Qualitative modeling of pressure vs. pain relations in women suffering from dyspareunia

Damiano Varagnolo
Luleå University of Technology

Steffi Knorn
Uppsala University

Reinhilde Melles & Marieke Dewitte
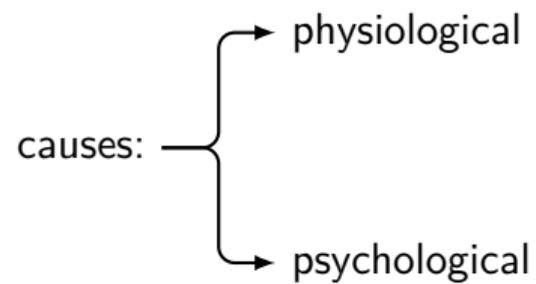*Maastricht Universitair Medisch Centrum*
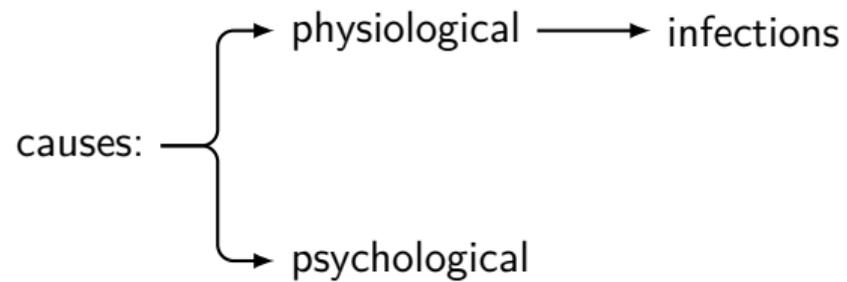
July 10, 2017
IFAC world congress

Qualitative modeling of pressure vs. pain relations in women suffering from *dyspareunia*

:= pain during penetrative sexual intercourse

Etiology

causes:
- physiological
- psychological

Etiology

causes:
- physiological ⟶ infections
- psychological

Etiology

causes:
- physiological
  - vaginal narrowing / shortening
    (side effect of cancer treatment, surgeries, genetic defects)
  - infections
- psychological

Etiology

injuries

vaginal narrowing / shortening
(side effect of cancer treatment, surgeries, genetic defects)

causes: — physiological — infections

psychological

Etiology

causes:

- physiological
  - auto-immune conditions *(Graph vs. host diseases)*
  - injuries
  - vaginal narrowing / shortening
    (side effect of cancer treatment, surgeries, genetic defects)
  - infections
- psychological

Etiology

causes:
- physiological
  - male to female gender confirmation surgeries
  - auto-immune conditions *(Graph vs. host diseases)*
  - injuries
  - vaginal narrowing / shortening
    (side effect of cancer treatment, surgeries, genetic defects)
  - infections
- psychological

