate trust in-group

Communication

- Predictable communication; regular pattern of communication; warning of absences
- Substantive and timely responses; explicit and prompt responses that the messages were read and evaluated

Member actions

- Leadership rotated among members
- Transition from procedural to task focus; movement from rules to emphasis on the task
- Phlegmatic reaction to crisis; ability to ride out turbulence



Important were:

– Regular meetings

– E-Mail responsiveness

⟶ A substantial response can also be “I have no time right now, I will react by Tuesday.”

(All this I have also observed in other complex projects with distributed teams.)

Conclusion

Making choices:

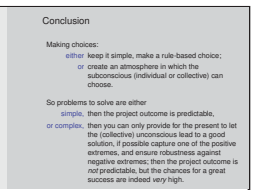
either keep it simple, make a rule-based choice;

or create an atmosphere in which the subconscious (individual or collective) can choose.

So problems to solve are either

simple, then the project outcome is predictable,

or complex, then you can only provide for the present to let the (collective) unconscious lead to a good solution, if possible capture one of the positive extremes, and ensure robustness against negative extremes; then the project outcome is *not* predictable, but the chances for a great success are indeed *very* high.



Predictable results? The Oracle (Matrix Reloaded):
"We can never see past the choices we don't understand."

Simple also means: don't expose yourself to too much choice!
[Schwartz 04]

From a certain complexity level onwards:

– Team Players required! People who cannot do teamplay cannot participate in complex projects.

– Don't divide and conquer! Rather bring together and lead a way.
(Goethe: "Entzwei und gebiete! Tüchtig Wort. — Verein und leite! Besserer Hort.")

Literature

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