Etiology

causes:
- **physiological**
  - → male to female gender confirmation surgeries
  - → auto-immune conditions *(Graph vs. host diseases)*
  - → injuries
  - → vaginal narrowing / shortening
    (side effect of cancer treatment, surgeries, genetic defects)
  - → infections
- **psychological**
  - → unconscious tightening of the pelvic floor muscles
    (a.k.a. vaginismus, often caused by sexual traumas)
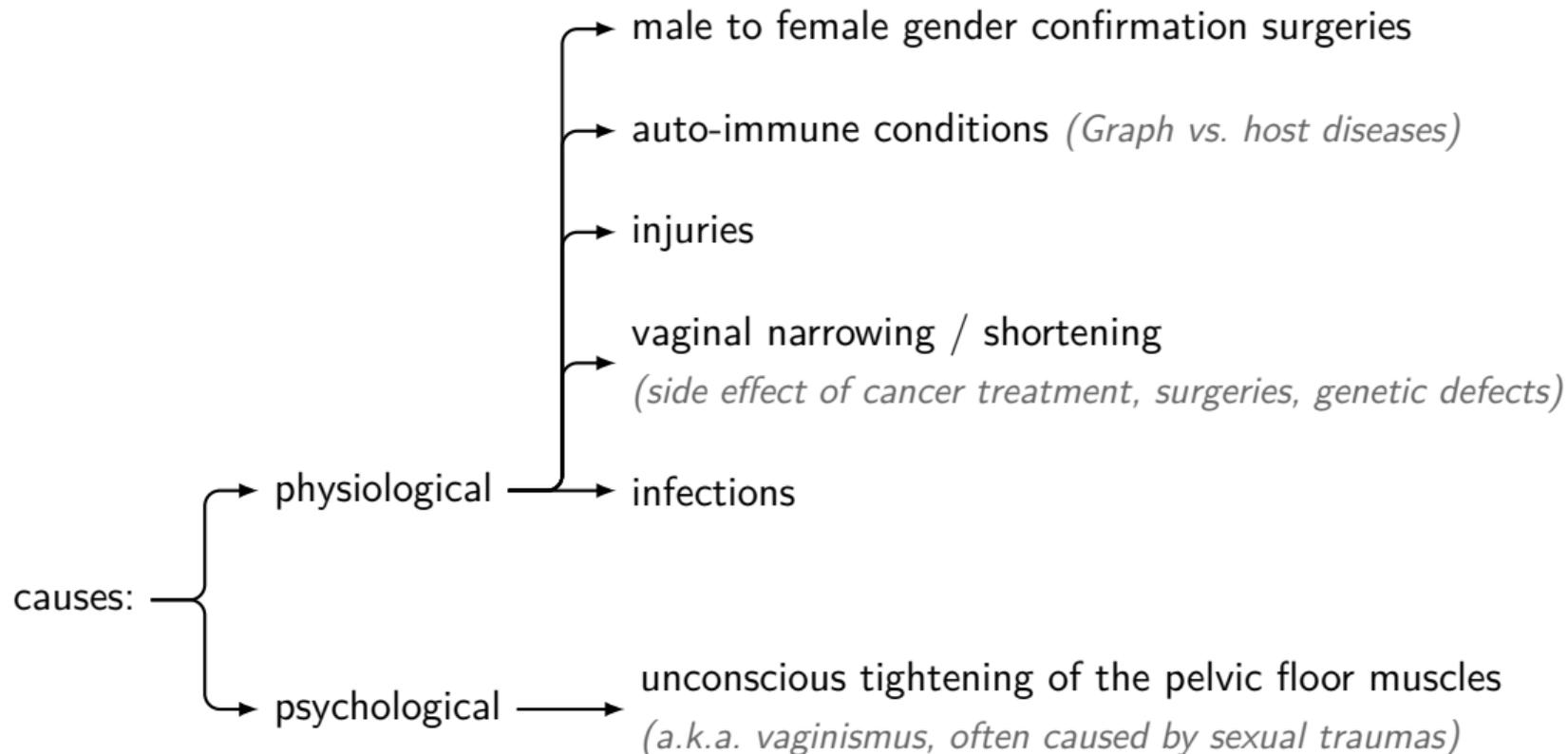
Relevance

approximately 15% of women[1] *in a variety of age groups*

[1]Hayes, Bennett, Dennerstein, Taffe & Fairley, *"Are aspects of study design associated with the reported prevalence of female sexual difficulties?"*, Fertility and Sterility, 2008.

Relevance

approximately 15% of women[1] in a variety of age groups

Indirect effects:

- self-shaming
- self-blaming
- isolation
- negative effects on patients' families and friends

---

[1]Hayes, Bennett, Dennerstein, Taffe & Fairley, *"Are aspects of study design associated with the reported prevalence of female sexual difficulties?"*, Fertility and Sterility, 2008.

How is it treated today?

gender confirmation surgeries

auto-immune conditions

injuries

vaginal shortening / narrowing

infections

vaginismus

How is it treated today?

gender confirmation surgeries

auto-immune conditions

injuries

vaginal shortening / narrowing

infections $\longrightarrow$ antibiotics & antifungals

vaginismus

How is it treated today?

gender confirmation surgeries

auto-immune conditions

injuries

vaginal shortening / narrowing

infections ⟶ antibiotics & antifungals

vaginismus

A	B	C	D	E	F
Diameter up to .6" (15mm)	Diameter up to .88" (22mm)	Diameter up to 1.04" (26mm)	Diameter up to 1.19" (30mm)	Diameter up to 1.35" (34mm)	Diameter up to 1.5" (38mm)
Length 3.48" (88mm)	Length 3.97" (101mm)	Length 4.46" (113mm)	Length 4.95" (126mm)	Length 5.45" (138mm)	Length 5.96" (151mm)

Universal handle fits all sizes

How is it treated today?

gender confirmation surgeries

auto-immune conditions

injuries

vaginal shortening / narrowing

infections ⟶ antibiotics & antifungals

vaginismus

+ counterconditioning

	A	B	C	D	E	F
Diameter	up to .6" (15mm)	up to .88" (22mm)	up to 1.04" (26mm)	up to 1.19" (30mm)	up to 1.35" (34mm)	up to 1.5" (38mm)
Length	3.48" (88mm)	3.97" (101mm)	4.46" (113mm)	4.95" (126mm)	5.45" (138mm)	5.96" (151mm)

Universal
handle fits
all sizes

Side effects

"uncomfortable", *"shameful"*

	Diameter up to .6" (15mm)	Diameter up to .88" (22mm)	Diameter up to 1.04" (26mm)	Diameter up to 1.19" (30mm)	Diameter up to 1.35" (34mm)	Diameter up to 1.5" (38mm)
	Length 3.48" (88mm)	Length 3.97" (101mm)	Length 4.46" (113mm)	Length 4.95" (126mm)	Length 5.45" (138mm)	Length 5.96" (151mm)

Universal handle fits all sizes

Side effects

"uncomfortable", *"shameful"*

↓

leads often to dropouts

	A	B	C	D	E	F
Diameter	up to .6" (15mm)	up to .88" (22mm)	up to 1.04" (26mm)	up to 1.19" (30mm)	up to 1.35" (34mm)	up to 1.5" (38mm)
Length	3.48" (88mm)	3.97" (101mm)	4.46" (113mm)	4.95" (126mm)	5.45" (138mm)	5.96" (151mm)

Universal handle fits all sizes

Side effects

"uncomfortable", *"shameful"*

↓

leads often to dropouts

↓

needs better treatments

	A	B	C	D	E	F	
Diameter	up to .6" (15mm)	up to .88" (22mm)	up to 1.04" (26mm)	up to 1.19" (30mm)	up to 1.35" (34mm)	up to 1.5" (38mm)	Universal handle fits all sizes
Length	3.48" (88mm)	3.97" (101mm)	4.46" (113mm)	4.95" (126mm)	5.45" (138mm)	5.96" (151mm)	

Side effects

"uncomfortable", *"shameful"*

↓

leads often to dropouts

↓

needs better treatments

↓

needs better understandings

	A	B	C	D	E	F	
Diameter	up to .6" (15mm)	up to .88" (22mm)	up to 1.04" (26mm)	up to 1.19" (30mm)	up to 1.35" (34mm)	up to 1.5" (38mm)	
Length	3.48" (88mm)	3.97" (101mm)	4.46" (113mm)	4.95" (126mm)	5.45" (138mm)	5.96" (151mm)	Universal handle fits all sizes

Our contributions

collect existing medical knowledge
and frame it into a consistent dynamical model

What is known about dyspareunia and the underlying physiological dynamics?

- $x_{\mathrm{phys.arousal}} > 0 \implies (x_{\mathrm{lubrication}} > 0, x_{\mathrm{vasocongestion}} > 0)$

What is known about dyspareunia and the underlying physiological dynamics?

- $x_{\text{phys.arousal}} > 0 \implies (x_{\text{lubrication}} > 0, x_{\text{vasocongestion}} > 0)$
- $u_{\text{vibration}} \in$ "suitable range" may $\implies x_{\text{pleasure}} > 0$

What is known about dyspareunia and the underlying physiological dynamics?

- $x_{\text{phys.arousal}} > 0 \implies (x_{\text{lubrication}} > 0, x_{\text{vasocongestion}} > 0)$
- $u_{\text{vibration}} \in$ "suitable range" may $\implies x_{\text{pleasure}} > 0$
- $x_{\text{fear}} > 0 \implies x_{\text{muscles}} > 0$

What is known about dyspareunia
and the underlying physiological dynamics?

- $x_{\text{phys.arousal}} > 0 \implies (x_{\text{lubrication}} > 0, x_{\text{vasocongestion}} > 0)$
- $u_{\text{vibration}} \in$ "suitable range" may $\implies x_{\text{pleasure}} > 0$
- $x_{\text{fear}} > 0 \implies x_{\text{muscles}} > 0$
- (if happening before or at the beginning of the penetrative act)
  $x_{\text{muscles}} > 0 \implies (x_{\text{lubrication}} \downarrow 0, x_{\text{vasocongestion}} \downarrow 0)$

The logical implications as a block-scheme

fear

pain   muscular
              tension

The logical implications as a block-scheme
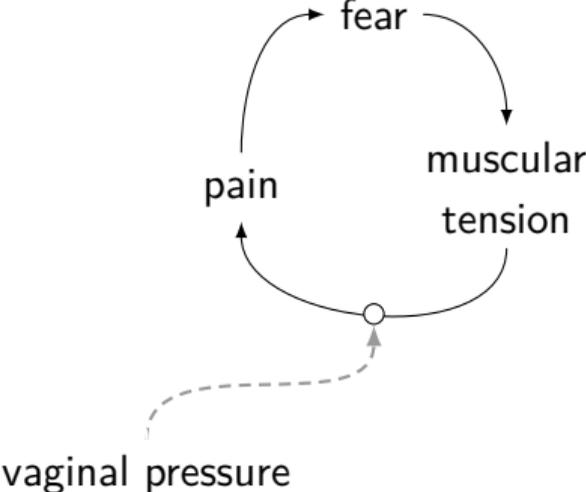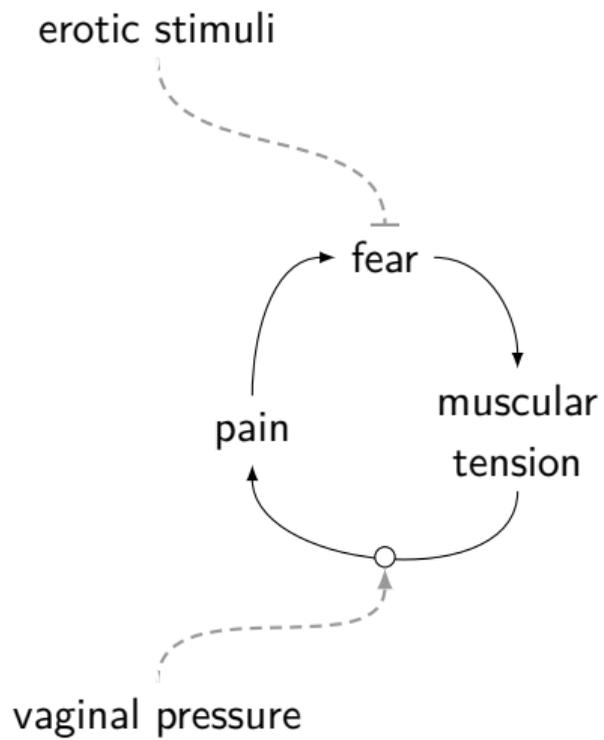
fear

muscular
tension

pain

vaginal pressure

The logical implications as a block-scheme

The logical implications as a block-scheme
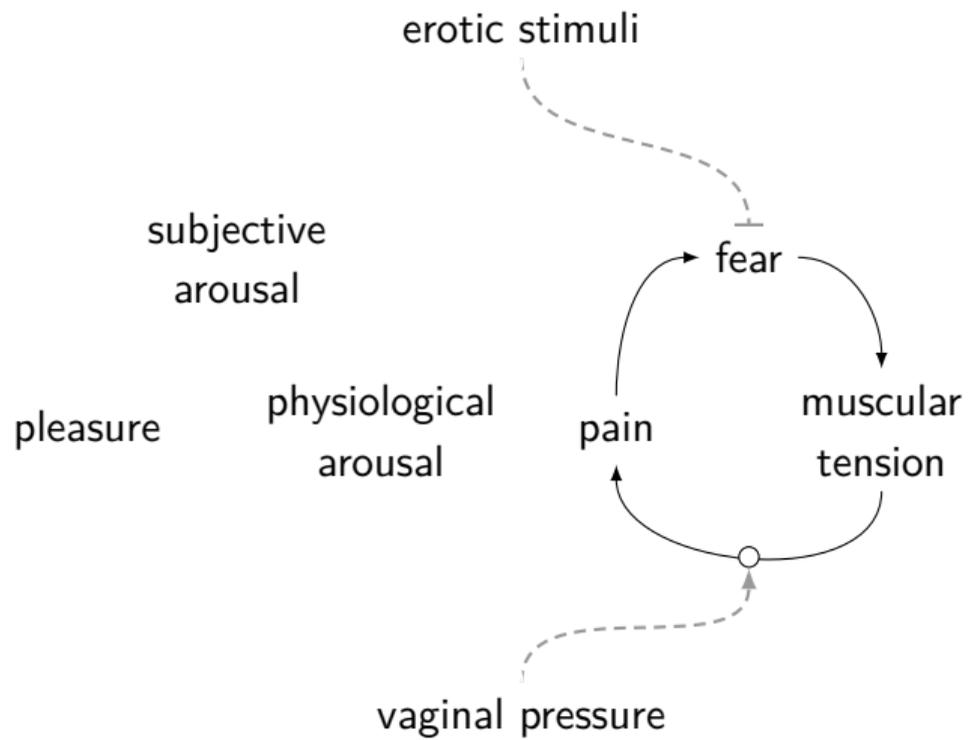
The logical implications as a block-scheme
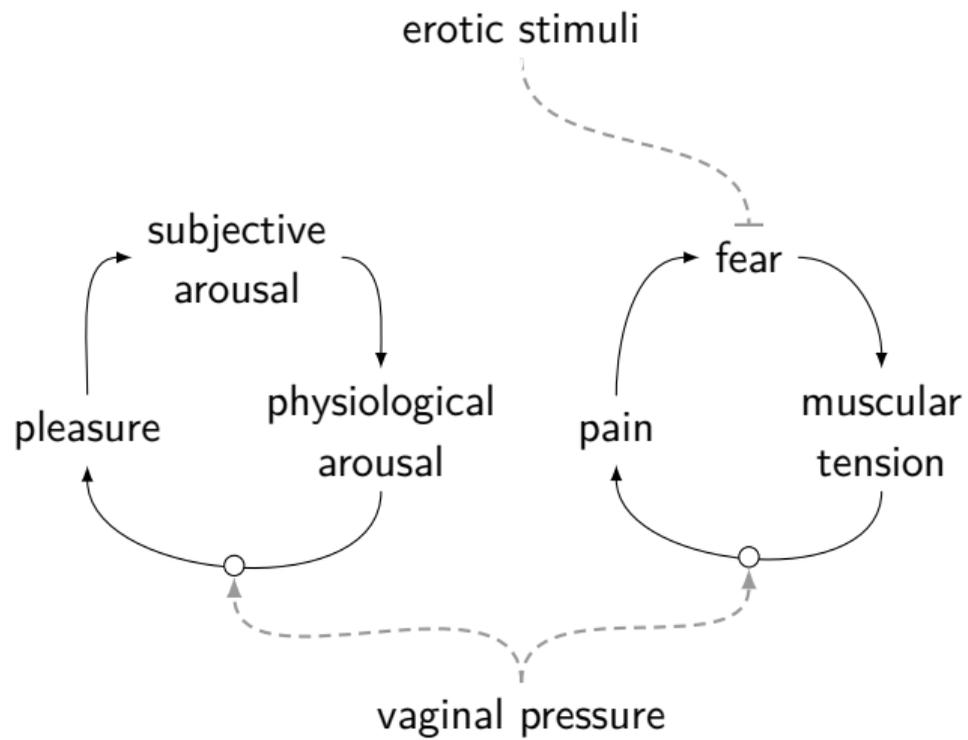
The logical implications as a block-scheme
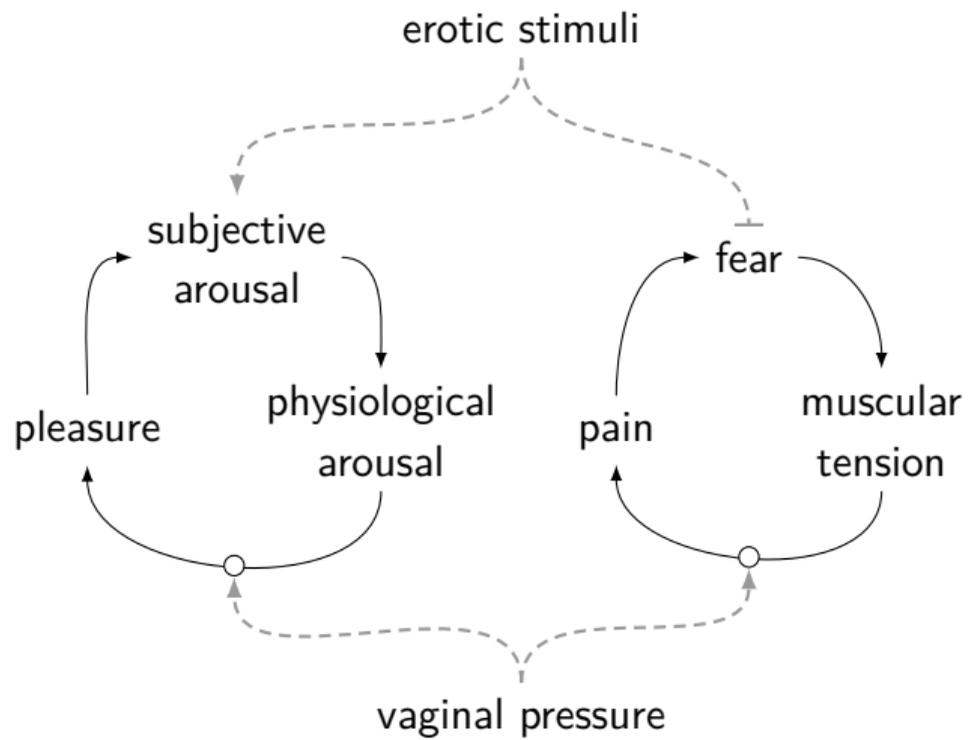
From logical implications to qualitative implications

important: the dynamics must lead to meaningful trajectories

From logical implications to qualitative implications

important: the dynamics must lead to meaningful trajectories

Cycle of fear (COF):

$$\dot{x}_{\text{pain}} = -x_{\text{pain}} + \sqrt{x_{\text{muscles}}}\, u_{\text{pressure}}$$

$$\dot{x}_{\text{muscles}} = -x_{\text{muscles}} + x_{\text{fear}}$$

$$\dot{x}_{\text{fear}} = -x_{\text{fear}} - x_{\text{fear}} u_{\text{stimulus}} + x_{\text{pain}}$$

From logical implications to qualitative implications

important: the dynamics must lead to meaningful trajectories

Cycle of fear (COF):

$$\dot{x}_{\text{pain}} = -x_{\text{pain}} + \sqrt{x_{\text{muscles}}}\,u_{\text{pressure}}$$

$$\dot{x}_{\text{muscles}} = -x_{\text{muscles}} + x_{\text{fear}}$$

$$\dot{x}_{\text{fear}} = -x_{\text{fear}} - x_{\text{fear}}u_{\text{stimulus}} + x_{\text{pain}}$$

Cycle of pleasure (COP):

$$\dot{x}_{\text{phys.arousal}} = -x_{\text{phys.arousal}} + x_{\text{subj.arousal}}u_{\text{stimulus}}$$

$$\dot{x}_{\text{pleasure}} = -x_{\text{pleasure}} + x_{\text{phys.arousal}}u_{\text{pressure}}$$

$$\dot{x}_{\text{subj.arousal}} = -x_{\text{subj.arousal}} + x_{\text{pleasure}} + u_{\text{stimulus}}$$

Which equilibria does the model allow?

$u_{\text{stimulus}} = 0$ $u_{\text{stimulus}} > 0$
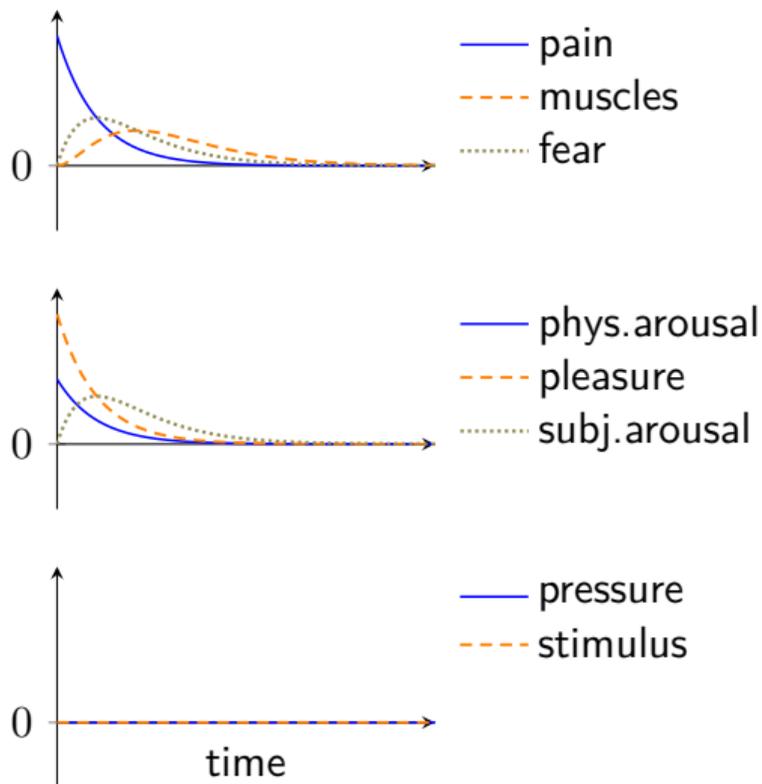
$u_{\text{pressure}} = 0$

$u_{\text{pressure}} > 0$
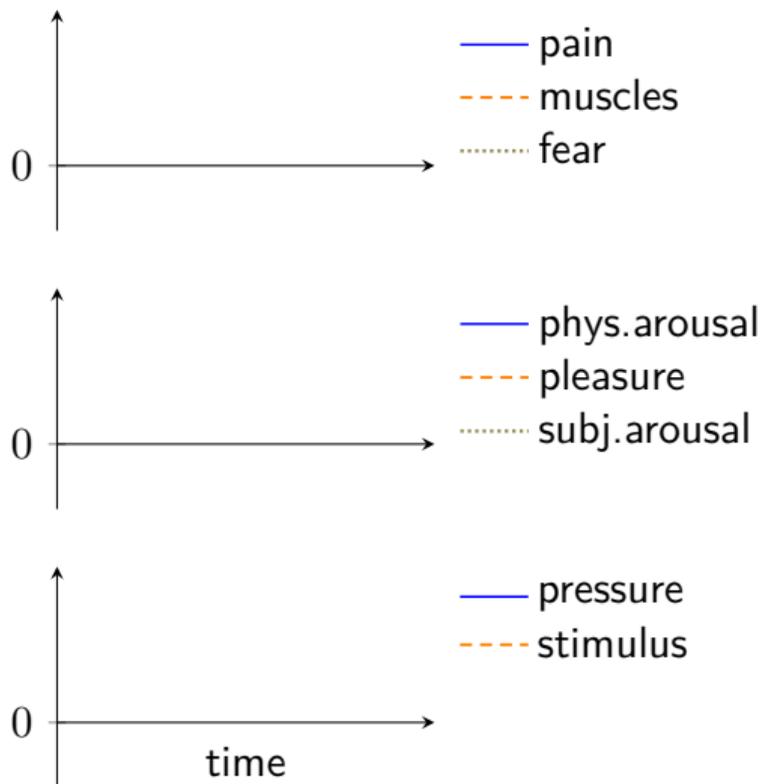
pain
muscles
fear

phys.arousal
pleasure
subj.arousal

pressure
stimulus

time

Which equilibria does the model allow?

$u_{\text{stimulus}} = 0$ $\qquad$ $u_{\text{stimulus}} > 0$

$u_{\text{pressure}} = 0$

(resting state)
$x_{\text{COF}}^* = 0$
$x_{\text{COP}}^* = 0$

$u_{\text{pressure}} > 0$

Which equilibria does the model allow?

	$u_{\text{stimulus}} = 0$	$u_{\text{stimulus}} > 0$
	(resting state)	(arousal state)
$u_{\text{pressure}} = 0$	$x^*_{\text{COF}} = 0$	$x^*_{\text{COF}} = 0$
	$x^*_{\text{COP}} = 0$	$x^*_{\text{COP}} > 0$
$u_{\text{pressure}} > 0$		
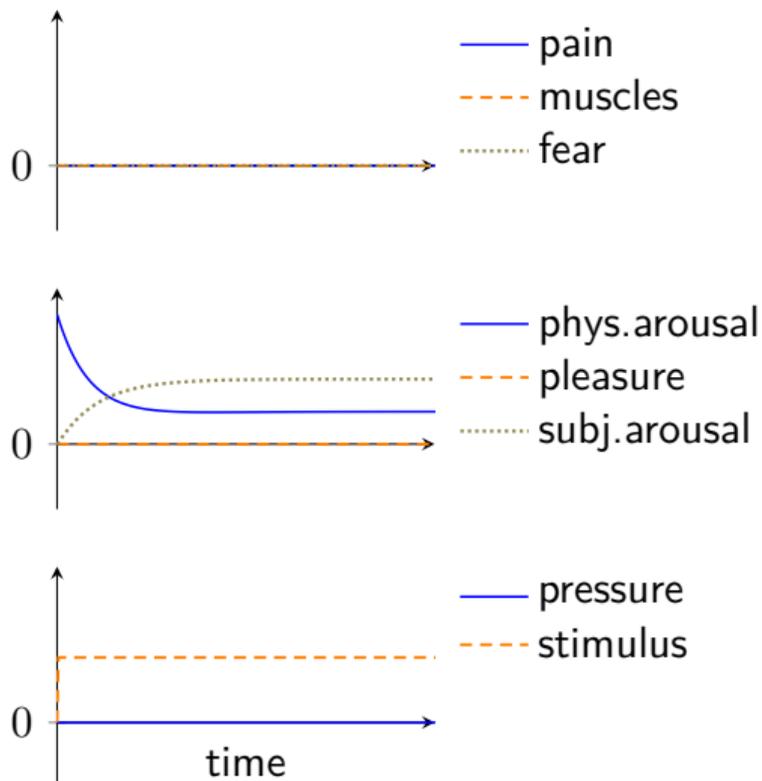
legend:
- pain
- muscles
- fear
- phys.arousal
- pleasure
- subj.arousal
- pressure
- stimulus

time

Which equilibria does the model allow?

	$u_{\text{stimulus}} = 0$	$u_{\text{stimulus}} > 0$
	(resting state)	(arousal state)
$u_{\text{pressure}} = 0$	$x^*_{\text{COF}} = 0$	$x^*_{\text{COF}} = 0$
	$x^*_{\text{COP}} = 0$	$x^*_{\text{COP}} > 0$
	(fear state)	
$u_{\text{pressure}} > 0$	$x^*_{\text{COF}} > 0$	
	$x^*_{\text{COP}} = 0$	
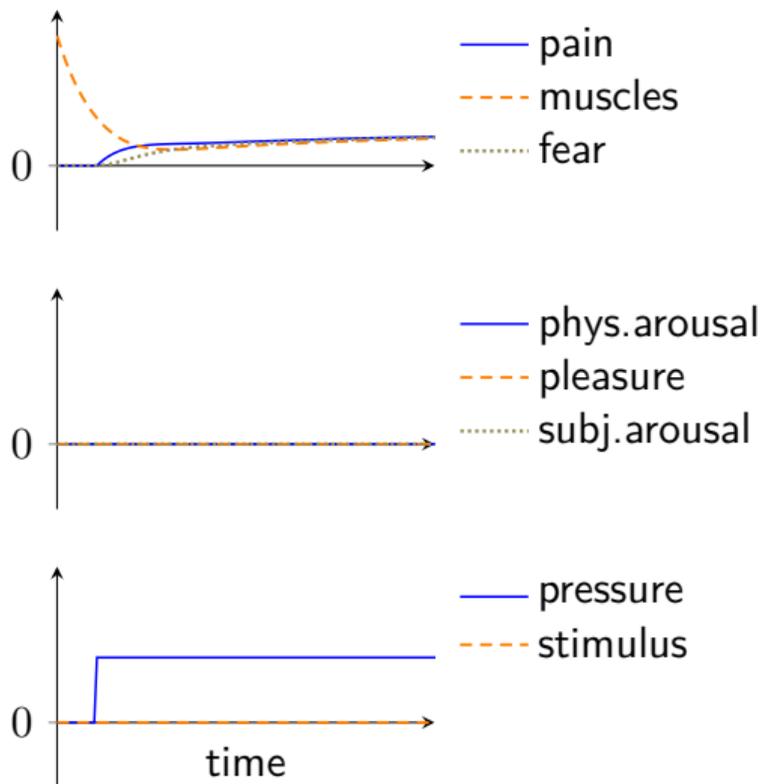
Which equilibria does the model allow?

	$u_{\text{stimulus}} = 0$	$u_{\text{stimulus}} > 0$
	(resting state)	(arousal state)
$u_{\text{pressure}} = 0$	$x^*_{\text{COF}} = 0$	$x^*_{\text{COF}} = 0$
	$x^*_{\text{COP}} = 0$	$x^*_{\text{COP}} > 0$
	(fear state)	(full state)
$u_{\text{pressure}} > 0$	$x^*_{\text{COF}} > 0$	$x^*_{\text{COF}} > 0$
	$x^*_{\text{COP}} = 0$	$x^*_{\text{COP}} > 0$
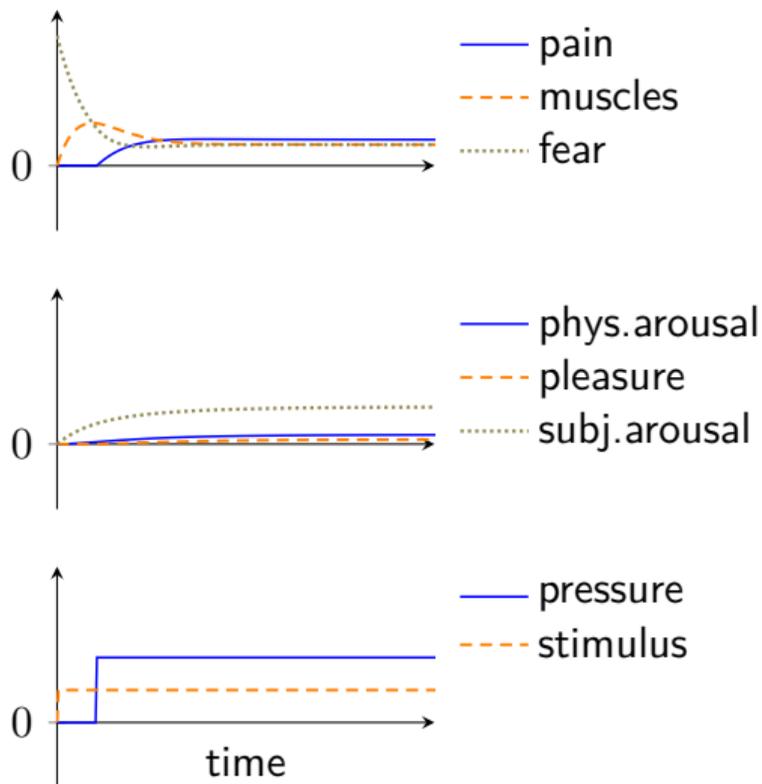
Conclusions

Conclusions

1. engineers can contribute to this area

Conclusions

1. engineers can contribute to this area

2. it is definitely a non-trivial socio-psychophysiological system

Conclusions

1. engineers can contribute to this area

2. it is definitely a non-trivial socio-psychophysiological system

3. this is just a first step

Conclusions and future directions

1. engineers can contribute to this area

2. it is definitely a non-trivial socio-psychophysiological system

3. this is just a first step

right now, system identification using real data

Qualitative modeling of pressure vs. pain relations in women suffering from dyspareunia

Damiano Varagnolo
Luleå University of Technology

Steffi Knorn
Uppsala University

Reinhilde Melles & Marieke Dewitte
Maastricht Universitair Medisch Centrum

July 10, 2017
IFAC world congress

Appendix

Example of datasets